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COAST GUARD – A CHALLENGE AND A NEED

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ABSTRACT

In the modern world, the sea is one of the most important resources for the economy and welfare of the country that has access to it and so is the sense of security. Meeting today's security challenges requires a wide spectrum of civil and military instruments and it calls for a national multifunctional structure. The article presents the search for new systematic forms to ensure adequate maritime security and safety at sea. Based on the research on successfully organized similar foreign institutions in relation to the national security institutions in the maritime domain the Coast Guard model of the Republic of Slovenia is designed. The model could significantly improve the level of efficiency and consistency of national authorities in the area of control, security and safety of the territorial sea and rationalize expenditures. Implementing the proposed model and placing it in the national security and defence system is a need and might be a challenge.

Keywords: Coordination of Services at Sea, the Coast Guard, rationalization, re-engineering

1 INTRODUCTION

Various factors and threats of modern times directly affect the changing global security environment. The armed forces should be adjusted to such changes, resulting in the redefinition of its role. The fact is that asymmetric threat can happen from the land, the air or the sea. The sea is an especially vulnerable area with its wide spaciousness of increasing interdependence. It provides free movement of persons, ideas, technologies and sources and is the environment in which identified threats of common security are known as terrorism, illegal proliferation of weapons of mass destruction, organized crime, illegal trade etc. Such challenges dictate the search for new systematic forms in order to ensure adequate maritime security and safety at sea [1].

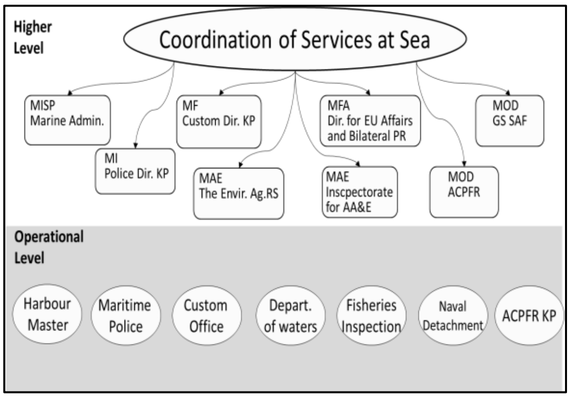
Nowadays even the European Union requests that its member states accept a more holistic approach to maritime management at all levels and more comprehensive management mechanisms, including improved cooperation and coordination, as well as consistency between agencies that are responsible for maritime domain awareness and for the interoperability of their supervisory systems at the European level [2-3].

The maritime domain and, in particular, the maritime security environment is of paramount importance to global economy. The volume of shipping is expected to increase during the coming decades, therefore, by definition, its importance will grow, as well [4]. The Slovenian coast and sea aquatorium are relatively small but on the other side sufficient enough not to be placed among almost fifty countries without national access to the sea. Slovenia is a maritime country and as such subject to provision of maritime security. It needs proper maritime capabilities in order to provide safety and security at sea and on the coast. The question that appears here is – what are the real maritime ambitions of the Republic of Slovenia in the fields of defence and security and how they should be most rationally provided [5].

The Republic of Slovenia possesses a substantial amount of personnel, technical, infrastructure and financial sources but we cannot connect and intertwine them into a really convincing and economic capability to ensure maritime security. It would be very irresponsible and irrational to pursue partition of services ensuring security at sea and on the coast [5].

2 NATIONAL MARITIME ACTIVITIES

In 2006 (2012) the so-called Coordination of Services at Sea was established to effectively and efficiently implement the common tasks that are associated with the sea and to insure information sharing at the inter-ministerial level in the pursuit of national maritime security [6-7]. Coordination of Services at Sea (*Figure 1*) integrates all Slovenian national resources related to maritime safety and is carried out at two levels: *at a higher level*, which is the Coordination of Services at Sea and *at the operational level*, which is the Operational Maritime Coordination.



Source: (Androjna, 2014)

Figure 1: Coordination of Services at Sea

The analysis show that due to a variety of interest this initiative did not succeed in a way that we might expect and all these respective security institutions continue to perform their duties in an autonomous manner. The existing subjects that ensure security and safety of the Slovenian sea have shown that the capabilities and resources available are limited for conducting operations within one state body or service. Merger or sharing of available capabilities would fundamentally raise efficiency and ability to respond to potential threats of modern times and at the same time provide the appropriate level of protecting the fields of interest of the Republic of Slovenia at sea. Actual economic situation and reduction of expenditure for capabilities development at the national level as well as in the international environment lead us to optimum use of sources available. In the field of defence of the EU one of the possible innovative solutions for optimum and efficient cooperation in the development of military capabilities is a project of *Pooling and Sharing* (https://www.eda.europa.eu/) which is in Nato supplemented by the concept of the so-called *Smart Defence* https://www.nato.int/docu/review/topics/en/smart-defence). The main purpose of the project is to reach appropriate capabilities, whereas the realization of projects can be achieved by association with countries that have similar goals within Nato, EU or regional initiatives. In our case we can talk about pooling and sharing of capabilities at the national level (in the context of Coordination of Services at Sea) which can be used to achieve increased functional or operational efficiency as well as cost effectiveness (equitable distribution of financial burdens). On one side the model stimulates synergy of pooling and sharing, whereas on the other side it prevents a parallel, independent establishment of comparable capabilities. A key precondition to enforce such a model is strong political will and readiness of all actors involved to take part in the process [8].

Being prepared to think about complete and radical changes is without a doubt an elementary basis for a fresh start and the first steps [9-10]. It is vital to establish a common, single subject of national security, which is under the unified command capable of providing the present tasks of the existing bodies ensuring security of the Slovenian sea.

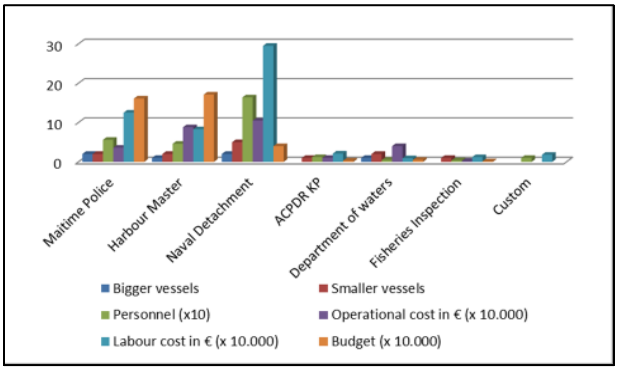
3 THE ANALYSIS OF COAST GUARD FUNCTIONS

The EU has strategic maritime interests [2-3] that need to be safeguarded and protected. Within the maritime areas surrounding the European continent there are many military and civilian organisations of several nations that have attracted our attention in our research. We have studied the organisation, methods of management and types of powers of individual coast guards of EU and non-EU member states bound by regional provision of maritime security in the Adriatic Sea (the Montenegrin Navy included), the Royal Norwegian Coast Guard and the Irish Coast Guard.

During the research the problem was to find a common denominator for all data collections and their classifications. Some information cannot be compared at all because of differences in the field of responsibility or operative management, whereas on the other side some individual pieces of data are insufficient or inaccessible to the general public (financial reference of management, staff completion etc.). Furthermore, some information, irrespective of the size of the aquatorium of the Republic of Slovenia, cannot be applied to the level desired or adjusted to our needs.

In the research special attention was given to the model that is placed under military supervision, whereas its function is formally, legally and civilly defined. In exercising their duties the members of the coast guard possess the police powers, authorisation to control fishery and shipping in the territorial waters as well as the powers to intervene at all possible incidents in their territorial waters and broader. In exercising other tasks they are in the position of a supporting body. Its concept of operation is based on an integrated coordination structure where two joined rescue coordination centres have the ability to independently lead land, air and maritime rescue activities [11]. Such a concept is unique and allows efficient and rational implementation of activities.

Our attention was given also to those factors that led to the formation of the Croatian coast guard, its normative regularity and time line set for reaching final operative capabilities. On the example of factors analysis that had an impact on the formation of the Coast Guard of the Republic of Croatia [12-13] it could be concluded that they were similar to those factors in the Slovenian maritime area. These factors are: the insufficient coordination of services at sea; ineffective planning and work projects at sea; mutual misunderstanding considering priorities; ineffective communication among individual services in cases such as: search and rescue at sea, sudden pollution at sea etc.; unassured constant presence of services at sea or possibility of overlapping tasks in the same area; ineffective use of staff resources; ineffective use of technical resources (vessels and equipment); unstandardized equipment: inefficiency of information systems; piecemeal approach to purchase of vessels, including design and construction; enhanced costs of maintenance; systematic problems of education of personnel in exercising supervision at sea; non-systematic and non-coordinated use of financial resources etc.



Source: (Androjna, 2014)

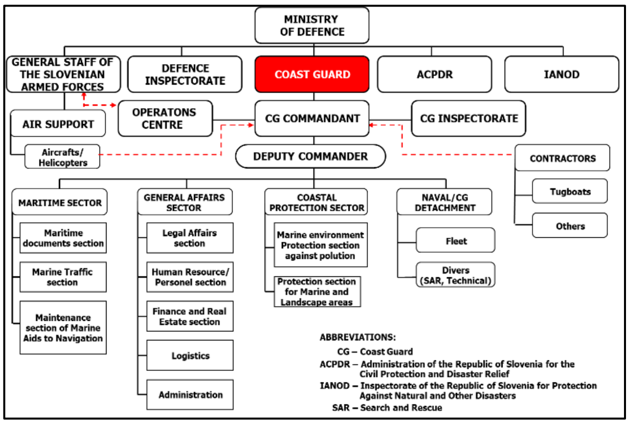
Figure 2: Overview of personnel, financial and material resources of Coordination of Services at Sea

Based on the analysis [14] carried out it can be claimed with the reliability that the quantitative cast of all the existing subjects providing security of the Slovenian sea is oversized considering the size of the area of responsibility. The analysis also identified a sufficient number of existing vessels and adequate budget *(Figure 2*).

In fact, the capabilities and resources available are limited for conducting operations within one state body or service, whereas their merger or sharing of available capabilities would fundamentally raise efficiency and ability to ensure adequate maritime security and safety at sea.

4 MODEL PROPOSAL OF THE SLOVENIAN COAST GUARD ORGANIZATION

In the present unpredictable and changing safety environment is essential to have troops available, organized in a flexible structure with clearly defined procedures, technologically equipped, and associated, with professionally trained personnel, capable of mutual cooperation at home and outside national boundaries. Such troops could be presented by the Coast Guard of the Republic of Slovenia (*Figure 3*).



Source: (Androjna, 2014)

Figure 3: Model proposal of the Slovenian coast guard organization

The model illustrated allows reduction of management levels, administration apparatus and consequently circulation of a larger number of workplaces dealing with operational tasks. The model of coast guard organization ensures definitions of processes used to delimit responsibilities and define tasks. With proper normative regime of the area a new organizational structure would provide effective mission performance and tasks of the coast guard, balanced development of its capabilities, more economical operations and rational use of staff and financial resources.

The model predicts management of the Slovenia coast guard under military supervision, whereas its function is formally, legally and civilly defined.

In such an organization the members of the coast guard possess police powers in exercising their tasks. The coast guard has all powers to control fishery and shipping in the territorial waters as well as to intervene in almost all possible incidents that can occur in the territorial waters and broader.

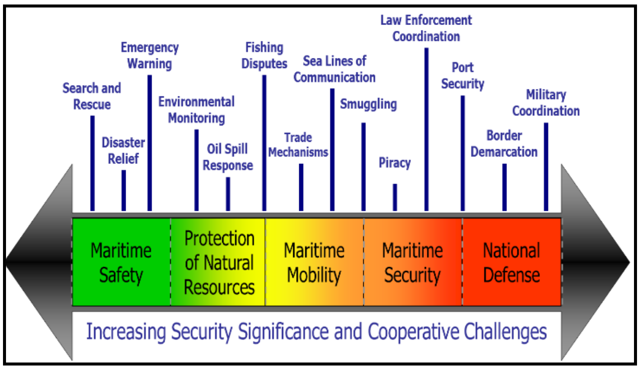
The proposed model presents a single subject of national maritime security which is capable of involving all the existing subjects of Coordination of Services at Sea and carrying out their tasks under unified command. Its most rational location would be within one of state-forming ministries, the so-called Ministry of Defence, because of:

- effective command and control structure (C2),
- existing maritime (integrated) surveillance system (maritime situational awareness),
- regulatory-normative framework,
- functional training and education system,
- effective chain of logistics supply, maintenance of material and technical means,
- existence of majority of resources necessary (personnel, vessels, infrastructure etc.).

The purchase of certain capabilities intended for establishing new organizational structures would be unsystematic and irrational in the early stages. With a view of rationalizing financial costs and use of personnel it would be logical, in individual cases and to a limited extent, to establish contractual arrangement of areas of work with contractors, especially for those activities which demand use of special equipment, capabilities or infrastructure (for example tugboats, warehouses, moorings, technical divers etc.). If necessary in certain cases other activities of the coast guard and other state institutions and organizations (emergency medical service, firefighters, various societies, volunteers etc.) can be activated or can join in.

According to Donohue (*Figure 4*) the proposed tasks of new interdisciplinary service can be classified into five different but closely connected areas [15]:

- national defence: protection of sovereignty, sovereign rights and jurisdiction,
- maritime security: suppression and prevention of terrorism, organized international crime and proliferation of weapons for mass destruction, oppression of piracy and other forms of non-peaceful use at sea,
- maritime traffic: control of maritime navigational routes and communications, control of maritime traffic,
- protection of natural resources: control and protection of sea environment, natural and cultural heritage, control of sea fishery, denial of sea pollution consequences,
- maritime safety: search and rescue (SAR), denial of sea accidents consequences.



Source: (Donohue, 2010)

Figure 4: Spectrum of coast guard roles

5 THE ANALYSIS OF STRENGTHS AND WEAKNESSES (RISKS) OF IMPLEMENTING THE PROPOSED MODEL

On the basis of the analysis of the existing situation of all structured elements that provide maritime security and protection at sea [16], the SWOT analysis (analysis of strengths, weaknesses, opportunities and threats) was used to evaluate the proposed theoretical organizational model of the Coast Guard of the Republic of Slovenia.

STRENGHTS of the proposed theoretical organizational model of the Coast Guard of the Republic of Slovenia by use of SWOT analysis are: increase of navigational safety; Command and Control structure (C2); better control at sea, over legal order and more effective intervention in extraordinary events; guaranteed continuous operation or permanent presence at sea – 24/7; improved mutual communication and coordination; reduction of total expenditure – rationalization; planed use of common capabilities (pooling and sharing); standardization of equipment, means and vessels; economic use of vessels and infrastructure; increasing concern for sea and inshore environment; experience and information exchange; motivated and qualified personnel and adaptability.

OPPORTUNITIES of the proposed theoretical organizational model of the Coast Guard of the Republic of Slovenia by use of SWOT analysis are: effective human resources management; standardization of procedures and measures consistent with international demands; systematic regime of supporting infrastructure; effective material sources management: systematic and planned approach to development, fitting out and modernization of the service; promising transparency; association of knowledge and employees' capabilities allows more effective realization of mission and obligations towards implementation of national and international legislation; higher identity of operation and friendly service for inhabitants of the Republic of Slovenia; taking part in the complete maritime policy of waters management at the level of the EU; more permanent and effective development of the Slovenian sea and the coast.

WEAKNESSES of the proposed theoretical organizational model of the Coast Guard of the Republic of Slovenia by use of SWOT analysis are: normative regime; limited financial sources; establishment of educational process for the coast guard members; limited professional and specialist competence (in the early stage), lack of powers as logical consequences; existing infrastructure; additional investments (mooring, infrastructure); mutual connectivity of information systems; diversity of equipment, means and vessels in the early stage and lack of awareness about positive effects of association into the common service.

THREATS of the proposed theoretical organizational model of the Coast Guard of the Republic of Slovenia by use of SWOT analysis are: unwillingness of integrated subjects to accept organizational changes; political absence at the formation and development of the common service; loss of military maritime tradition; ineffectiveness at elicitation and elaboration of normative acts.

The analysis shows a number of strengths and opportunities that the implementation of the proposed organizational model would bring, but we must be aware of the threats that could worsen the effectiveness of its operation [8].

6 CONCLUSION

There are two main issues in this article. First one, address the search for new systematic forms to ensure adequate maritime security and safety at sea and present the designed Coast Guard model of the Republic of Slovenia that could significantly improve the level of efficiency and consistency of national authorities in the area of control, security and safety of the territorial sea and rationalize the expenditures. The second one, address *a need* for changes and *challenges* that might be accompanied with.

Given the fact of limited financial, personnel and material potentials and despite having only 47 km of coast, there is *a need* for a national comprehensive and coordinated approach. At the same time it is necessary to overcome any narrow interests of individuals, groups or interagency rivalry, on a possible unification of entities into a common interdisciplinary service to establish an effective authority capable of adapting to and countering the threats that could potentially jeopardize national maritime security. A model pointed out also guidelines for developing consistent national maritime policy where flexibility (ability to adapt and adjust budgets and other resources) could be the key to success.

There are certain preconditions (*challenges*) without which a common interdisciplinary service can be difficult or even impossible to achieve. Firstly, there must be a political will for unification of our entities into a common interdisciplinary service. Secondly, everyone has to accept being coordinated or coordinating with others. Finally, it must be understood that the shift to something resembling a common interdisciplinary service happens between the ears before it can happen in reality [8].

To summarize, the proposed model is beneficial. Once realized, it will have an impact on our traditional competencies and therefore force us to considerably change our operational and procedural way of acting for which we need to be prepared well in advance. We can only wish that the development will follow the right path. But this demands a complex and complete accession to changes that are realizable, indispensable and financially favourable.

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IMPLEMENTATION OF THE THEORY OF PLANNED BEHAVIOR ON RIDERS OF POWERED TWO-WHEELERS

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ABSTRACT

Globally, every year 1.25 million people gets killed in traffic accidents, and about 20 to 50 million of people gets injured. On a global scale around ¼ of traffic accidents are accidents with powered two-wheelers involved. In Serbia, risky behavior is one of the key factors for involvement of powered two-wheelers in traffic accidents. The vast majority of those involved in accidents are young male riders, and sport motorcycle riders are largely at risk of fatal injuries. With that in mind, the goal of this paper is the examination of factors that impact the behavior of riders, with the implementation of the Theory of Planned Behavior (TPB). According to the theory, intentions are in direct relation to behavior, and on the other hand, attitude, perceived behavioral control and subjective norm are predictors of intentions. In order to examine the impacts on behavior of riders, a two part survey was conducted (1-demographic and general questions, 2-TPB questions). For the purpose of data analysis the following tools were used: MS Excel, IBM SPSS and IBM AMOS. Structural Equation Modeling (SEM) is used as a method for the purpose of analysis with the TPB model. It was established that attitudes and perceived behavioral control are the two significant predictors of riders' intentions, while the subjective norm was not found to be a predictor.

Keywords: powered two-wheeler riders, Theory of Planned Behavior, road safety

1 INTRODUCTION

Every year around 1.25 million people gets killed and around 20 to 50 million people gets injured in traffic accidents (WHO, 2015). Moreover, traffic accidents are currently the ninth death cause in the world, and are predicted to become the seventh cause of death by the year of 2030. Moreover, unfortunately traffic accidents are the main cause of death among the youngsters (15 to 29 years of age).

According to the WHO report (2015) riders of powered two-wheelers (PTWs) represent 23% of all casualties in traffic accidents. This percentage is higher in underdeveloped countries and developing countries. In other words, this percentage is highest in Indonesia and Australia (34%) and Southeast Asia (34%), while in Europe it is around 9%. According to the Traffic Safety Agency (ABS)[1] in 2016 the PTW fatalities in Serbia had a 9% share among all fatalities in traffic accidents. Moreover, during the same period the total number of PTW fatalities was 52 (including both, the riders and the passengers). The picture is even more disturbing with the indicators relative to the number of registered vehicles. Namely, compared to the average of the annual number of fatalities relative to 10,000 vehicles for all road user categories, this relative indicator for PTW alone is about 4 times higher. This is clearly indicating that PTW riders in Serbia have much higher risk of involving in an accident with fatal injuries. Moreover, young PTW riders and passengers have the highest risk in relation to other age categories (i.e. 52% of all PTW fatalities are related to the 15-34 years old PTW riders and passengers)[2].

Obviously, it is crucial to focus on improvement of the PTW safety in traffic. One of the best and even most human oriented ways is to focus on prevention of traffic accidents with PTW. Elliott et al. (2007) supposed that PTW accidents are independently or combination of (a) a machine element (i.e., the PTW), (b) an environmental element (e.g., road type and conditions) and (c) a human element (i.e., the rider). They also claimed that there is an extensive research about risk factors associated with machine and environmental elements, there is relatively little research about how the human element is related to

[1] Traffic Safety Agency in Serbia

[2] Traffic Safety Agency (ABS) – Annual Statistical Report for 2016

the motorcyclists' accident risk and what the elements of human element are.

After the extended analysis of road safety in Serbia, it was found that one of the most influential factors for involvement in traffic accidents is related to behavior of PTW riders. Thus, the purpose of this paper is the further analysis of elements related to the PTW riders' behavior leading to safe/unsafe behavior. In other words, it is important to know what elements should be in focus when designing the measures for improving the road safety.

There are multiple proven models for the analysis of human factor as an important element in traffic safety. For the given analysis in this paper the model of Theory of Planned Behavior (TPB) is chosen.

1.1 Theory of planned behavior (TPB)

The theory of planned behavior is a well-known theory in traffic research that can be used to explain and predict the behavior of individuals (Ajzen, 1991). This theory is an extension of the previous Theory of Reasoned Action (Fishbein and Ajzen, 1975).

According to the Theory of Planned Behavior (TPB), people's intentions are the most common interpreters of behavior. Also, according to this theory, prediction of intentions is based on *attitudes* (positive or negative evaluation of the realization of certain behavior), *subjective norms* (perceived social pressure or approval of the realization of certain behavior), and *perceived behavioral control* (perceived ease or difficulty for realization of behavior).

Based on the meta-analysis, 185 TPB tests provided support in terms of model efficiency in explaining approximately 39% of the variance on average for intentions and 27% of variance in behavioral averages, in terms of different contexts (Armitage and Conner, 2001).

The theory of planned behavior is implemented in various domains of traffic research. Namely, besides the application for examining the behavior of the rider of powered two-wheelers, there are some examples of application to pedestrian behavior in terms of crossing the street in a certain way (Diaz E. M., 2002), and as well to the behavior of drivers and car passengers regarding the usage or non-usage of the seat belt (Ozlem et al., 2007), etc.

Many researchers cited the relative weakness of the subjective norm in predicting the intentions of individuals, and suggested the reconceptualization of the normative component in order to better illustrate social influences (Terry and Hogg, 1996; Terry et al., 1999). For example, in the context of traffic safety, in some studies the researchers attempted to strengthen the component of the subjective norm by referring to the characteristic reference groups (eg. other drivers) in order to present normative beliefs (Parker et al., 1992).

Also, in some studies, researchers have modeled the theory of planned behavior extending with additional components to increase the predictive power of the model (Tunnicliff et al., 2011).

Looking at separate factors that can predict the behavior of the driver of the powered two-wheelers, variables such as gender, age, traffic exposure, etc. have been distinguished through studies (Elliott et al., 2007).

In addition to these variables, the theory of planned behavior stands out as an important predictive model. In fact, it has been found, for example, that those mopedists who (1) had positive attitude towards fast driving, (2) thought that there is approval from the their close friends and relatives for speeding, and (3) a strong intention not to drive in accordance with the limit, had a greater tendency to drive faster (Steg and van Brussel, 2009). Jamson et al. (2005) found that past behaviors (i.e. risk behavior in the past), attitudes and beliefs (eg. beliefs that one can enjoy in riding while speeding and that fast riding can contribute to getting to the destination more quickly) proved to be significant predictors of intents for risky behavior among older riders. Similar results were obtained by Watson et al. (2007) among PTW riders in Australia.

Graphic interpretation of the Theory of planned behavior is presented in Figure 1. Arrows represent the effects of individual factors on the individual's intention, while the intention is presented as a direct predictor of behavior.

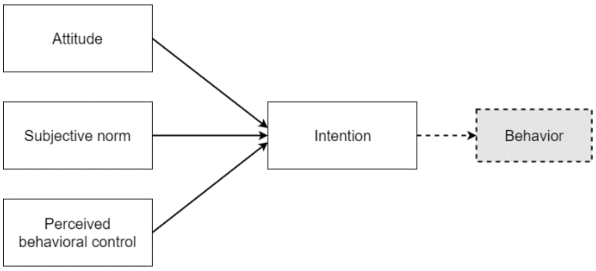


Figure 1: Theory of Planned Behavior

According to ACEM[3], there is one universal term "powered two-wheeler", which refers to different styles of motorcycles (conventional, sport, enduro, chopper, etc.), and thus includes even mopeds, tricycles and four-wheelers. In this paper, the term "powered two-wheeler" will be used for motorcycles and mopeds, and the distinction between certain groups of PTWs is made according to the study of Jevtic et al. (2014) which refers to the analysis of PTW traveling speeds relative to PTW styles in Belgrade. It is suggested in many studies, including the study of Jevtic et al. (2014), that PTW classification by style is highly convenient. Moreover, Jevtic et al. found that according to average traveling speed, certain PTW styles could be represented as a group. Consequently, three groups of PTW styles emerged: (1) sport motorcycles, which were faster than the other styles; (2) scooters, which were slower; and (3) group of PTWs that consists of conventional, touring, enduro, and chopper motorcycles with speeds that were statistically not significantly different (i.e. the group three). PTW

[3] Association of European Motorcycle Manufacturers

classification in the current paper is applied in accordance to these findings. Moreover, in some parts of the analysis, the classification is made based on the engine size (expressed in cubic centimeters – ccm).

2 METHOD

Since the purpose of this study is to examine the influence of individual factors on the intentions of the PTW riders to behave in a certain way, the TPB model was used. The TPB model measures the impact of attitudes, subjective norms and perceived behavioral control on the intention of the respondents to behave in a certain way. In addition to the factors offered by the TPB model, it was also important to include additional information, that is, general information, such as gender, age, PTW style, etc.

Therefore, a questionnaire consisting of two parts was created (1. Demographic and General items and 2. Items representing the factors of the TPB model).

Items related to demographic and general issues related to gender, age, frequency of riding a PTW, number of kilometers traveled with a PTW, number of offenses, number of traffic accidents, as well as the style of PTW and the engine size.

The second part of the questionnaire (TPB model) was formed on the basis of foreign experiences in the field of analysis of behavior of PTW riders where this model was applied. The items in this section of the questionnaire are designed so that groups of particular items represent the latent variables of the TPB model (i.e. the factors that represent the TPB model). All latent variables are represented with three observational variables (items).

All observation variables for the TPB model were measured on 6-point Likert type scale. In particular, observational variables are measured in the context of agreement, or not in agreement with the offered statement (1 - completely disagree to 6 - completely agree).

It should be noted that after forming the questionnaire, the minimum required sample size was examined from the aspect of applying the SEM analysis. In this case, the minimum number of respondents was 200.

The formed questionnaire was transformed into a digital type of questionnaire in order to be distributed online.

Since the target group are the PTW riders, the questionnaire was distributed through websites that could be classified as “virtual places” where PTW riders interact (online forums), as well as on “pages and groups” on the social network called "facebook" (motorcycle clubs). The questionnaire was completed in the period from the August 1st, 2017 until the August 20th, 2017. The responses were collected from 214 respondents, which is sufficient enough given the previously examined minimum sample size.

The responses collected from the respondents were processed using the following tools: MS Excel, IBM SPPS and IBM AMOS. The analysis consisted of two parts:

1. General data analysis; and
2. Structural equation modeling (SEM).

Prior to the analysis, the normality of variables from the sample was examined. To test the existence of a normal distribution, a Shapiro-Wilk test was used.

In addition to obtaining information about the impacts between factors, SEM analysis is used to examine and test the theoretical model in terms of model fit, the predictor power of the model, and the reliability of the model.

Therefore, the purpose of this paper is twofold. Namely, using SEM analysis and the TPB model, it was examined:

1. Applicability of the TPB model in case of the PTW riders in Serbia;
2. Impact of individual factors on the intentions of PTW riders in Serbia (where the factors were predefined by the theory of planned behavior).

3 RESULTS

3.1 General data analysis

General data analysis is conducted in order to examine the sample structure (the portion of male versus female PTW riders, structure from the age perspective, respondents’ exposure in traffic, frequency of riding, involvement in traffic accidents, commitment of offences, etc.).

Among the respondents, 97% were male riders, and a great portion of them (70%) were 19 to 35 year old riders. Around 54% of riders ride a PTW every day, and around 27% ride a PTW 3-5 times a week. More than a half of all respondents reported they are riding the conventional, enduro, touring and chopper style of PTWs (group three), while there was a small number of those riding scooters (18%). In terms of PTW style vs. PTW engine size relation, it was found that bigger engine size was typical among sport style and group three style of PTWs, while 82% of all scooters were having the engine size of <50ccm.

From the perspective of gender, male riders were found to be more exposed to traffic, both during the one year of riding period and during the lifetime. On the other hand, those riding a group three style of PTWs are more exposed to traffic. Moreover, the positive correlation was found between age and number of km travelled, both during one year period and a lifetime period of riding, respectively ($r = .334, p < .01; r = .711, p < .01$).

The respondents reported a total of 95 offenses while riding a powered two-wheeler, for which they were fined. Out of 52 respondents who committed offenses, 21 respondents were recidivists and all of them were male. Observed in relation to gender, about 96% of all offenses were committed by male riders. However, as the participation of female PTW riders in the sample is low, the percentage of female riders who committed an offence should not be considered negligible. In addition, around 76% of all offenders were 19 to 35 year old riders (it should be noted that female offenders are distributed through these age groups, as well). It was also found that the number of committed offences was consistent with the frequency of riding (i.e. with high frequency of riding, there was a larger number of committed offences).

There were 50 traffic accidents reported in total by the respondents. Among these riders, eight of them were involved in more than one traffic accident. From the gender point of view, around 90% of riders who were involved were male. Again, since the number of female riders in the sample is small, the remaining 10% which represent females involved in an accident should not be considered negligible. The number of accidents is significantly higher among 19 to 25 year old riders (54%). Like in case with committed offences, the number of accidents is larger when the frequency of riding is higher.

3.2 Structural equation modeling (SEM)

Since the SEM in general implies the process of grouping observational variables (questionnaire items) into latent variables (i.e. factors), a good approach is to first of all check if the observational variables could indeed be grouped in a way they can represent certain factors as groups.

The KMO indicator (Kaiser, 1970, 1974)[4] and Bartlett's test of sphericity (Bartlett, 1954) were examined. According to Tabachnick and Fidell (2007), the value of .60 is recommended as the minimum acceptable value of KMO indicators for good factor analysis. As for the Bartlett's test, it is necessary that the test is statistically significant. The result for KMO indicator was .801, and the Bartlett's test showed that there is a statistical significance ($p < .01$).

Principal component analysis (PCA) with a Kaiser criterion is used for factor extraction. There were four components with eigenvalues greater than 1. This was an indicator of the extraction of four factors with 86% of variance explained.

Furthermore, the four extracted factors were examined using the method of Varimax rotation. Table 1 shows how the observational variables were distributed among four groups (i.e. factors).

To test the reliability of latent variables (i.e. factors), the Cronbach's alpha coefficient was used. Ideally, this coefficient should be greater than .70 (DeVellis, 2003).

The results of Cronbach's alpha test showed that all four latent variables could be considered as reliable. Namely, Cronbach's alpha values for Intentions, Attitudes, Perceived behavioral control and Subjective norm were: .881, .830, .964 and .940, respectively.

Table 1: Rotated component matrix

	Component			
	1	2	3	4
TPB-1			.881	
TPB-2			.837	
TPB-3			.812	
TPB-4			.358	.714
TPB-5				.801
TPB-6				.876
TPB-7	.912			
TPB-8	.935			
TPB-9	.945			
TPB-10		.935		
TPB-11		.951		
TPB-12		.927		
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

Source: SPSS

Finally, the model fit for the theoretical model of TPB in case of Serbian PTW riders was examined. There are multiple opinions regarding the values of model fit indexes that imply a good fit. However, most commonly used values for these indexes are:[5] CMIN/df < 3 (or at least < 5), CFI > .90, GFI > .95, RMSEA < .08 (or at least < .10). Moreover, the *p-value* for CMIN/df should not be statistically significant.

The model fit indexes in case of Serbian PTW riders are as follows: CMIN/df = 2.659 ($p < .05$), CFI = .926, GFI = .970, RMSEA = .088. In other words, three out of four indicators are showing a good model fit.

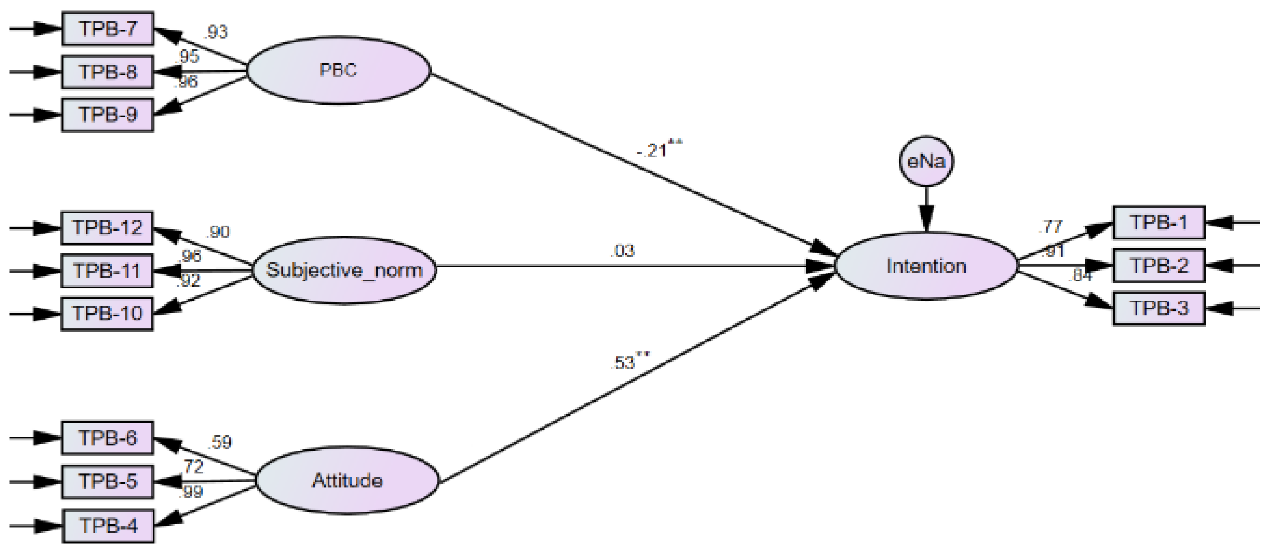
Finally, in order to examine the impact of *Perceived behavioral control*, *Subjective norm* and *Attitude* on the PTW riders *Intentions* the SEM was performed over the TPB model constructed in the AMOS environment (Figure 2).

In particular, *attitude* is considered as a predictor of the riders' *intention* with a positive regression coefficient $\beta = .53$, $p < .01$. In other words, with positive attitudes, the intentions could be found to be positive, too.

Regarding the *perceived behavioral control*, it could be also considered as a predictor of the *intention* ($\beta = -.21$, $p < .01$). Moreover, since the regression coefficient is negative, it is concluded that as the level of *perceived behavioral control* increases, so does the likelihood that a PTW rider will have positive *intentions* towards the behavior. It is worthwhile to explain the seemingly illogical interpretation of this negative regression. Namely, due to the more natural questionnaire structure, the items for measurement of the *perceived behavioral control* were designed so that a greater degree of agreement with the statement means less control over the behavior (e.g. "When I drive in accordance with the speed limit, it is difficult for

[4] Keiser-Meyer-Olkin Measure of Sampling Adequacy

[5] Li-tze and Bentler, 1999



Source: AMOS

Figure 2: Representation of the SEM analysis over the TPB model

me to maintain such behavior" or "When I see other riders doing a wheelie, it triggers the desire within me to do it too", etc.), while the questions for *intention* were designed so that a greater degree of agreement with the statement is more positive in terms of behavior (e.g. "During a daily ride, I will be aware of other road users", etc.).

The only factor that is not considered as a predictor of the riders' *intention* is the *subjective norm*. Namely, the regression coefficient was very low ($\beta = .03$), and there was no statistical significance as well ($p = .653$).

4 DISCUSSION

The aim of this paper was to examine the impact of factors influencing the behavior of powered two-wheeler riders in Serbia, using the theory of planned behavior. Although, there are many other theories on which the behavioral analysis of this type of road users can be conducted, the scope of this study was the examination of certain factors provided by the TPB. There are at least three reasons for this theory to be implemented in the current research: (1) the theory is a proven theory for the behavioral analysis in many use cases (not only in traffic research), (2) there are multiple successful implementations in the field of road safety and especially in studies with motorcycle riding context (Tunnicliff et al., 2011; Elliott, 2010; Jamson et al., 2005), (3) the implementation of the theory among Serbian PTW riders could be beneficial in terms of providing the basis for future research in this field. Moreover, one of the main reasons of this research is to provide the understanding of PTW rider behavior in order to provide the basis for designing the safety measures that could potentially lead to higher level of road safety among PTW riders.

By examining the current state of road safety in Serbia, it has been found that the largest number of accidents with PTW riders involved arises due to taking unreasonable actions by riders, misrepresentation of actions by riders, as well as because of a riders' failure due to inexperience, inappropriate and inadequate behavior. Therefore, the factors that contribute to the involvement in accidents PTWs are indeed related to PTW riders, i.e. their behavior, inexperience and errors while riding.

Great portion of respondents were riders of PTWs that are classified as the group three (conventional, enduro, touring and chopper). On the other hand, about 25% of the respondents were driving two-wheelers with the engine size of 300-650 ccm, and 29% with the engine size of 650-1000 ccm. The most common engine sizes are characteristic for some of the styles in the group three, as well as for the sport style. However, regardless of the size of the engine, the sport style is certainly considered as a PTW style that is more related to the risk behavior (for example, even sport motorcycles with engine size ranging from 125 ccm to 250 ccm are very often built with a sense of aggressiveness in terms of acceleration and speed - some of them can reach the speed of 200 km/h and even above that).

Respondents are exposed to traffic in large amount, but there are some differences relative to gender, and relative to the style of the respondents' powered two-wheeler, as well. Namely, male riders travel more than female riders, both annually and during the lifetime period. Also, the largest number of kilometers both, in case of annual mileage and during the lifetime period is related to the group three of PTW styles (conventional, enduro, touring and chopper). However, the differences are bigger in case of comparison on a lifetime period level.

Based on the analysis of road safety data from database of Traffic Safety Agency in Serbia, and even on the analysis of the data gathered by self-reporting from the questionnaire, it is found that young male riders of PTWs are the most risky category of PTW riders in Serbia. This is concluded based on data about both, the accident and the offences involvement.

According to the theory of planned behavior, the intentions of the PTW rider are affected by attitudes, perceived behavioral control, and subjective norms. Examination of these impacts was carried out using Structural Equation Modeling (SEM), which implies that prior to the testing of individual influences, it is necessary to check the validity of the sample for the application of factor analysis, the reliability of certain factors that represent the elements of the theory of planned behavior (intentions, attitudes, perceived behavioral control and subjective norm), as well as the validity and credibility of the model itself.

By applying the accompanying analysis that precedes the impact assessment, it has been found that there is a good enough validity and fitness of the sample for the application of Structural Equation Modeling, as well as the good validity and credibility of the theoretical model that explains the effects of attitude, perceived behavioral control and subjective norm on the intentions of the rider of a powered two-wheeler.

By analyzing the influence of these factors on the intentions of the PTW rider, the "attitude" factor emerged as the predictor. Namely, it was established that attitude has a statistically significant impact on the intentions of the PTW riders in Serbia ($\beta = .53, p < .01$). That is, those who had positive attitudes towards road safety had the intention of behaving more safely. In addition, the "perceived behavioral control" factor emerged as the second predictor. It was found that those who had higher perceived behavioral control, also had intentions to behave more safely in traffic ($\beta = -.21; p < .01$). However, it was found that the subjective norm is not a predictor of the intention of the two-wheeler riders. Namely, the influence of this factor was not statistically significant ($\beta = .03; p = .653$). This finding is consistent with previously obtained findings in other studies (Tunnicliff et al., 2011; Armitage and Conner, 2001), where the subjective norm also did not emerged as a predictor of the intentions of the PTW riders, while the other two factors were found to be significant predictors.

In other words, the opinions of close friends and family members of these respondents obviously do not affect the PTW riders' intentions to act in accordance with regulations.

5 CONLUSION

Since findings in this research provide the sense of the elements of behavior which should be impacted, some suggestions on safety measures could be made. Since it was found that opinions of close friends and family don't have an effect on the behavior, and that attitude and perceived behavioral control certainly have an impact on the behavior, the safety measures should designed with focus on education of riders about dangerous and risky situations that could occur in traffic.

This is very important to be done in a way that affects the attitude of a rider (attitudes towards risky behaviors should be eliminated and/or transferred to more positive attitudes about road safety, and on the other hand, those who already have positive attitudes should be affected in a way so that the attitude could remain positive and be sustainable). Moreover, educational workshops should be also designed in a way so that the perceived behavioral control (i.e. self control in terms of doing/not doing certain behavior) could be affected. For instance, young and novice riders with very low levels of riding experience should be educated in a way so they are as much as possible aware of consequences that low level of behavioral control can have.

In addition to the educational workshops, active trainings of safe PTW riding could also have high effects on attitudes and perceived behavioral control. This is true since riders could be presented with nearly real life situations and what should be done to prevent them.

Campaigns are one of the most popular approaches for affecting the certain groups of population (in many ways). In this case, the audience should represent the PTW riders with risky attitudes and low self control over the behavior. One of the most popular types of promotion of safe behavior in traffic are campaigns presented via channels such as television, radio, roadside billboards, etc. One of the good approaches to do the promotions in the case of PTW riders is the promotion at the place and in time of special events, i.e. biker gatherings. However, besides these traditional approaches, one that still has a relatively low level of exploitation and yet is very powerful is the promotion through social media. Indeed, nowadays there are multiple social media networks with high number of young inexperienced riders that are very active as members of those networks. Moreover, over the time the backend of the social media platforms became very powerful in terms of predictive analysis, machine learning algorithms, etc. which all basically provide very serious platform for marketing purposes (and many people/companies use them to improve their businesses). In other words, since every member is tracked in terms of their interests, content they like, gender, age, types of friends, etc., it is very easy to target certain types of people. For instance, the promotional material designed to affect young riders' attitudes and perceived behavioral control could be directed specifically to 15-35 year old male persons who have interests in motorcycles, motosport, and who are as well members of groups and pages that promote materials with motorcycle kind of contexts, etc. This way, certain and precise messages can be directed to the desired audience more precisely.

Further research on the behavior of the PTW riders in Serbia should be more focused on other factors that affect the behavior. For instance, the extended model of theory of planned behavior should be implemented in order to test the applicability and hopefully to provide more precise guidelines for improving the behavior of PTW riders.

One successful implementation of the extended TPB model could be found in the study of Tunnicliff et al., 2011, where some of the additional factors (i.e. group norm, self-identity, sensation seeking, and aggression) were found to be significant predictors of PTW rider behavior. In addition to the extended theory of planned behavior, other proven theoretical models could also be examined (Health Belief Model – HBM, Locus of Control – T-LOC, Motorcycle Rider Behavior Questionnaire – MRBQ, etc.).

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APPLICATION OF PTV VISSIM SIMULATION TOOL TO EVALUATE IMPACT OF AUTONOMOUS VEHICLES ON TRAFFIC FLOW

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ABSTRACT

The development of road vehicles automation dates to the 20s of the last century when it was presented for the first time, car without driver, equipped with antenna and controlled by radio impulses of another vehicle. This paper analyzes the historical review of automation of road vehicles control. In recent years, systems for the development of autonomous vehicle technologies have progressed significantly, and with their implementation, changes will occur in the traffic flow. The advantage of autonomous vehicles is manifested in increasing the capacity of the road due to the possibility of driving at a lower distance at higher vehicle speeds and reduced space use. Benefits of implementation will also include: reduced emissions of harmful gases and reduced number of traffic accidents. Despite all the advantages of autonomous vehicles, there are some drawbacks. For example, the reliability of steering algorithms, the behavior of autonomous vehicles in urban environments and the sensitivity of the sensors to bad weather (abundant rain, snow, fog). The significant problem is also how to mix autonomous vehicles with conventional traffic and how to define rules and working algorithms if there are multiple scenarios during the traffic accident. The aim of this paper is to apply simulation tools in modelling traffic flows after the introduction of autonomous vehicles. The basic traffic parameters will be analyzed and compared (level of service, travel time, queue length, the emissions of harmful gases etc.) using microsimulation tool PTV Vissim on the example of urban intersection. The first scenario will be modeled with conventional vehicles and the second one with autonomous vehicles.

Keywords: Autonomous vehicles, microsimulation tool, PTV Vissim, road capacity, traffic flow

1 INTRODUCTION

The development of automotive road automation dates to the 20s of the last century when it was presented for the first time vehicle without driver and equipped with antenna and controlled by radio impulses of another vehicle. This event has begun an intensive research in the field of autonomous vehicles that will lead to significant discoveries in the coming decades. In recent years, interdisciplinary programs of various sciences (mechanical engineering, computer science, electrical engineering, transport science, etc.) are advancing in the field of automotive vehicle technology development and will be followed by changes in traffic flow.

Turning point in introduction of autonomous vehicles in the traffic flow will be 5G networks and equipment of road infrastructure with network infrastructure, which would lead to faster introduction to Internet of Things (IoT) and vehicle connectivity with vehicle-to-infrastructure V2I, V2V vehicle-to-vehicle and vehicle-to-everything V2X.

The Society of Automotive Engineers (SAE) in its report (SAE J3016) suggests a functional classification that would significantly facilitate understanding of autonomous vehicles [1]:

- Level 0: the full-time performance of the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.
- Level 1: the driving mode-specific execution by a driver assistance system of either driving or acceleration / deceleration using information about the driving environment, and with the expectation that the human driver performs all remaining aspects of the dynamic driving task.
- Level 2: the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration / deceleration using information about the driving environment, and with the expectation that the human driver performs all remaining aspects of the dynamic driving task.
- Level 3: the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.
- Level 4: the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.
- Level 5: the full-time performance of an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.

The advantage of autonomous vehicles is manifested in increasing the capacity of the road due to the possibility of driving at a lower distance at higher vehicle speeds, reduced space use, reduced emissions of harmful gases and reduced traffic accidents. Despite all the advantages of autonomous vehicles, there are some drawbacks. For example, the reliability of steering algorithms, the behavior of autonomous vehicles in urban environments, the sensitivity of the sensors to bad weather (abundant rain, snow or fog), mixing autonomous vehicles with conventional traffic, defining rules and working algorithms if there are multiple scenarios during the traffic accident and ultimately unauthorized use of autonomous vehicles.

The aim of this paper is to apply PTV Vissim simulation tool in modelling traffic flows after the introduction of autonomous vehicles. The basic traffic parameters will be analyzed and compared (level of service, vehicle travel time, the emission of harmful gases etc.) on the concrete example of the intersection where the first scenario will be modeled with conventional vehicles and the other with autonomous vehicles. Vissim is a microsimulation tool used for modeling traffic networks, motorways, pedestrian flows and public transport networks. Vissim uses psychophysical model of driver behavior developed by Rainer Wiedemann in 1974. There are two separate models used in Vissim, Wiedmann 74 for the city network with a lot of overflow flows, and Wiedmann 99 for high speed motorways and little overflow flows.

2 HISTORICAL OVERVIEW OF THE DEVELOPMENT OF AUTONOMOUS VEHICLES

The development of automotive road automation dates to the 20s of the last century when it was presented for the first time as a vehicle without a driver equipped with an antenna and controlled by radio pulses of another vehicle, the so-called Linriccan Wonder [2]. The car was equipped with a portable antenna located in the back of the car and was controlled by a rear-facing transmitter. According to [2], the following key milestones in the development of autonomous vehicles can be distinguished:

- 1953 - Radio Corporation of America Labs (RCA Labs) constructed a miniature vehicle that was driven by wires in the laboratory floor. Inspired by RCA Labs, Leland Hancock applied this idea to the section of the highway. The electric bulbs that were on the edge of the pavement were detector circuits and had the ability to send the impulses with which the vehicle was operated.
- During the 1960s, the United Kingdom's Transport and Road Research Laboratory tested a car without a driver who interacted with magnetic wires fitted to the pavement. During the test drive, it drove at a speed of 130 km /h without significant deviation from speed or direction.
- In the 1980s, Mercedes - Benz designed a van vehicle that was referred to by the visual perception of a computer. This event is a turning point in the development of autonomous vehicles of the newer era due to the use of computer algorithms.
- In 1985, EUREKA (Organization for pan-European research and development funding and coordination) launched a program for the development of autonomous vehicles which had lasted until 1995. DARPA (Defense Advanced Research Projects Agency) in the same period developed a LIDAR, an obstacle detection system that uses laser beams, and has equipped it with an "autonomous land vehicle" (ALV).
- In 1991, Daimler - Benz, in cooperation with Ernst Dickmanns, developed autonomous vehicles, VaP and Vita - 2. They demonstrated the semi - autonomous drive on the Paris motorways at speeds of 130 km/h. It successfully mastered the "platoon" ride, shifting and overtaking conventional vehicles.
- In 1995, the Navlab project achieved 98.2% of autonomous driving over cross-country trips 4500 km long. The semi-autonomous vehicle, the Pontiac Minivan, used neural networks to control the vehicle, but acceleration and deceleration were dependent on the human factor.
- In 1996, Alberto Broggi constructed more advanced autonomous vehicles at the University of Parma. It launched the Argo project aimed at enabling the car to monitor the horizontal signaling on the highway.
- In the early 2000s, the Netherlands presented Park Shuttle, an autonomous vehicle for the transportation of several persons. It used magnetic wires built into the pavement for the control.
- The 2010 VisLab Intercontinental Autonomous Challenge (VIAC) has tested an autonomous vehicle for transporting goods from Parma, Italy to Shanghai, China on a 15,000 km long trip.
- An important venture was made by Audi with its autonomous TTS model driving the Pikes Peak race in a 27-minute period, which is very close to the 17-minute humane record.
- Volkswagen's "Temporary Autopilot" (TaP) is a significant achievement for safer driving. This system has several driver-assisted features such as ACC (adaptive cruise control), side monitoring for safer lane change with radar and ultra-sonic sensors. The vehicle can maintain a safe distance, check the horizontal signaling to maintain the side clearance and automatically slow down when it comes to road damage.
- One of VisLab's advanced autonomous vehicles was BRAIVE, the first fully autonomous vehicle [2]. It successfully drove through city streets, intersections and roundabouts, and it recognized traffic lights.
- Tesla developed an autopilot in 2014 and later upgraded it, allowing completely autonomous ride. The autopilot consists of eight cameras that provide 360-degree visibility up to 250 meters away. Twelve ultrasound sensors complement the cameras, enabling detection of the smallest objects. The radar located on the front of the vehicle collects data on a wavelength environment that can see obstacles through heavy rain, fog, sleet or dust [3].
- In 2017, Waymo (Google) announced plans to conduct research with fully autonomous vehicles without drivers in the front seat [2].

3 ADVANTAGES AND DISADVANTAGES OF AUTONOMOUS VEHICLES

Road transport is one of the initiators of the economy, but on the other hand road traffic is inevitably linked to negative external influences such as environmental pollution, traffic accidents and human victims. External costs are imposed on the society in general and include costs such as traffic accidents (costs of lost human lives, costs of damaged property and costs of easily injured persons), lost time in traffic jam, environmental pollution, increased noise levels and traffic safety. It is considered that autonomous vehicles will be considerably alleviated if they do not eliminate some of the above mentioned external costs. For example, in Croatia, in 2016, 307 people died, 11,849 people were easily injured, and 2,747 seriously injured [4]. The average age of the vehicle fleet in Croatia is 13.99 years [5], so it is not surprising that the number of people that died in traffic has increased in recent years.

Some authors [6] estimate that people are responsible for more than 90% of traffic accidents and that the number of traffic accidents will be reduced by 35% [7, 8] if a significant number of vehicles has additional equipment such as an adaptive lighting system, front collision warning system, blind-spot detection system, side airbags or lane departure warning system. Autonomous vehicles would certainly reduce the occurrences of traffic accidents and thus eliminate one of the causes of traffic congestion.

Anderson et al. [9] attribute three major factors to autonomous vehicles that affect traffic congestion, namely: reducing traffic delay due to a reduction in vehicle crashes, enhancing road capacity and changes in the total vehicle-kilometer traveled (VKT).

Progress in car design and efficiency of the internal combustion engines will reduce fuel consumption. The emergence of Level 3 autonomous vehicles will lead to optimized driving. Smooth acceleration and deceleration in the "platoon" will reduce fuel consumption. Vehicles will be lighter, greatly contributing to lower fuel consumption [10].

Autonomous vehicles constantly monitor the environment with radar and sensor located in the vehicle and will be able to communicate with each other. These technologies allow driving at smaller headways at higher vehicle speeds. Thus, the "platoons" of the vehicle, i.e. the road train will be formed. As a result, the capacity of the road will be increased. Some authors believe that the capacity will increase more than 4 times [11].

It is known that the value of land increases as the land is located closer to the center of the city. Autonomous vehicles will have a significant impact on land use outside large cities. They will allow people to utilize time in vehicle on other productive activities en-route. This could result in an increase in the number of inhabitants in rural areas and outside the cities. On the other hand, autonomous vehicles will not need to be parked, because they will be able to drive to the parking lot outside the city. At the exact time they can also come to the destination requested by the user. Parking places could be converted to some other use, which could cause even more residents in the cities.

By developing autonomous vehicles, it is considered that increased use of the "carpooling" system will be considered as making this system more convenient and cheaper than having a vehicle. It is anticipated that due to cheaper driving prices, new demands will arise. It is undisputed that due to increase in the use of autonomous vehicles the VKT will increase [10].

Negative consequences would be reflected in the increased use of autonomous vehicles and lower use of public transport, which would result in longer travel to work by public transport and in increase of the number of trips (empty trips without passengers and travelers).

Ecological problems, coupled with higher gas prices in the last decade, were the driving force for the development of electric vehicle technology (EV). However, the electric vehicle has several disadvantages, such as battery capacity and battery size. A major problem is caused by fire, because a large amount of water is needed when extinguishing. After the fire has been extinguished, the vehicle must be in quarantine for a specified period [10].

One of the major problems is the implementation of the legal framework and the establishment of government regulations for autonomous vehicles. One of the disadvantages is also the possible use of autonomous vehicles in criminal activities.

4 DEVELOPMENT OF MICROSIMULATION MODEL

4.1 Traffic network

Simulation tools have become an invaluable help in evaluating and choosing the optimal solution for different traffic situations. For developing a simulation model and evaluating the implementation of autonomous vehicles, the intersection was chosen in the City of Zagreb. The intersection was chosen as one of the most heavily congested intersection in the city with private and public transport and with approximately 15,000 vehicles in the morning peak period. After defining the intersection geometry, it is necessary to enter the traffic volumes, vehicle composition and the distribution of traffic flow. Traffic simulation was developed for the morning peak period from 7 AM to 9 AM. The intersection of City of Vukovar Street and Marin Drzic Avenue is controlled by a fixed signal program with a cycle length of 125 seconds. The cycle has five stages with protected left turns on all approaches. In the north and south approach, the right turns are separated by a triangular island and have to give priority to all vehicles on the main street. In Vissim [12] this way of managing traffic is determined by "priority rules" or "conflict areas". In this model, the "conflict areas" functions are used, where minimum critical time gap values can be entered. Finally, public transport timetables and data of the signal program are given with the intergreen matrix. Figure 1 shows developed Vissim model.

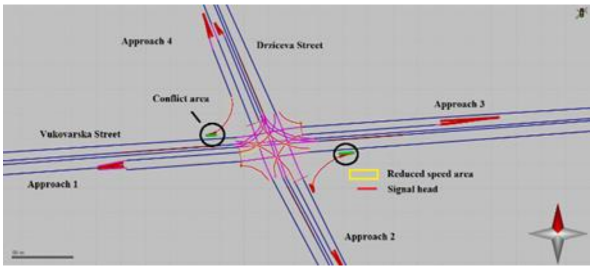

Figure 1: Vissim model

4.2 Development of microsimulation model of autonomous vehicle

In the simulation model of autonomous vehicles, it is necessary to create new vehicle type (autonomous vehicles – AV) which will differ from conventional vehicles by certain parameters. Parameters that differ from conventional vehicles and need to be modified are distance between vehicles during driving, distance between vehicles waiting on an intersection (standstill distance) and reaction after changing traffic light signals. Driving speed, acceleration and deceleration of the autonomous vehicles are defined without a distribution among vehicles. Figure 2 shows the maximum acceleration of conventional vehicles and autonomous vehicles. The left figure shows the distribution of the maximum acceleration of conventional vehicles. Green points are the minimum and maximum acceleration values for the defined speed. The right figure shows the maximum acceleration without a distribution that was applied in the model of autonomous vehicles.

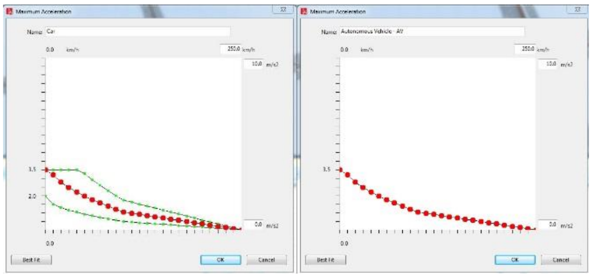

Figure 2: Maximum acceleration of conventional vehicles and autonomous vehicles

The following figure shows the speed distribution of conventional vehicles and autonomous vehicles with corresponding values. The left figure shows the desired speed of conventional vehicles with a lower value of 58 km/h and an upper value of 68 km/h. The right figure shows the desired speed of autonomous vehicles without a distribution. It should be noted that due to program constraints it is not possible to enter the same speed for the minimum and maximum value, therefore the lower limit for the desired speed in autonomous vehicles is determined at 59.99 km/h and the upper limit at 60 km/h.

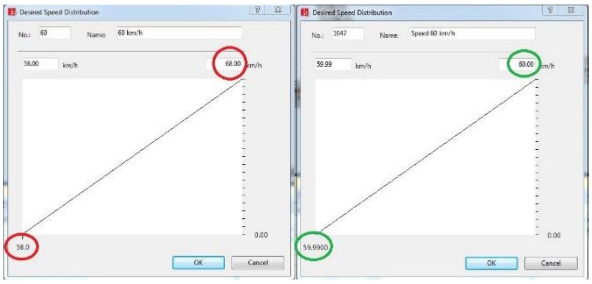

Figure 3: Speed distribution of conventional vehicles and autonomous vehicles

In the end, it is necessary to adapt the Wiedemann 74 model to credibly display the driving mode of autonomous vehicle. Autonomous vehicles have the ability to drive at a lower headway at higher speeds, so a parameter average standstill distance (ax) of 1.0 m is defined in the microsimulation model. Additive part of safety distance (bxadd) is value used for the computation of the desired safety distance d. Value which was used in microsimulation model of autonomous vehicle is 1,5. Multiplicative part of safety distance (bxmult) is value used for the computation of the desired safety distance d. Greater value = greater distribution (standard deviation) of safety distance. Value which was used in microsimulatoion model of autonomous vehicle is 0,0 [12].

5 VALIDATION AND EVALUATION OF SIMULATION MODEL

5.1 Validation of the model

The model validation is the process of adjusting the model parameters to ensure a satisfactory match between the collected data on field and data obtained from the model. Data comparison is performed by statistical and empirical methods. Microsimulation models that are not properly calibrated can result in unrealistic and erroneous results. The accuracy of the collected and simulated output results is tested by comparing traffic volumes. The credibility of the data is obtained using GEH statistics. In traffic modeling, the GEH value of less than 5.0 indicates a good calibration of the simulation model, from 5.0 to 10.0 indicates possible model errors, and values greater than 10.0 indicate problems with traffic demand or data input. It should be noted that in the simulation model of conventional vehicles the highest value of the GEH statistics is 1.12 (approach 1 and approach 4) and the smallest on the approach 2 with the GEH statistic 0.05. In the simulation model of autonomous vehicles, the highest value of GEH statistics is 0.42 (approach 4) and the smallest value is 0.06 (approach 3).

5.2 Evaluation and comparison of model results

The analyzed intersection of City of Vukovar Street and Marin Drzic Avenue is located on the south - eastern side of the City of Zagreb and is of utmost importance to the City. It is important to note that in both models (conventional and autonomous vehicles) 30 simulations with 30 "random seeds" were performed to better show the stochasticity in traffic flow. The simulation heating was

900 s (15 minutes) to provide a representative simulation [12].

According to the HCM [13] manual in model with conventional vehicles, the lowest level of service F is present in 3 of 4 approach (approach 1,2,3), while the level of service D has been recorded on the other approach 4. The highest average queue length and the maximum queue length have been recorded on the approach 1, 224.7 meters, regarding 430.1 meters. Considering the length of the vehicle and the safety distance, there are 62 vehicles waiting for the crossing in one lane, or 186 vehicles in three lanes. The maximum average vehicle delay was recorded at the approach 1 and was 153.0 seconds per vehicle. It is concluded that the existing traffic situation at this intersection is unsustainable and significant losses are experienced in waiting time, emissions of harmful gases, noise level, and ultimately growing social cost.

Autonomous vehicles can drive at lower headways at higher speeds. They react immediately after changing the lights at the traffic light and there is no speed distribution among vehicles. As a consequence of constant speed distribution "shock waves" are eliminated.

In the model of autonomous vehicles, according to the HCM manual, the level of service F was not recorded on a single approach, which is a significant improvement compared to conventional vehicles. The lowest recorded level of service is D, which indicates increased waiting times, but the traffic situation is still viable.

The highest average queue length was recorded at the approach 1 with the value of 33.2 m. The maximum queue length was recorded on the same approach and was 132.1 meters. The highest average vehicle delay was recorded at the approach 1 and was 47.6 seconds per vehicle. Figure 4 shows the comparison of the average travel times of the vehicles. The largest improvement in vehicle travel time was recorded at the approach 2 with improvement of 1.5 minutes, respectively 51%. At approach 1, travel time decreased by 47%, from 3.4 minutes to 1.8. On the approach 3 and approach 4 vehicle travel times decreased by 33% and 34% respectively.

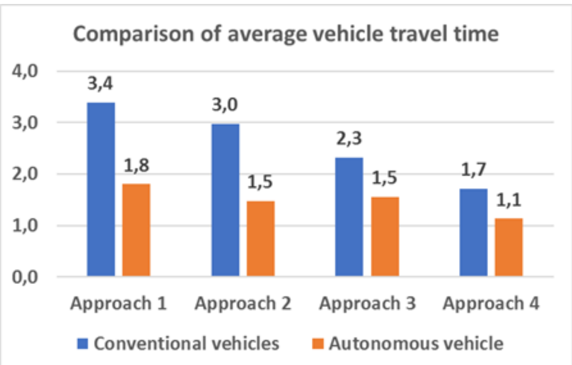

Figure 4: Comparison of average vehicle travel time

Figure 5 shows the comparison of the vehicle delay of conventional vehicles and autonomous vehicles by approaches. It is noticeable that the maximum reduction in vehicle delay time of 70%, or 143.6 seconds to 42.4 seconds, was recorded on approach 2. At approach 1, the vehicle delay of the vehicle decreased by 105.4 seconds, or by 69%.

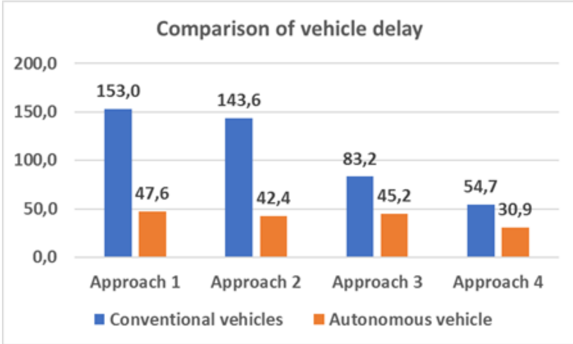

Figure 5: Comparison of vehicle delay

6 CONCLUSION

Exponential development in interdisciplinary sciences such as computing, mechanical engineering, electrical engineering and traffic science has a significant impact on the development of autonomous vehicles. The arrival of the 5G network and Big data will be a milestone in the introduction of autonomous vehicles in the traffic flow due to the ability to communicate vehicle-to-vehicle V2V, vehicle-to-infrastructure V2I and vehicle-with-everything V2X. The advantages of autonomous vehicles are reflected in increasing the capacity of the road because of the possibility of driving at a lower distance at higher speeds, reducing vehicle travel time, reducing noise levels, lower fuel consumption and reducing harmful emissions. Autonomous vehicles will leverage the use of rural land and overhaul the parking lot in the city center. The disadvantages of autonomous vehicles are reflected in the lower utilization of public transport because of the car comfort and the increase in the total vehicle kilometers traveled. Compared to the traffic flows of conventional and autonomous vehicles, the intersection of the City of Zagreb was chosen, which is of great importance for the whole city. After recording traffic and collection of all necessary traffic parameters, calibrated simulation models were developed in the microsimulation tool PTV Vissim. By comparison of the analyzed traffic parameters, the reduction of the travel time of the autonomous vehicles model is observed on approach 1 in 1,6 minutes, or by 47%,. At approach 2, the reduction in travel time is 1,5 minutes or 51%. On the approaches 3 and 4, the travel time of the vehicles is decreased by 33% and 34% respectively. The vehicle delay at approach 1 is decreased by 105.4 seconds or by 69%. On the approach 2 vehicle delay time is decreased by 101.2 seconds or 70%, while the vehicle delay time on approach 3 and 4 is decreased by 46% and 44%, respectively.

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TEMPORAL-SPATIAL ANALYSIS OF TRAFFIC ACCIDENTS ON RURAL ROADS WITH APPLICATION OF THE RELIABILITY THEORY

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ABSTRACT

The temporal and spatial aspect of occurrence accidents and their consequences are the most basic approaches in the traffic safety analysis. In the previous studies about traffic safety that are related on time when accident happened, a number of authors research the frequency of traffic accidents in a certain period of time, while others are concerned on forecasts the number of accidents.

This paper shows possibility of applying the basic principles of the reliability theory for testing the time distribution of traffic without accidents and safety parameters of rural road sections, such as the density function of accidents, function of reliability/unreliability, the mean time between two consecutive accident and accident frequency function

Keywords: traffic safety, accident, reliability theory, temporal aspect

1 INTRODUCTION

Road traffic injuries are a significant problem of global public health (Evans, 2004), which requires joint efforts for effective road accidents prevention and their consequences. Road traffic is the most complex and most dangerous system of all systems that people face every day. According to the World Health Organization (WHO) estimations, each year 1.25 million people worldwide are killed in road accidents, while the number of injured is between 20 and 50 million (Global status report, 2015).

Research in Europe indicate that in 2016, 25,500 people lost their lives on EU roads, a further 135,000 people were seriously injured on the road. The research in Europe showed that the EU28 collectively reduced the number of road deaths by 19% over the period 2010-2016 (Adminaite et al., 2017). According Statistical Report on the State of Traffic Safety in the Republic of Serbia for the year 2016 In the Republic of Serbia in 2001, in road accidents 1,275 persons killed, while in 2012 the number of persons killed in road traffic has dropped to 688. The latest data from 2016 show that 607 person were killed on the Serbian road (Road Traffic Safety Agency Republic of Serbia, 2016).

The analysis of the road safety by road type in 2015 in most European countries shows that more than 50% of accidents occur on rural roads. For example, more than 50% of fatalities occurred on rural roads in Hungary (54%), Slovenia (55%), Denmark (56%), United Kingdom (59%), while more than 70% occurred in Finland, Ireland, New Zealand, Sweden and Lithuania. Less than 50% occurred in a small number of countries, including Greece, Switzerland and Serbia. In Serbia in 2015, 62.6% of fatalities occurred inside urban areas, 27.5% on rural roads and 9.8% on motorways (Janstrup, 2017). One of the main reasons for this situation in built-up areas is that the main state roads pass through built-up areas and local roads and street networks lack adequate features to protect vulnerable road users.

The development of methods of road accidents analysis on rural roads takes an important role in the modern approach to road safety management. Existing systems for accident monitoring allow access to data of accidents that occurred at a particular location or road network. The road safety management system requires knowledge and assessment of the future state. For effective countering the negative phenomena that accompany road traffic, it is inevitable to have knowledge of the state of road safety in the past, as well as the one that currently reflects the present, but also those that can be expected in the near or distant future, depending on taken prevention measures. Hence, it clearly imposes the importance of the temporal models of the accident frequency.

2 PROBLEM DESCRIPTION

The road accident frequency has traditionally been the subject of a large number of researches, with a number of different methodological approaches of modelling of the road accident occurrence in the previous period (Lord and Mannering, 2010).From the aspect of temporal analysis of traffic accident occurrence, two approaches were singled out (1) collective and (2) individual. The collective approach determines the road accident frequency during a longer period of time (Hauer, 1986; Persaud, 1991; Miaou and Lum, 1993; Milton and Mannering, 1998; Golob and Recker, 2003). The individual approach determines the probability of the accident occurrence in real time (Hughes and Council, 1999; Lee, et al., 2003; Golob and Recker, 2004) (Abdel-Aty and Pande, 2007).

During the development of spatial models, in the initial stages, analyses were started as observations of the problems of traffic safety in the space (the concept of identification and treatment of hot -spots locations), and later the developed concept was innovated by respecting of temporal characteristics of the road accident occurrence. Spatial models of road accidents were the subject of research by numerous authors (Sørensen and Elvik, 2007; Montella, 2010; Siddiqui et al., 2012; Hummer et al., 2012). Sørensen and Elvik (2007) point out that dangerous road sections should be identified as road sections that have a higher expected number of accidents than the usually expected number on similar road sections, due to their the specific local characteristics. Mapping of road accidents, their consequences, traffic or public risk also belongs to a group of spatial analyses (Lipovac et al., 2009).

Spatial models of the road accident frequency were used in analyses of accident-related traffic safety factors. The Highway Safety Manual (HSM) proposes the use of the prediction model and the empirical Bayes' theorem for estimating the accident frequency on road sections and intersections (AASHTO, 2010). Due to its physical approach, spatial analysis is easier to understand, i.e. less abstract, and therefore it is more often the subject of research in the field of traffic safety. Because of its physical approach, spatial analysis is easily understandable and less abstract, and therefore more frequently is the subject of research in the field of traffic safety analysis.

The classic temporal analyses do not provide an answer why and where it should act first. They are, in fact, only the starting steps without which it is impossible to begin any analysis, but insufficient for the implementation of certain measures. Within temporal analysis, it is possible to carry out mapping in time and in this way to emphasize the critical time (calendar) intervals, but this approach does not provide the achievement of significant progress and innovation. The first researches from a temporal aspect were concerned with the influence of certain factors on the change of the number of traffic accidents over time (changes by years) (Zlatoper, 1984, Partyka, 1984, Oppe, 1991). In addition, some researchers presented the results of changing the number of accidents by months (Levine, 1995; Folkard, 1997). In addition, Jovanović et al., (2010) presented the results of the combination of the distribution of accidents by time units (hour, day and month). The numerous researches show the dependence between the traffic volume and the number of traffic accidents (Martin, 2002; Qin et al., 2006). When analysing the road accident frequency, the emphasis is placed on the seasonal impact, i.e. the impact of meteorological conditions on traffic safety (Radun and Radun, 2006; Songchitruksa and Balke, 2006; Brijs et al., 2008; Andersson and Chapman, 2011).

Some researchers modelled the impact of traffic flow (average annual daily traffic - AADT), the number of kilometres travelled per vehicle, or the number of vehicles passing on a certain road section. This parameters are important indicators of exposure to traffic accidents (Elvik and Vaa, 2004; Qin et al., 2006).

Research and development of spatial-temporal analysis of traffic accidents have become actual in recent years (Kingham et al., 2011; Blazquez and Celis, 2013; Bačkalić et al., 2013). This group includes methods for identifying and visualizing of hot- spots in temporal domain (e.g. distribution of accident frequency per hours and detection of "dangerous hours") (Li et al., 2007; Plug et al., 2011).

Decision-makers want to know where and when to act with certain measures. As has been presented in previous studies fluctuation in the number of accidents (accident rate) expressed in different time units (hour, day, month and year) in itself is incomplete and insufficient, as well as the frequency of the number of accidents in an area of observation (specific location, road section and zone). This clearly highlights the importance of the distribution of the number of accidents in space and time, as well as the importance of their joint presentation.

Based on a detailed review of the literature from the field of the accident frequency modelling, in terms of spatial, temporal and spatial-temporal models, it is noted that so far has not been developed a model that monitor and analyse the time between the occurrences of two consecutive road accidents (Jovanović et al., 2011; Bačkalić et al., 2013). The aforementioned problem has defined the basic assumption that the road accident frequency, based on individual access, can be analysed using the reliability theory models. By analysing road traffic and occurrence of a road accident, in other words traffic interruption or failure due to an unplanned and unwanted event, there are many similar processes and dependencies that also studied in theory of reliability of technical systems (Vukadinović, 1986; Ushakov and Harrison, 1994; Dhillon, 2005).

For the application of any traffic safety analysis model, it is necessary that there are accurate information of characteristics of road accidents, consequences and other influential factors. In addition to the importance of the existence of a road accident databases, their reliability and quality of information they provide, from the aspect of mathematical models, there are some difficulties that experts have to take into account when modelling road accidents.

In order to tackle the problems of data on traffic accidents and methodological issues (which could jeopardize the statistical validity of the analysis if they are not properly applied), a wide range of methods are applied. Mannering and Bhat (2013) describe the models that are commonly used in the field of traffic safety in detail, which in their paper emphasize certain advantages and disadvantages of each model. The presented model belongs to the class of duration models.

For the road authority, it is very important to know which model to apply in order to increase the traffic safety. Models that observe the time between two traffic accidents, unlike other models that are used to analyse the accident frequency, require only data about time of occurrence of a road accident and location. These models have a number of advantages for the road authority. Jovanović et al., 2011 and Bačkalić et al., 2013, showed the practical application of these models in analysing the road accidents frequency on rural roads.

This paper presents the results of applying the reliability theory model according to the methodology developed in (Jovanović et al., 2011).

3 METHODOLOGY AND RESULT

The subject of research is the analysis and modelling of road accidents on rural road sections, and belongs to the field of road accident modelling (spatial, temporal and spatial-temporal models). Within the subject of research, the data are analysed from the time and spatial aspect. The basic time units related to the accident occurrence that were used for testing the model are: hour, day, month and year. The road change represents the basic spatial variable, which defines a new spatial variable – road section in which the accident occurred.

Temporal and spatial data about the road accident occurrence are input parameters for the testing of reliability models of the road and the road sections, which takes into account the time between the occurrences of two consecutive accidents on the observed road.

The parameters of road reliability are then calculated from a temporal aspect according to the forms of the technical systems reliability theory (Ushakov and Harrison, 1994, Dhillon, 2005, Pham, 2003). When analyzing the probability and the occurrence of accidents on the sections, and on the road as a whole, we observed the period of t = 365 (days) = 8,760 (h).

The methodological procedure for the road accidents analysis and their consequences is aimed at improving the existing classical temporal-spatial approach in the traffic safety management system.

To test the model we selected a state road (made up of 20 sections of a total length of 255 km), which is within the model observed as a system of 20 serially connected elements (Table 1). The sections represent parts of the road network between two consecutive traffic nodes and are used to provide for continuous and unobstructed traffic flows (Hauer et al., 2002). Each section is specific by the structure and volume of the traffic, road environment, units and road equipment. The analysis of traffic accident data on the observed road covers a period of 9 years (from 2005 to 2013), during which 1,217 traffic accidents occurred.

Table 1: Basic characteristics of observed road

Road section (i)	Length (km)	Observed number of accident	Mean time between two accidents T_{0i} (h)	Accident rate function λ_i (year^{-1})
1	0.333	5	13195.80	0.66384758
2	0.931	23	3312.83	2.64426799
3	33.000	63	1243.30	7.04575630
4	6.639	24	3128.75	2.79984019
5	4.668	0	infinite	0.00000000
6	5.491	62	1252.23	6.99554341
7	36.265	101	756.49	11.57987042
8	1.752	15	4995.40	1.75361332
9	19.574	117	648.38	13.51067756
10	15.996	105	750.41	11.67362583
11	15.701	83	943.16	9.28795891
12	1.661	7	9861.71	0.88828369
13	8.622	89	867.17	10.10184249
14	34.030	134	583.99	15.00038337
15	25.520	231	340.63	25.71690008
16	5.296	2	27127.00	0.32292549
17	2.033	5	5256.00	1.66666666
18	1.251	5	8872.80	0.98728698
19	28.672	128	600.55	14.58670482
20	7.678	18	4362.06	2.00822751
Road	255.113	1217	62.92	139.2342227

All the traffic accidents have been allocated based on the time of occurrence (year/month/hour) and location on the road (kilometre/meter), which provides us with the temporal–spatial distribution of traffic accidents per section. Testing whether the empirical time distributions between successive accidents on the sections match the theoretical distributions was performed using the χ^2 test.

According to formulas explained in paper (Jovanović et al., 2011), it were calculated the main parameters of sections (i=1,2,3,…,20) and road as:

- Accident rate function (λ)
  $$\lambda = \frac{1}{T_0} \tag{1}$$
- Distribution function (F)
  $$F(t) = \int_0^\infty f(t)\,dt = \int_0^\infty \lambda\, e^{-\lambda t}\,dt = 1 - e^{-\lambda t} \tag{2}$$
- Reliability function (R)
  $$R(t) = 1 - F(t) = e^{-\lambda t} \tag{3}$$
- Mean time between two accidents (T_0)
- $$T_0 = \int_0^\infty R(t)\,dt = \frac{1}{\lambda} \tag{4}$$
- Probability that there will not be an accident (P_0)
  $$P_0 = e^{-\lambda t} \tag{5}$$
- Probability of n recoveries (P_n)
  $$P_n = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \tag{6}$$

Comparison of accident frequency rates among road sections (the number of accidents during one week - λ_i), highlights the section 15 as the most unfavourable, i.e. on this section accidents happen most often than on other road section (Figure1). On the observed road, on average, 139.234 accidents happen per year, that is 100.736 accidents per year, i.e. a traffic accident happens every 62.92 hours (Table 1).

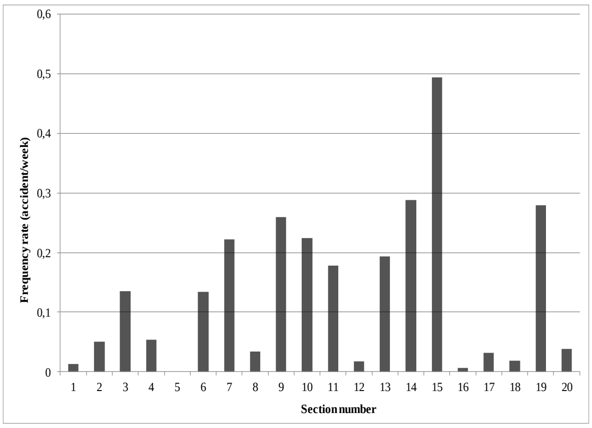

Figure 1: Frequency rate (accident/week) per road section i (i=1,2,3,…,20)

Comparing the reliability/unreliability of the road sections (Figure 1 and Table 2) we can see that section 15 is the least reliable, followed by sections 19, 14, 9 and 7, while the most reliable sections are 5 (without single accidents), followed by sections 16, 1, 12 and 18. The reliability of the road as a system during one week is 0.0692352352, within one year is 0, or unreliability is 0.9307647648 and 1, respectively.

Table 2: Main results of the reliability analysis of observed road for the period *t* = 365 (days) = 8760 (h)

Road section (i)	$R_i(t)$	$F_i(t)$
1	0.5148665243813350	0.48513347561867
2	0.0710573489288721	0.92894265107113
3	0.0008710977964047	0.99912890220360
4	0.0608197813502452	0.93918021864976
5	1.0000000000000000	0.00000000000000
6	0.0009159549099387	0.99908404509006
7	0.0000093524667369	0.99999064753326
8	0.1731471748860710	0.82685282511393
9	0.0000013563984574	0.99999864360154
10	0.0000085154718645	0.99999148452814
11	0.0000925317325428	0.99990746826746
12	0.4113611686532370	0.58863883134676
13	0.0000410039360776	0.99995899606392
14	0.0000003057850702	0.99999969421493
15	0.0000000000067810	0.99999999999322
16	0.7240277934568100	0.27597220654319
17	0.1888756028375620	0.81112439716244
18	0.3725861512235020	0.62741384877650
19	0.0000004624604365	0.99999953753956
20	0.1342263778355360	0.86577362216446
Road	0.0000000000000000	1.00000000000000

Figure 2 show the probabilities of accident occurrence ("equal or more than a certain number", "a certain number" and "less or equal than a certain number") for observed the periods of t = 365 (days) = 8,760 (h) on the road as a whole, or in the Figure 3 on all of road sections.

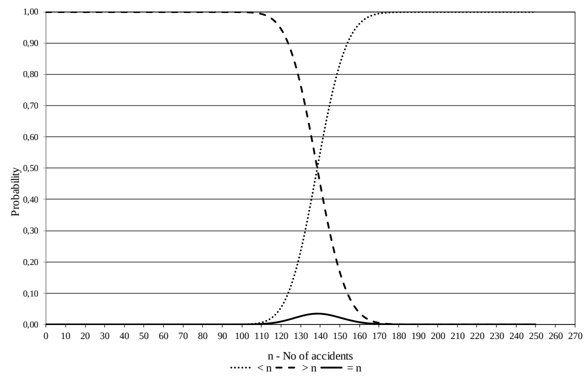

Figure 2: The probabilities of accident occurrence ('equal or more than a certain number', 'a certain number' and 'less or equal than a certain number') on the road as a whole for the period *t* = 365 (days) = 8,760 (h).

In Figure 2 probability curve points to the probability of a certain number of accidents, which is greater, smaller or equal to *n*, in other words, it points to the probability of certain speed of traffic accident occurrence. With probability of 1.0, it can be asserted that the speed of traffic accident occurrence will be greater than 73 and less than 217, i.e. with probability of about 0.9 it can be asserted that the speed of traffic accident occurrence will be between 124 and 154 traffic accidents in 365 days (Figure 2). On an annual basis, the number of 139 accidents has the highest probability of occurrence.

On weekly or seven days basis, with probability of about 0.9 it can be asserted that the speed of traffic accident occurrence will be between 0 and 5. In other words, the number of 2 accidents has the highest probability of occurrence per week.

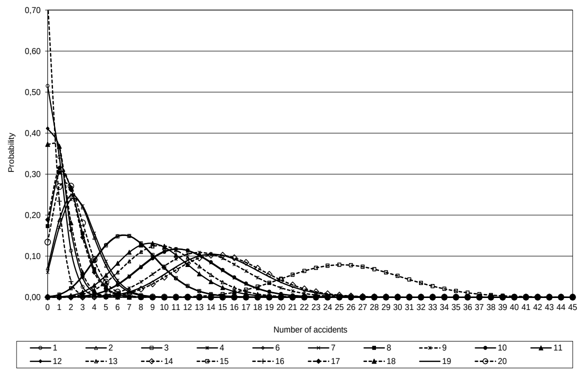

Figure 3: The probabilities of the occurrence of a certain number of accidents on the road sections as units ($P_n(t)$) for the period *t* = 365 (days) = 8,760 (h).

There are obvious differences between shapes of probability curves. Section 15 corresponds to flattened probability curve of a certain speed of accident occurrence, which means that the interval of possible speeds of accident occurrence is wider. On the other hand, all the other curves have prominent peak, i.e. the speed of accident occurrence with greatest probability (Figure 3).

4 DISCUSSION

An overview and detailed analysis of literature in the field of traffic accidents frequency analysis proves that models that observe the time between two consecutive traffic accidents are paid the least attention in the previous research. The advantage of these models is in the ease of application (do not require detailed databases, the application of some of the complicated mathematical tool) and the speed of answering where they first work in order to increase traffic safety. Because of that it useful especially for developing countries that do not have detailed databases.

For road authority it is very important to know which model to implement in order to increase road traffic safety. Models that observe the time between two traffic accidents, unlike other models that are used to analyse the frequency of traffic accidents, require only data on the occurrence of a traffic accident and locality. This model is especially useful tool for the road authority in decision making process on the application of traffic safety measures on the roads. In this way, the responsible person receives information about the road safety in real time. Namely, road authority main mission is to make the time between two consecutive traffic accidents on a road to be as long as possible, or that the accident occurrence rate is as low as possible. The reliability of the road is increased in this way, as well as the traffic flow system.

Earlier models for ranking two independent paths according traffic safety are based on a simple comparison of the number of accidents that occurred in the same defined observation period. The problem occurs when it is necessary to compare the reliability of several roads and when the period during which the data is obtained varies. One of the main advantages of presented model, which is based on analysis of time between two traffic accidents, is a dynamic time component that also allows active real-time operation, and can be applied to data obtained in a relatively shorter time (weeks, months, years). Instead of the passive number of registered traffic accidents that occurred in a given period, the proposed model promotes permanent and active tracking and measurement of the time between two accidents.

ACKNOWLEDGEMENTS

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SELECTION OF THIRD PARTY LOGISTICS PROVIDER (3PLP) CONSIDERING SOCIAL SUSTAINABILITY CRITERIA

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ABSTRACT

To obtain the most sustainable 3PLP possible, all three aspects of sustainability (economic, environmental and social) should be addressed. Social sustainability is an often overlooked criterion of sustainability in the selection of an appropriate 3PLP. The aim of this paper is to put forward the most relevant social sustainability criteria and sub-criteria to take into account when evaluating and selecting a 3PLP. The mixed-methods approach was used starting with an extensive and broad review of the literature regarding social sustainability criteria in the selection of 3PLPs. The detected criteria were then upgraded using generic social sustainability criteria which resulted in a set of social sustainability criteria for selecting a 3PLP. A set of identified criteria was further evaluated and a pair-wise comparison for each single criterion was performed via expert interviews. A hierarchy between the criteria was defined using the Analytic Hierarchy Process (AHP) method. The proposed model of criteria contributes to theory development. Finally, all three groups of sustainable criteria are defined. The model also facilitates managerial decision making and fosters social sustainability capabilities and the performance of 3PLPs.

Keywords: selection, third party logistics provider, 3PLP, third party logistics, 3PL, social sustainability, Analytic, Hierarchy Process, AHP

1 INTRODUCTION

Sustainability is defined as “meeting the needs of the present without compromising the ability of future generations to meet their needs” (Dillard, Dujon, & King, 2008; Hutchins & Sutherland, 2008; Vallance, Perkins, & Dixon, 2011). There are three interrelated pillars of sustainability, ecological, social, and economic (Hutchins & Sutherland, 2008). All three pillars must be addressed in order to achieve sustainable outcomes (Vallance et al., 2011). Social sustainability is the least developed of the three pillars (Dillard et al., 2008). It is therefore evident that increased knowledge and awareness of the social sustainable development are needed (Hutchins & Sutherland, 2008; Vallance et al., 2011).

A supply chain is made up of a number of companies and the sustainability of the whole chain depends on the sustainability of each company. To build a sustainable supply chain, a manufacturer on the leading edge of the supply chain needs to select the most sustainable partners and monitor their sustainable performance. A brief literature review executed by Bajec, Twrdy, & Zanne (2015) found that some partners - namely manufacturers, wholesalers, and suppliers, have already put significant emphasis on sustainability, while the progress of 3PLPs lags behind considerably.

Regarding the fact that 3PLP plays a crucial role in the supply chain (more and more producers decide to outsource all or part of logistical activities) and because the logistics chain contributes considerably to the competitiveness of the supply chain, the article focuses solely on 3PLP and not other partners. The selection of the sustainable 3PLP depends heavily on the identification of appropriate selection criteria. Therefore, the early-bird stage, focused on the selection of the 3PLP by the manufacturer is researched in this paper. And finally, social sustainability selection criteria are highlighted in this study since only Jung (2017) has investigated a third-party logistics (3PL) provider evaluation problem taking social sustainability into consideration in detail. Jung (2017) defined the social sustainability evaluation criteria, further proposed an approach for evaluating criteria but did not exclusively evaluate the social sustainability criteria. This paper aims to fill this gap and ranks social sustainability criteria according to their importance.

2 RESEARCH METHODOLOGY

The mixed-method approach (qualitative and quantitative studies) was integrated in this paper in order to gain a better and deeper understanding of the research problem (Johnson & Onwuegbuzie, 2004). Quantitative data are more objective and result in a numerical representation. Qualitative data, on the other hand, are more subjective but allows for an interpretation of the research problem from the viewpoint of practice.

The paper starts with data collection using a systematic literature review on social sustainability criteria in the selection of a 3PLP. A systematic review provides a level of higher transparency, greater objectivity, includes a broader selection of studies, and reduces researcher bias (Mallett, Hagen-Zanker, Slater, & Duvendack, 2012). A traditional and brief literature review was executed in the next step in order to upgrade the detected set of sustainability criteria with generic sustainability criteria in business. E-mail interviews were then conducted to evaluate criteria and collect additional information regarding sustainability criteria. In the end, that information was used to define a hierarchy between criteria using the (AHP). Finally, a classification of sustainable selection criteria is proposed.

3 LITERATURE REVIEW AND REPORT OF RESULTS

A very extensive and profound review of the literature on selection criteria was conducted. The time window was not limited. The study therefore includes articles published from 1999 (when the first articles in this field began to appear) to 2017.

Only two criteria limited our collection of studies, namely, we chose to include only studies written in English and studies regarding the selection of 3PLPs and no other providers of logistics outsourcing. To collect the greatest number of diverse articles, a three-stage process was followed, presented in Figure 1.

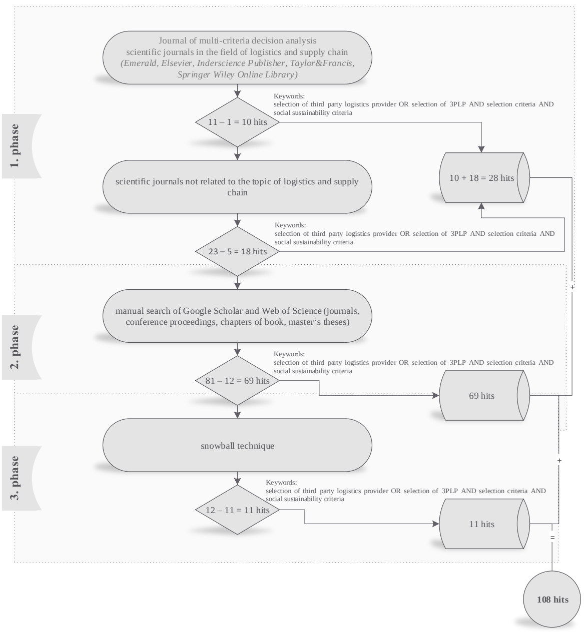

Figure 1: Multi-step approach to select literature

Social sustainability criteria were detected in only 14 of 108 articles. Moreover, only 5 groups of social sustainability criteria were detected (see Table 1):

1. Safety refers to the safety of employees.
2. Security practices ensures that everything complies with the laws of a given country, human rights declaration, fair employment practice standards (Labuschagne, Brent, & Van Erck, 2005).
3. Human resource management is mainly focused on employee training and learning, labor and employee relations, compensation and benefits (group insurance, retirement benefits, sick leave, vacation, profit sharing etc.), performance appraisal and rewards.
4. Human relationships define "for or with whom one works and under what rules. These rules (implicit or explicit, written or unwritten) determine the type of work, type and amount of remuneration, working hours, degrees of physical and psychological strain, as well as the degree of freedom and autonomy associated with the work" (Hofmeester, Lucassen, Lucassen, Stapel, & Zijdeman, 2015).

Table 1: Distribution of the most frequently used social sustainability criteria

Reference	Type of social sustainability criteria
(Hsu, LIAO, YANG, & CHEN, 2005), (Rajesh, Ganesh, & Pugazhendhi, 2013), (Soh, 2010), (Gupta, Sachdeva, & Bhardwaj, 2011)	safety
(Tsai, Wen, & Chen, 2007)	security practices
(Huang & Shieru, 2012), (Göl & Çatay, 2007), (So, Kim, Cheong, & Cho, 2006), (Sahu, Datta, & Mahapatra, 2013)	human resource management, human resource policy
(Leina, Tiejun, & Guoqing, 2010)	employee satisfaction level
(Çakir, 2009),(Rajesh, Pugazhendhi, Muralidharan, & Ganesh, 2009), (Li, Sun, & Du, 2008), (Jharkharia & Shankar, 2007)	human relationships

4 SOCIAL SUSTAINABILITY CRITERIA FROM LITERATURE REVIEW VS. SOCIAL SUSTAINABILITY CRITERIA IN BUSINESS

In order to increase the credibility of the detected criteria (Table 1) and to propose the most useful classification system of social sustainability criteria for selecting a 3PLP, the listed criteria in Table 1 were compared with general social sustainability criteria and sub-criteria in business.

Many articles have been written on general social sustainability criteria in business (Hutchins & Sutherland, 2008; Jung, 2017; Mavi, Goh, & Zarbakhshnia, 2017; Yu, 2016). In particular, the article by Labuscagne, Brent & Van Erck (2005) was found to be particularly helpful both in terms of the business aspect of social sustainability and in the multitude and variety of the literature that has been examined. They proposed a framework consisting of four main groups of criteria, which are further divided into sub-criteria (see Figure 2):

1. Internal human related criteria.
2. External population related criteria.
3. Stakeholder participation related criteria.
4. Macro social related criteria.

A comparative analysis of the criteria listed in Table 1 with criteria listed in Figure 2 revealed that all of the criteria already used for the selection of a 3PLP are included in Figure 2. Their number is very limited, however, and they are all internally (shareholder) oriented. No criterion was found to be externally or stakeholder oriented.

Source: (Labuschagne et al., 2005)

Figure 2: General social sustainability criteria and sub-criteria in business

5 IDENTIFICATION AND EVALUATION OF SOCIAL SUSTAINABLE CRITERIA USING AHP METHOD

Since social sustainability criteria differ across industries (Jung, 2017), several Slovenian experts from the logistics industry and logistics faculties were asked to upgrade the list of criteria in Table 1 with the relevant criteria in Figure 2.

E-mail interviews were conducted during the months of January 2017 to March 2018. Structured interviews were employed. Three 3PLPs, three buyers of logistics outsourcing and three researchers from Slovenia were interviewed. The authors invited their participation by sending them e-mail messages with brief explanation and one multiple choice close ended question (in the first phase) and one rating scale multiple choice questions. 80 % of participants replied to 1-4 follow up e-mails. Only 20 % of participants had more e-mail exchanges.

Participants were interviewed in two separate phases. In the first phase, interviewees upgraded the list of already used criteria. The results of this phase are presented in Table 2.

Table 2: Identification of social sustainable criteria

	Interviewees									
Criteria	1	2	3	4	5	6	7	8	9	10
C_1 −health and safety practices	x	x	x	x	x	x	x	x	x	x
C_2 −security practices (human rights, employment practices)	x	x	x	x	x	x	x	x	x	x
C_3 −equity	x	x	x	x		x	x	x	x	x
C_4 −learning and training	x	x	x	x	x	x	x	x	x	x
C_5 −education								x		x
C_6 −impact on community				x					x	x
C_7 −information shared										
C_8 −impact on the economic system	x		x		x		x	x	x	x

In the second phase, a hierarchy between the criteria was defined using the AHP method. Each interviewed person was contacted again and asked to make a pairwise comparison of the criteria using the nine stage linguistic comparison scale proposed by Saaty (1986). The evaluations obtained were matched in a common comparison matrix using a geometric mean value. Results are presented in a final comparison matrix

$$A=[a_{ij}] \text{ with } i,j=1, \ldots, 8. \quad (1)$$

Then, the priority vector was computed by normalizing the Eigen vector using the arithmetic mean which defines the weights of the elements:

$$w_i = \frac{1}{8}\sum_{j=1}^{8}\frac{a_{ij}}{A_j} \; for \; i = 1, \ldots, 8. \quad (2)$$

where $A_j = \sum_{i=1}^{8} a_{ij}$ for $j = 1, \ldots, 8$;

An approximation of the maximum eigenvalue was computed as:

$$\lambda_{max} = \sum_{i=1}^{8} A_i \cdot w_i \quad (3)$$

The consistency of the comparison matrix was computed using the consistency index defined as:

$$CI = \frac{\lambda_{max} - n}{n-1}, \quad (4)$$

where λ_{max} is the maximum eigenvalue and n is the comparison matrix dimension, in our case 8.

After that, the consistency ratio $\frac{CI}{RI}$ was computed (in case of consistency must be less or equal to 0.1). RI is the random consistency index and $RI = 1.41$ for $n = 8$.

Weights associated with the criteria defined in Table 3 are the components of the priority vector defined by equation (2):

Table 3: Priority vector

Criteria	Priority vector (weights w_i)
C_1 −health and safety practices	0.32
C_2 −security practices (human rights, employment practices)	0.11
C_3 −equity	0.16
C_4 −learning and training	0.22
C_5 −education	0.02
C_6 −impact on community	0.04
C_7 −information shared	0.07
C_8 −impact on the economic system	0.05

It is possible to note that C_1 −health and safety practices, C_4-learning and training and C_3-equity cover up 70 % of the scores, therefore one can see that the other criteria are considered marginal by the experts.

Obtained weights can also be used to define a multi objective goal function as a linear combination of the computed weights and the criteria values.

The obtained goal function evaluates the 3PLP's social sustainability performance, taking into account not only the value of each criterion but also the weight that it has in the overall assessment.

6 CONCLUSION

In this paper social sustainability criteria for selecting 3PLP were addressed. A framework of eight social sustainability criteria, ranked according to their importance was proposed. Health and safety practice criteria was found to be the most important, followed by equity criteria. In third place is security practices, and in fourth place is health and safety practices. Then comes information shared, followed by impact on the economic system and impact on the community. Education criteria is in last place.

C_1 −health and safety practices, C_2-security practices, C_3 − equity and C_4 −learning and training are internally oriented and focused mainly on employees. C_5 −education, C_6 −impact on community, C_7 −information shared and C_8 −impact on the economic system are externally oriented.

The findings contribute to theory development and facilitate managerial decision making when selecting appropriate criteria and also foster social sustainability capabilities and performance of a 3PLP.

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HYDROCARBONS IN THE GULF OF TRIESTE-THE IMPACT OF MARITIME TRAFFIC

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ABSTRACT

Hydrocarbons of natural and anthropogenic origin are widely distributed in the marine environment throughout the world. Maritime traffic is one of the most important sources of these compounds in marine environment. The aim of this study was to assess the impact of maritime traffic on pollution with hydrocarbons. The Gulf of Trieste was used as the investigated area since it is the most urbanized area in the northern Adriatic and characterized by intensive maritime traffic to the ports of Trieste, Koper and Monfalcone.

The distribution, content and origin of aliphatic and polycyclic aromatic hydrocarbons (PAH) in seawater and marine sediments will be presented. Concentrations of both groups of hydrocarbons were higher close to pollution sources (ports, marinas) and they decreased toward the offshore areas. Aliphatic hydrocarbons were of petrogenic and biogenic origin. Petrogenic origin is connected to the pollution by oil and oil products, while biogenic hydrocarbons are derived by rivers or synthesized in the sea by algae and microalgae. PAHs were mainly of two origins, the pyrogenic and petrogenic. Petrogenic PAHs are derived from oil and oil products, while pyrogenic PAHs originate from combustion of organic matter, especially fossil fuels.

Keywords: Hydrocarbons, PAH, pollution, Gulf of Trieste, maritime traffic

1 INTRODUCTION

Hydrocarbons, both aliphatic and polycyclic aromatic (PAH), are ubiquitous pollutants in the environment throughout the world. The most important sources of these compounds are oil seepage, oil spillage, traffic, urban runoff, wastewaters and sewage effluents, as well as atmospheric deposition [1]. Determination of the various sources of the introduction of such compounds into the marine environment as well as the concentrations of these compounds in seawater, sediments and marine organisms is of crucial importance to adequately assess the state of the environment. This is especially important where extensive industrial activity or traffic might be expected. Hydrocarbons, especially polycyclic aromatic hydrocarbons (PAH), have been recognized as hazardous environmental chemicals [1]. Many marine organisms, living in contaminated areas, accumulate hydrocarbons. As a consequence, the elevated concentrations of these compounds in sea food could also be harmful to human health.

Hydrocarbons are hydrophobic compounds. Because of their low solubility in water, they tend to adsorb on organic or inorganic particles in the water column. The enriched suspended matter settles to the sediment surface. Because of this, marine sediments often contain hydrocarbons of higher concentrations than those in the overlaying water. For this reason, sediment samples are usually used for analyses since the concentration in the seawater is usually very low due to the fast dilution.

The aim of the present work was to determine the content and origin of aliphatic and polycyclic aromatic hydrocarbons in seawater and surficial sediments in the southeastern part of the Gulf of Trieste in order to assess the influence of different pollution sources, with the emphasis on maritime traffic.

1.1 Study area

The investigated area in the southeast of the Gulf of Trieste is a part of the northern Adriatic (Fig. 1). The marine environment along the coast is affected by pollution from different sources since this area is one of the most urbanized around the northern Adriatic. The estimated quantity of petroleum carried by ships to the three ports (Koper, Trieste, Monfalcone) in the Gulf of Trieste is about 41 million tons per year. In addition to the intensive maritime traffic, nautical tourism is also well developed (several marinas, 3 of them in the investigated area). The area around the Slovenian coast is also affected by intensive road traffic, especially in the summer period due to developed tourism. Moreover, the marine environment within the studied area receives wastewaters from several sewage treatment plants and fresh water from rivers, which also carry wastewater from local industry, as well as waters which drain rather large agricultural areas.

Figure 1: Sampling sites in the investigated area

2 RESULTS AND DISCUSSION

2.1 Hydrocarbons in seawater

Concentrations of hydrocarbons in surface seawater of the Gulf of Trieste differed markedly in the winter and summer seasons. Concentration of total PAHs in winter ranged from 0.07 µg l^{-1} to 0.73 µg l^{-1} (Table 1). The highest concentration was found in the Marina of Portoroz (Station PM), while the lowest was observed at the offshore site F.

Table 1: Concentrations of hydrocarbons in seawater in the Gulf of Trieste (µg l^{-1}, Chrysene eq.)

Station	Location	Concentration	
		Winter	Summer
PM	Marina of Portoroz	0.73	48.51
MA	Bay of Piran	0.10	0.13
F	Offshore site	0.07	0.10
PK	Port of Koper	0.22	2.05
K	Bay of Koper	0.10	0.14
KK	Cape Debeli Rtic	0.65	0.20
CZ	Center Gulf of	0.09	0.01

Concentrations of hydrocarbons in surface seawater in summer were similar to those in winter, except in the Marina of Portoroz and the Port of Koper, where they were significantly higher. The highest concentrations were detected in the Marina of Portoroz. This is a first confirmation of the impact of maritime traffic (mostly pleasure craft traffic) on the pollution with hydrocarbons in the Gulf of Trieste.

Concentrations of aliphatic hydrocarbons in seawater in the Port of Koper and Marina of Portoroz are presented in table 2. Concentrations of aliphatic hydrocarbons in the Port of Koper are significantly higher compared to those in the Marina of Portoroz. Despite this difference, the maritime traffic could be considered as the main source of these compounds at both investigated areas. A chronic pollution with intensive degradation processes is evident from high amount of the unresolved complex mixture (UCM), as well as from rather high UCM/RES ratio. On the other hand, a continuous fresh input of aliphatic hydrocarbons is also evident from rather high C17/Pri and C18/Phy ratios. The carbon preference index (CPI) confirms the prevailing petrogenic input at station PK, while a somewhat bigger contribution of naturally derived hydrocarbons is shown at station PM. To better estimate the proportions of natural and petroleum n-alkanes, the "natural to anthropogenic ratio" (NAR) was calculated. This ratio is close to zero for petrogenic origin of hydrocarbons, while in the case of naturally derived hydrocarbons it is close to one. In our case, the calculated NAR confirm the prevailing petrogenic origin of hydrocarbons, with a bit higher contribution of the natural origin in the Marina of Portoroz.

Table 2: Concentration of aliphatic hydrocarbons in seawater (ng g^{-1}, d.w., UCM in µg g^{-1}, d.w.) and some evaluation indices

	PK	PM
C14-C34	438933	8082
C17	78860	682
Pri	31420	54
C18	87332	249
Phy	40591	27
RESOLV	510944	8163
UCM	1815.6	97.8
UCM/RES	3.6	12.0
LMW/HMW	2.3	0.2
Pri/Phy	0.8	2.0
C17/Pri	2.5	12.6
C18/Phy	2.2	9.2
CPI	0.8	2.3
NAR	0.11	0.33

2.2 Hydrocarbons in sediments

Concentrations of aliphatic hydrocarbons are presented in table 3 and figure 2. The major component of the aliphatic fraction was the unresolved complex mixture UCM, higher than 90%, which is considered as a mixture of branched aliphatic hydrocarbons, cyclic saturated hydrocarbons and degradation products [2]. The high abundance of UCM at all sampling sites is an indication of chronic oil pollution. The spatial distribution of the UCM indicates important petroleum related pollution sources on the coast (marina, port). The highest concentrations of resolved aliphatic hydrocarbons were observed in the port of Koper (site PK) and marina of Portoroz (site PM). The concentrations then decreased along transects to the central part of the Gulf of Trieste. The lowest content was obtained in the area off Piran (site F). A high predominance of long-chain homologues (C21-C34), deriving from higher plant waxes [3], was observed (more than 90%) at all sampling sites.The biogenic origin of aliphatic hydrocarbons is also evident from high pristane to phytane ratio (Pri/Phy), which is higher than 1 at all sampling sites, except at site 5 in the marina of Portoroz, where a low ratio indicates an important input of petroleum derived hydrocarbons [3].

Table 3: Concentration of aliphatic hydrocarbons in sediments(ng g^{-1}, d.w., UCM in µg g^{-1}, d.w.) and some evaluation indices

Aliphatic hydrocarbons	Sampling site						
	PK	**K**	**KK**	**CZ**	**PM**	**MA**	**F**
n-heptadecane (C17)	47	104	37	51	334	370	45
Pristane	89	55	22	47	8	44	12
n-octadecane (C18)	22	14	7	11	9	9	5
Phytane	36	14	2	9	47	17	1
∑n-C14 – n-C34	2 969	2 019	1 238	1 472	3 104	2 283	665
Total resolved aliphatic	3 094	2 088	1 262	1 528	3 159	2 344	678
UCM	75. 0	47.3	33.9	30.6	40.3	11.1	13.3
Resolved/UCM	0.04	0.04	0.04	0.05	0.08	0.21	0,05
Pri/Phy	2.5	3.9	11.0	5.2	0.17	2.6	12.0
Odd/even ratio	3.7	3.2	3.1	3.1	5.7	4.7	2.6

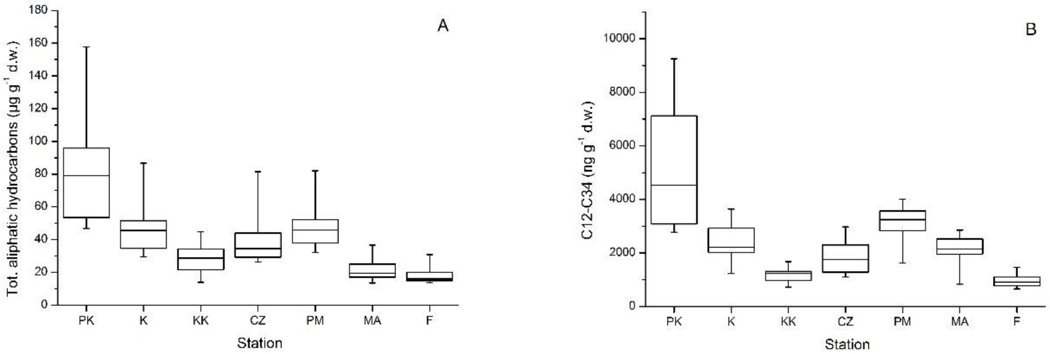

Figure 2: Concentrations of total aliphatic hydrocarbons (A) and resolved aliphatic hydrocarbons (B) in sediments from 2004 to 2013

Concentrations of PAHs are presented in table 4. The highest PAH concentrations were observed at station 5 (Marina of Portoroz). Concentrations in the middle of the Gulf of Trieste (site CZ), Bay of Koper (site K) and in the port of Koper (site PK) were lower, but still higher, compared to site F, which appeared as the least polluted area. The highest PAH concentrations at site PM are associated with the pollution from boats in the marina. This is also a semi-enclosed area with a higher accumulation of pollutants. Concentrations of PAH in the Port of Koper are relatively low, despite the important pollution sources (maritime traffic and port activities). The port area is not so closed and the circulation of water masses is faster, many maintenance activities in the port channels as well as ship screw can mix the surface sediments in the port. This could lead to a decrease in hydrocarbon concentrations.

Table 4: Concentration of polycyclic aromatic hydrocarbons (PAH) in sediments (ng g^{-1}, d.w.)

PAH	Sampling site						
	PK	**K**	**KK**	**CZ**	**PM**	**MA**	**F**
Naphthalene	6	<0.5	9	<0.5	2	8	6
Acenaphthene	1	<0.5	<0.5	5	1	<0.5	1
Acenaphthylene	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	24	23	26	24	35	27	36
Anthracene	3	2	2	2	4	3	2
Fluorene	54	6	5	17	2	9	3
1-methylphenanthrene	17	12	36	6	12	6	8
2-methylphenanthrene	16	2	1	9	6	9	8
Fluoranthene	40	67	39	80	189	36	38
Pyrene	39	68	33	80	170	37	31
Chrysene	49	33	17	58	84	33	20
Benzo[a]anthracene	22	33	17	35	64	19	11
Benzo[b]fluoranthene	33	42	26	48	82	21	19
Benzo[k]fluoranthene	31	40	13	57	99	27	21
Benzo[a]pyrene	15	34	44	92	99	52	22
Indeno[1,2,3-c,d]pyrene	20	37	53	13	94	23	19
Dibenzo[a,h]anthracene	45	42	29	25	107	19	32
Benzo[g,h,i]perylene	31	12	15	28	52	18	13
Total PAH	**446**	**453**	**365**	**579**	**1102**	**347**	**290**

At all the sampling sites, the higher molecular weight PAHs were more abundant compared to the lower molecular weight compounds (Fig. 3). PAHs with 4, 5 and 6 aromatic rings comprised more than 80% of the total concentration. The amount of 2 and 3-ring compounds was higher than 20% only at site PK. This is a first indication of the prevailing pyrolytic origin of PAHs in the investigated area. PAHs with 2 or 3 fused aromatic rings are present in petroleum, while higher homologues are mostly formed during combustion processes [4].

Two origins are usually considered in the case of PAHs, petrogenic (from petroleum) and pyrolytic (combustion of organic matter, e.g. fossil fuels). In the natural environment, we are often dealing with mixed sources, with different prevalence of particular sources. To distinguish between petrogenic and pyrolytic origins, different evaluation indices have been used [5,6].
Table 5 shows different calculated ratios, which are usually used for the determination of the origin of PAHs. The use of these ratios provides information about anthropogenic sources of PAHs. The diagnostic ratios, presented in table 5, revealed that PAHs in sediments of the investigated part of the Gulf of Trieste are mostly of pyrolytic origin. Some ratios, which do not fit exactly in the proposed range for pyrolytic origin, indicate a minor contribution of a petrogenic source.

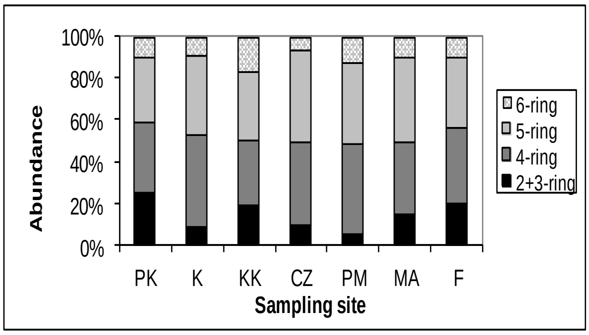

Figure 3: Distribution of PAHs in sediment samples according to the number of aromatic rings

Table 5: Some diagnostic ratios for the determination of PAH origin

Sampling site	Ratio			
	LMW/HMW	PHE/ANT	FLTH/PYR	BaANT/CHR
PK	0.35	8	1.02	0.45
K	0.10	11	0.99	1.00
KK	0.24	13	1.18	1.00
CZ	0.11	12	1.00	0.60
PM	0.06	9	1.11	0.76
MA	0.17	9	0.97	0.58
F	0.25	18	1.23	0.55
Pyrolytic	<1	<10	>1	>0.9
Petrogenic	>1	>15	<1	<0.4

3 CONCLUSIONS

Results of the present study revealed that maritime traffic is an important source of contamination by hydrocarbons in the Gulf of Trieste. Its impact seems to be rather limited to areas near the contamination sources. Concentrations of hydrocarbons are higher near the expected sources and still elevated in the adjacent offshore areas. This is more pronounced in the northern part of the Gulf of Trieste (ports of Koper and Trieste). Results show fresh inputs of aliphatic hydrocarbons and intense degradation processes. The impact of maritime traffic in terms of PAH concentrations and distribution is not so uniform. In general, concentrations are higher close to contamination sources and the petrogenic PAH origin is not negligible. However, the prevailing origin is pyrolytic, with an important input from other sources on the coast. Nevertheless, the investigated area is only moderately polluted with hydrocarbons, despite the important pollution sources. Among them, the maritime traffic appears to be quite important.

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CONCERNING SOME SIMULATION TECHNIQUES IN ASSESSING SHIP'S HULL DETERIORATION DURING ITS EXPLOITATION

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ABSTRACT

In the paper it will be presented some possibilities of using simulation techniques like Monte Carlo simulation in the prediction of degradation of a ship's hull during its exploitation. It will also be shown that multi-criteria linear regression analysis can model, with some approximations, functional dependence between the hull structural deterioration (dependant variable – D.V.) and the time of ship's exploitation, the frequency of preventive maintenance, as well as the type of cargo being transported (independent variables – I.V.1,2,3). In order to carry out these analyzes, secondary literary sources and the appropriate data bases with homogeneous historical data on ship's hull degradation will be used, along with the results of the interviews being carried out among a number of the practitioners and the experts in the field from the maritime academic community. Therefore, through the combination of technological and physical measurements in situ and the professionals' empirical and intuitive assessments, two different approaches or models will be proposed.

Keywords: Ship's hall structural degradation, simulation techniques, physical measurements, experts' assessment

1 INTRODUCTION

The corrosion is one of the most important factors affecting structural safety and integrity of ageing bulk carriers. The extension of the bulk carriers' operational life requires permanent measurements of the steel plates' thickness. For commercial ships, like bulk carriers, the corrosion waste is usually measured by the classification society, through regular ships' surveys [1]. Besides the regular steel thickness measurements, corrosion protection measures are necessary, as well. These measures include paint coatings and sacrificial anode systems for immersed areas. Since these measures are not always wholly effective, continual maintenance is required, but not always applied [9]. In order to provoke and support more intensive maintain measures, several bulk carriers' time-variant corrosion losses probability models have been developed [15-18]. However, the researchers in this domain are usually faced with some serious difficulties, like: very complex nature of the interaction of the ship with its environment, the interaction between the different parts of the ship's hull, the insufficient data for the ship's hull structures deterioration caused by the corrosion, and the lack of the data about the changes of the mechanical properties of the shipbuilding material during its operation and reparations [11;12]. The large scattering of the data obtained by the different established corrosion probabilities, or time-dependant models has been noted. Additionally, most of the corrosion prediction models for the ships take little or no account of the operational parameters, and profile of the ships. Consequently, we did an effort through the analysis being presented in this article to stress the operational parameters that commonly affect the structural safety and stability of ageing bulk carriers' structural member locations (areas/zones) and intensify corrosion processes onboard. The particular attention has been devoted to the type of cargo (*Approach 1*). Also, an attempt has been made towards setting a functional dependence between corrosion waste, from one side, and time of ship's exploitation, frequency of preventive maintenance, and type of cargo it carries, from another side (*Approach 2*).

2 APPROACH 1: METHODOLOGY AND RESULTS

In the previous probabilistic analysis of the corrosion losses over aging bulk carriers, it has been shown that the considered data exhibit great scattering [3-8;9;10;13;14]. The same was with the data which were available for the purpose of this research. Namely, we have been in position to realize some probabilistic analyses over 21 aging bulk carriers, i.e., over 1841 gauged points. The analyzed set of corrosion losses we have divided into four groups: those belonging to the 20 years old bulk carriers, which have transported grain and iron cargo, and to the 25 years old bulk carriers, which have also transported grain and iron cargo. The collected data set represent the corrosion loss in the form of corrosion depth [mm]. The data are provided by UTM Company Invar-Ivosevic, Ltd. It was difficult to fit the data collected by regular and standardized ships' measurements on site to the most commonly used Weibull distribution, which usually, along with normal and lognormal distribution, best fits the corrosion wear over ageing bulk carriers [15-18]. Consequently, it was necessary to find out a way of pre-processing the collected data in an attempt to fit them better into Weibull distribution function. For that purpose, a generator of random numbers based on Weibull distribution:

$$f(x) = \frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1} \exp\left(-\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right)$$

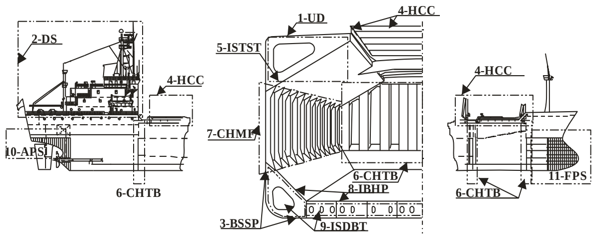
where,

α - continuous shape parameter ($\alpha > 0$);

β - continuous scale parameter ($\beta > 0$); and,

γ - continuous location parameter ($\gamma \equiv 0$ yields to two-parameter Weibull distribution), has been used. The proposed algorithm should be explained as follows:

- Inserting into the Excel worksheet measured values of the corrosion depth [mm], over the ageing bulk carriers' inner bottom and hopper plating member locations (Figure 1);
- Generating random numbers for the inverse Weibull distribution function with predefined subjectively estimated distribution parameters (α, β, γ);
- Examining where the measured values of corrosion wear in situ correspond to the pseudo randomly generated numbers, and then forming the new series of those values;
- Identifying the frequencies of appearing of each different measured values in the new-formed series; and,
- Finally, by the EasyFit software (ver. 5.6), finding out which of the distributions within the software database best fits the selected data from the set of measured values, while the selection of the data was done, as it is still noted, in accordance with randomly generated numbers from inverse Weibull distribution law [8].



Legend: UD-Upper deck; DS-Deck superstructure; BSSP-Bottom and side shell plating; HCC-Hatch cover and coamings; STST-Structure in top side tanks; CHTB-Cargo holds transverse bulkheads; CHMF-Cargo holds main frames; IBHP-Inner bottom and hopper platting; ISDBT-Internal structure in double bottom tanks; APS - After peak structure

Figure 1: Key areas of the bulk carrier hull

Afore listed steps have been realized by the Excel special function NTRANDWEIBULL (α,β,γ), Excel imbedded functions: LOOKUP (value, range) and COUNTIF (range, criteria). The function NTRANDWEIBULL returns Weibull pseudo random numbers. From another side, the LOOKUP (value, range) function returns values from the input data set on corrosion losses being measured in situ that belongs to the corresponding random numbers intervals being generated from inverse Weibull distribution. The whole process of finding out the correlation between measured values and random generated numbers has been in accordance to Monte Carlo simulation method [2]. The results of these simulation experiments are shown in Tables 1 and 2. The main structural features of the previously listed eleven member locations of bulk carriers (Figure 1) are described in more details in [4-7]. Some operation parameters that usually affect bulk carriers' member locations are described in [10;20-22], and they are listed here: sea water, ballast water, fuel, cargo, open atmospheric conditions, semi-closed, or voided spaces, manipulative equipment, maintenance, contact zones, temperature, etc. In this research work, emphasize is put on the type of cargo. Through the authors' previous research work [3-8], it has been found out that the most sensitive and vulnerable member location of aging bulk carriers is the inner bottom and hopper platting. Namely, during the operational cycles of ships, they carry various kinds of more or less corrosive cargo. The physical and mechanical properties of materials: density, bulk angle, the coefficient of friction, sulfur content, moisture, etc., are some of the factors that influence the progress of the corrosion process. More corrosive cargo will cause early removal of surface coatings (e.g., coal, iron ore), while the less corrosive materials (e.g., grains) contribute to a slight acceleration of the corrosion process. Increased frequency of cargo exchanges will also requires more frequent use of manipulative equipment. The use of manipulative equipment with heavy burden (heavy shovels and loading bucket) will contribute to the earlier removal of surface protection over some ships' member locations. Intensive operations with the corrosive cargos will require adequate maintenance system, whose absence will speed up the corrosion degradation.

Table 1: Corrosion losses - historical data: Grain cargo

20 years of exploitation: Grain cargo			25 years of exploitation: Grain cargo		
Corr. loss [mm]	Freq. of app.	Probab.	Corr. loss [mm]	Freq. of app.	Probab.
0.0	6	0.010753	0.0	0	0.000000
0.1	41	0.073477	0.3	0	0.000000
0.2	0	0.000000	0.4	0	0.000000
0.3	24	0.043011	0.5	0	0.000000
0.4	38	0.068100	0.6	0	0.000000
0.5	32	0.057348	0.7	0	0.000000
0.6	50	0.089606	0.8	0	0.000000
0.7	0	0.000000	0.9	0	0.000000
0.8	53	0.094982	1.0	0	0.000000
0.9	0	0.000000	1.1	1	0.004202
1.0	18	0.032258	1.2	1	0.004202
1.1	28	0.050179	1.3	2	0.008403
1.2	27	0.048387	1.4	0	0.000000
1.3	20	0.035842	1.5	3	0.012605
1.4	25	0.044803	1.6	0	0.000000
1.5	15	0.026882	1.7	2	0.008403
1.6	21	0.037634	1.8	6	0.025210
1.7	11	0.019713	1.9	11	0.046218
1.8	12	0.021505	2.0	18	0.075630
1.9	15	0.026882	2.1	16	0.067227
2.0	13	0.023297	2.2	24	0.100840
2.1	18	0.032258	2.3	35	0.147059
2.2	8	0.014337	2.4	31	0.130252
2.3	11	0.019713	2.5	25	0.105042
2.4	8	0.014337	2.6	26	0.109244
2.5	4	0.007168	2.7	18	0.075630
2.6	4	0.007168	2.8	10	0.042017
2.7	9	0.016129	2.9	9	0.037815
2.8	4	0.007168	4.2	0	0.000000
2.9	17	0.030466	4.6	0	0.000000
3.1	24	0.043011	4.7	0	0.000000
4.6	1	0.001792	5.2	0	0.000000

Cleaning and scraping double bottom cover, or inner bottom and hopper platting will contribute significantly to earlier removal of surface protection of the steel plates of ships' holds, so that the corrosion process begin much earlier over this hull structure member area than with other structural elements and areas. A large number of strokes caused by the handling equipment over the double bottom produce the deformation of the steel plate covering the double bottom, which will cause cracking of the surface protection to the underside of the steel plate inside the tank. Due to intense ballasting and shifts wet and dry cycles, the early crack of the surface protection will contribute accelerating the corrosion of steel plate from bottom, or from the ballast tanks. Thus, the intensive corrosion process will occur in these structural areas on both sides, upper and lower, which is not the case with other constructive areas. That is why the intensity of corrosion of the inner bottom and hopper platting structural zone is much higher than over other zones.

Table 2: Corrosion losses - historical data: Iron cargo

20 years of exploitation: Iron cargo			25 years of exploitation: Iron cargo		
Corr. loss [mm]	Freq. of app.	Probab.	Corr. loss [mm]	Freq. of app.	Probab.
0.0	6	0.075949	2.5	1	0.001473
1.8	9	0.113924	2.6	0	0.000000
2.2	0	0.000000	2.7	0	0.000000
2.3	6	0.075949	2.8	0	0.000000
2.4	4	0.050633	2.9	1	0.001473
2.5	1	0.012658	3.0	0	0.000000
2.6	25	0.316456	3.1	1	0.001473
3.0	6	0.075949	3.2	1	0.001473
3.1	2	0.025316	3.3	2	0.002946
3.2	4	0.050633	3.4	0	0.000000
3.3	4	0.050633	3.5	0	0.000000
3.4	4	0.050633	3.6	1	0.001473
3.5	3	0.037975	3.7	2	0.002946
3.6	3	0.037975	3.8	2	0.002946
3.7	1	0.012658	3.9	9	0.013255
3.9	1	0.012658	4.0	11	0.016200
4.0	0	0.000000	4.1	21	0.030928
4.1	0	0.000000	4.2	18	0.026510
4.2	0	0.000000	4.3	23	0.033873
4.3	0	0.000000	4.4	33	0.048601
4.4	0	0.000000	4.5	46	0.067747
4.5	0	0.000000	4.6	47	0.069219
4.7	0	0.000000	4.7	48	0.070692
-	-	-	4.8	65	0.095729
			4.9	89	0.131075
			5.0	82	0.120766
			5.1	68	0.100147
			5.2	52	0.076583
			5.3	32	0.047128
			5.4	16	0.023564
			5.5	8	0.011782

2.1 Weibull probability based model of corrosion losses

Within this subsection are presented some of the numerical and graphical results obtained by NTRANDWEIBULL function, which is imbedded into Excel, and combined with the Monte Carlo simulation concept of generating random numbers, along with examining how these random generated numbers correspond to the measured values of corrosion wear over inner bottom and hopper platting member location of analyzed aging bulk carriers. Thus, probabilistically have been analyzed the data on the corrosion losses over ageing bulk carries within two different points of time, i.e., after 20th and 25th year of the ships' exploitation. Both bulk carriers for grain and those for iron ore have been taken into the consideration. Since the greater wear of the bulk carriers' structure steel due to the corrosion is observed over the ships which carry the iron ore, than over those carrying grain, these two groups of bulks were treated separately by the previously proposed probabilistic and simulation methods, and the following results have been obtained:

- In the case of 20 years old bulk carriers, which carry grain and iron ore the model of corrosion losses over inner bottom and hopper platting area is developed by Weibull probability function (Figures

2 and 3). The parameters of the Weibull distribution are: (a) for grain: $\alpha = 1.4954; \beta = 1.4744$; (b) for iron ore: $\alpha = 5.4571; \beta = 2.9741$

- In the case of 25 years old bulk carriers, which carry grain and iron ore the model of corrosion losses over inner bottom and hopper platting area is developed by Weibull probability function in the same manner (Figures 4 and 5). The parameters of the Weibull distribution are: (a) for grain: $\alpha = 9.2124; \beta = 2.4513$; (b) for iron ore: $\alpha = 15.762; \beta = 4.9708$.

These probabilistic data may be the subject of further more rigorous analysis, but, they can give a general overview how and to which extent corrosion affects ageing bulk carriers in the certain point of time. It becomes obvious that the corrosion wear rapidly grows with time, which the ship spends in exploitation. Namely, the parameter beta of Weibull distribution considerably grows as the time of service becomes longer. As well, the corrosion losses are much more in the cases when bulk carriers were used for the transportation or dense cargoes like iron ore, than in the cases when they were used for the transportation of grain and other smallness, or dusty bulk cargos. By the proper modifications in the input data set (exactly measured values of the corrosion losses on site) it is achieved that some of the collected data well fit into the Weibull distribution function that can be used later effectively for predicting corrosion depth depending on time which bulk carrier spent in service. The modifications are based on matching the collected data by those randomly generated from the inverse Weibull distribution with arbitrary chosen parameters. This model might be proposed as rather general one for pre-processing data, which are likely to be properly fitted to the Weibull distribution function.

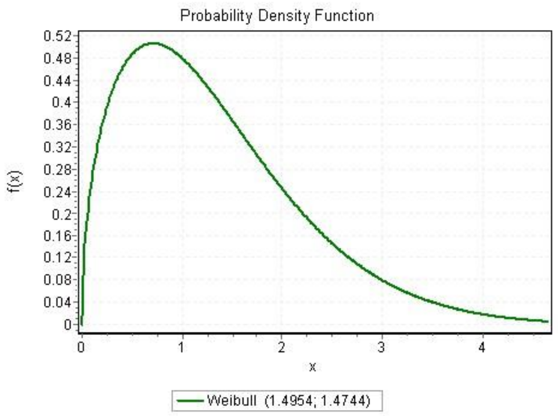


Figure 2: Corrosion loss - 20 years of bulk carriers' exploitation - grain cargo (Mean value: 1.3 [mm])

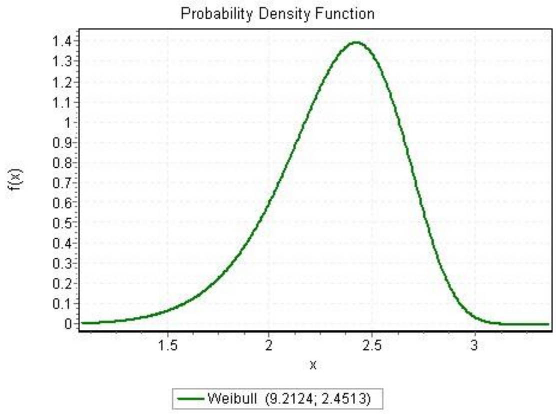


Figure 3: Corrosion loss - 25 years of bulk carriers' exploitation - grain cargo (Mean value: 2.7 [mm])

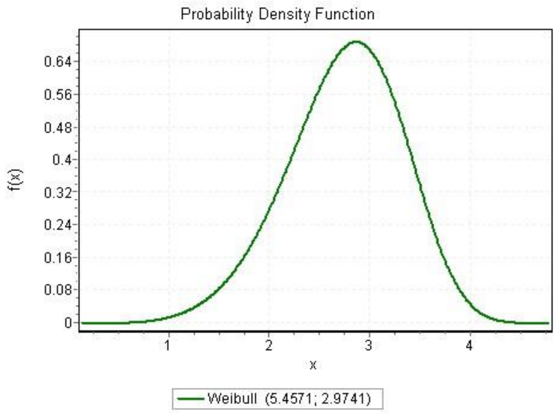


Figure 4: Corrosion loss - 20 years of bulk carriers' exploitation - iron cargo (Mean value: 2.3 [mm])

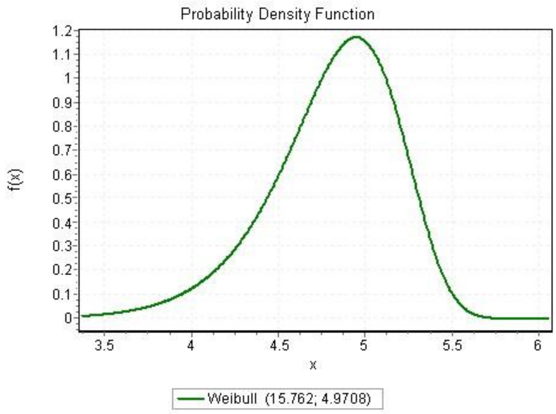


Figure 5: Corrosion loss - 25 years of bulk carriers' exploitation - iron cargo (Mean: 4.8 [mm])

3 APPROACH 2: METHODOLOGY AND RESULTS

Unlike the previously proposed approach, based on precise measurements of corrosion losses over the most sensitive part of the ship's hull, this approach is based on an intuitive assessment of the influence of some corrosion factors on the hull safety and stability. A pilot study was conducted over 50 responders: 10 practitioners and experts in the field and 40 postgraduate students at Maritime Faculty Kotor of University of Montenegro. The responders were supposed to estimate by one number of Likert's scale (from 1 to 5), the significance of corrosion for ship stability, as well as the importance of impacts like time of ship's exploitation, frequency of preventive maintenance and type of cargo. The students from the Department of Maritime Studies were selected as responders, besides the professionals and experts in the field, and they were previously familiarized with the issue and referred to the relevant literature sources. Based on the responses, with the aid of Excel-Modules imbedded functions, an attempt has been made to establish multiple linear dependence between the dependent variable (D.V. – hull structural deterioration caused by general corrosion) and independent variables (I.V.1,2,3 – time of ship exploitation; frequency of preventive maintenance; and type of cargo). In Table 3 and in Figure 6 are given the obtained results. According to the results given in Table 3, one can conclude that the multiple regression linear functional dependence between dependent and independent variables in the model is as follows:

D.V.=0.353·I.V.1+0.536·I.V.2+0.293·I.V.3-0.622

Where

D.V. – is ship hull structure deterioration caused by general corrosion;

I.V.1 – is time of ship exploitation;

I.V.2 – is frequency of preventive maintenance; and, I.V.3 - is type of cargo.

Based on the data in Table 3, we can conclude the following:

- Mean absolute percentage error (MAPE) is low, i.e., 7.08%;
- D.V. values can vary based on standard error of regression estimate (SE) for the values +/- 0.388;
- Correlation coefficient value (r) is above 0.6, i.e., 0.793. So we can conclude that the established linear dependence is strong;
- Coefficient of determination (r2) indicates that 63% of the dependent variable variations is explained by three considered independent variables, which is quite high percentage.

Due to the Figure 6, it can be concluded that variations between actual and forecast values of the multiple linear regression model are rather small and that the model shows satisfying level of accuracy.

Table 3: Multiple linear regression model values

Parameter	Value
b_0	-0.622
b_1	0.351
b_2	0.536
b_3	0.258
MAPE	7.08%
SE	0.388
r	0.793
r^2	0.630

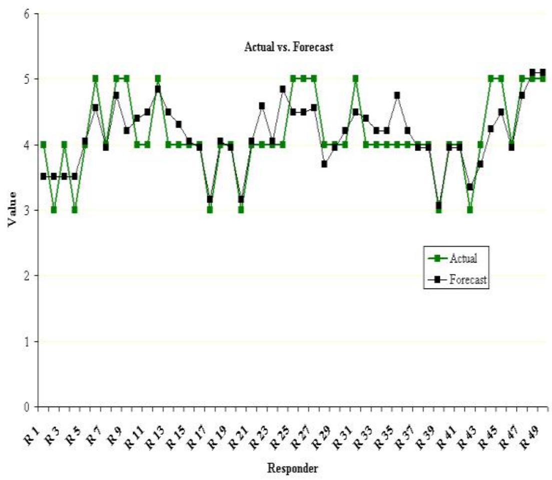


Figure 6: Causal model plot

4 CONCLUSIONS

The paper presents two approaches to assessing the corrosion damage impact on ship's hull stability and safety. The first approach is based on exact measurements of corrosion losses over the ships that have been in service for a number of years (20 and 25 years). The predictive model for damage assessment has been based on Monte Carlo simulations and random number generator based on Weibull distribution. The obtained results fit quite well into Weibull distribution, which shape parameter is greater than 1 in all analyzed cases. This clearly indicates that the failure (damage) rate increases with time. It is characteristics for an aging process, or parts that are more like to be damaged as time goes on. By the second applied approach, it has been experimentally demonstrated that by multiple linear regression analysis, the satisfactory functional dependence between corrosion deterioration and factors, as: time of ship exploitation, frequency of maintenance, and type of cargo, can be established. For further research, a larger base of homogeneous historical data on corrosion losses should be available, collected over various segments of the bulk careers at different time intervals during their exploitation, when it comes to the first used approach. In the second case, the number of responders should be larger and more diversified. In such manner, a more reliable multiple linear regression model could be developed.

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GNSS JAMMER DETECTION, CLASSIFICATION AND SPECTRUM ANALYSIS

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ABSTRACT

The radio signal at 1575.42 MHz (the L1 GPS frequency) was monitored for the presence of the eventual GNSS jamming devices at the toll station on the Slovenian A1 highway using a SDR (software defined radio) receiver device. An abnormal behavior triggered the acquisition of the signal in the bandwidth of 2 MHz around the central frequency for the later post-processing and analysis. For each such event the power frequency distribution was calculated. The power spectrum analysis was then used as a basis for the classification of the various jamming devices. The task was particularly challenging because of the narrow acquisition bandwidth of the SDR receiver (2 MHz), while the jammer transmission bandwidth is typically few 10 MHz wide.

Keywords: jamming detection, software defined radio, spectrum analysis

1 INTRODUCTION

GNSS jamming and spoofing have attracted much attention in the recent time. Specially the latter has gained a great amount of media coverage after the (in)famous Iranian deflection of a US Army drone RQ-170 in 2011 [1]. However, at present in transportation GNSS spoofing is of a least concern. The main reason is probably that there are no spoofers on the market commercially available and mostly are in the domain of research and military facilities, although there are already some open source solutions available on the web [2], that however still require some programming skills (beside a SDR transmitter). The situation might change soon. There have been reports of increased demand of spoofers among Uber drivers [3]. Jammers on the other hand are widely available, low priced and mass produced although illegal in most countries.

The motivation of using the jammer varies among users. With the availability of low priced GNSS (which means almost exclusively GPS) acquisition devices there has been a dramatic increase of GPS based solutions like tracking, geo-fencing, tolling, including demands for satellite positioning in advent of autonomous driving. It is common to all of the jammer users that they want to somehow obfuscate their real physical position. A possible reason for the increment of the jamming devices could be attributed to their will to fraud their employer or contractor, although there could be legitimate uses (yet still illegal) as well.

The increasing awareness of the presence of such devices arose the need of their detection. At the moment there is no mass produced jamming detection device on the market available and the existing ones are very expensive [4], [5].

This is why we sought for a solution that would be low priced and simple. For this reason, we choose to use a software defined radio (SDR) based on a modified DVB-T USB dongle with the popular RTL 2832U chipset.

The jammer detector was installed in a building at one of the toll stations on the Slovenian A1 highway (see Fig. 1). The results represent the measurements taking place from 2/14 till 3/14/2018.

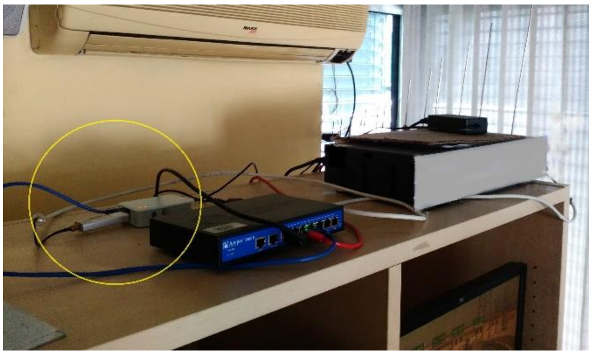
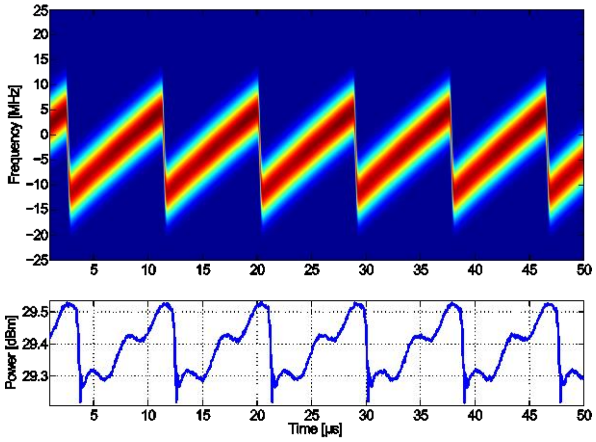


Figure 1: SDR with Raspberry-Pi after installation

2 BASIC PRINCIPLES

SDR signal acquisition is based on directly sampling the in-phase and quadrature signal at some intermediate frequency (IF) and performing the post-processing in software. It has become very popular in recent times because of mass produced low priced acquisition (and even transmission) devices, specially the USB dongles based on the RTL 2832U chipset. In our case it was combined with the R280T2 tuner. According to the tuner's datasheet [6] the maximum tuning frequency should be 1000 MHz. However, with the proper thermal power dissipation the acquisition range can be extended up to 1600 MHz and above [7], just enough to monitor the GPS L1 frequency band. It should be stressed out that the R280T2 produces a very low DC offset.



Source: Borio et al. [4]

Figure 2: Spectrum (waterfall representation) and emitted power of a typical GPS jammer

Virtually all of the GPS signal jammers emit a chirp-like signal (see e.g. Fig. 2) extending over a frequency band of few 10 MHz around 1575.42 MHz with a period of an order of magnitude of 10 µs [4], [8]. The downside of using such a low budget SDR device is that it comes its own limitations and instabilities. In our particular case this was the sampling rate of 2 million samples per second (the dongle is able to go slightly beyond this limit for the price of a drastic increase of the rate of dropped samples). According to the Nyquist-Shannon sampling theorem (in-phase and quadrature signals up to 1 MHz can be acquired without aliasing) that would impose a frequency band limit of 2 MHz (1 MHz in each direction from IF) which is far below the frequency width needed to properly acquire the entire signal. Furthermore, the signals between the band limit and the LPF cutoff frequency will manifest as aliases in the band of interest.

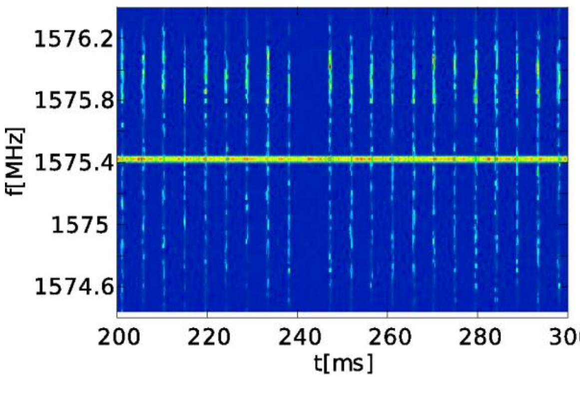


Figure 3: Waterfall (linear) representation of the acquired jamming signal

Keeping those limitations in mind a spectral distribution can be calculated on a larger time scale and finer frequency scale. As it can be seen from figure 3, various parameters can be deduced as the rate of jamming signal emission, the duration of the chunk ... Unfortunately, for a detailed spectrum a sampling rate of at least 40 (preferably 60) million samples per seconds would be needed.

3 ACQUISITION TRIGGERING

Even with a sampling rate of 2 MSps (for each of the in-phase and the quadrature signal) on an 8-bit ADC a large amount of data is produced at a high rate. In order to keep the stored measurements within reasonable limits a triggering mechanism should decide whether the acquired data should be recorded. In the beginning the triggering condition was based on received power only. Although this showed to be just enough to capture the most problematic signals it sometimes missed the weaker ones. It should be mentioned in this place that although the jamming signal should be strong enough to cover the genuine GPS signal at the receiving device in the vehicle, its strength could fade out quite a bit at a far distance. For this reason, the triggering mechanism was somehow modified. The signal in the narrow band around the central frequency (1575.42 MHz) was dropped out from the total power calculation. This allowed for lowering the threshold power level, because the DC offset and the genuine signal (assuming the FFT bin width to be long enough) were not included in the calculation. This way much weaker signals could be detected.

Although such an approach seems to use a lot of computational power on a first look, it is in fact really simple if two simplifications are used. The first is the Parseval's identity stating that the power in the time domain is proportional to the power in the frequency domain. And the second is that the value of the Fourier transform at the zero frequency (in this case the downconverted IF) is just the sum of all the values in the selected window. This allows for a very simple computation of a quantity *T* that is proportional to the out-of-band power level:

$$T = N \sum_{n=0}^{N-1} i_n^2 + q_n^2 - \left(\sum_{n=0}^{N-1} i_n \right)^2 - \left(\sum_{n=0}^{N-1} q_n \right)^2$$

where *N* is the number of samples in the particular bin (262144 in this particular case), *i* and *q* are the in-phase and the quadrature signals respectively in time domain. With such an approach the trigger condition can be calculated even on computationally weaker embedded devices (e.g. Raspberry PI), since no FFT or other computationally intense calculation is needed in real time.

4 TIME DISTRIBUTION

As it can be seen from figure 4 that the number of detected events is quite evenly distributed among the days of the week with a variation of less than 30%. A slightly increased activity is detected on Mondays that decreases till the mid of the week and then slowly increases till the end of the week. Sundays do not follow this pattern and show a slightly lower activity which is not surprising.

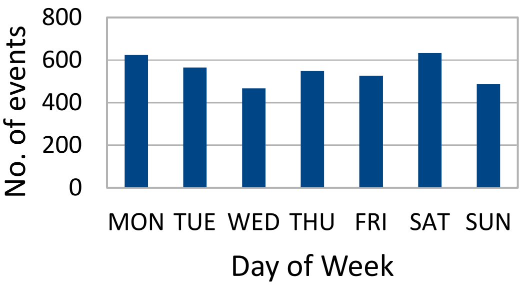


Figure 4: Distribution of the events with respect to the day of the week

On the other hand, the distribution of the events based on the time in a day show an interesting behavior (see fig. 5).

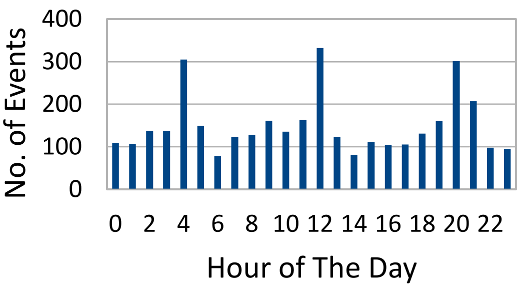


Figure 5: Distribution of the events with respect to the hour of the day

There are three very pronounced peaks at 4-5am, 12am-1pm and 8-9pm. It is hard to interpret this data on its own. Even the cross correlation between the day of the week and the hour of the does not give a definitive answer. For instance, if only the events between 4pm and 5pm (the first peak) are to be taken into account, there is an increased activity only on Mondays and Saturdays, while the events between 12am and 1pm happen to be more frequent on Sundays and Fridays. The peak in the evening (8-9pm) on the other hand is evenly distributed on all working days with lower activity on Saturday and Sunday.

5 SPECTRAL ANALYSIS

The acquisition program was written in plain C using librtlsdr library (version 0.5.3-3). The SDR device was rtl-sdr v3 (using R820T2 tuner). AGC was turned off and the gain was set to its maximum (49.6 dB).

The acquired signal was not postprocessed in real time, since it was running on the popular Raspberry PI (model 1B) platform running Raspbian that does not have the appropriate computational power. Instead, it was saved on the local SD card. From there a cron job connected to a working station once a day via a SSH tunnel and moved all the data there.

The discrete Fourier transform of the acquired data was then calculated. The window size was selected such that the frequency and the time resolutions were within reasonable boundaries. A value of 1024 or 2048 seemed a sensible choice, since the sampling rate was 2 MHz. That allowed for 1 kHz frequency and 1 ms time resolution.

Due to a large number of recorded events and the lack of an automation algorithm a full classification has not been established yet. However, from the sampled events the following classes emerged.

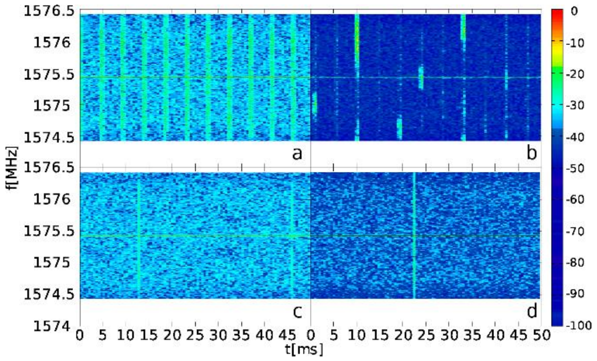


Figure 6: Typical representatives of the collected jamming events in the logarithmic (level based) waterfall representation: periodical (class a), random (class b), continuous (class c) and single shot (class d)

As it can be seen from fig. 6, the inspected events can be classified in four major classes. The first class of jammers periodically emits a chunk of some sort of signal (supposedly chirp) with an almost uniform spectrum within the frequency band in question. The second class of jammers has a pretty much random pattern in terms of central frequency but periodic in time. The chunks are narrow band. In the third class fall all the jammers that emit a continuous broadband signal. And the last class of jammers includes all the devices that emit an isolated broadband shot with a very slow rate (order of 10 per second). This is why the name single shot jammers was implied.

In order to analyze all of the recorded events an automatic recognition algorithm is being developed in order to build a statistical database and to eventually spot potential jamming events that could not fit in any of the classes mentioned above.

6 CONCLUSION

The presented work forms a base for a more systematic approach to the jamming device detection and jamming signal analysis. The frequency of detected events superseded all the expectations. For such a big number of the detected events a manual inspection is clearly not an options. For this reason, the first step would be to develop an automatic classification algorithm.

Although the presented analysis showed that even with a low budget hardware some rough conclusions could be done, it is clear that the limitations such a hardware presents call for a more sensitive equipment. The next step in this direction would be to try the same acquisition with a SDR device with a much faster sampling rate (like HackRF, BladeRF, SDRplay ...).

There is also much to be done on the hardware side, like the antenna optimization. So far passive log-periodic type of antenna has been used. This soon involves simultaneous acquisitions of different polarizations.

ACKNOWLEDGMENT

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DEVELOPING ROAD FEEDER SERVICE FOR SUPPORTING LCL BUSINESS IN THE EASTERN ADRIATIC REGION

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ABSTRACT

The research analyses actual development of LCL (Less than Container Loads) business in the eastern Adriatic region and highlights the possibilities for inland network optimization. LCL operators experience a lack of regular volume of inbound and outbound shipments that would support the establishment of direct services and facilitate inland delivery up to the main economical basins in the eastern Adriatic region and vice-versa. On this basis, three options of oncarriage services from the port of discharge (POD) are elaborated from the costs and service perspective.

The first option, to transport full containers (FCL) directly from POD to different cities in the eastern Adriatic region is compared to Full Truck Load (FTL) transport. Different variables in service set-up and main bottlenecks are highlighted. Namely, FTL technology requires additional handling of LCL consignments and causes higher time consumption. However, shipment combination possibilities and last mile transport flexibility can provide better services to LCL products. Finally, using a Less than a Truck (LTL) service is the third option. A vast number of LTL services already exist in SE Europe that use different cross-docking freight stations (CDFS) in the Balkans. The combination of these services secures a wider Road Feeder network, with high frequency of services and a higher degree of flexibility. All three options are compared from the point of view of total costs to understand the "all-in" freight policy of LCL products and to enable the development of competitive LCL service in the region.

Keywords: Intermodality, container, LCL – less than a container load, LTL – less than a truck load

1 INTRODUCTION

Container transport, as is widely known, increased drastically on the global scale over the last ten years. The total weight of cargo transported by container vessels surpassed 1.7 billion tons in 2016. At the same time all container ports handled almost 700 mil. TEU that represents 57.8% increase from the year 2006 (Drewery, 2017). Containerization and hence intermodal transport have been achieving constant growth. This is evident in the ports of the eastern Adriatic coast. The port of Koper achieved a throughput of 911,528 TEU in 2017, with strong growth of 8.9% over 2016. The Rijeka port also achieved growth in the throughput of containers. The port handled 210,377 TEU in 2017. These ports are important entry points for the national market, but they also have an important regional role. Nowadays, the gravity area of the port of Koper stretches deeply into the markets of central and SE Europe, while the gravitational area of the Rijeka port covers predominantly eastern areas, the markets of Bosnia & Herzegovina and Serbia.

With such an extension of gravitational areas, both ports' positions are interesting for the operation of Less than a Container Load (LCL) services, as they can play the role of consolidation and deconsolidation hubs for smaller overseas cargo consignments. LCL transport combines several smaller shipments into a common freight unit, whereby different shippers share the cost of transporting the entire container. It is a more economical mode of transport when the individual consignor or receiver does not have enough cargo to organize his own transport using an entire container.

LCL transport is becoming more economical with the growth of the number of consignments per container. A large number of shipments from a single port allows full occupancy of the cargo space. The goal is to fill a 40' HC (high cube) container that provides the largest volume of cargo space. LCL consignments should be grouped according to the final destination, in order to transport the full container to the final destination and to eliminate additional handling of the containerized cargo. The consolidation (LCL) warehouses should be as close as possible to the greater number of shippers, and at the destination, as near as possible to the largest number of good's receivers. Land transport of each consignment should be as short as possible, enabling also last mile transport optimization, in order to minimize delivery costs.

Market fragmentation, lack of business knowledge in the field of LCL transport and unreasonable concern over the protection of commercial shipments' data, inhibit faster LCL service development in the eastern Adriatic region. In addition, a certain percentage of LCL consignments are still transported through northern European ports such as Hamburg, Antwerp and Rotterdam.

It is difficult to organize regular LCL services from loading ports with a goal to deliver full container to destination market, where market fragmentation and demand fluctuations exist. In such cases, it is necessary to evaluate all the possibilities of delivering LCL shipments to the final destination. In addition to the direct delivery of full containers, Full Truck Loading (FTL) service or LTL (Less than a Truck Load) service can be used. The LTL service is a very important option when shippers or consignees place their shipment orders irregularly. The operation of a land road-feeder service as organized in air transport (Bartodziej, 2009) can be crucial for the phase development of LCL transport regionally. LCL and air shipments are quite similar, with the main difference in time-frame delivery. Beifert (2016) highlights that road-feeder service can help the development of air product regionally, thus it could be valid for LCL product as well. Consequently, the goal is to organize and use road-feeder services for oncarriage transport of LCL shipments, but gradually move to direct delivery of consolidated containers up-to deconsolidation warehouses.

2 LCL TRANSPORT

2.1 Basis of LCL transport

LCL transport offers to importers and exporters a transport service for small consignments that are not sensitive to longer transport times. Usually these are consignments of up to 8 or 9 m^3 and with a total weight of up to 8-9 tons. For the consignments exceeding that volume or weight it is more economical to carry them with the use of FCL transport (Full Container Loads). Smaller shipments and time-sensitive ones often pass into air traffic. The price for air consignment is a few times higher than LCL transport, which is at the same time also a few times slower.

Acciaro and Mckinon (2013) emphasize that the use of LCL transport is rapidly evolving in markets of greater and more diversified production and consumption. Consumers expect a variety of goods that are available in just a limited time. Consequently, smaller volumes of cargo are ordered and transported. Such market development pushes freight forwarders and NVOCC (Non Vessel Common Carrier Operators) operators to organize new and direct LCL services from main production points till the consumption market, rather than represent clients just as their agents (Martin & Thomas, 2001). Notteboom and Merckx (2006) note that even Container Lines are entering into LCL business, as they can control different cargo and clients, and are able to easier fulfill LCL boxes. Freight forwarders and LCL consolidators need to know the market demands, the diversity of goods, the operation of container shipping services, the role of distribution warehouses and finally transport distribution possibilities (Caiazza, Volpe & Stanton, 2016).

Planning LCL transport and logistics services is a complex process. Jamrus and Chien (2016) underline the need for coordination and prioritization in combining cargo with respect to the final destination, weight and volume, the ability to fold in height, the time priority and the optimal occupancy of the freight space of the container. Creazza et al. (2010) highlight the importance of LCL transport when setting up the logistics network. Namely, the transport of the entire container is not always the most economical mode of transport in the operation of supply chains. Delivery of containerized cargo to hinterland markets is often influenced by empty container transportation to the hinterland container terminal or even by the return of empty units to the port. Zhang et al. (2010) see the latter as an important transport-operational problem that needs to be addressed through proper planning and continuous optimization.

2.2 LCL tariff policy and costs

The calculating method for LCL transport is set according to the volume and/or weight of the shipment. A special weight/measurement unit (w/m) is used. The basic tariff contains the price of the transport service per m^3 of cargo or tons of the shipment. The manipulation costs of receiving the consignment in the consolidation LCL center and the manipulation costs at the destination LCL hub warehouse, are determined according to w/m price units as well. The cost of preparing the necessary documentation, such as the issue of a loading list, different certificates or cargo release (nulla osta), is most often formed per shipment. Bhathar et al. (2011) highlight the complexity of planning and calculating LCL transport in global supply chains, since operational and commercial variables change frequently and rapidly.

The structure of the total cost of LCL transport can be expressed as (C_T):

$$C_T = C_{lt} + C_{co} + C_d + C_{st} + C_{dc} + C_{de} + C_{dd} \quad (1)$$

where applicable:

C_{lt} = cost of land transport up to loading port (precarriage);

C_{co} = cost of consolidation/handling;

C_d = cost of documentation in loading port;

C_{st} = cost of sea transport;

C_{dc} = cost of de-consolidation/handling;

C_{de} = cost of land transport/delivery (oncarriage);

C_{dd} = cost of destination documentation.

C_{st} is calculated based on cost of sea transport for 20’, 40’ and 40’ HC containers. The cost for FCL is divided by the volume of container. The 20’ container has max capacity of 33 m^3, meanwhile 40’ container max capacity is 67 m^3. As the ocean freight is less than double for 40’ container, compared to the 20’, the price per volume is more convenient if a 40’ full container is used for LCL transport. Moreover, the ocean freight for 40’ HC is very often the same as for 40’ standard container, but 40’ HC has cca. 13% bigger capacity, thus the price per m^3 is even lower.

LCL consolidators calculate their ocean tariff based on 75 to 80% space utilization. This should be the break-even point of cost vs. price; therefore more cargo is consolidated and LCL products make more profit. The calculated price per w/m is based on the input cost of the ocean FCL transport, which is divided by 25 m^3 for 20' and approx. 60 m^3 for 40' HC container. The LCL operator therefore takes an economic risk if a groupage container has to be shipped without at least 75% of consolidated cargo.

The calculation of consolidation and de-consolidation manipulations are based on average cargo usually handled or palletized/de-palletized per 20', 40' or 40' HC container. Some LCL operators also include the carrier's THC (Terminal handling charge) cost or ISPS (International Ship and Port Facility Security) cost in the LCL handling cost. The price is finally calculated and expressed in w/m.

C_{lt} and C_{de} costs are more difficult to calculate on a w/m basis, as LCL operators can arrange precarriage and oncarriage transport of LCL shipments in different ways. In case an LCL container is transported to a hinterland deconsolidation point by rail or truck, such an FCL rate is divided in the same way as in the case of a C_{st} calculation per m^3. When inland transport is provided by regular truck (FTL) truck rate (around 1.1 EUR/km) is divided per m^3 of LCL shipments under transport. In such a case handling costs are higher due to additional manipulations in the warehouse-truck and truck-warehouse directions. This additional cost can be included directly in the C_{lt} or C_{de} price.

The third option for using the LTL transport network poses even more limitations and price uncertainty. Namely, an LTL tariff is usually expressed per 100 kg of cargo or by laden meter, which is difficult to calculate or exchange in w/m tariff. The LCL operator takes some risks when he offers a w/m tariff for oncarriage and last mile delivery, where the incoming costs are calculated based on the LTL tariff.

On this basis, it is very difficult to make a standard tariff policy for an LCL product when the precarriage and oncarriage transport is changing transport technology. These changes are very often driven by a certain volume of LCL shipments to be collected or delivered, by FTL truck availability and price, by request of empty container repositioning or empty drop-off charge posed by the Container Line for a certain inland container depot or by LTL service availability and price policy.

Finally, C_T cost includes costs that are calculated per w/m and per entire LCL shipment (C_d and C_{dd}). The basis for w/m calculation is used for at least 1 ton of weight or 1 m^3 of volume, always based on higher value.

3 THE CASE IN THE NORTHERN ADRIATIC

3.1 LCL service development

Various logistics companies have offered LCL from port of discharge (POD) Koper for two decades already. Firstly, the product was run through northern European ports such as Antwerp, Rotterdam and Hamburg. LCL containers were transported between the loading port in Asia or the US and the unloading port in northern Europe. Land transport from northern European ports was organized by regular truck transport, once a week. All central Europe and the markets of SE Europe gravitated mainly to these mentioned ports, though some of the cargo was transported via the Italian port of Genoa.

With the development of the smaller and consolidated container shipments for imports from Asia, part of central Europe gradually turned to Koper and Trieste. The grouping of shipments for several hinterland markets allowed the development of regular import services from Asian ports. With the development of LCL transport in the region of SE Europe, regular LCL services were also established through the Rijeka port.

At the beginning, there were fewer direct services. LCL services have linked major LCL points in Asia, such as Singapore, Hong Kong and Shanghai. At these points, the regional LCL nodes were formed, which collected LCL shipments from the wider region, and then formed weekly LCL services for Koper. The cargo was mainly for the Slovenian market and the broader Balkan market. With the growth of LCL traffic and redirection of the markets of Hungary, Austria and Slovakia to the Adriatic transport route, the number of shipments from each loading port increased, which enabled the development of new direct lines. Consequently, the regional role of LCL hubs in Singapore and Hong Kong has diminished.

With the development of the wider gravitational area of the northern Adriatic ports, the following basic operational questions in LCL development appear:

- Where to establish a regional LCL hub warehouse (in Koper or in the hinterland of Slovenia or even in Croatia),
- How to connect key economic basins in neighboring countries such as Hungary, Croatia, Slovakia, Serbia, part of Austria, etc., depending on the cargo structure?
- How many direct LCL services to organize and their frequency?
- Which oncarriage service offers the best service and price support?

The LCL consolidator must elaborate different variables in order to set-up an optimal LCL service. The focus is on precarriage set-up in Asia and oncarriage transport via the northern Adriatic transport route. Namely, different direct ocean container services from China and SE Asian ports exist, with transit time around 30 to 35 days, thus the ocean transport and related C_{st} costs are competitive enough to those of POD Genova, Hamburg or Antwerp.

The precarriage set-up is predominantly dependent on the LCL hub warehouse point. It is primarily important for the exporters as they have to organize the delivery of LCL shipments to the hub warehouse when FOB, CIF/CFR/CPT or DAP/DAT terms of delivery are agreed. Only when EXW is agreed the LCL operator has to pick-up the consignment at the exporter's door. As the EXW shipments are quite infrequent, the precarriage transport predominantly lies on exporters or their forwarders. On the other hand, European importers very often request delivery to the terminal or door delivery, as an extended service, part of previously agreed terms with the seller. This service can already be included in an LCL transport term or is additionally agreed upon arrival of LCL shipment in the regional Hub point.

3.2 Defining an oncarriage model for LCL transport

Oncarriage from POD Koper to the regional LCL Hub warehouse can be organized in three ways:

- By transporting FCL from Koper to a deconsolidation warehouse;
- By FTL service from a deconsolidation warehouse (Koper, Sežana, Ljubljana) up to the warehouse in the hinterland basin;
- By combining FTL or FCL and LTL services, where in the first leg between a deconsolidation warehouse and regional LTL hub is organized by FTL or FCL transport; and transport from a regional LTL cross-docking warehouse up to the final terminal in the economy basin is performed by LTL service.

For the first option, of direct FCL transport by rail or truck to a deconsolidation warehouse in an economical basin of a certain market (Hungary-Budapest, Croatia-Zagreb, Serbia-Belgrade, Slovakia-Bratislava, etc.) the following criteria must be fulfilled:

- Enough cargo in an LCL container for direct delivery to a deconsolidation warehouse at a certain market,
- No cargo for other markets that should be unloaded in a regional deconsolidation warehouse, in order to avoid extra costs for these consignments,
- Cost effective FCL transport by rail or truck, including returning of empty container to a hinterland terminal (eventual drop-off surcharge included) or returning an empty container back to POD.
- In case one of the above criteria cannot be secured by FCL transport then the other two alternatives should be elaborated to understand and perform cost-effective oncarriage transport.
- The second option of organizing FTL transport between a deconsolidation warehouse in POD up to the warehouse in an economical basin of a certain market should fulfill the following criteria:
- Enough cargo to organize cost-effective FTL transport, as the transport price if fixed per truck,
- That return transport costs are partially calculated (return transport should be covered by other agreed transports),
- Cost effective "all-in" transport service, including deconsolidation costs at Koper (moving container from container yard to a warehouse, issue customs and other documentation, unloading LCL consignment and loading them on FTL).

All of the above criteria have a significant influence on the cost-effective oncarriage transport of a single LCL shipment; therefore the LCL operators should elaborate them in advance. When no criteria can be matched, then the third option of combining LTL services should be analyzed.

The oncarriage service, where a combination of FTL and LTL transport services is used, is the most complex. Namely, the transport chain consists of three individual transport products (LCL, FTL and LTL) that must be operationally synchronized and at the same time cost effective. Such a transport chain requires multi-handling processes as consignments are handled at least three times. Consequently, a multi-layer decision process must be elaborated, with the following input criteria:

- Existing LTL service to destination area, with terminal or destination warehouse in target economical basins,
- Acceptable position of regional LTL hub point from connection and cost perspective,
- Cost effective FTL or FCL transport up to the regional LTL hub point,
- Acceptable "all-in" oncarriage costs from POD up to end-terminal or door-delivery.

3.3 Cost comparison

The analysis includes "all-in" FOB calculation for LCL consignments, from main Chinese ports to POD Koper, with oncarriage of LCL shipment to different economic basins in SE Europe. The ocean freight of FCL transport from Shanghai, Ningbo, Chiwan, Xiamen, Hong Kong to POD Koper is on average at a level of USD 825 for 20' and USD 1,350 for 40' dry box or 40' HC container.

Table 1: FCL and FTL trucking prices

Destination LCL warehouse	FCL from Koper (EUR)	FTL from Koper (EUR)
Belgrade	1,350	1,000
Zagreb	550	400
Split	1,000	1,200
Sarajevo	1,300	1,350
Banja Luka	950	875
Ljubljana	250	225
Maribor	450	400

Source: Own market research

By transforming the rate in w/m the cost for the ocean rate C_{st} is USD 33 w/m in case 20' container is used, and USD 25 w/m for 40' HC. The selling price is formulated on a little bit higher level. Undoubtedly, the LCL operator tries to organize LCL transport by 40' HC container, because the costs per single shipment is lower.

The cost for oncarriage C_{de} is different, in connection to one of three options for land transport to delivery terminal or door delivery. The analysis includes rate comparison for transport to LCL warehouses in Belgrade/Serbia, Zagreb and Split/Croatia, Sarajevo and Banja Luka/Bosnia and Herzegovina, and Ljubljana and Maribor/Slovenia (*see Table 1*). The first option of FCL transport from POD Koper to the selected destination includes the empty container repositioning back to Koper, as Container Lines do not have empty container depots in selected economic basins or they charge high drop-off fees. FCL transport is organized by truck in both directions. Data in Table 1 also shows FTL rates from Koper to the destination warehouse in the selected city.

The calculation method for oncarriage of FCL expressed in w/m uses the same basis as for C_{st} calculation; meanwhile, the FTL rate must include the additional cost of container positioning to a warehouse and handling cost at Koper. This is an additional cost of 300 to 350 EUR per 40' container. In both cases, Container Lines' costs must be paid as THC, ISPS, delivery fee and for transit customs documentation. These costs are not included in prices presented in Table 2.

Table 2: FCL and FTL trucking prices expressed in w/m

Destination LCL warehouse	FCL from Koper (EUR)	FTL from Koper (EUR)
Belgrade	23	22
Zagreb	10	12
Split	17	26
Sarajevo	22	28
Banja Luka	16	20
Ljubljana	5	9
Maribor	8	12

Source: Own market research

The transport costs by FTL are higher due to additional manipulations of LCL consignments, but this service offers better solutions when LCL shipments from different loading ports and direct services are grouped for the same destination. The difference between FCL and LTL transport costs expressed in w/m is even double for closer destinations, because handling costs have greater influence on total oncarriage cost.

The third option, where FCL or FTL transport is combined with LTL transport, is calculated based on cross-docking freight stations (CDFS) in Ljubljana. Different trucking companies and freight forwarders offer their daily groupage service from Ljubljana to main destinations in SE Europe. Consequently, the first transport leg, from Koper to Ljubljana, can be organized by FCL or FTL mode. According to data presented in Table 1 and Table 2 FCL transport is a better solution. The LTL tariff is calculated per 100 kg and laden meter. Combined costs from Koper via Ljubljana to selected warehouses at the destination, for LCL shipments, with weight between 400 and 600 kg, are presented in Table 3.

Table 3: Combined FCL and LTL trucking prices

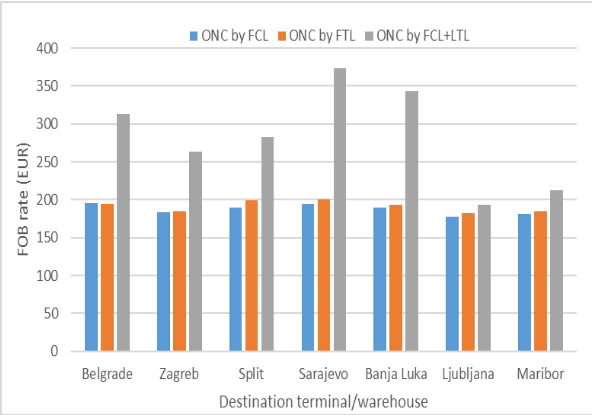
Destination warehouse	From Koper (EUR)
Belgrade	140
Zagreb	90
Split	110
Sarajevo	170
Banja Luka	200
Ljubljana	20
Maribor	40

Source: Own market research

For FOB Shanghai price calculation, costs of documentation in the loading port (C_d), cost of de-consolidation/handling (C_{dc}) and cost of destination documentation (C_{dd}) must be added. The cost C_d is different per LCL consolidator and on average the price is USD 50 per shipment. The cost C_{dd} is higher as it includes the forwarding fee, delivery fee and customs documentation. The price is around EUR 75 per shipment. Finally, the cost for deconsolidation and handling must be added. This cost in some cases includes also THC and ISPS for container and handling costs, and therefore is different among LCL operators. On average the prices are between EUR 20-25 per w/m.

4 DISCUSSION

The cost comparison analysis shows that three different options for oncarriage transport of LCL shipments offer different transport processes and consequently transport prices. The most competitive one is the first option of organizing direct transport of an entire container to a destination terminal or LCL warehouse. This technology should be the first oncarriage choice (*see Figure 2*), but can be performed only when all shipments inside one container are for a certain market (Serbia, Croatia, Bosnia and Herzegovina, etc.). Due to lack of regular LCL shipments from one Asian port for a single destination market, this transport technology is only occasionally used (in most cases for Ljubljana, Belgrade, Zagreb).

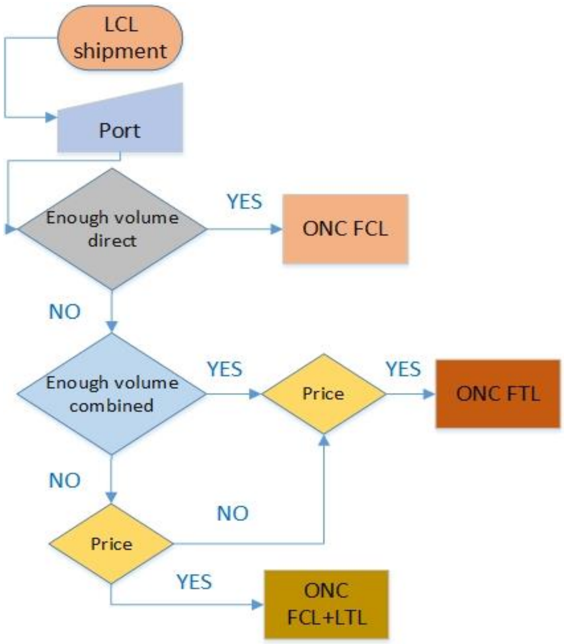


Source: Own market research

Figure 1: Comparison of FOB Chinese port LCL rates by three oncarriage transport services

More convenient is the second option, to organize oncarriage by using FTL transport. Though this transport technology is not price competitive compared to the first option of oncarriage service, it offers more flexibility for fulfilling one FTL with LCL shipments from different Asian ports that are for the same destination market. Moreover, the total FOB cost difference of one LCL shipment (500 kg and 1 m^3) moved by FCL or FTL oncarriage, is minimal (*see Picture 1*). It is important that LCL operators have more LCL services to POD Koper, enabling them to combine enough LCL shipments for a single market. In addition, an FTL line can be organized with multi-stops where Zagreb or Banja Luka can be reached with FTL transport to Belgrade or Sarajevo. This way an optimal transport process from a financial point of view can be organized, with a certain impact on time quality.

The third option, of organizing road-feeder service by combining FCL and LTL products, is very expensive and according to our study hardly supports LCL transport development regionally. Such a transport technology should support the initial phase of LCL product development, as LCL operators face a lack of LCL shipments from and to different markets in the starting period. Namely, already ongoing LTL services from CDFS operate daily transports to main economic basins in the eastern Adriatic region. By tariff adaption, it would be possible to route LCL shipments to ongoing LTL services, because LTL service works at high operational standards and high transport frequency. In case price adaption closer to the market expectation is not possible, than LCL operators should see whether FTL transport, with co-loading possibilities, offers more competitive transport rates. The process of selecting an appropriate oncarriage transport is presented in Figure 2.



Source: Prepared by authors

Figure 2: Workflow for oncarriage set-up

5 CONCLUSION

LCL transport has development potentials in the eastern Adriatic region. Presently the market is fragmented and importers very often do not place their bookings permanently. Consequently, LCL operators must combine cargo from different origin ports on their oncarriage service for delivery up to destination warehouses or to door delivery.

The market of the eastern Adriatic region is increasing but there are still volume limitations to organizing direct FCL transport to destination terminals in Belgrade, Sarajevo, Banja Luka, etc. LCL operators face difficulties in oncarriage optimization, especially in the starting period when new LCL services are introduced on the market. Three analyzed oncarriage services offer different transport services, from time and price points view. The combination of FCL and LTL transport offers flexible service, but it is more expensive. On the other hand, oncarrriage by FCL offers higher time quality service and competitive rates, but enough regular volume from origin point to destination terminal must be booked before sailing ex Asian port. The analyses shows that oncarriage service for LCL shipments by FTL is the best, considering service, price and volume risk basis. This transport technology requires a higher number of inbound LCL services, as the basis to collect enough cargo for certain final destination terminals.

Based on research cognition, the cooperation between LTL and LCL product should be the basis to organize price-competitive road-feeder service in the eastern Adriatic region. Such a service would eliminate or decrease volume risks for optimal oncarriage transport and would support the establishment of new LCL services by smaller freight forwarding companies. These companies have more difficulty achieving LCL volume for different direct inbound LCL services and this is limiting their service expansion.

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IMPROVMENT OF CONTAINER TRANSPORT BY DEVELOPING EXTREMELY BIG CONTAINER SHIPS

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ABSTRACT

In the last decade, the container market is growing at about 8% a year. Studies show that the performance of Ultra Large Container Ships (ULCS) is not only feasible but may be necessary if this expansion on the market has to be placed in the most cost-effective framework. Conducted terminal capabilities, along with possible improvements in onshore and offshore design, it is obvious that the largest number of ports in the world can serve a ULCV capacity of more than 14,500 TEU, which corresponds to an approximate VLCC board size. Most container ports in Asia do not impose any restrictions on ULCS dimensions. Infrastructure constraints, height and / or limitations of the ship draft, the maximum limit of 400m today is imposed on several major ports of northern Europe (Antwerp, Bremerhaven, Hamburg, Le Havre, Valencia, and Zeebrugge). This is due to the fact that some of them are located in tidal waters at the mouth, or even many miles of upstream rivers. Furthermore, it is believed that ULCS of lengths up to 430 m which are specially equipped for efficient maneuvering and control (with sufficient power of bow thruster / stern thrusters or double propeller propulsion, strong tugs with sufficiently strong towing bits etc.) can be maneuvered in areas where the length of the boat is currently limited to 400 m.

Keywords: ULCS, container ports, container transport, equipment and limitations

1 INTRODUCTION

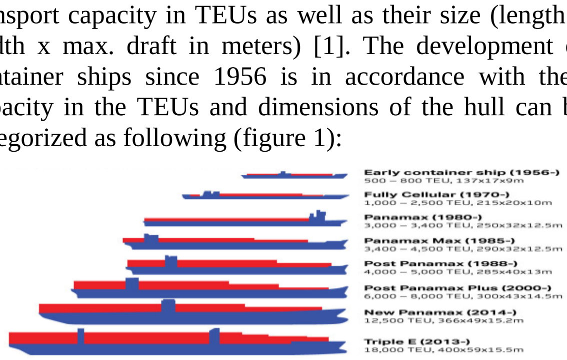
Containerizations refers to the process of packaging goods, stowing of cargoes in containers and transport by one or more forms of transport, principally from the place of embarkation from the internal areas of a country to the place of destination in the internal areas of another country. From the point of view of transport by containerization, the idea is to realize that a large number of individual commodities of different shapes, types, sizes and masses form or merge into a larger unit of cargo, which becomes a unique handling unit. The constant demand for transport of cargo in containers has caused a rise in container ships. Transport of containers is an event that marked the twentieth-century seamanship. It has made it easier and faster to handle the load and door to door service. Today, about 85-90% of cargo is transported in containers which are loaded to container ships, and approximately 26% of these containers originate from China. Since 2005, 18 million containers have made over 200 million journeys per year. Shipbuilding engineers are already constructing and are already in exploitation ships that can transport over 20000 TEUs. It is expected that container ships in the near future will be up to 450m long and up to 60m beam, and that even the passage of Malacca Strait will present a constraint. It is also anticipated that such a rise in containerization will lead to a large increase in the world fleet.

2 CLASSES OF CONTAINERS

Container ships are designed to maximize cargo optimization. Compare to a larger ships, smaller ships are equipped with their own cranes with a capacity up to 2900 TEU (*Feeder Container Ships*). These container ships are divided according to the type of loading the cargo on:

- container ships with vertical guides,
- container ships with horizontal loading,
- large ocean going container ships and
- small feeder ships for supply larger ships.

All container ships are open constructions and must be so constructed that their structure allows free loading / unloading of crane containers. In order to obtain unobstructed and rectangular storage facilities, they have a high degree of strength with regard to fully open decks, these ships are usually constructed with ″Double Hull System″. Container ships are developed in response to market demands, and in that context they increased their transport capacity in TEUs as well as their size (length x width x max. draft in meters) [1]. The development of container ships since 1956 is in accordance with their capacity in the TEUs and dimensions of the hull can be categorized as following (figure 1):



http://www.container-transportation.com/container-ships.html

Figure 1: Classes of container ships

3 EXTREMLY LARGE CONTAINER SHIPS

Under the term "*Extreme Large Container Ships*" is implied *Ultra Large Container Ship* (ULCS) or *Ultra Large Container Vessel* (ULCV) also known as *Megaboxer*, is the group of the largest container ships used in container transport. It seems that the width will increase to 24 rows, increasing the nominal capacity for about 1,000 TEUs while simultaneously keeping the fuel costs per TEU unchanged. By increasing the ULCS maximum 24-row width range of 16m to 17m, capacity can be increased by about 10% which increases fuel efficiency - especially for heavy containers. If greater nominal capacity is required than prolonging the ship for a single cargo hold (2 BAYs = 26 BAYs total), this would result in TEU entry of about 23,300, with fuel costs per TEU reduced by about 4.5%. By increasing the width to 25 rows and length up to 26 BAYs, ULCS capacity could reach 26,300 TEUs. Such a design would be limited to entry into numerous ports and could not go through the Suez Canal with its current limitations in fully loaded condition. This would also require a new concept of structural construction. That is why it is unlikely that such size of vessel will be ordered in the near future, even if it promises another 3.5% reduction in fuel costs by TEU [2] [3].

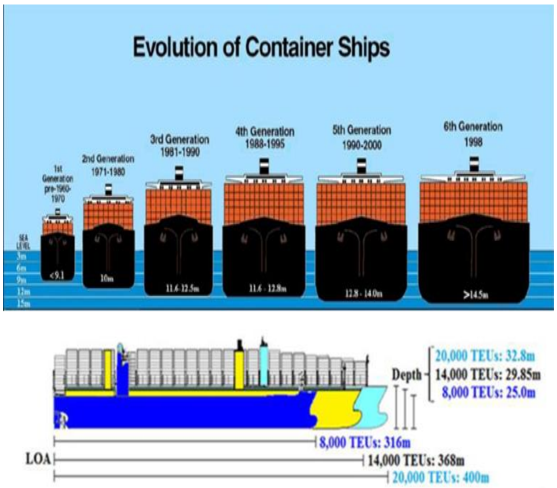


Figure 2: Evolution of container ships

3.1 Triple e class of extremely big container ships

Maersk Line has built a new "Triple-E" class of container ships of 15,500 TEUs. The first 10 ships were delivered in 2013 and 2014, and another 10 vessels in the period 2014 and 2015. The class of ships was named Triple-E class because has recognized three main purposes economical, energy efficiency and ecological improvement. These new container ships are setting new standards that outperform the current efficiency and CO2 emissions per container. The newest Triple-E is a 400-meter-long, 59m wide and 73m high, 14.5m draft, deadweight of 165,000 mt, 600 TEU Reefer Container, 23 knots maximum, with 18,000 TEUs capacity. Triple-E class produces 20 percent less CO2 per container, which is 50 percent less than the average of Asia and Europe's industry. This class consumes about 35% less fuel per container than ships of 13,100 TEUs delivered to other liner container carriers in the previous years, which also operates on the line of Asia-Europe. Triple-E ship is a significant step towards addressing the environmental challenges associated with cargo transportation around the world. Each ship costs 190 million dollars. In addition to the size that provides superior size compared to other vessels (more cargo means less CO2 per container), the efficiency of Triple-E class comes with its innovative design. Two slow running engines are running by two big propellers, and this combination is called the ‘’Twin Skeg’’. The reason to use this combination is derived from the Maersk Line study that showed that with two slow-motion engines which are running the two propellers, it results in an energy saving of a further 4 percent compared to a single engine propeller design. Especially optimizing the hull and bow shape makes it possible to achieve a maximum speed of 23 knots, compared to Emma Maersk whose max. speed is 25 knots. This small difference in maximum speed reduces the output power of the machine by 19 percent, allowing less engine speed and more economical (lower) fuel consumption. To reduce the environmental impact of ships beyond their lifecycle, Maersk Line has set new standards for vessels in terms of their recycling. All materials used to build the Triple-E Class will be documented and mapped on board as a Cradle-to-Cradle Passport. This means when a ship is sent to scrap yard, this document will ensure that all materials can be reused, recycled or disposed of in the safest and most efficient manner.

3.2 Transport efficiency for next generation of ulus/ulcv

The ship MOL Triumph from company Tokyo-Mitsui O.S.K. Lines, Ltd. (MOL) in March 27, 2017. was delivered by the Samsung Heavy Industries Co. This ship is first delivered in series of six vessels of 20,000 TEU class containers for this company. The ship is 400 m long and 58.8 m wide, with a capacity of 20,170 TEUs, and the first such ship of 20,000 TEU classes ever built [4].

Figure 3: ULCV MOL Triumph 20,170 TEU Container vessel [5]

Ship particulars for ULCV MOL Triumph:

- LOA = 399,87m
- Breadth = 58,80m
- Depth = 32,50m
- Designed draft = 14,50m
- Deadweight approximately = 192672 MT
- Capacity of TEU's = 20170 TEU

- Builder: Samsung Heavy Industry

The ship is equipped with a variety of new technologies to ensure more efficient fuel economy and improved ecological efficiency. In accordance with MOL's policy and environmental standards, a new 20,000 TEU class container ship is equipped with a variety of high-tech energy saving technologies including underwater colour with very low resistance, high performance propulsion and steering wheel, Savour Stator Propulsion, and optimized fine hull shape which together further reduce fuel consumption and CO2 emissions per container by about 25-30% compared to 14,000 TEUs container ship. In addition, the ship was also designed with the possibility to switch over to LNG fuel, and in view of the rules set by IMO regulations to limit SOx emissions in marine fuels, which will come into force in 2020.

Also, in April 2017, another ULCV 20,568 TEUs, Madrid Maersk, was delivered to A.P. Moller-Maersk Group. Less than two months after MOL Triumph has won the world's largest container ship as the first ship to cross 20,000 TEUs on May 15, 2017. Samsung Heavy Industries in Geo, South Korea delivered a new ULCV for the Overseas Container Line (OOCL) in Hong Kong. With a capacity of 21,413 TEUs, OOCL Hong Kong has record of the world's largest ship with TEU capacity [5]. Ship particulars for OOCL Hong Kong:

- LOA = 399,87m
- Breadth = 58,80m
- Depth = 32,50m
- Designed draft = 14,50m
- Deadweight approximately = 191,317 MT
- Capacity of TEU's = 21413 TEU
- Builder: Samsung Heavy Industry

One of the major constraints for these types of ships is max. draft, which makes it difficult and restricts the passage through the Suez and Panama Canals. The Suez Canal imposes restrictions on the maximum main dimensions of ULCS with max. draft of 20.10m, width 59m (ULCS 18.000 TEUs). As for the New Panama Canal (neo-Panama Locks) after its expansion, the locks are 427m long, 55m wide. In accordance with Panama Canal Authority (Aug. 2016) it can service ships with max. Draft of 13.4m (44 ft.), 49m wide (ULCS 13.500 TEUs). The draft limitation is based on the current level of water in Gatun Lake and the weather forecast for the next few weeks. Another limitation is the infrastructure and the available land-based crane technology in commercial ports, with regard to the final outreach of the crane and the height of stowed deck containers, which can limit the number of containers that can be loaded on the deck of ULCS vessel. The most ports on the waterway Far East-North Europe in the meantime upgrade their gantry cranes so they can service ships up to 25 rows of containers. Nevertheless, in some ports, the height of the crane may still be a factor limiting the number of heights loaded containers on the deck, especially when considering the ULCS design with its depth of about 33 m.

4 BUILT CONTRUCTION OF EXTREMELY BIG CONTAINER SHIPS

The most important technical problem with extremely large container ships (ULCV) is of a structural nature. Conventional ships have a huge and strong deck that contributes to the rigidity of the ship, while in container vessels the cell type deck surface is limited only to narrow parts between the cell storage and the hull of the ship, so the cellular structure serves both stability and strength of the ship. Given the extreme dimensions of the latest generation of ULCV and especially in identifying structural problems Lloyd's Register has developed two conceptual designs associated with ships of this type and size [6]:

- Wide Skin Option (WSO)
- Narrow Skin Option (NSO)

With the Wide Skin Option concept, the lateral structure is designed to accommodate two rows (two widths) of deck containers on each side. Double side hull and double bottom tanks are used only for ballast. The basic characteristic of such ships is L x B x D = 381 x 57 x 29m. One of the major challenges for naval architect of container ship is the flexibility of the hull, especially for torsion. For this reason, containers stowed on deck are very sensitive and vulnerable to damage, especially to cross lashing and even possible to damage the containers. Containers mounted on lateral supports outside of the hatch cover are therefore even more vulnerable. This concept of hull allows up to 12,100 TEU [6].

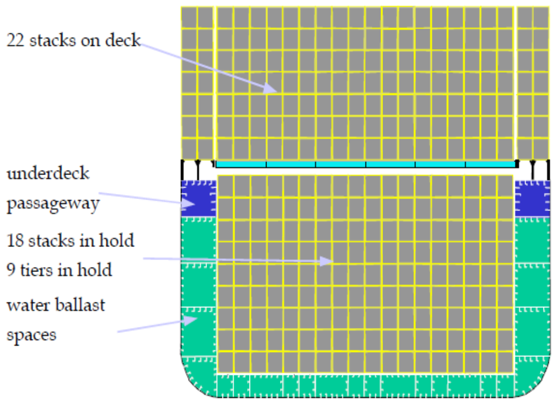


Figure 4: Conceptual design - *Wide Skin Option* [6]

A further design concept was developed with a narrow lateral structure, wide enough to accommodate only one row (width) of deck containers on each side. However, it is structurally much more demanding and difficult, and requires more careful consideration of structural aspects. This design has a capacity of 12,500 to 13,000 TEU containers [6].

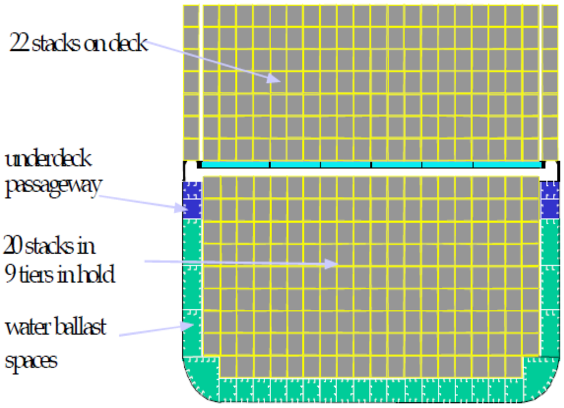


Figure 5: Conceptual design - *Narrow Skin Option* [6]

4.1 Ulcc construction characteristic

According to the SOLAS criteria of visibility from the navigational bridge, the maximum distance for the blind sector in front of the bow is determined by SOLAS chapter V. according to rule 22 (Navigation Bridge Visibility). Each vessel of 45 meters long or longer, built on September 7, 1990. or after that time, under load or ballast from the observation position on the command bridge may not have a blind sector in front of the bow, which is longer than two lengths of a ship or 500 meters, depending which size is smaller [7]. Because of their large ULCV length, their superstructure is located at approximately 1/3 of the length of the bow, to ensure visibility from the command bridge. Superstructure with a bridge over a conventional position above the engine room, with container vessels of capacity 12,000 TEU containers and above is no longer possible. No need for stern visibility.

Figure 6: Fully Cellular Container Ship 13300 TEUs [8]

The engine room is located on the one third length of ship from stern with aim to reduce the propeller shaft length from the main propulsion to the propeller. This avoids large deflections of the propeller shaft as a result of its large length. Particular attention is paid to the hydro-dynamic properties of container ships because they are designed to achieve a high economic speed. The main decks are placed high and carry heavy loads. The high position of the deck can reduce the value of righting lever for uprighting the ships so tanks on these ships are very important. Large ballast tanks and powerful pumps are very important to trim the ship and to prevent hogging and sagging. Therefore, shipbuilders are trying to improve optimum regarding length, width, draft and other dimensions during building such a ships. Containers are stacked one above the other, with a weight of 20-foot containers up to 25 mt and 40-foot containers up to 30 mt. This has the resulting effect on the load of hatch covers and on the load of tank top fully through the four corner posts i.e. rest pads containers.

4.2 Holds characteristic for container ships

Inside the double bottom tank where are situated highly concentrated loads, should be ensured additional stiffeners. The size of the container to be transported greatly determines the construction performance. Vertical cell guides, shaped by the angular profiles, are the only additional structures in the storage space used for stacking the container when the ship rolling.

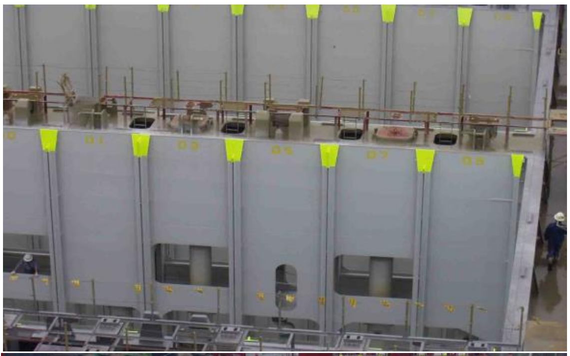


Figure 7: Cell guides in holds of container ship [9]

The hatch covers are heavy and big and present support to containers stowed on decks.

Figure 8: Hatch covers of container ship [9]

5 CONCLUSION

From all of the above, it is concluded that increasing draft improves the efficiency of transporting all variants for most homogeneous load conditions, increasing the widths for one or two rows, but maintaining the length only improves the efficiency of transport with a low homogeneous load condition. Further, it can be concluded that increasing the length for one ship's cargo hold (two BAYs), but holding the width of 23 rows improves transport efficiency for about 5% for all load conditions. Just increasing the width additionally increases the capacity, but does not have a positive effect on transport efficiency. The increase in length of ship for two holds (total of 28 BAYs) in relation with increasing the width to 25 rows would increase the transport efficiency by about 8% to 11%, depending on the average weight of the container. According to Maersk Line's, there is enough capacity in an existing merchant fleet to support a 3 percent annual growth in world trade over the next five years. Chinese carrier president and chief representative for North Asia said there is no need for new tonnage in the liner shipping industry. The existing fleet has 19 million TEUs (20-foot equivalent units), 2 million TEU in idle status, and a 3 million TEU order book has not yet been delivered. That's a total of 24 million TEUs. Until 2022, a million TEUs will be cancelled, leaving the world's fleet by 2022. of about 23 million TEUs. If world demand for goods increased by 3 percent per annum, from now on until 2022. a total of 22 million TEU would be needed.

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DETERMINING THE MOST IMMEDIATE DANGER DURING A MULTI-VESSEL ENCOUNTER

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ABSTRACT

There are many multi-vessel encounters at sea. Such situations are not governed by the rules of COLREGS and decisions are left to the knowledge and experience of the navigators. The current system, which serves as a decision support aid in collision avoidance situations, is ARPA radar integrated with the AIS system. These are both compulsorily integrated with ECDIS on large vessels so that the navigator has a lot of information available on a single screen. In addition to the fact that the radar's collision avoidance tool Trial Maneuver still requires manual settings, there are no integrated COLREGs rules in the system itself; their implementation in individual cases is left to the knowledge and experience of the individual who runs the vessel. The article proposes an algorithm for determining the most dangerous vessel in a multi-vessel encounter situation, taking into consideration COLREGs rules - the navigation area, the type of navigation situation and the type of vessel. At some point this algorithm could be implemented in navigation decision systems.

Keywords: Collision Avoidance, Decision Support Algorithm, COLREGs Rules

1 INTRODUCTION

International Regulations for Preventing Collisions at Sea, 1972 (COLREGS) governs the rules for collision avoidance at sea and must be strictly consider in all situations, regardless of time, sea area and weather conditions. Since the human factor has still the largest proportion in accidents at sea, knowing the COLREGS rules is not enough to prevent collisions, but also requires the experienced navigator, who is capable of properly assessing a situation and making the correct decision at the right time, to avoid other vessels at sea.

In 1972, the COLREGS rules were revised for the last time and since then the regime at sea has changed in terms of greatly increased size and number of vessels. This mass of traffic is causing increasing doubts about the applicability of the COLREGS rules, especially in determining the right of way in complicated situations where several vessels are simultaneously involved. Such situations are common near the Dover and the Singapore Strait, where a Traffic Separation Scheme regulates the navigation regime, but, as has often been proven, this arrangement does not provide adequate protection against, above all, human error, which is unavoidable in maritime transport.

According to Lloyd's List Intelligence, about 100,000 vessels annually pass through the Straits of Singapore and 110 accidents occurred between 2001 and 2011, with 55% of these accidents being collisions (Qu et al. 2012). Similar traffic fluctuations occur in the area of the Dover Strait's Traffic Separation Scheme, where 12 collisions were reported for the period between 2000 and 2016. The low number of accidents, despite the high traffic, is likely attributable to the Vessel Traffic Service (VTS) which operates in these areas, and its navigation and consultant policy no doubt has a positive impact on the safety of maritime traffic (Mou et al. 2015).

Since not all encounter situations can be regulated by the rules, the approach with technological solutions is an appropriate step towards improving safety and preventing collisions at sea. Today, progress has been noticeable in several areas of navigation systems development, especially for controlling devices regarding the movement of other vessels. Consequently, the vessel's bridge these days is crowded with electronic devices, some of which are not even integrated though they should be. Therefore, we encounter situations where at the bridge, besides the navigator, at least two people would need to analyze the navigational situation - monitor active information from devices, observe the dynamics of traffic chaos at sea, communicate with other vessels, etc.

In 2006, the International Maritime Organization issued a "Strategy for the development and implementation of E-navigation" (MSC85 - report, annex 20 and 21) in order to relieve the navigator of an overload of information from the current technology used on vessels. The concept of E - navigation development is to improve the safety of maritime transport by integrating existing and new navigation devices in a structured way; simplification of vessel processes to prevent information overload and increase safety by aggregating information in those that are truly important and relevant to navigation (IMO, 2009).

Navigation decision models are a recent approach for improving safety at sea. In addition to their information function, their task is to create a solution (decision). An important component of the navigation decision model is the component for the navigation situation analysis. The analysis of the navigational situation includes two functions of the decision model, the detection of the risk of collision with the target vessel and the determination of the COLREGS rules which determine the right of way between the vessels. Among the quantitative methods for detecting the risk of collision is the calculation of the DCPA (Distance to Closest Point of Approach), which is the first indicator of the risk of collision. Some ARPA radars (Automatic Radar Plotting Aid) contain a tool called Predicted Area of Danger method (PAD), which, unlike the DCPA method, takes into account the dimensions of both vessels, courses and speeds (Bole, Wall, & Norris, 2013; Perera, Carvalho, Soares, 2011).

1.1 State of the art

On the high seas, the most common situations are two vessel encounters, which avoid a collision in accordance with the COLREGS rules. The risk of collision is, in such cases, most rapidly determined based on DCPA. When its value is less than the desired vessel's safety domain, the right of way is governed by the COLREGS rules.

In congested water, the number of vessels in the area increases. In multi-vessel encounters near a coast or in traffic Separation Schemes the threat of own vessel's safety domain is possible from multiple directions. The first important step in these situations is to identify the most dangerous vessel among them. Several authors have dealt with this identification.

Zhuo and Tang (2008) presented the algorithm for calculating the LTTA (Last Time to Take Action) and TL (Time Left to Take Action) for each vessel separately, to identify the most dangerous vessel in a multi-vessel encounter. Elements of influencing the LTTA value are the DCPA, TCPA (Time to Closest Point of Approach), the dynamics of the target vessel, maneuvering characteristics of own vessel, the bearing of the target vessel and the state of the sea. LTTA is calculated using an adaptive self-learning system that works in combination with neural networks and fuzzy logic techniques. The TL value is the difference between the TCPA and LTTA values. The target vessel with the smallest TL value represents the biggest threat to own vessel.

Zhang et al. (2015), on the other hand, focused solely on situations where COLREGS Rule 15 (Crossing situations) is applied. He observed an angle of approach of a target vessel, the value of the angle influenced on the course of a simple algorithm, by which he determined the stand-on vessel. Tam et al. (2013) determined a dangerous vessel with a simple algorithm, taking into account the COLREGS Regulation 15, the target vessel maneuverability (course change performance and stopping capabilities), distance and TCPA of the target vessel.

Hasegawa et al. (2012), who deals with the problem of a multi-vessel encounter, has presented the calculation of the risk of collision using fuzzy logic. He used DCPA and TCPA values as input data of the fuzzy inference system, and collision risk value (CR) as an output decision. A target vessel with the highest CR value was a stand-on vessel. Bukhari et al. (2013), like Hasegawa, used DCPA and TCPA values for input data, adding the value of VCD (Variation of a Compass Direction) which shows the time change of a target vessel's bearing. The output decision was the degree of risk of collision, and the vessel with the highest level was a stand-on vessel. Ahn et al. (2012) focused on situations with limited visibility where he calculated the risk of collision using neural networks. As input variables, he used the speed, own and target vessel's course, the distance between vessels, the bearing of the target vessel and the vessel's safety domain.

1.2 The gap

Within the European project ACTs (Avoiding Collisions at Sea), an extensive public opinion survey was conducted in 2014 and 2015, involving 1498 professional and 288 non-professional seafarers (Mohović, et al. 2015). The survey included, among other things, the knowledge and understanding of the COLREGS rules, where it turned out that most respondents had problems understanding the COLREGS Rule 9 (Narrow Channels), Rule 10 (Traffic Separation Schemes), Rule 18 (Responsibilities Between Vessels) and Rule 19 (Conduct of Vessels in Restricted Visibility).

A literature overview shows that proposed decision models tend to disregard the COLREGS Rules 9, 10 and 18, which specifically regulate the right of way according to the vessel's status and navigation area. The latter rules substantially change responsibilities between vessels and completely replace COLREGS rules 14 and 15. Similarly, rules 9, 10 and 18 have a decisive effect on the analysis of the risk of collision and the designation of most dangerous vessel; therefore, they are a very important part in the process of collision avoidance at sea.

2 PROPOSED ALGORITHM

The proposed algorithm (Fig. 1) determines the most dangerous vessel in the situation of a multi-vessel encounter. The input data used are:

- DCPA,
- TCPA,
- RB (Relative Bearing)
- course and speed of the target and own vessel,
- type of target vessel and
- COLREGS Rules 8, 9, 10, 13, 14, 15, 16, 17, 18 and 19.

In the "parameter processing" step, the algorithm collects AIS/ARPA input parameters of the target vessel (initial conditions) within the range of navigational devices. The parameters are bearing, distance, DCPA, TCPA, RB and target vessel's type.

In the next step, the algorithm sorts the vessels according to the value of DCPA - for further processing the algorithm collects vessels with DCPA smaller than a safety vessel's domain (depending on the area of navigation and meteorological/ oceanographic conditions).

If there is only one vessel in the area, the algorithm determines the right of way according to COLREGS rules and proposes a decision. If there is more than one vessel, for each of the vessels it determines the right of way according to the COLREGS rules. Stand-on target vessels are further classified with respect to the value of TCPA. In the last stage, the algorithm chooses to avoid a vessel with the smallest TCPA.

Two exceptions are used in the algorithm:

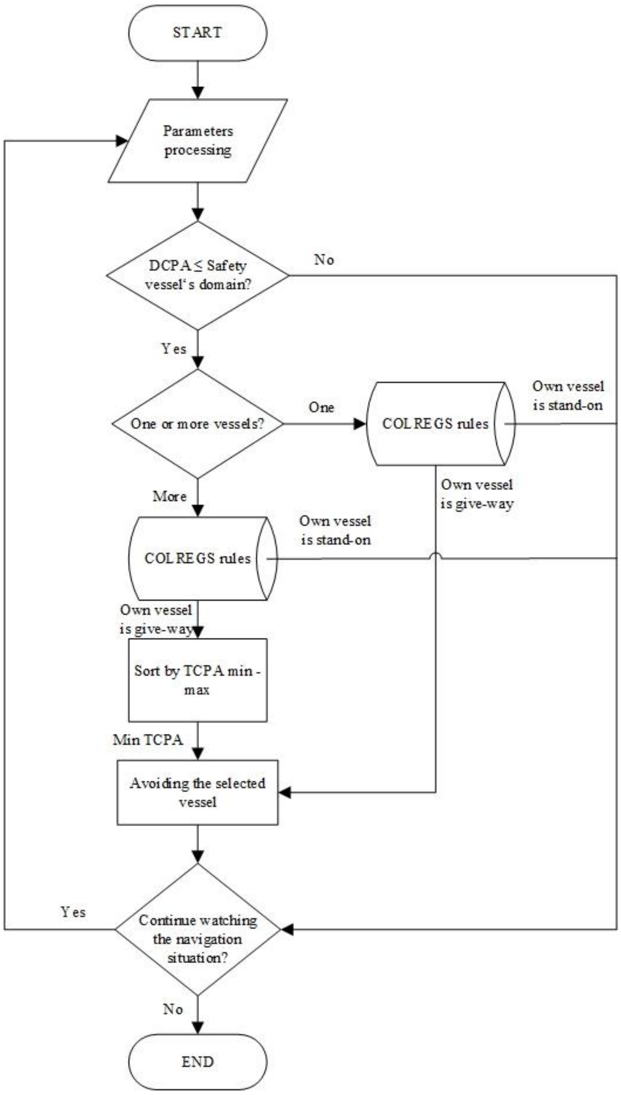
Exception 1 - Each target vessel is considered as a stand-on vessel in the event that the target vessel (with or without priority) is at a distance of less than or equal to 2 NM, irrespective of the position and status.

This can be justified by the COLREGS rule 17:

(Action by Stand-on Vessel)

(2) …if vessel required to keep her course and speed finds herself so close that collision cannot be avoided by the action of the give-way vessel alone, she shall take such action as will best aid to avoid collision. (IMO, 1972)

Exception 2 - If there are two stand-on vessels in Sector I or IV, own vessel avoids the one which is closer.



Source: Author

Figure 1: Algorithm for identifying the most dangerous vessel

2.1 Determining the right of way at sea - COLREGS rules

In the algorithm, 90 conditional sentences are used to determine the right of way according to the COLREGS rules. Their structure is as follows:

IF	A =	Navigation area
AND	B =	Position of the target vessel by sector
AND	C =	Type of navigation situation
AND	D =	Navigational status of the target vessel
THEN	E =	The right of way

Hereinafter are explanations of the individual elements of conditional sentences.

a. Navigation area

The navigation area is divided into the Open Sea, Traffic Separation Scheme and the Narrow Channel, where:

- Open sea area is a marine environment without natural horizontal and vertical constraints, where all COLREGS rules are applicable, except rule 9 (Narrow Channels) and 10 (Traffic Separation Scheme).
- Traffic Separation Scheme is a sea area, usually without natural horizontal and vertical restrictions, where COLREGS Rule 10 applies and other rules that do not govern the right of way.
- Narrow Channel is a sea area with horizontal and vertical restrictions, where COLREGS Rule 9 applies and other rules, which do not govern the right of way.

b. Position of the target vessel by sector

Viewed from the perspective of own vessel, the target vessel may be located in one of the four sectors according to their relative bearings (Fig. 2):

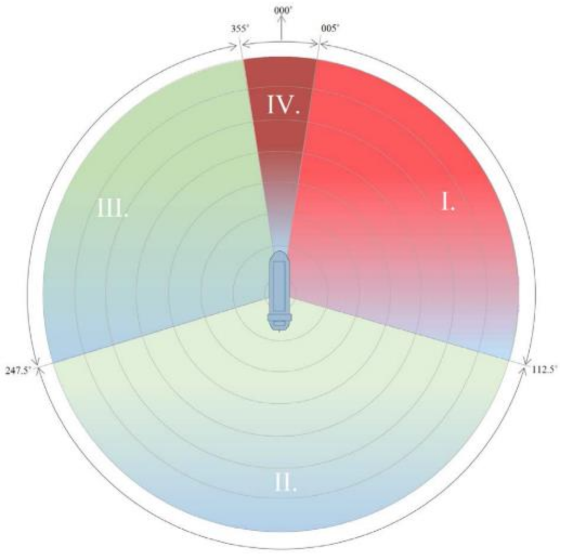
- Sector I
- Sector II
- Sector III
- Sector IV

The boundaries of sectors I, II and III are determined by COLREGS rule 13. The boundaries of sector IV are not specified by rule 14, which governs the conduct of vessels in the head-on situation. This rule applies in situations where the vessels sees the opposite vessel's side lights (green and red). On the other hand Annex I (5) of the COLREGS rules determines that both side lights must be visible 1º - 3º outside the prescribed limits which means that Rule 14 applies to situations where the vessels are in reciprocal position or nearly reciprocal position, thus in the relative bearing of +/- 3º (Cockcroft & Lameijer, 2011). Various authors used higher boundaries for this sector (Y. Liu & Shi, 2005; Su et al., 2012; Tam & Bucknall, 2010; Tsou & Hsueh, 2010; Xu, 2014; Zhang et al., 2015; Zhao, Li, & Shi, 2016). Most of them limited this sector to a value of +/- 5º of the visible angle, as 355º - 005º, which is also used in this algorithm.

Sector I covers the area of own vessel's relative bearing from 005˚ to 112.5˚. In the event of collision risk, target vessel located in the area of sector I is a stand-on vessel and must be avoid. Position of the target vessel in sector I is expressed by the equation:

P_t secI = 5° ≤ RB ≤ 112.5° (1)

RB = BRG_t - COG_o (2)



Source: Author

Figure 2. Division of the own vessel's domain into sectors

where P_t is the position of the target vessel, RB is Relative Bearing of the target vessel, BRG_t is the bearing of the target vessel, and COG_o presents the own vessel's course over ground.

Sector II covers the area of own vessel's relative bearing from 112.6˚ to 247.5˚ which can be expressed by the equation:

P_t secII = 112.6° ≤ RB ≤ 247.5° (3)

Section III is an area covering the area of own vessel's relative bearing between 247.6˚ and 354.9˚ and is expressed by the equation:

P_t secIII = 247.6° ≤ RB ≤ 354.9° (4)

Sector IV is an area of relative bearing from 247.6˚ to 354.9˚. We expressed this with the equation:

P_t secIV = 355° ≤ RB ≤ 004.9° (5)

c. Type of navigation situation

With the following conditional statements, the type of navigation situation encounter (Rule 13, 14 or 15) is determined. These rules only apply, if there is a risk of collision.

CROSSING SITUATION, Rule 15:

IF Target vessel = P_t secI

THEN Rule 15

Based on the COLREGS rules, when the target vessel is in sector I, situational rule 15 is used, whereby the own vessel must take an avoidance maneuver and a target vessel must keep her course and speed. In case the target vessel is located in the RB between 90˚ – 112.5˚, own vessel should avoid an alteration of course towards a target vessel abeam or abaft the beam, especially in poor visibility (COLREGS Rule 19).

IF Target vessel = P_t secIII

THEN Rule 15

If target vessel is located in sector III and both vessels are power-driven vessels COLREGS rule 15 also applies here, whereby the own vessel is a stand-on vessel. Otherwise, Rule 18 is applied. Rule 18 deals with responsibilities between vessels of different type.

HEAD-ON SITUATION, Rule 14:

IF Target vessel = P_t secIV

AND COG_o – COG_t ≈ 180˚

THEN Rule 14

Where COG_t is the course over ground of the target vessel.

If the target vessel is located in sector IV, while both vessels are in reciprocal course or nearly reciprocal course, COLREGS Rule 14 should be applied.

OVERTAKING SITUATION, Rule 13:

IF Target vessel = Pt sec I,II, III or IV

AND COG_o ≈ COG_t

THEN Rule 13

COLREGS rule 13 is applied:

- If a target vessel is located in sector II and is sailing in a similar course as own vessel (COG_o ≈ COG_t). In this case, a target vessel is a give-way vessel. The specialty of this rule is that it applies irrespective of the type of the vessel or the area of navigation.
- If the target vessel is in sectors I, III or IV and has a similar course as own vessel, COLREGS rule 13 is also applied. In this case, own vessel is a give-way vessel.

d. Navigational status of the target vessel

At sea, the right of way is not only determined by COLREGS rules 13, 14 and 15, since the navigation status of the vessel, which is obtained by AIS, plays an important role. It is information that is visible to all the surrounding vessels that have an AIS device. AIS, in accordance with the COLREGS rules, provides for vessels the following navigation status:

- Power-driven vessel;
- Moored;
- Not under command;
- Restricted in her ability to maneuver;
- At anchor;

- Constrained by her draught;
- Aground;
- Engaged in fishing;
- Sailing vessel.

According to COLREGs rule 18 vessels have different priorities in regard to other vessels, based on their navigational status. This rule replaces rules 14 and 15, which apply only in situations where there is a risk of collision between power-driven vessels.

Vessel identification procedure determines the responsibilities between two vessels. According to rule 18, the power-drive vessel must keep away from vessel:

- Engaged in fishing,
- Sailing vessel,
- Not under command,
- Restricted in her ability to maneuver,
- Constrained by her draught.

Rules 14, 15 and 18 are unconditionally applicable in the Open Sea area. A slight tolerance in the right of way is found in the Traffic Separation Scheme (rule 10) and Narrow Channels (Rule 9); therefore the area of navigation is the basis for determining the rule of the road at sea.

e. The right of way

The responsibility of own vessel changes in different navigation conditions. The algorithm yields one of two possible decisions:

- The target vessel has the right of way or
- The own vessel has the right of way.

According to COLREGS rules, the stand-on vessel should keep her course and speed while the give-way vessel must execute the avoidance maneuver.

3 TESTING THE ALGORITHM

Example 1: Five target vessels, Open Sea area. The distance to target vessels is less than or equal to 10 NM. The vessel's safety domain requirement is one nautical mile.

STEP 1: Initial data of own and target vessel

In step 1, the algorithm collects input parameters of the target vessels (initial conditions) within the range of navigational devices. Data obtained by AIS and ARPA radar are:

- Course Over Ground (COG),
- Speed Through Water (STW),
- Range to target vessel (RNG),
- Bearing of the target vessel (BRG),
- DCPA,
- TCPA,
- RB (calculated, using equation (2)).

Table 1: Initial data of own and target vessels

	COG [º]	STW [NM/h]	RNG [NM]	BRG [º]	Navig. Status
Own vessel	82	12			Power driven
Target 1	288	10	7.9	85	Constrain by draft
Target 2	70	27	3.2	233	Power driven
Target 3	262	15	9.4	79	Power driven
Target 4	181.5	15	8	32	Power driven
Target 5	32	23	7.8	174	Engaged in fishing

Table 2: Obtained data DCPA and TCPA, calculation of RB

	DCPA [NM]	TCPA [min]	RB [º]
Target 1	1.208	21.8	3
Target 2	0.43	12.3	151
Target 3	0.492	20.9	357
Target 4	0.61	23.1	310
Target 5	0.948	26	92

STEP 2: Determining the navigation situation for vessel with DCPA less than vessel's safety domain

The next step is the classification of vessels (which has DCPA less than 1 NM) into sectors based on RB value. The determination of the navigational situation is also based on the difference between course of own and target vessel. Since target vessel 1 has DCPA larger than 1 NM, it is not a subject of classification.

Table 3: Classification of vessels according to Navigation situation

	RB	Sector	COG_O-COG_T	Nav. situation
Target 2	151º	II	12º	Rule 13
Target 3	357º	IV	180º	Rule 14
Target 4	310º	III	99.5º	Rule 15
Target 5	92º	I	50º	Rule 15

STEP 3: Determining the right of way on the Open Sea area

At step 3, the algorithm activates conditional sentences (see paragraph 2.1) to determine the right of the way for each vessel according to the COLREGS rules.

Table 4: Determination of the right of the way in Open Sea

	Target 2	Target 3	Target 4	Target5
Sector	II	IV	III	I
Vessel's type	Power-driven	Power-driven	Power-driven	Engag. in fishing
Nav. Situation	Rule 13	Rule 14	Rule 15	Rule 15
Vessel with the right of the way	Own vessel	Target vessel	Own vessel	Target vessel

STEP 4: Determining the most dangerous vessel in a multi-encounter vessel situation

The last stage in the algorithm is a determination of the most dangerous vessel in a multi encounter situation. Since both stand-on vessels are located in sectors I and IV, the algorithm includes Exception rule no. 2, which dictates that own vessel should avoid the one nearest. In this case, target vessel no. 5 is that vessel, which should avoided.

Table 5: Determining the most dangerous vessel

	TCPA [min]	RNG [NM]	Vessel to avoid
Target 3	20.9	9.4	
Target 5	26.0	7.8	X

Example 2: Five target vessels, Narrow Channel area. The distance to target vessels is less than or equal to 10 NM. The safety domain requirement is 1 NM. Initial data of own and target vessels are the same as in example 1. Own vessel is proceeding along the course of a narrow channel. Algorithm steps 1 and 2 are the same as in example 1:

- Calculation of DCPA, TCPA and RB parameters;
- Classification by sectors I, II, III or IV;
- Determination of the navigational situation, Rules 13, 14 or 15.

The main difference is in step 3.

STEP 3: Determining the right of the way in a Narrow Channel area

At the step 3, the algorithm determines the right of way according to the COLREGS rules in Narrow Channel.

Table 6: Determination of the right of the way in Narrow Channel

	Target 2	Target 3	Target 4	Target 5
Sector	II	IV	III	I
Vessel's type	Power driven	Power driven	Power driven	Engag. in fishing
Nav. Situation	Rule 13	Rule 14	Rule 15	Rule 15
Vessel with the right of the way	Own vessel	Target vessel	Own vessel	Own vessel

In a Narrow Channel area, target vessel no. 5 becomes a give-way vessel. According to the results, the only vessel to avoid is target vessel no. 3. An avoidance maneuver must be done based on a COLREGs rule 14:

“When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the other.” (IMO, 1972)

Example 3: Initial data of own and target vessels are the same, except that the navigational area is Traffic Separation Scheme. Own vessel sails in the general direction of traffic flow.

Algorithm steps 1 and 2 are the same as in example 1 and 2:

- Calculation of DCPA, TCPA and RB parameters;
- Classification by sectors I, II, III or IV;
- Determination of the navigational situation, Rules 13, 14 or 15.

STEP 3: Determining the right of way in the Traffic Separation Scheme

At step 3, the algorithm activates conditional sentences to determine the right of the way for each vessel according to the COLREGS rules in Traffic Separation Scheme area.

Table 7: Determination of the right of the way in Traffic Separation Scheme

	Target 2	Target 3	Target 4	Target 5
Sector	II	IV	III	I
Vessel's type	Power-driven	Power-driven	Power-driven	Engag. in fishing
Nav. Situation	Rule 13	Rule 14	Rule 15	Rule 15
Vessel with the right of the way	Own vessel	Target vessel	Own vessel	Target vessel

STEP 4: Determining the most dangerous vessel in a multi-encounter vessel situation

As in example 1, target vessels no. 3 and 5 are stand-on vessels. The algorithm uses Exception rule no. 2, and target vessel no. 5 is the most dangerous vessel in a multi-vessels encounter.

Table 8: Determining the most dangerous vessel

	TCPA [min]	RNG [NM]	Vessel to avoid
Target 3	20.9	9.4	
Target 5	26.0	7.8	X

4 CONCLUSION

Understanding COLREGs rules is left to individuals, who may interpret each rule differently. As been highlighted in the introduction, the rules do not cover all situations at sea, including multi-vessel encounters. Also, in some Narrow Channels a Traffic Separation Scheme is organized, and here we come to the question which rule to apply, COLREGs rule 9 or 10? Examples 2 and 3 in the paper indicate that the determination of the right of the way in the Narrow Channel and in the Traffic Separation Scheme varies.

The proposed algorithm can help navigators to avoid a collision at sea, in different navigation areas, such as the Open Sea, a Traffic Separation Scheme or a Narrow Channel. The algorithm also distinguishes the right of way according to the type of the vessel (COLREGs rule 18) and the navigation situation (COLREGs rules 13, 14 and 15); thus, it could be a useful tool, especially for young navigators.

In the case of navigation in the Narrow Channel, where at the same time a Traffic Separation Scheme is organized, avoidance according to COLREGs Rule 9 should be the appropriate decision, since, in particular, larger vessels are restricted in maneuvering due to natural geographical barriers.

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PID AUTOPILOT DESIGN FOR HEADING CONTROL PROBLEM OF A CONVENTIONAL SHIP

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ABSTRACT

The PID is the most commonly used control strategy worldwide. In this paper PID autopilot design for heading control problem of a conventional ship is considered. In order to determine the optimal PID control parameters for autopilot the Particle Swarm Optimization (PSO) algorithm will be used. To analyze the advantages of optimized parameters by using PSO, comparisons are made with the previous results, i.e. with the results obtained by using pole placement technique.

Keywords: PID, autopilot, design, PSO algorithm

1 INTRODUCTION

It can be said that the auto-pilot system represents one of the most technically sophisticated navigational equipment tools on ships [1]. It is synchronized with the position sensor (gyro compass) to steer manually input courses, with reference to the gyro heading. In fact, auto pilot steers the manually input course by controlling the steering gear to turn the rudder in the required manner [1-2]. Furthermore, modern auto-pilot systems are capable of being synchronized with the Electronic Chart system (ECDIS) enabling to follow the courses laid out in the Voyage plan.

To design an autopilot for ship is always a challenging problem [1-5]. Any ship, and therefore a ship dynamics is influenced by unpredictable environmental disturbances (waves, winds, currents etc). For that reason, the autopilot must assure performance conditions in both course-keeping and course-changing control problems. It must be PID type to assure null stationary error for both step and ramp variations on reference and disturbances inputs. Also, in course-changing control problems, PID autopilot can act as a tracking system to a desired trajectory, consisting of line segments [4].

With the development of control theory and method, the control of autopilot is gradually improved. Therefore, many researches in the field of PID ship autopilot can be found in literature [6-15]. Concretely, for PID ship autopilot design/definition can be used fuzzy logic [6-8], neural network [9-10], Kalman filter [11], observer technique [12], adaptive algorithm [13], genetic algorithm [14] etc.

This paper represents improvement of the paper [15], in which a simple analytical expression for PID controller parameters is presented. Namely, in this paper PSO algorithm for PID parameters optimization is used, taking into account that expected optimal value of the parameters are around values which are obtained with model presented in [15]. Therefore, in this paper, PID autopilot design for heading control problem of a conventional ship is considered in simulations. The ship model is obtained from the equations describing the horizontal motion of the ship, while, it is assumed that PID controller contains a supplementary degree of freedom, as it is suggested in [15].

The paper is organized as follows. Section 2 provides mathematical models for the plant and PID controller. In Section 3, short description about PSO algorithm is presented. Section 5 describes the simulation results obtained by using PSO together with results found in literature. Conclusions are presented in Section 6.

2 SHIPS MODEL AND PID CONTROLLER

Conventional ship autopilot for course-keeping and course-changing control problems involves the heading angle feedback, as shown in Fig. 1. The yaw motion of the ship is described by the transfer function H_p (s) from the rudder angle (δ) to the course angle (ψ). The autopilot generates the rudder commands, based on the course error (ε), which appears due to external disturbances. It should be noted that the external disturbances are generated by environmental conditions (for example waves, wind, marine currents) or by control systems (for example steering system, propulsion system).

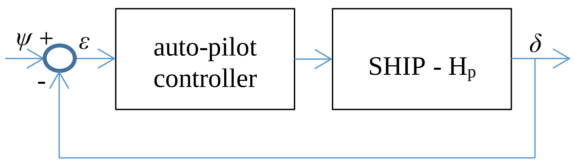

Figure 1: Block diagram of ship and autopilot controller

A linear model of the ship's dynamics for yaw motion, without considering any perturbations, can be represented as a first order *Nomoto* model [3], whose differential equation is:

$$\ddot{\psi}(t)+\frac{1}{T_p}\dot{\psi}(t)=\frac{k_p}{T_p}\delta(t) \tag{1}$$

The corresponding transfer function is:

$$H_p=\frac{k_p}{s\left(sT_p+1\right)}, \tag{2}$$

where the parameters k_p and T_p depend on the operating conditions such as ship's speed, load or ballast situation, water depth. It should be noted that the *Nomoto* model provides a reasonably accurate representation, if the rudder angles are relatively small. This is the case for course keeping control and for slight course changes.

As it is suggested in [15], PID with supplementary degree of freedom, for autopilot course keeping control, should be used. Its mathematical equation is in the following form:

$$H_c=\frac{k_c}{sT_c}\left(sT_c+1\right)\frac{\left(sT_c'+1\right)}{\left(sT_1+1\right)} \tag{3}$$

It should be noted that in [15] PID controller design by combining pole placement technique with symmetrical optimum criterion is presented. This model is based on low-order plant model with pure integrator. If the natural frequency ω_0 and damping coefficient ξ are known, the unknown parameters for PID can be obtained as follows:

$$k_c=\frac{\omega_0}{k_p},\ T_c=\frac{2\xi+1}{\omega_0}$$

$$T_c'=T_p,\ T_1=\frac{1}{\left(2\xi+1\right)\omega_0} \tag{4}$$

3 PSO ALGORITHM

PSO algorithm is said to represent a derivative-free algorithm, which utilizes cooperation together with experience of the population individuals along with probabilistic transition rules of search [16-17]. It is a member of the evolutionary routines family, which mimics the social behavior of a swarm of birds (particles) seeking the richest food source in a large field [16-17].

Each particle in PSO keeps track of its co-ordinates in the problem space, which are associated with the best solution (best fitness) it has achieved so far. This value is called *pbest*. Another ''best'' value that is tracked by the global version of the particle swarm optimizer is the overall best value and its location obtained so far by any particle in the swarm. This location is called *gbest* [16-17].

Each particle tries to modify its position using information about the current position, the current velocity, the distance between the current position and the *pbest* and the distance between the current position and the *gbest*. Namely, let *X* denotes the particle's position and *V* denotes the particle's corresponding velocity in search space. At iteration *K*, each particle *j* has its position and velocity defined by $X_j^K = [X_{j,1}, X_{j,1} \dots X_{j,N}]$ and $V_j^K = [V_{j,1}, V_{j,1} \dots V_{j,N}]$, respectively, in search space *N*. In the next iteration, velocity and position of each particle can be calculated as follows

$$V_{j,n}^{k+1} = W \cdot V_{j,n}^{k} + C_1 \cdot rand_1\left(pbest_{j,n} - X_{j,n}^{k}\right) + C_2 \cdot\ rand_2\left(qbest_n - X_{j,n}^{k}\right), \tag{5}$$

$$X_{j,n}^{k+1} = \begin{cases} X_{j,n}^{k} + V_{j,n}^{k+1} & X_{min,j,n} \le X_{j,n}^{k+1} \le X_{max,j,n} \\ X_{min,j,n} & X_{j,n}^{k+1} \le X_{min,j,n} \\ X_{max,j,n} & X_{j,n}^{k+1} \ge X_{max,j,n} \end{cases} \tag{6}$$

where j=1, 2, …, m; n=1, 2, … N; m is number of particles in the swarm, N is the number of dimensions in each particle, K is the pointer of iterations, $V_{j,n}^{k}$ is the velocity of particle j at iteration k, W is weighting factor, C1 and C2 are acceleration factors, rand1 and rand2 are random number between 0 and 1, $X_{j,n}^{k}$ is the current position of particle j at iteration k, $pbest_{j,n}$ is the personal best of particle *j* and $qbest_n$ is the global best of the group. For weighting function W the following expression is usually used:

$$W = W_{max} - (W_{max} - W_{min})\frac{iter}{iter_{max}}, \tag{7}$$

where W_{max} and W_{min} are the initial and final weight respectively; *iter* is the current number and $iter_{max}$ is maximum iteration number.
In this paper, PSO algorithm is used for solving PID parameters estimation problem (identification of the PID parameters). Namely, the goal is to find the PID parameters (k_c, T_c, T_c' and T_1) that minimise the absolute difference between input step impact and corresponding system response.

Therefore, the *ISE* (**I**ntegral **S**quare **E**rror) function has been selected as the optimum function, with its mathematic form:

$$ISE = \int_0^\infty e^2(t)dt, \tag{8}$$

where *t* – is time, and *e(t)* – is the difference between the rudder angle (δ) and course angle (ψ).

The constraints of the used optimization technique in the present research paper are (k_c, T_c, T_c' and T_1) which must be bounded within some pre-specified limits. These limits may be mounted as follows

$$k_c^{min} \le k_c \le k_c^{max},\ T_c^{min} \le T_c \le T_c^{max}\ T'^{min}_c \le T'_c \le T'^{max}_c,\ T_1^{min} \le T_1 \le T_1^{max} \tag{9}$$

where the superscripts *min* and *max* speak for the minimum and the maximum values of the respective variables.

4 SIMULATION RESULTS

Proposed method is used for PID parameters determination of ship model which parameters are as follows k_p=-0.0834, T_p=5.98 [15]. Also, it is assumed that the natural frequency ω_0 is 0.1rad/s while damping coefficient ξ is 0.9 [15].

Analytical results of the PID parameters obtained by using analytical model [15] are presented in Table I. For PSO algorithm, the bounds of the unknown parameters are assumed that have value +10% (upper limit) and -10% (lower limit) of values obtained by using model [15]. Obtained results are presented in Table I, too.

The step responses of the closed-loop transfer function for both cases are illustrated in Figure 2. The step reference input is represented with dotted line. Similarly, the ramp responses of the proposed system are illustrated in Figure 3. Also, the ramp reference input is represented with dotted line.

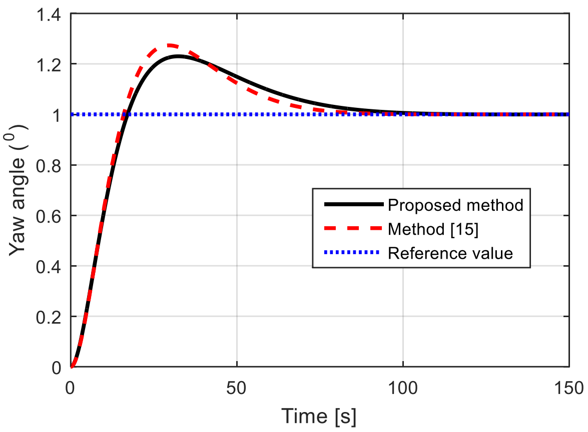

Figure. 2: Step response of the closed-loop system.

As it can be seen, in both case, PID autopilot assures null stationary error for both step and ramp variations on reference inputs.

However, looking the results presented on these figs, as well as the results presented in Table II, it is evident that PSO parameters ensure lower peak response. Furthermore, it is very important result which guarantees that when some step error happens the system response will have a lower peak response. For both analyzed PID results, the system rise times are almost equal.

Table 1: Comparison of results

parameters	Analytical results from [15]	Proposed method - PSO
K_c	-1.2	-1.1102
T_c	28	30.8
T'_c	5.98	6.4569
T_1	3.57	3.3035

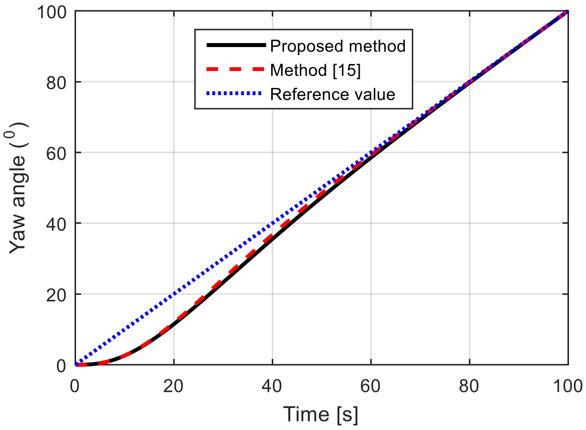

Figure 3: Ramp response of the closed-loop system.

Table 2: Characteristics of obtained signals

parameters	Analytical results from [15]	Proposed method - PSO
Stedy state	1	1
Maximal value	1.2734	1.2302
Rise time[s]	8.38	8.44

5 CONCLUSION

In this paper the usage of PSO algorithm for PID parameters determination of ships autopilot is presented. In that goal, a literature known ship model, as well as PID model is used.

Obtained results are compared with results found in literature (with analytical solution). It is shown that proposed method enables obtaining results with better characteristics – in concrete case we have obtained lower peak response for input step change.

In future work, the usage of PSO algorithm for improvement of magnitude-frequency characteristic will be analyzed. Also, the impact of the wider bound of parameters will be analyzed on both time and frequency characteristics.

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TRANSPORT COMMUNITY TREATY- INFLUENCE AND ASPECTS FOR BOSNIA AND HERZEGOVINA

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ABSTRACT

In order to accelerate the EU integration processes in the field of transport, the Treaty on the establishment of the Transport Community between the EU and the Western Balkans countries promotes progressive integration of transport markets of these countries in accordance with the relevant EU *acquis*, covering the areas of technical standards, interoperability, safety, security, traffic management, social policy, public procurement and environmental issues as been signed. The main objective of the Treaty is the establishment of the Transport Community for different transport modes: road, rail, maritime transport and inland waterway, as well as the development of the transport network between the EU and Western Balkans countries. In addition to the support of the development of the indicative TEN-T extension of the comprehensive and core networks of the Western Balkans, according to the EU Regulation 2016/758, the Transport Community will contribute to the development of the key transport links and interconnections required to eliminate the existing bottlenecks and interconnections of national Western Balkans networks and the ones within the EU TEN-T. Bosnia and Herzegovina as a signatory of the above Treaty is obliged on the full implementation of the Transport Community and the Transitional Arrangement between the EU and Bosnia and Herzegovina which progress will be the subject of the assessment in that respect. This paper gives a deeper elaboration on different aspects of the Treaty and assesses possible benefits on further Bosnia and Herzegovina transport sector development and the influence on its integration in the EU.

Keywords: Transport Community, integration, transport market, transport network, EU *acquis*, development

1 INTRODUCTION

Intensification of regional integration process of Western Balkans countries with the European internal transport market is a focal point of EU diplomacy efforts[1]. With the vision to develop the competitive transport system and high quality and safe services, transposing EU legislation in order to strength the economic development, the Transport Community Treaty (TCT[2]) has been signed on Trieste Western Balkans Summit (12 July, 2017).

Evidently poor conditions of the transport infrastructure in the South East European[3] countries, as well as, non-harmonized legislative and institutional framework, were the initial issues for the Treaty on Transport Community.

This paper aims to provide the deeper analysis of the main objectives and principles, as well as the organizational structure of the Transport Community with the special emphasis on the evaluation of the following:

2 EU TRANSPORT COMMUNITY TREATY

2.1 Main objectives and principles

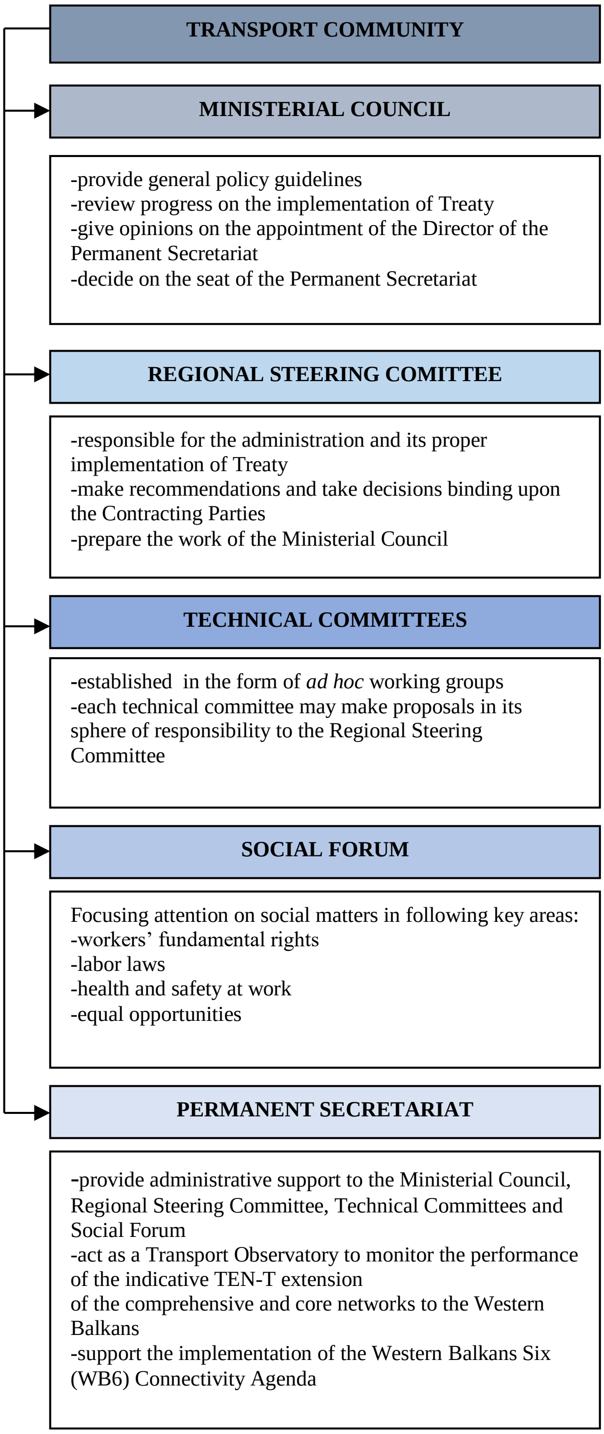
The main objective of the Treaty is the establishment of the Transport Community (hereafter ''TCT'') in the field of road, rail, maritime transport, inland waterways and the development of the transport network between the European Union and the SEE countries. Main principle of the Transport Community is based on the progressive integration of transport markets of the SEE countries into the European Union transport market on the basis of the relevant *acquis*[4], for all modes of transport excluding the air transport in the following areas: technical standards, safety, interoperability, traffic management, security, social policy, public procurement, and environment.

2.2 Organizational structure and TC bodies

Implementation of the Transport Community objectives will be enabled throughout the following organizational structure and relevant bodies: Ministerial Council, Regional Steering Committee, Technical Committees,

[1] Summits hold in: Berlin (28 August, 2014), Vienna (27 August, 2015) and Paris (4 July, 2016)
[2]For the purpose of this paper will be used acronyms: TCT and TC for EU Treaty on establishing Transport Community and Transport Community, respectively
[3]The South East European Parties (SEE): the Republic of Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Kosovo, Montenegro, the Republic of Serbia what corresponds to the also to the Western Balkans Region (WB). Both acronyms will be used equally in this paper.
[4] Regulatory rules applicable to different modes of transport covering specific regulatory areas are presented in Annex I of the Treaty.

Social Forum and Permanent Secretariat. Their scope of activities and obligations is presented in the Figure 1.



Source: Authors based on TCT

Figure 1: TCT Organizational structure chart

2.3 Operating scope and conditions for different transport modes

The operating area of different transport modes within the scope and conditions of the Treaty and the relevant acts are specified in an Annex I.

2.3.1 Rail transport

For the purpose of operating international rail passenger or freight services providing the right of access to the infrastructure in all EU member states and SEE countries to all railway undertakings licensed in an EU or by a SEE country is obliged. Also, the TCT will not allow any restrictions on the validity of licenses of railway undertakings, safety certificates, the certification documents of train drivers and rail vehicle authorizations granted by the relevant authority of EU Member State or SEE country.

2.3.2 Road transport

In the road transport the TCT is focusing on the promotion of the efficient and safe road transport operations in all SEE countries, as well as, the enforcement of stronger co-operation in order to harmonize the operating standards and policies on EU road transport, by implementing the road transport *acquis.*

2.3.3 Inland waterway transport

Focal point in the field of inland waterway transport is the promotion of the efficient and safe operations. It is also required to establish a higher level of co-operation between all SEE countries aiming to reach the convergence towards operating standards and policies on inland waterway transport.

2.3.4 Maritime transport

Promotion of the efficient and safe maritime transport operations and co-operation between the EU and SEE countries shall aim to reach the convergence towards operating standards and policies on maritime transport of the EU.

2.4 TCT budget contributions

Transport Community budget is defined by the contributions[5] of the EU and SEE countries (Annex V).

[5]The level of contributions may be reviewed every three years, on request of any Contracting Party, by a decision of the Regional Steering Committee.

Table 1: TCT parties budget contribution

Parties	Contribution in percentage
European Union	80,00%
Republic of Albania	3.20%
Bosnia and Herzegovina	3.55%
FYR Macedonia	2.88%
Kosovo	2.57%
Montenegro	2.38%
Republic of Serbia	5.42%

Source: TCT, EU,2017.

In order to cover the operational expenses for functioning of its bodies it shall be adopted every year by the Regional Steering Committee. Contribution to the budget of the transport community of each party is presented in Table 1.

The budget contribution is divided into two parts: 80 % for the EU and 20 % for the six SEE countries. Distribution of the 20% of the contribution among the six SEE countries is presented in Figure 2.

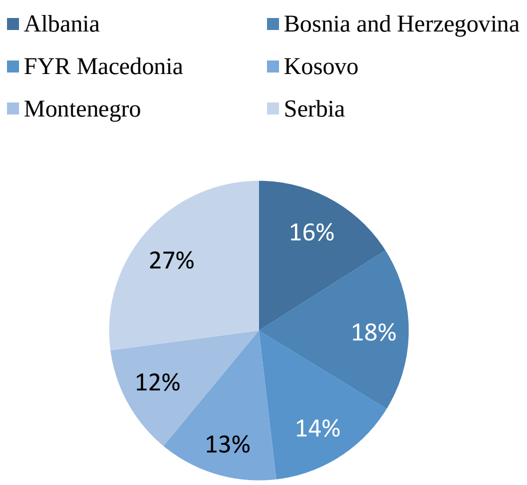


Figure 2: Distribution of budget contributions among SEE countries (%)

The 20 % for the South East European Parties will also be broken down according to the following scheme: each Party contributes with 2 % to the budget and the remaining 8 % will be distributed among the six South EasternEuropean parties depending on their share in the total GDP of the South Eastern European parties' (Annex V).

2.5 TCT rules on competition and state aid

According to the Treaty's transitional measures, in order to avoid discrimination, progressive adjustment of any state monopolies is required, and the Regional Steering Committee shall monitorthe measures adopted to attain this objective.In that respect, approximation of the existing legislation on state aid and competition of the SEE countries to that of the EU is needed, in order to ensure that their existing and future laws on state aid and competition are gradually compatible with the *acquis*by the end of the Treaty's second transitional period.

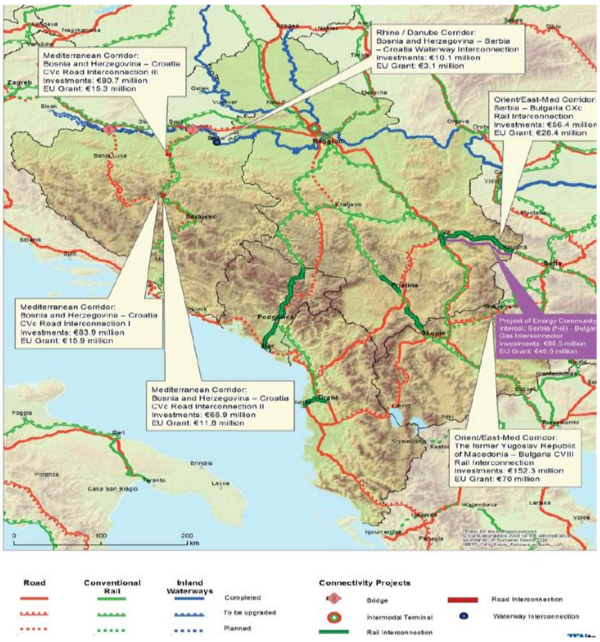
Competition rules and other economic provisions[6] are focused on following issues:

1. The practices that are incompatible with the proper implementation and functioning of the Treaty include: (a) All agreements between undertakings, decisions by associations of undertakings and concerted practices between undertakings which have as their object or effect the prevention, restriction or distortion of competition; (b) Abuse by one or more undertakings of a dominant position in the territories of the Contracting Parties as a whole or in a substantial part thereof; (c) Any state aid which distorts or threatens to distort competition by favoring certain undertakings or certain products.
2. Each SEE country shall ensure that an operationally independent public body is entrusted with the powers necessary for the full application of previous points (a) and (b), regarding private and public undertakings and undertakings to which special rights have been granted.
3. Each SEE country shall designate or establish an operationally independent authority which is entrusted with the powers necessary for the full application of point (c). This authority shall have the powers to authorize state aid schemes and individual aid grants as well as the powers to order the recovery of state aid that has been unlawfully granted.
4. Full transparency in the area of state aid should be ensured by providing a regular annual report, following the methodology of the EU survey on state aid.

3 TCT AND TEN-T INFRASTRUCTURE DEVELOPMENT COMPATIBILITY

Regarding the future transport infrastructure development in the SEE countries, the TCT is fully consistent with the indicative Trans-European Transport Networks (TEN-T) extension of the comprehensive and core networks to the Western Balkans according to EC Regulation 2016/758.

[6]Rules on competition and state aid referred to in Article 17 of the main Treaty are stated in ANNEX III



Source: Connectivity agenda, EC, 2017.

Figure 3: Investment projects in 2017 co-financed through Pre-Access Assistance and Western Balkan Investment Framework (WBIF)

The map of the indicative TEN-T network extension of comprehensive and core networks to the Western Balkans is presented in the Figure 3. Extending the core TEN-T network corridors to the Western Balkans transport infrastructure is a key integration driver of a closer integration within the EU region, as well as the precondition for increasing its economic competitiveness.

The European Union's commitment to improving connectivity with and within the Western Balkans builds on past support given to the region: by 2014, EU had leveraged investments worth more than EUR 3 billion for infrastructure projects in the Western Balkans through EUR 660 million in grants (Connectivity Agenda, EC, 2017).Table 2 shows the major investment projects in Western Balkans for the period 2014-2017.

Table 2: Investment projects in Western Balkans (2014 – 2017)

Country	Connection	Mode	Mil. €	
			Invest ment	EU Grant
Bosnia and Herzegovina	Mediterranean Corridor	Road	80.7	15.3
			66.9	11.8
			83.9	15.9
	Rhine / Danube Corridor	IWW	10.1	3.1
FYRM	Orient/East-Med Corridor	Rail	152.3	70
Serbia	Orient/East-Med Corridor	Rail	56.4	28.4
	Djerdap/ Danube	IWW	25	11.4

Source: EU financial support in Western Balkans Transport projects, EC 2017

The Regional Steering Committee shall report every year to the Ministerial Council on the implementation of the TEN-T described in TCT, assisted by Technical Committees in drawing up the report, taking into account the related bilateral and multilateral agreements concluded by the EU and SEE countries, including the development of key links and interconnections needed to eliminate bottlenecks and to promote the interconnection of national networks and with the EU TEN-T networks.

A five-year rolling work plan for the development of the indicative TEN-T extension of the comprehensive and core networks to the Western Balkans will be developed by the Transport Community every two years. This plan will identify priority projects of regional interest in line with the best EU practice and should contribute to balanced sustainable development in terms of economics, spatial integration, environmental and social cohesion. The five-year rolling work plan[7]will be complied with the relevant legislation of the EU, in particular when funding of the EU is envisaged, in accordance with donors' funding rules and best international standards and practices provide the best-value-for-money, and giving a special attention to environmental sustainability and broader socio-economic impacts. Also, it has to consider the funding opportunities from donors and international financial institutions, inparticular through the Western Balkans Investment Framework (WBIF). In order to monitor and review the condition and performance of the indicative TEN-T extension of the comprehensive and core networks to the Western Balkans an information system will be put in place by the TC Permanent Secretariat.

4 ASSESMENT OF TCT EFFECTS FOR BOSNIA AND HERZEGOVINA

4.1 Progress overview in EU standard implementation

The low quality and density[8] of transport network influence the high costs of inputs, production and distribution, and therefore low national competitiveness. In Bosnia and Herzegovina there was no consistent development for all modes of transport networks, what creates the huge inter-modal gaps. For 1500km of roads in post-war period it has been invested cca3 bln EUR, and at the same time for almost the same length of rail network it has been invested ten time less, just 385 mil EUR (Ferizović, 2017). It is, also, important to underline that Bosnia and Herzegovina is the only-one country in the region without physical sea port infrastructure, even it is a coastal country, what reduce the possibility for its real integration in maritime sea flows. In terms of implementation of the EU legislation a slow progress has been registered. Some progress has been made last year, which included the adoption of the Framework Transport Strategy and the Action plan. More efforts are still needed to strengthen the financial and technical capacity of the authorities in all transport sectors.

According to the EC Report on Bosnia and Herzegovina (EC, 2016), the country has partly aligned its legislation

[7]stated in the Article 9 of the Treaty

[8] It is more than two times lower than EU average.

with the *acquis* on rail transport. The separation of train operations from infrastructure management has progressed but independence of infrastructure managers to make decisions has not been fully achieved. The Railway Regulatory Board is functioning as an independent safety and regulatory authority in Bosnia and Herzegovina and it has certified incumbent undertakings (ŽFBH and ŽRS) to the access to the network, since the railway market is not opened yet, primarily due to safety reasons. Technical specifications for interoperability and COTIF[9] regulations are transposed by the B&H Railway Regulatory Board as railway regulations. On maritime transport there is no alignment with the EU *acquis*[10]. Bosnia and Herzegovina has a coastline of 27 km and lacks ports and a fleet.

Regarding the inland waterway transport, navigation is the responsibility of the entities authority, which has adopted legislation on maritime and inland navigation. Bosnia and Herzegovina has not adopted legislation on merchant shipping and it is required to align the same with the relevant EU legislation and a state-level authority for inland waterways needs to be established. B&H is a signatory to the main international and bilateral agreements on inland waterways[11]. Even the development of the Sava River is based on the B&H transport Master plan (2001), preparation of the Study on Market and Demand for River Transport in B&H (2008) and of the Transport Strategy (2017) has been considerable delayed which influenced overall rehabilitation of the Sava River navigation route.

4.2 TCT Transitional Arrangement between the EU and Bosnia and Herzegovina

Transitional arrangement between the European Union and Bosnia and Herzegovina, which is the part of TCT, from the timelineframework,has been set up in two periods, first and second transitional period.

Table 3: TCT measures referred to B&H

I TRANSITIONAL PERIOD	
Rail	**Have to implement all railway legislation as provided for in Annex I**
	Have to make sufficient progress in implementing the rules on State aid and competition included in an agreement (Article 17 of the Main Treaty or in Annex III)
	Railway undertakings licensed in B&H shall be granted access to railway infrastructure in B&H
Maritime transport	Have to implement all maritime legislation (Annex I with the exception of Regulation (EEC) No 3577/92)
	Nationals of B&H and shipping companies established in B&H will have the right to carry passengers or goods by sea between any port of a EU and any port or off-shore installation of another EU state or of a country that is not a member of the EU
	Union ship owners will have the right to carry passengers or goods by sea between any port or off-shore installation of a MS and B&H and any port or off-shore installation of a country that is not a member of the EU and B&H
II TRANSITIONAL PERIOD	
Rail	By the end of the second transitional period B&H shall apply this Treaty, including all railway legislation and the rules on State aid and competition
	Railway undertakings licensed in B&H shall be permitted to exercise the traffic rights provided for in the railway legislation referred to in Annex I on railway infrastructure of any other South East European Party
IWW	B&H shall apply Treaty, including all legislation set out in Annex I
	B&H shall enjoy the right to carry passengers or goods by inland waterways between any port of an EU Member State and any port or off-shore installation of another Member State.
Maritime transport	B&H shall apply Treaty, including all legislation set out in Annex I
	Union ship owners operating ships registered in a EU Member State or in B&H and flying the flag of that EU Member State or B&H will be granted freedom to provide maritime transport services within B&H under conditions laid down in Regulation (EEC) No 3577/92
	Ship owners of B&H operating ships registered in EU Member State or in B&H and flying the flag of that EU Member State or B&H will be granted freedom to provide maritime transport services within any Member State under conditions laid down in Regulation (EEC) No 3577/92

Source: TCT, EC, 2017.

Table 3 provides summarized measures that have to be implemented in order to reach the defined goals for the rail, inland waterway and maritime transport in the first and the second transitional period,respectively.

4.3 SWOT analysis

For the purpose of this paper, the SWOT analysis has been developed in order to assess all the benefits and concerns in regards to the obligations derived from the TC and its impact on Bosnia and Herzegovina case. Figure 4 summarizes the key aspects of the SWOT analysis.

- The main strengths of the TC in B&H are:
- Strengthening of the transport regulatory framework and administrative capacities will ensure continuous benefit from the TC;
- Implementation of the high priority projects

[9] Convention concerning International Carriage by Rail (COTIF)

[10] Bosnia and Herzegovina ratified the Maritime Labour Convention in 2010 which entered into force on 20 August 2013. Bosnia and Herzegovina should continue its efforts to become party to all basic conventions of the International Maritime Organization and to follow up on its membership application to the Paris Memorandum of Understanding. Bosnia and Herzegovina participates in the EU Strategy for the Adriatic-Ionian Region, (EC, 2.016)

[11]B&H participates in the EU strategy for the development of the Danube Region and is a as well as a number of bilateral agreements withneighboring countries, such Sava River Commission Agreement (EC, 2.016).

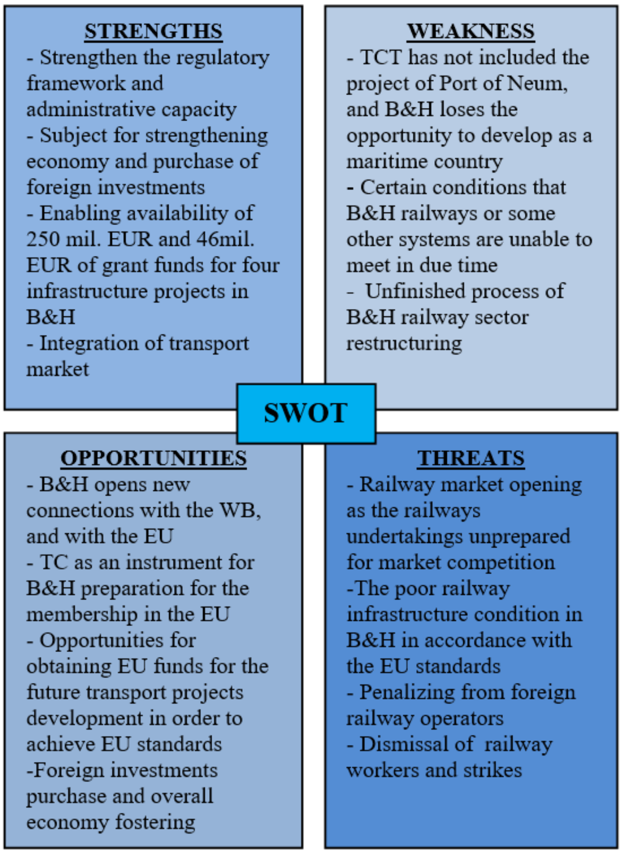
- improvement and development of the transport infrastructure will contribute to the improvement of the environment in B&H what will be the basis for strengthening of the economy and attracting foreign investments;
- Signing of an Agreement on B&H's entry into the Transport Community, will in the nearest future enable availability of 250 mil.EUR and 46mil.EUR of grant funds for four infrastructure projects in B&H. Three of the above projects are the projects on the Corridor Vc and the fourth project is the revitalization of the Port of Brčko on the Sava River(http://www.mkt.gov.ba)
- Establishment of competitive, reliable and safe B&H transport system.
- Eliminating of bottlenecks on some sections of transport network;
- The core network corridors, once completed, will provide quality transport services for citizens and businesses; and
- Connections with the TEN-T core and comprehensive network and integration of transport market.

Weakness of the Treaty can be summarized to as follows:

- The Treaty has not covered the project of the Port of Neum, on the outside of the Klek peninsula. An advantage to the already existing port, a river port in the Brčko District, which certainly has its significance.
- Some of the Treaty conditions cannot be fulfilled by the railways in B&H or by some other transport systems in this moment. The World Bank has indicated that it is necessary to undertake the previous restructuring of the railway companies, so to strengthen the domestic railway operators in order to counter the competition that will inevitably come, but it is unlikely that much can be done to improve the rail transportation services we now provide, since the quality of the service itself mostly depends on the quality of the railway infrastructure and its capacity.

TC will provide the numerous opportunities of a large significance for B&H future status in the Western Balkans region:

- TC is a suitable instrument for B&H preparation for the EU membership and preparing of its legislation in the field of transport within the framework of this community and adjusting transport infrastructure to the EU standards that citizens are expecting.
- The Transport Community Treaty opens new connections between B&H and the region of Western Balkans, and with the EU, as well as increases the effectiveness of border crossing procedures.
- Above will be a subject for faster progress of overall economy, including the tourism potential development.
- Possibilities to access to the entire corridor rather than merely national segments would attract investors and purchase of foreign investments..
- From the theoretical and empirical aspects, opening of the railway market would results in users' benefit in terms of providing better and more efficient services.
- The B&H economy is heavily dependent on railway transport services (some of the users of their transport are ElektroprivredaBiH, coal mines, Arcelor Mittal, Aluminij Mostar and others), and through strengthening of environmental friendly modes of transport and modal shift will be of a great contribution to the development of sustainable transport system.



Source: Authors

Figure 4: TC SWOT analysis for B&H case

The threats are arising as a consequence of the current state of the railway system in B&H, both in the technical and administrative areas:

- Concerns regarding the mission of railway undertakings in B&H after the entrance in TC regarding the poor railway infrastructure state in B&H, comparing with the European standards.
- Railways undertakings are unprepared for market competition. If the market opened this would lead to the uninhabited position of the railway companies and could result in the dismissal of workers and strikes.
- Incumbent railways are afraid that the opening of the market would lead to weakened segments of rail

operations, and consequently reducing of allocations for rail infrastructure. Also, if the market is opened with this condition of the infrastructure, where the railway network is restored only 30 %, the potential carrier would be able to make additional penalties due to delays and weather losses caused by the condition of the railway infrastructure, which should go to burden of the owner, in this case entities governments.

- Any early opening of the market requires a minimum of 400mil. EUR of EU funding that is necessary to invest in the railway infrastructure.

Railways transported nearly 14 million tons of goods and that the transport market share in financial terms amounts to about 75mil. EUR and cca 700 mil.EUR as a lost income of inhabitant railway undertakings in the next decade (www.zfbh.ba, www.zrs.ba).

5 CONCLUSION

The Treaty on the establishment of the Transport Community represents the beginning of the new era of intensive cooperation between the EU and the Western Balkans resulting in a faster and complete inclusion of this region in the European transport system.

The elaborated organizational structure, operating scope and roles of Transport Community shown that its establishment should provide realization of appropriate objectives and measures resulting in improvements of the transport infrastructure and services in whole Region.

Even the SWOT analysis has shown some concerns regarding the implementation of the Treaty on the Transport Community in Bosnia and Herzegovina, it would still provide numerous benefits in terms of strengthen the regulatory framework and obtaining the EU funds for the future transport infrastructure development, which would enable integration of transport market and country's integration process into the EU.

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BIRD STRIKE RISK ASSESSMENT MODELING IN AIRCRAFT OPERATIONS

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ABSTRACT

Nowadays, air transport industry is dedicated to resolving safety issues regarding bird strike during the aircraft operations. Therefore, bird strike is defined as one of the most important safety performance indicator within key risk areas defined by EASA. Although bird strikes do not always involve the aerodrome as they cannot be wholly prevented through bird management schemes, they typically occur in the aerodrome environment. The number of accidents and serious incidents involving bird strikes at or near EASA aerodromes could significantly vary depending of season, geographical position, etc. This paper proposes model for defining bird strike risks potential (by severity and probability), which could be used as a decision making tool for commercial aircraft operations. Developed model is based on the series of simulations provided within FlyLab to investigate possible consequences in the case of A320 landing on Hudson River due to the bird strike which led to both engine shut down. Providing adequate risk assessment for this sensitive issue allows proactive measures and procedures development. Good practice from the certain case study could be used for safety promotion activities on other airports and or aeries worldwide. The provided results could be used for further gap assessment regarding bird strike damaging potential and also to investigate financial loses which could be avoided in the future.

Keywords: Bird strike, aircraft, operations, safety, risk assessment, transport modeling & simulation

1 INTRODUCTION

Increased air traffic volume and growing bird population in almost every part of the world contributes to the bird strike risk increase. Collisions between birds and aircraft are daily events and in the most cases there is no safety impact on the flight. On the other hand some events of this kind did have catastrophic consequences in the past.

Nowadays, variety of numerical methods and validation procedure available for bird strike modeling have been developed. Bird strike simulations on aircraft structures have been performed and improved since the late 1970s (Heimbs, 2011). Safety engineers are faced to numerical methods for bird strike simulations based on aircraft structure or bird characteristics and behavior upon impact (Lavoie et al., 2007).

Bird strike modeling takes significant role in aircraft certification process. For example, A validated simulation methodology has been developed to support the bird-strike certification of the carbon fibre epoxy composite, moveable trailing edge (MTE) of the Boeing 787 Dreamliner. Subsequent use of the validated modeling procedures during the analysis of the MTE facilitated the evaluation of numerous bird-strike scenarios, leading to improved design efficiency and safety, while significantly reducing certification costs (Georgiadis et al., 2008). Aside the aircraft safety concerns, some authors are dedicated to helicopter safety during the bird strike (Tho and Smith, 2011).

Other aspect of bird strike modeling considers cost effective side of the possible damage which is important in resolving of 2P's dilemma (ICAO, 2013). This theory is well known as 'Protection vs. Productivity' and requires adequate resource allocation within the observed system. Some authors use cost benefit analysis to determine possible consequences of aircraft damage generally (Čavka and Čokorilo, 2012) or caused by bird strike (Nešić et al., 2016; Nešić et al., 2017; Nešić and Čokorilo, 2017).

The risk of bird strike cannot be completely eliminated and there will always be a likelihood of collision no matter how much they have invested in the prevention. On the other hand, the question arises if it is not possible to completely eliminate such events as soon as possible to mitigate their consequences and thereby prevent the emergence of high costs. The Hudson river bird strike with A320 in New York (2009) may give an answer to this question. Good practice from the certain case study could be used for safety promotion activities on other airports and or aeries worldwide. The provided results could be used for further gap assessment regarding bird strike damaging potential and also to investigate financial loses which could be avoided in the future.

In the public the case is known as the "Miracle of the Hudson" due to circumstances that caused accident, extraordinary pilot skills and no human loses. Although, the accident did have consequences such as serious injuries and the airplane was substantially damaged. The landing on the water surface is highly undesirable but in this case probably was the only possible solution. Therefore, one of the goals is to investigate if there was more suitable place for landing than Hudson river.

2 FLIGHT 1549 BIRD STRIKE CASE

The most famous collision between aircraft and birds happened on 15th of January 2009 when US Airways flight 1549 operating on Airbus A320-214 collided with flock of birds short after take-off from LaGuardia (LGA) airport. The ingestion of large birds into each engine resulted in an almost total loss of thrust in both engines which caused loss of thrust in both engines and subsequent ditching on the Hudson river.

All data regarding flight 1549 that have been used in the paper are actual historical data published in the official accident report issued by NTSB in 2010.

2.1 Flight 1549 data

Actual flight 1549 data that have been used in the simulation:

- Aircraft operator: US Airways
- IATA code: US
- ICAO code: AWE
- Aircraft type: A320-214
- Engine type: CFM56-5B4/P
- Date: 15th January 2009
- Departure airport: LaGuardia New York KLGA – Runway 4
- Destination: Charlotte Douglas International Airport, Charlotte, North Carolina, KCLT
- 150 passengers + 5 crew members on board

Two METAR reports for LGA airport for a period of time in which the accident occurred are:

SA 15/01/2009 20:51 METAR KLGA 152051Z 36008KT 10SM SCT044 M06/M15 A3025 RMK AO2 SLP242 T10611150 53014=

SA 15/01/2009 19:51 METAR KLGA 151951Z 34013KT 10SM BKN035 M06/M14 A3022 RMK AO2 SLP234 T10611139=

More precise meteorological conditions are given in the official accident report. The closest automated surface observing systems was located about 1.6 miles east of the accident site and two meteorological reports closest to the accident occurred are:

1451LT:

Winds 290° at 8 kts/ Visibility 10 miles/ Cloud ceiling 3,700 feet broken/ Temperature -6° C/ Dew point -15° C / Altimeter setting 30.24 inches of mercury (Hg).

1551LT:

Winds 310° at 9 kts/ Visibility 10 miles/ Few clouds at 4,200 feet/ Temperature -7° C/ Dew point -16° C/ Altimeter setting 30.28 inches of Hg.


(LGA5.LGA) 17285 AL-289 (FAA)
LA GUARDIA FIVE DEPARTURE
LAGUARDIA (LGA)
NEW YORK, NEW YORK

DEPARTURE ROUTE DESCRIPTION

TAKEOFF RUNWAY 4: Climb heading 044° to 600, then right turn heading 055°, maintain 5000, Thence....
TAKEOFF RUNWAY 13 (Coney Climb: TURBOJETS ONLY - Requires minimum ATC climb of 900′ per NM to 1500, if unable, advise ATC): Climbing right turn heading 180° to intercept CRI R-043 (do not exceed 230K until intercepting CRI R-043) to CRI VOR/DME then on CRI R-223. Cross LGA 2.5 DME at or above 1500′, maintain 5000, Thence....
TAKEOFF RUNWAY 13 (Flushing Climb): Climb heading 134° to LGA 2.5 DME, then left turn heading 050°, maintain 5000, Thence....
TAKEOFF RUNWAY 13 (Maspeth Climb: TURBOJETS ONLY - Requires minimum ATC climb of 900′ per NM to 4400, if unable, advise ATC): Climbing right turn heading 180°, at LGA 4.1 DME turn right heading 340°, maintain 5000, cross LGA R-220 at or above 5000, Thence....
TAKEOFF RUNWAY 13 (Whitestone Climb: Requires minimum ATC climb of 500′ per NM to 1500, if unable advise ATC): Climbing right turn heading 180° to LGA 2.5 DME, then left turn heading 040° (do not exceed 210K until established on heading 040°). Maintain 5000, Thence....
TAKEOFF RUNWAY 22: Climbing left turn heading 070°, maintain 5000, Thence....
TAKEOFF RUNWAY 31: Climb heading 314° (or as assigned by ATC), maintain 5000, Thence....

....Expect vectors to assigned route/fix. Expect clearance to filed altitude/flight level within ten (10) minutes after departure.

NOTE: Rwy 31 Departures: Expect turn on course leaving 6000.
NOTE: Traffic filed over BIGGY, LANNA, ELIOT, PARKE, ZIMMZ, NEWEL: Do not exceed 250 KIAS until reaching 11000.
NOTE: BAYYS Departures expect vectors to BDR/BDR R-054.
NOTE: COATE Departures expect vectors to SAX/SAX R-311.
NOTE: SHIPP Departures expect vectors to JFK/JFK R-139.
NOTE: WAVEY Departures expect vectors to JFK/JFK R-156.
NOTE: WHITE Departures expect vectors to COL/COL R-204.
NOTE: BIGGY Departures expect vectors to SBJ/SBJ R-237.
NOTE: DIXIE Departures expect vectors to COL/COL R-192.
NOTE: ELIOT Departures expect vectors to SAX R-252. ELIOT authorized for all aircraft types but restricted to a final altitude of 14000 or 16000.
NOTE: ZIMMZ Departures expect vectors to SAX R-250. ZIMMZ authorized for all aircraft types but restricted to a final altitude of FL180 and above.
NOTE: NEWEL Departures expect vectors to SAX R-264. NEWEL authorized only for jet aircraft requesting a final altitude of FL180 and above.
NOTE: GAYEL Departures expect vectors to DPK R-320.
NOTE: GREKI Departures expect vectors to CMK R-057.
NOTE: LANNA Departures expect vectors to PTW R-059.
NOTE: MERIT Departures expect vectors to LGA R-055.
NOTE: NEION Departures expect vectors to LGA R-322.
NOTE: PARKE Departures expect vectors to BWZ/BWZ R-250.
NOTE: HAAYS Departures expect vectors to HUO.

(CONTINUED ON FOLLOWING PAGE)

LA GUARDIA FIVE DEPARTURE
(LGA5.LGA)
NEW YORK, NEW YORK
LAGUARDIA (LGA)

Source: https://acukwik.com

Figure 1: Official SID routes for runways at LGA airport

Basic flight plan that has been used for flight KLGA - KCLT:

BIGGY J75 GVE LYH IVANE2

The flight plan was developed for simulation purpose only. Due to the fact that the flight 1549 was never realized and landing at the Hudson surface happened few minutes after take-off just basic navigation points are used.

2.2 Aircraft, fuel and pax mass

When it comes to aircraft and engines technical conditions according to the investigation findings the accident aircraft was operable. The airplane was equipped with two CFM International CFM56-5B4/P dual-rotor, turbofan engines.

On date of flight no problems with any navigational or communicational aids were reported. According to the airplane’s maintenance records, the daily and overnight checks conducted the day before the flight and the last weekly check, conducted on January 10, 2009, noted no discrepancies (NTBS, 2010).

The airplane departed LGA with a takeoff weight of 68 723.8 kg (151 510 pounds), which was below the maximum limitation takeoff weight of 68 764.6 kg (151,600 pounds).

Furthermore, all relevant weights are shown:

TOW= 68,723.8 kg (151,510 pounds)

MTOW= 68,764.6 kg (151,600 pounds)

Pax mass = 13,267.6 kg (29,250 pounds)

Fuel mass = 10,024.4 kg (22,100 pounds)

Baggage + cargo mass = 1,319.9 kg (2,910 pounds)

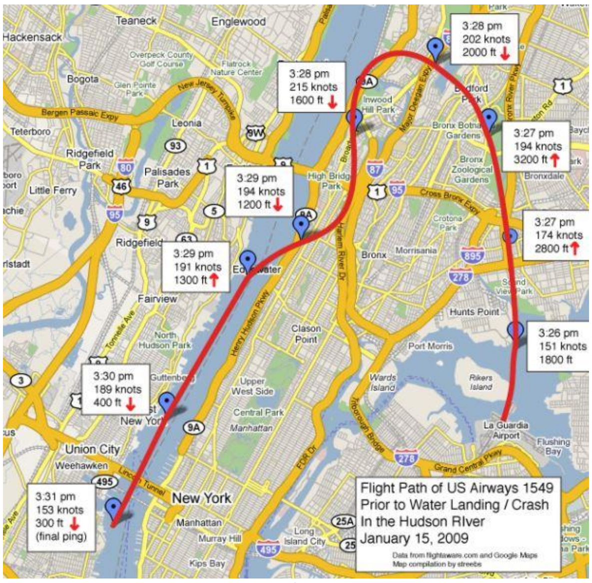
Taxi fuel = 340.2 kg (750 pounds)

2.3 Flight path

On January 15, 2009 at 15:24 local time (20:24 utc time) flight 1549 was cleared for takeoff to the northeast from LaGuardia's runway 4. For the simulation purpose departure route that has been used matches official departure route for runway 4. As previously shown at Figure 1 departure route in case of take off from runway 4 is:

TAKEOFF RUNWAY 4: Climb heading 044° to 600, then right turn heading 055°maintaning 5000. Thence...

After the aircraft takeoff from runway 4 and at 15:27 local time (20:27 utc time) encountered a flock of birds, two minutes after departure.



Source: http://flightaware.com

Figure 2: Flight path of 1549 from the moment of departure until ditching on the Hudson river

3 SIMULATION OF LAGUARDIA BIRD STRIKE CASE

The skillful crew with extraordinary landing saved human lives and the only question is if there was any way to avoid aircraft's substantial damage. It is known that immediately after collision flight crew was thinking over possible alternate airports but eventually they informed air traffic controller that can't make any airport.

After declaring emergency to the air traffic control the captain's first option was returning to LGA airport. Unfortunately, strong impact caused heavy damage on both engines and almost entire loss of thrust making this plan impossible. Teterboro (TEB) airport was captains second option but short after the crew realized that can't reach this airport either.

Considering the fact that around LGA airport is area with high population density only nearby airports will be considered as the suitable locations for landing for the simulation. For simulation purpose three different scenarios has been considered as the most realistic outcomes:

- Airborne return to airport of departure (LGA),
- Diversion to Teterboro airport (TEB),
- Diversion to Westchester airport (HPN).

For each scenario three simulations have been performed.

Source: www.privatefly.com.de

Figure 3: The airports located in the area nearby LGA

3.1 Scenario 1: Airborne return to airport of departure

First scenario considered possibility of returning to departure airport, LaGuardia. Immediately after impact flight crew announced that will return to LGA airport. The decision was expected considering the fact that the impact occurred just a few minutes after take-off and LaGuardia airport was the closest airport in regard to aircraft position. Scenario 1 will show what would happen if the crew stuck to this plan.

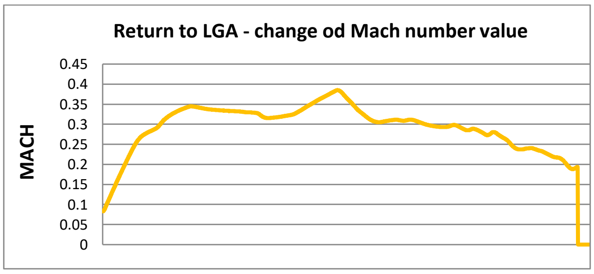


Figure 4: Simulation 1 – Mach number change during simulation of flight which is diverting to LGA

Simulation of return to LGA airport has shown that with existing conditions the aircraft would not be able to reach departure airport. LGA airport was the closest but in order to return the aircraft needed to make a complicate turn over which was impossible due to low altitude and low speed.

3.2 Scenario 2: Diversion to Teterboro airport

Teterboro airport is the second closest airport in regard to location where bird strike happened. Because of its closeness to the location of the occurrence it was considered as a potential diversion airport by flight crew. Also, comparing to LGA, the location of TEB airport was slightly advantageous when it comes to flight path and maneuver complexity. Scenario 2 will show what would happen if the crew decided to divert to TEB.

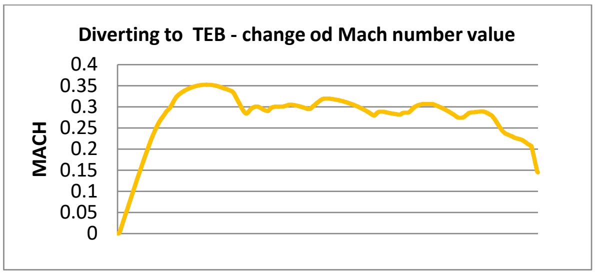


Figure 5: Simulation 2 – Mach number change during simulation of the flight which is diverting to TEB

Simulation has shown that despite its closeness airport TEB was not suitable as diversion airport due to aircraft's altitude at that time.

Second part of Scenario 2 investigates what was minimal required altitude in order to reach TEB. Results have shown that it was required at least 500ft higher altitude of the aircraft in order to make a necessary maneuver.

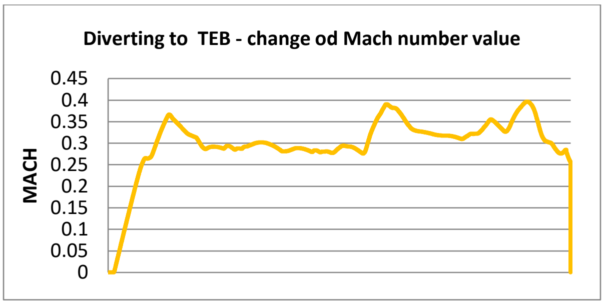


Figure 6: Simulation 2.1 – Mach number change during simulation in case of +500ft altitude

Scenario 3: Diversion to Westchester airport

Westchester airport is the second closest airport in regard to location where bird strike happened. Even though HPN airport was not discussed as potential alternate airport during flight the authors simulated case of diversion to HPN. Reasons for considering the HPN as potential diversion airport were closeness to location of the occurrence and simple flight path without complex turns which would cause additional altitude decrease.

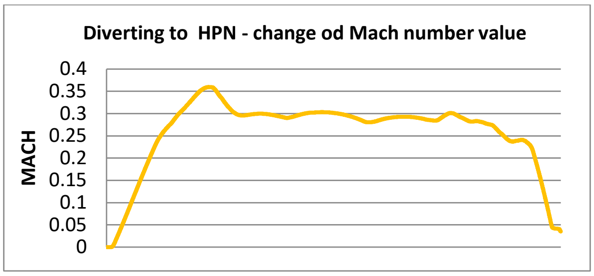


Figure 7: Simulation 3 – Mach number change during simulation of the flight which is diverting to HPN

During simulations maintaining and controlling the speed and the altitude with both engines inoperative was extremely difficult, especially when it comes to complex maneuvers. The HPN location was the most favorable in order to avoid complex turns and altitude loss. Unfortunately, in this case airports distance was crucial and Westchester airport was too far.

4 BIRD STRIKE RISK ASSESSMENT BASSED ON FLIGHT 1549 SIMULATIONS

Two elements define the safety risk in the air traffic and those are the predicted probability and severity of the consequences or outcomes of a hazard. Proper evaluation of both elements is needed in order to determine the risk accurately. Analyzing and evaluating both elements needs to be done independently for each the severity and the probability.

The bird strike risk in aviation requires a comprehensive approach and a detailed analyze of historical data. The case of the flight 1549 has shown that problem of birds presence in the aviation represents ever present danger and big challenge in the future.

4.1 Safety risk in aviation

Safety risk is the projected likelihood and severity of the consequence or outcome from an existing hazard or situation. While the outcome may be an accident, an intermediate unsafe event/consequence may be identified as the most credible outcome (ICAO, 2013).

Table 1: Safety risk probability

Likelihood	Meaning	Value
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Source: ICAO Safety Management Manual (SMM) - Doc 9859

In the aviation common approach to the likelihood evaluation is by using historical data in order to categorize unsafe event or condition. When analyzing likelihood of the unsafe event except historical data preventive measures needs to be taken into the account.

The consequences of the hazard are determined by analyzing what could happen if the hazard manifested itself into an accident or incident. Some consequences may be obvious, with there being only one possible outcome as the result of a particular hazard but other hazards may result in a range of consequences of varying (CAA, 2010).

Table 2: Safety risk severity

Severity	Meaning	Value
Catastrophic	- Equipment destroyed - Multiple deaths	A
Hazardous	- A large reduction in safety margins, physical distress or a workload such that tasks can't be accurately or completely performed - Serious injury - Major equipment damage	B
Major	- A significant reduction in safety margins, a reduction in the ability to cope with conditions as a result of an increase in workload or as a result of conditions impairing efficiency - Serious incident - Injury to persons	C
Minor	- Nuisance - Operating limitations - Use of emergency procedures - Minor incident	D
Negligible	Few consequences	E

Source: ICAO Safety Management Manual (SMM) - Doc 9859

4.2 Simulation results as safety indicators

As said before the bird strike risk is ever present risk that can't be completely eliminated. These events are difficult to predict with a wide spectra of possible outcomes. Considering that the majority of bird strikes happens in the airport vicinity when it comes to risk evaluation the most accurate approach would be bird strike risk assessment for the specific airport.

That way evaluating likelihood of bird strike would be estimated based on historical data of these events, ecological characteristics of the airport area and preventive measures that are implemented.

Bird strike safety risk severity is defined as the extent of harm that might reasonably occur as a consequence of collision with birds. When assessing bird strike severity first element that needs to be considered is how many lives may be lost. Second indicator would be what is the possible extent of aircraft, property or equipment damage.

For the flight 1549 there were no fatalities although one flight attendant and four passengers were seriously injured. Of course, the aircraft landing on the water surface caused sustainable damage and significant costs. The investigation of the accident has established that the right engine was attached to the wing but the left engine was found separated from the wing. Beside other damages door frame structure was fractured at multiple locations and the aft cargo door handle was fractured into multiple pieces (NTBS, 2010). The simulation has shown that in this case after suffering bird strike the flight crew had no other option than to perform highly risky landing.

Figure 8: A320 after crash-land into Hudson river

5 CONCLUSION

Per (EASA, 2008) 96% of strikes occur during takeoff, climb, approach and landing. Strikes enroute are much less frequent but 34% of these result in damage when they do occur. It is clear that when it comes to bird strikes problem lower altitude means higher risk and airport areas should be first element to look for mitigation bird strike risk. Beside operational and safety influence additional problem with bird strikes are extra costs.

Bird strike risk is very complex for evaluation due to a range of possible outcomes and in some cases those might be very serious. It is known that in most cases consequences of these events are minor or negligible but the simulation of US flight has shown that due to bird strike the flight crew may find themselves in the hopeless situation.

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BIOMETRICS AND THE SIGNIFICANCE OF BIOMETRIC DATA COMPRESSION IN TRANSPORT SYSTEMS

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ABSTRACT

Biometrics is being increasingly used in different areas of human activity, and transport systems are no exception. Biometrics in transport contributes to increased safety, and at the same time automates already existing security protocols, such as passenger verification or suspect identification. The paper provides a brief overview of the most significant global biometric applications in maritime, air and rail transport over the last two decades, but also lists some of the potential future applications. This gives insight into biometrics representation in these types of transport, as well as insight into the biometric application types and biometric methods most commonly used in transport. Biometric data compression represents an important issue in applications that process large volumes of biometric data (e.g. biometric applications in transport). Importance and advantages of biometric data compression in transport are discussed and highlighted with the emphasis on raw and unprocessed biometric data usage.

Keywords: biometric data, compression, transport

1 INTRODUCTION

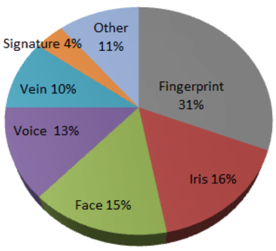
Biometrics as a modern age technology is being increasingly used for recognition, i.e. verification and identification of persons based on certain physical characteristics in different transport systems. Biometric verification confirms that a person who has undergone a biometric recognition process is indeed the one he/she claims to be. In biometric verification, currently taken person's biometric data is compared with the previously stored biometric data of the same person (e.g. biometric data on the passport chip is compared with the currently taken biometric data of the person that is holding a passport) [1]. Biometric identification is different, and in order to determine the person's identity, currently scanned biometric data is compared with biometric data of many people whose biometric data are stored in databases (e.g. surveillance system at the airport that uses face biometrics for the purpose of finding potential suspects) [1]. Significant increase in the biometrics usage for the purpose of transport safety and security was noted to a large extent after the 09/11 event, especially in US air transport [2], [3]. Biometrics is currently the most widely used in air transport with regard to the existence of national and international security requirements involving mandatory identification of persons at border crossings. The fact is that in recent years there has been a rise in terrorist attacks in transport in general, so governments and various organizations are increasingly adopting biometrics as a security solution. Aside from the anti-terrorism measure, biometrics has been increasingly applied within the spectrum of security applications over the past fifteen years, not only in air but also in land and sea transport. Potential applications within which biometrics can be used for transport safety and security are: surveillance of important areas (such as airports, railway stations, seaport terminals, etc.), physical access control for passengers, crew and working personnel (access to sensitive areas, cargo, vehicles), ticketing systems, border control, automated and biometric assisted identity check on airports and border crossings, support for intelligent transport systems. In other words, biometrics can potentially be applied in every situation that requires identity verification or identity finding. Currently the most widely used biometric methods are face, fingerprint and iris biometrics (see the next chapter), and the future belongs to these methods as well [4]. The increasing use of biometric systems also results in an increase in the amount of originally collected biometric data that should be stored within databases and very often sent through various communication channels (e.g. the Internet) for the purpose of exchanging biometric data with different parts of the biometric system. Therefore, reduction of the amount of such data is imperative. A logical solution is the compression of biometric data. The paper provides an overview and a brief description of the most important biometric applications in transport (air, maritime and rail transport). The paper also analyzes the possibility of biometric data compression, the importance of biometric data compression for transport systems, and highlights the advantages of using raw biometric data.

2 RESEARCH METHODOLOGY

This paper provides an author's perspective on the topic and summarization of results and foundlings from scientific papers, books, conference proceedings and available online sources from different respectable organizations and companies. About 60 different sources have been screened. Sources listed in the references that are most closely related (in terms of supporting arguments) with compression of biometric data in transport systems and existing biometric applications were selected. Searched databases and systems were: IEEE/IET Electronic Library (IEL), Google Schoolar, ScienceDirect, Scopus, Web of Science, Springer Journals, Elsevier Journals, ResearchGate system, websites and online reports from respectable organizations and companies. General searching criteria referred on topics such as: Biometrics in transport systems (separately for maritime, air and railway transport). After determining the dominant biometric methods (Chapter 3) search was performed on topics such as: Face biometrics in transport systems (separately for maritime, air and railway transport), Iris biometrics in transport systems (separately for maritime, air and railway transport), and Fingerprint biometrics in transport systems (separately for maritime, air and railway transport).

3 BIOMETRIC RECOGNITION METHODS ON THE MARKET AND TRANSPORT SYSTEMS

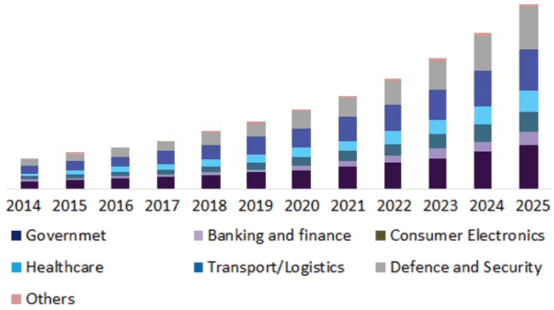
The biometric technology market is expected to reach 34.5 billion US dollars by 2022 [5]. Currently, the most widely used biometric methods in the market include: fingerprint, face and iris biometrics [6], and the market situation has not changed significantly in the last ten years [7] (Figure 1).



Source: [6]

Figure 1: Biometric recognition methods in the market

According to biometrics market research, biometric applications in the transport industry occupied the largest share of the biometrics market in 2015 [8], [9]. It is believed that biometric applications in transport will continue to be among the leading applications in the biometrics market by at least 2023, and it can be seen from the forecast shown in Figure 2 [10].



Source: [10]

Figure 2: American biometric technology market 2014 – 2025

The share of biometric methods in the transport industry does not deviate significantly from the statistics shown in Figure 1, and in this sector, the most widely used biometric methods are fingerprint, face and iris biometrics [11]. The nature of transport systems contributes to that practice as well (e.g. in such systems the face image of a person is much easier to collect than a signature, voice, DNA sample, etc.). This can be a reason for the rare voice biometrics usage in transport (air, maritime and rail transport), and other methods such as hand geometry biometrics are used instead. Biometrics in the overall market is most widely used for physical access control, which also coincides with the nature of transport systems, and further justifies the idea of using biometrics in transport. It is believed that the future belongs to the fingerprint, face and iris biometrics, by combining multiple biometrics together (multimodal biometrics) in order to reduce recognition errors [12]. Furthermore, other biometric methods that may be suitable for transport systems are being developed as well. For example, gait recognition biometrics is still not widely applied, but research shows that there is a great potential in combining this method with some other methods when it comes to biometric identification applications [13], e.g. biometric surveillance systems used in different transport systems (airports, seaports, cargo terminals, etc.). Gait recognition biometrics is suitable because it is not invasive (similar as face biometrics), and allows remote and secret detection of suspects.

4 BIOMETRIC APPLICATIONS IN TRANSPORT

After the 09/11 terrorist attack, biometrics in transport safety began to accelerate rapidly, primarily in international air transport. Mentioned terrorist attack and the nature of air transport that involves high security level due to border crossings and entry into other states are the main reason for greater representation of biometric applications in this type of transport. This chapter gives an overview of some of the most significant biometric applications of today's air, maritime and rail transport, and potential biometric applications that are planned to be implemented in the near future.

4.1 Maritime transport

TWIC (Transportation Worker Identification Credential) is an American program implemented in the US maritime sector for the purpose of employee identity verification (worker verification), and it is probably the most significant biometric application in maritime transport worldwide [14]. TWIC is the name of the program, but also the name for government smart cards that all maritime sector workers must wear to access vulnerable maritime installations, infrastructures and vessels that are under the regulation called Maritime Transportation Security Act of 2002 [15]. Transportation Security Administration (TSA) and US Coast Guard are the initiators of the TWIC program. The TWIC card contains a memory chip that holds the information about the worker and workers biometric data. TWIC cards use fingerprint biometrics, and worker verification is performed in a way that biometric reader reads the "live" fingerprint of the worker and the fingerprint stored on the TWIC card, and then compares these two prints. Thus, only the real owner of the TWIC card may have access to the restricted area. The program was originally started in maritime transport, but expansion is also planned for other types of transport [14].

US Coast Guard has been using fingerprint biometrics and portable fingerprint scanning devices since 2008 for capturing immigrants and smugglers at sea within the scope of the „Biometrics at Sea“ initiative [16]. Iris and face biometrics are also taken into consideration for the near future. Instead of smart cards, the system uses databases for immigrant biometric data storage. The purpose of this program is to prevent illegal entry into the US territory and the smuggling of people.

Antwerp and Zeebrugge ports in Belgium use fingerprint biometrics for employees and visitors since 2013 [17], [18]. Fingerprint biometrics was introduced as a replacement for previously used hand geometry biometrics that caused identification errors due to the large number of people who were within the system. This biometric system includes both ports and 17000 truck drivers. 10000 port workers were initially registered within the system as well. Visitors are also required to register their biometric data in the registry offices and kiosks that are located at the ports. The system uses smart cards that contain biometric data of individuals. The main function of the new biometric system is the more efficient (automated) and safer identification of employees and visitors who are using different port facilities and areas.

Largest European port in Rotterdam (one of the major European trading centers known for container terminals) uses hand geometry biometrics for the verification of truck drivers approaching the port since 1999 [19]. The system also uses smart card technology, with biometric data designed in the way that drivers do not have to leave the vehicle during verification procedures at the entrance to critical port areas (drivers use the window to place the hand and a smart card on an external reader).

4.2 Railway transport

According to this research and comparison with air and sea transport, currently the least biometric applications are recorded in rail transport. On the other hand, there are numerous plans related to the implementation of biometrics in rail transport in the near future. The Canadian National Railway (CNR), the fifth largest railway on the North American continent, uses fingerprint biometrics in its Speedgate control system [19]. The Speedgate system monitors and accelerates access control to truck drivers at CNR intermodal terminals that are deployed on the North American continent. The fingerprint biometry is used at the entry of intermodal terminals in order to verify the driver with the particular cargo as well as to associate the driver identity with the delivered cargo. This system accelerates the traffic flow, reduces the possibility of theft and scams, and creates a digital trace of every transaction performed.

In 2016 Beijing begins to use face biometrics on some of its railway stations for the purpose of checking the passenger tickets [20]. The system works in such a way that passengers are required to insert their Resident Identity Card (official personal identification document in the Republic of China) and train ticket into reading device to access the face scanner. If the face image of a person’s personal document matches with a live scanned image of a passenger's face, the passenger is allowed to access the train.

Indian rail transport is the world's largest transport system for passenger transport, and 20 million passengers travel daily on Indian Railways [21]. India is in the forefront of biometric introduction plans for its own rail transport, and intends to include employees and passengers into biometric systems [21], [22]. Currently, several Indian railways are using biometric systems to control their employees working time, and in the near future biometrics will be expanded to the billing and ticket control system, as well as passenger control.

Russia plans to install biometric surveillance system with cameras in Moscow subway during 2018 [23]. The surveillance system will include 20000 cameras and use face biometrics for suspect detection whose face images are previously stored in the database.

The British rail organization Rail Delivery Group plans to introduce fingerprint and iris biometrics into its billing and ticket control system that would replace physical tickets [24]. The Rail Delivery Group represents British passenger rail companies (23 rail companies) that provide British rail freight services.

4.3 Air transport

There are many examples of the use of biometric systems in air transport, and this paper presents some of the most significant biometric applications in this type of transport.

One of the major measures that has contributed to the increasing global use of biometric passports and the spread of biometrics to air transport is the standardization of biometric passports through the document entitled "Document 9303" that was published in 2006. The document refers to travel documents that are machine readable, and defines detailed technical specifications and ISO standard related to biometric passports [25]. The standard provides interoperability between countries and passport manufacturers. Biometric passports contain an electronic microchip with an antenna, and contactless communication between microchip and a reading device is enabled. The chip contains personal information and biometric data, and three types of biometric data are supported: face, fingerprint and iris biometrics. Regardless of a biometric passport, a personal inspection of the match between a person's face and a digital face image within the biometric passport is required and performed by official personnel as usual practice. Over the last few years this is changing, and automated passport control systems are beginning to replace the traditional way of controlling passports in many international airports in America, Canada, Portugal, United Kingdom, Estonia, Australia, New Zealand, Japan, etc. These systems are called Automatic Border Control Systems (ABC systems).

After the testing, last year British Airways (BA) has introduced automated passport control for a part of domestic flights at London's Heathrow Port [26]. The system works in a way that passengers pass through a security passage where their face is scanned and recorded in the database. Afterwards, passengers have access to a control self-service biometric gateway where they attach a boarding pass, after which the system scans the passengers face again and compares a new digital face image with the previous digital face image that was recorded as passengers were passing through a security passage. If the images match, the passenger is automatically allowed to enter the plane. Official personnel acts only if recognition errors occur.

Ben Gurion Airport in Tel Aviv (Israel) uses hand geometry biometrics for the purpose of automatic control of passports and their owners since 1998. Passengers using this system have previously registered their biometric data and received a magnetic card with recorded biometric data. When arriving or departing from the airport, passengers put their magnetic card on magnetic reader and their hand on a hand scanner to perform verification. If no problem occurs, the control procedure lasts for about twenty seconds [27]. Since 2010, Ben Gurion has used another new biometric system called Unipass [28]. Unipass is actually a multimodal system, i.e. fingerprint biometrics and face biometrics are both used to increase the level of security. Passengers register their biometric data during their first visit to the airport, and receive their own Unipass smart card with recorded biometric data. At the next use of the Ben Gurion Airport, passengers are automatically checked by placing the Unipass card on the device, finger on the appropriate scanner and face in front of the camera. The procedure is analogous to the procedures described in previous examples.

In 2015, Schiphol Airport in Amsterdam announced the testing of various biometric methods for automatic safety checks in order to evaluate the efficiency of each biometric method in real working conditions [29]. In 2010, the same airport started the iris biometric test program, and in that program iris scanning was performed from a greater distance then in conventional iris biometric systems while subject was moving.

Since 2006, the Canadian Air Transport Security Authority has been using fingerprint and iris biometrics for working personnel in sensitive areas of major Canadian airports. The Canada Border Services Agency (CBSA) offers volunteer programs to travelers, such as NEXUS and CANPASS for automated security checks at airports [30].

Since 2003, the United Arab Emirates (UAE) is using iris biometrics as a part of the „Iris Expellees Tracking and Border Control System" program to reduce the number of illegal immigrants in the country [31]. Irises of the immigrants who have been expelled are scanned and stored in the central database that is maintained by the General Directorate of the Abu Dhabi Police. Irises of all foreigners entering UAE for the first time are scanned and stored in the central database as well. In this way, people with a ban on entering the UAE have been prevented from re-entering the country with the help of their new identity and falsified travel documents.

The Office of Biometric Identity Management (OBIM), or former US-VISIT, is the US border protection program against illegal immigrants, terrorists and criminals [32]. The program requires the use of biometrics in order to verify the identity of most passengers who do not have an American passport. Passengers who submit a request for an American Visa in their native countries are required to provide face image and fingerprint scans. Those biometric data are stored in database and compared with so-called „Watch List" of identified criminals and terrorists whose biometric data are previously stored in the database. Upon receipt of a Visa, a passenger who arrives at the US airport is required to provide biometric data again in order to determine that the person who is entering the country is the same person to whom the Visa was issued.

After the 09/11 event, video surveillance systems using face biometrics for detecting suspects were also recorded. Such systems perform identification, not verification. These systems work in real-time by capturing faces of the people who are walking on the airport, and then comparing their face images with the previously stored face images of the wanted criminals and terrorists. An example of such a system was Palm Beach Airport in Florida where testing was conducted with the help of airport personnel in 2002 [33]. Project was not successful since the face biometry used in automatic video surveillance for identification purposes is still not reliable. Improvements in this field have been noted, but still insufficient, which is why such application types are still not commercially and widely used [34].

5 BIOMETRIC DATA COMPRESSION

With the constant increase in the use of biometric applications/systems, it is logical to address the issue of handling and storing originally collected biometric data (e.g. fingerprint, iris and face images, voice audio data, etc.). In biometric systems, large amounts of biometric data are stored in databases, and often sent through various communication channels (e.g. Internet) to enable communication between different parts of the biometric system (e.g. a portable fingerprint scanner that sends biometric data to the database via internet, or a camera that captures passengers at the airport and sends the face biometric data to the database on the server using local area network). Most existing biometric systems do not operate with original biometric data (e.g. fingerprint, face and iris images), but with unique features in the form of digital templates that are generated from the originally collected biometric data using specialized algorithms, and each digital template is unique for each individual person [35]. A simpler and more desirable solution implies the use of originally collected biometric data, as this avoids intermediate steps involving the use of specialized algorithms to generate unique templates. In addition, different policies and strategies actually advocate the use of original biometric data instead of digital templates, as this results in interoperability and neutrality with regard to suppliers [36]. Other disadvantage when using digital templates are also reflected in the fact that digital templates are irreversible, i.e. original biometric data (fingerprint, face and iris images) can not be reconstructed from digital templates [37]. Previously mentioned disadvantages in the use of digital templates, and the fact that direct use of the original biometric data would consume a lot of resources (storage media and transmission media occupancy, longer data transfer time), as a solution impose the use of compressed original biometric data. Studies have shown that such an approach is reliable and that recognition accuracy when compressing biometric data is not significantly affected [38], [39]. The use of the original compressed biometric data additionally affects the standardization of biometrics in general, since in the case of improvement of algorithms that are used for e.g. in the extraction phase of distinct features, the original biometric data of the person does not have to be re-collected. This compression can be either lossy or lossless compression. Lossless compression algorithms ensure that each bit of original information is preserved, but such compression does not allow high compression ratios (reduction of original information) as lossy compression does. In biometric applications, lossy compression is more interesting since the primary goal is to maximally reduce the amount of data that should be stored or transmitted through communication channels, while retaining acceptable data quality (e.g. quality of iris image) [40].

The benefits of compression of biometric data in transport systems are unquestioned with regard to the nature of transport systems and biometric applications used in such systems. Biometric applications in passenger transport systems often include a large number of people and their biometric data that needs to be stored (in databases, smart cards, biometric passports, etc.) or transmitted through communication channels. Under such conditions, storage capacity savings and the reduction of biometric data transfer time are of great importance (e.g. reading and eventual transfer of biometric data from a smart card to a database for the purpose of verifying passengers at the airport will be faster if the biometric data takes up less memory). Distributed biometric systems are systems where the location of biometric data collection is different from the location of the verification procedure. In such systems, the verification process itself can be dislocated (scanning is performed at one, and biometric data matchup at another location). Compression of biometric data is of great importance in such biometric applications [41], and such biometric applications prevail in transport systems. That can be seen from the overview of the biometric applications in the previous chapter. For example, airports that have numerous biometric scanning devices to automatically identify passengers (automatic border control gates), different dislocated seaports that use the same biometric system, portable fingerprint/iris scanners, etc. On the other hand, biometric applications such as biometrics used to unlock the smartphone (biometric data collected and user verification performed at the same place/device), or biometrics used to record the employee's work time within a building (small number of people, one location) certainly do not have the same need to compress biometric data as previously mentioned biometric applications in transport systems. Furthermore, additional requirements for compression of biometric data arise from the fact that standardization bodies, such as the ISO (International Organization for Standardization) [42], and an industrial consortium, such as the Registered Traveler Interoperability Consortium [43] that incorporates biometric data into smart cards, seek to avoid the inclusion of patented techniques in data formats and standards because it would favor monopolies. Avoiding patented techniques in data formats implies avoiding the use of digital templates that are generated from original biometric data through various patented algorithms. On the other hand, storage of uncompressed biometric data consumes precious memory space on the cards (up to a thousand times more space than using digital templates), increases data transfer time, and is sometimes disabled due to specifications that limit the occupancy of memory space on smart cards. For example, the Registered Traveler Interoperability Consortium (RTIC) specification for iris images on smart cards is only 4000 bytes per eye. From the overview of biometric applications in the previous chapter, it is obvious that the use of portable biometric data (smart cards, biometric passports, various tokens with biometric data) is very widespread in transport systems, which is why biometric data compression in transport systems becomes even more important.

6 CONCLUSION

Biometrics is becoming more and more present in many areas of human activity, and so it is in transport. Biometrics in transport enhances the security and safety of transport (transport of people and cargo), and at the same time automates the transport process. For example, the biometrics used at the airport for the purpose of passenger verification excludes a person from the process of identity verification (the human factor is in most cases the leading cause of errors), and at the same time it automates that same process that would otherwise take much more time. Given the global growth of transport processes that consume a lot of time and resources, rising thefts, terrorist attacks and illegal immigrations, biometrics will play an important role in the future. Multimodal transport also contributes to the growth of biometrics usage due to the increase in security measures that are required during the transition zone passages (changes between types of transport while transporting people or cargo). Furthermore, biometric solutions are also favored by the growth of computer power, the price drop in sensors and the development of technology in general. The paper provides a brief insight into the biometrics market and its share in transport. A review of the most significant global biometric applications in transport shows that biometrics in transport is mostly used for physical access control. It has been found that the most commonly used biometric methods in transport (air, maritime and rail transport) are fingerprint and face biometrics, while iris biometrics as one of the most accurate methods of identification, is still not widely used (iris biometrics is still too expensive). Air transport is at the forefront of biometrics when compared to maritime transport, and especially to rail transport, where biometrics is in its initial stage. Given the potentially large number of people and the amount of biometric data, as well as the component displacement of biometric applications in transport systems, the compression of biometric data in such systems is of great importance. Furthermore, different political bodies and standardization bodies (e.g. ISO) seek to avoid biometric digital templates and their patented techniques and algorithms, as well as impose limits on biometric data storage media. Also, biometric digital templates are irreversible. On the other hand, raw uncompressed biometric data are not practical to use due to resource consumption. Various experiments already shown that the compression of raw biometric data does not distort the accuracy of biometric systems, so in this paper the importance of using compressed raw biometric data is highlighted and proposed as a biometric data storage solution for transport systems. Generally speaking, biometrics brings a higher level of security, automation and productivity for transport sector, and it is just a matter of time before significant expansion of biometric applications occurs in this sector.

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TOOL LIFE EVALUATION IN HIGH SPEED MILLING OF STEELS FOR SHIPBUILDING INDUSTRY

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ABSTRACT

This paper observes tool life tests for different materials used in shipbuilding industry. Materials include stainless steels AISI316L, S235JR, and 42CrMo4V, milled on 5 axis CNC machine, with oil-water emulsion, or with air cooling. Emulsion tested is industrial coolant. The aim is to analyse and compare milling tool life for each material in different conditions, which can optimise machining process. The experiment is conducted in milling centre in Croatia.

Keywords: Experimental testing, CNC machine, milling, shipbuilding, tool life, steel, optimisation

1 MATERIALS USED IN SHIPBUILDING

Shipyards use milling technologies to produce parts, such as longitudinal and longitudinal and cross side CNC milling machines which mill plates or tank segments, spherical segments, hatchets, profiles, and other small parts used on vessels. Materials used in shipbuilding industry include AISI 316L which is being used in various structures exposed to marine environment, such as tanks and LNG vessels, or material for pipelines on chemical tankers, S235JR, and 42CrMo. Materials were tested on Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture for hardness determination, which provided feed rate while milling. This paper observes test results for tool life while milling those 3 common steels used in shipbuilding industry. Milling is performed in different circumstances, such as milling with oil-water emulsion, and milling without one. Emulsion tested is Kavo coolant 2. The CNC machine used for testing is Yenadent D 43, 5-axis, with specification given in table 1.

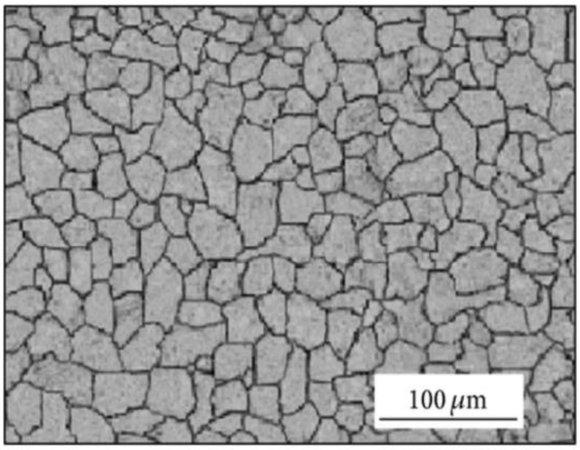
Table 1: Specification of the machine

MOVEMENTS	350X230X140MM
CONTROL	HIGH SPEED YLS
AXIS MOTORS	AC SERVO
SPINDLE POWER	2.5KW
SPINDLE SPEED	60000 RPM
NUMBER OF BLOCKS	1
TOOL CHANGER	24 POCKET
TOOL LENGTH SENSOR	STANDARD
WEIGHT	670KG
DIMENSIONS	100X79X175CM
POWER REQ	220V MONOFAZE 2KW
CAM	5 AXIS

Stainless steel CrNi has small percentage of (C), going from 0.03% to 0.12%. AISI 316L (X2CrNiMo) has C approximately around 0.03%. Materials used in shipbuilding industry include AISI 316L which is being used in various structures exposed to marine environment, such as tanks and LNG vessels, or material for pipelines.

1.1 Stainless steel AISI 316L

AISI 316L is used in various structures exposed to marine environment, such as tanks and LNG vessels, or as material for pipelines on chemical tankers. Hardness of steel used in paper is measured on Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, and is 228 HV10 or 225HB, which implicates improvement and heat treatment of steel. Microstructure of the stainless steel AISI 316L is shown by Figure 1.



Source: Microstructure, Strength, and Fracture Topography Relations in AISI 316L Stainless Steel, as Seen through a Fractal Approach and the Hall-Petch Law

Figure 1: Microstructure of the stainless steel AISI 316L

Chemical composition of material is shown in Table 2.

Table 2: Chemical composition of the stainless steel AISI 316L

C	Mn	P	S	N	Cr]	Mo
≤0.03	≤2.0	≤0.045	≤0.03	10-14	16-18	2-2.5

Source: Microbial Effects On Heat Treated 316L Weldments In Marine Water. Advanced Materials Research. 794. 606-617.

Mechanical characteristic of the steel is shown in table 3.

Table 3: Mechanical characteristics of the stainless steel AISI 316L

Hardness, Brinell	Hardness, Rockwell B	Hardness, Vickers	Tensile Strenght, Ultimate	Tensile Strenght, Yieid
149	80	155	515MPa	205MPa

Source: ASM Aerospace Specification Metals Inc., Retrieved from URL.

Recommendation for 316L stainless steel is for low speeds and constant feed rates, because it tends to work harden if machined too quickly. For lower carbon content, when compared to 316 stainless steel, it is easier to machine.

1.2 Stainless steel S235JR

Material used for testing is 125 HV10 or 130HB, tested on 3 different places, and isotopic. Chemical composition % of the stainless steel S234JR is shown in table below.

Table 4: Chemical composition (%) of the stainless steel S235JR (BS EN 10025, 1993)

C	Mn	P	S	N
max 0.21	max 1.5	max 0.055	max 0.055	max 0.011

Source: Evaluation of the properties of S235JR structural carbon steel in Lebanon. Lebanese Science Journal, Vol. 3, No. 2

With C max 0.21 steel S235JR is a low carbon structural steel. It has good ductile properties as well as excellent weldability. S235JR steel is being used in numerous applications, and one of them is fabrication of water vessels.

1.3 Stainless steel 42CRMO4v

Table 5: Chemical composition (%) of the stainless steel 42CRMO4v

C	Si max	Mn	Cr	Mo	S max
0.38-0.45	0.40	0.60-0.90	0.90-1.20	0.15-0.30	0.035

Source: The Loucefin group. Retrieved from URL.

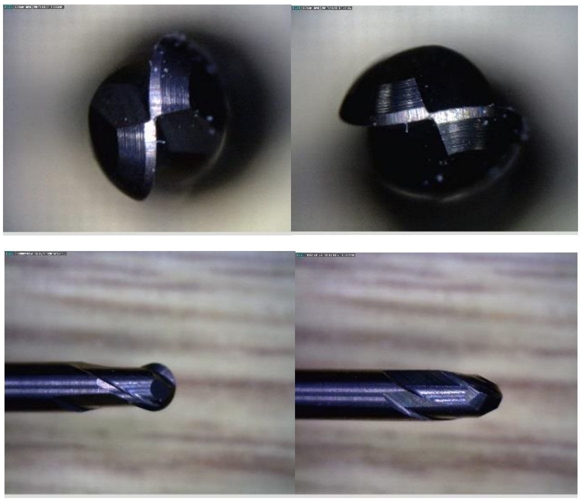
Material is tested as harder than S234JR or AISI 316L, with 336 HV10 or Brinell hardness HB 332, which implies the steel is without improvement.

2 MILLING PROCEDURE

Tool wear tests are performed in different cutting conditions, with tool wear progression in machining hardened steels are experimentally analyzed.

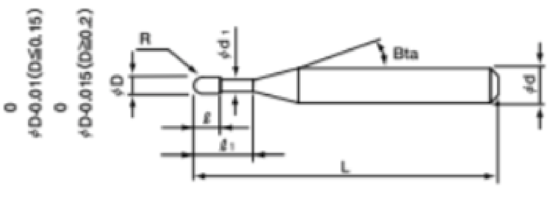
2.1 Tools used for testing procedure

Carbide burs are used for testing, which are observed by microscope and shown by Figure bellow, to analyze tool wear comparison after conducting experiment.



Source: Pictures taken in Laboratory for Metallographic Analysis at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture

Figure 2: Images of the surface of a tool used for testing



Source: Union tool Tungsten Carbide End Mills UNIMAX Series, Volume 17.

Figure 3: Geometry and dimensions of tool used for testing

Tools are UNION TOOL's CSELB 2020 120, with tool radius 1mm, or diameter 2mm. Cutting length is 1.6mm and effective length is 12mm. Parameters and geometry of tool are shown below, with experimental conditions of milling. Constants are f_Z = 0.081 mm (feed per tooth); a_P = 0.1 mm (axial depth of cut). The radial depth of cut during the experimental machining was a_e = 0.35 mm.

2.2 Mass of tools used for testing procedure

Table shows mass of tools before testing, which will be compared to analyze mass loss after conducting experiment.

Table 6: Mass of tools

Tool 1 / air AISI 316L	Tool 2 / wet AISI 316L
7.4602g	7.4648g
Tool 3 air / 42CRMO4v	Tool 4 wet/ 42CRMO4v
7.4592g	7.4507g
Tool5air / S235JR	Tool 6 wet / S235JR
7.4402g	7.4547g

Source: Table made by author, mass measured on Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture

Tool 1 is used for air milling of AISI 316L stainless steel, with mass 7.4602g. Tool 2 is used for wet milling of stainless steel AISI 316L, tool 3 is used for air milling of 42CRMO4v with mass 7.4592 [g], and tool 4 is used for wet milling of 42CRMO4v. Tools 5 and 6 are used for air and wet milling of S235JR.

2.3 Parameters used for testing procedure

Primary machining variables include speed, feed and depth of cut, and these are shown in Figure 4. Constants are f_Z = 0.081 mm (feed per tooth); a_P = 0.1 mm (axial depth of cut). The radial depth of cut during the experimental machining was a_e = 0.35 mm.

For this study, a test piece was designed and adapted, with two models from which one will be milled with, and another without emulsion. The toolpath is same for both wet and dry testing, for all three materials. Testing is conducted in experiment conditions of milling, with roughing and finishing cycles with same burrs.

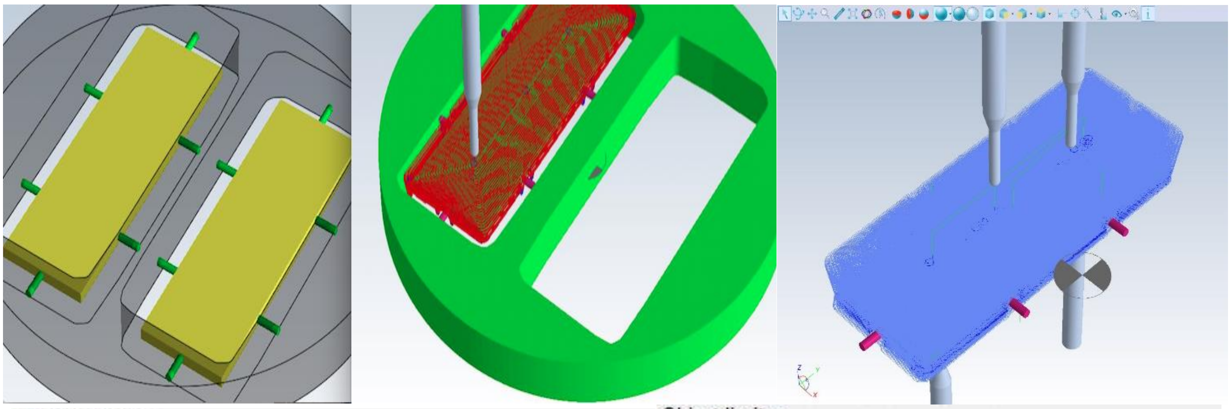
Milling Conditions for CSELB

WORK MATERIAL			COPPER / ALUMINUM ALLOYS				CARBON STEELS / ALLOY STEELS S45C / S50C / SK / SCM (~325HB)				PREHARDENED STEELS NAK80 / STAVAX / HPM38 (30~45HRC)				HARDENED STEELS STAVAX / HPM38 / SKD61 (45~55HRC)			
Model Number	Radius of Ball Nose (mm)	Effective Length (mm)	Spindle Speed (min⁻¹)	Feed Rate (mm/min)	a_p Axial Depth (mm)	a_e Radial Depth (mm)	Spindle Speed (min⁻¹)	Feed Rate (mm/min)	a_p Axial Depth (mm)	a_e Radial Depth (mm)	Spindle Speed (min⁻¹)	Feed Rate (mm/min)	a_p Axial Depth (mm)	a_e Radial Depth (mm)	Spindle Speed (min⁻¹)	Feed Rate (mm/min)	a_p Axial Depth (mm)	a_e Radial Depth (mm)
2020-120		12	30,000	2,000	0.18	0.54	30,000	2,000	0.12	0.36	30,000	2,000	0.1	0.35	10,800	850	0.08	0.32

Source: Union tool Tungsten Carbide End Mills UNIMAX Series, Volume 17

Figure 4: Milling conditions where constants are fZ = 0.081 mm (feed per tooth); aP = 0.1 mm (axial depth of cut). The radial depth of cut during the experimental machining was ae = 0.35 mm.

Tools are under maximum stress, to compare better milling without emulsion and with one. Machined area is 68x28mm, and disc used for testing are 95x10mm. Figure shows position of model, and toolpath simulation. Discs are adapted for testing on CAM software used for toolpath development MaykaPicasoft. Figure 5 shows position of model in disc, for milling with and without emulsion. Also, it shows toolpath used for testing, and information as number of points, length of cutting and machining time.



Object limits :
X : min = 4.138 mm; max = 30.895 mm; diff = 26.757 mm
Y : min = -33.480 mm; max = 33.943 mm; diff = 67.423 mm
Z : min = -10.100 mm; max = 10.100 mm; diff = 20.200 mm
Number of points : 195752
Length of cutting : 188 m 100 mm
Machining time : 2 h 37 min 40 sec

Object limits :
X : min = -31.251 mm; max = -4.556 mm; diff = 26.695 mm
Y : min = -33.810 mm; max = 33.684 mm; diff = 67.494 mm
Z : min = -10.100 mm; max = 10.100 mm; diff = 20.200 mm
Number of points : 193986
Length of cutting : 188 m 794 mm
Machining time : 2 h 38 min 14 sec

Source: Made by author in CAM software MaykaPicasoft

Figure 5: Position of model, and toolpath simulation

3 RESULTS

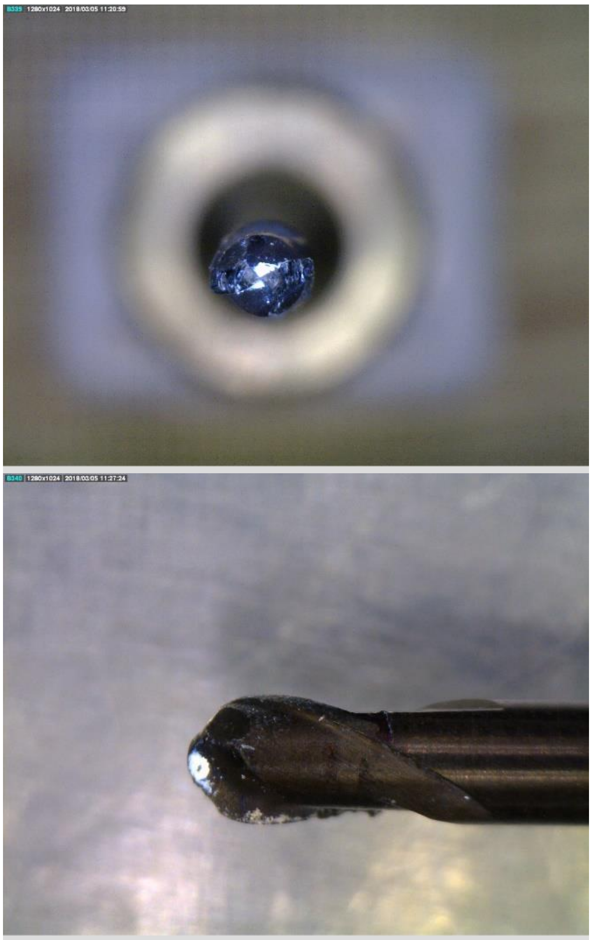
For milling without emulsion length of cutting is 188 [m] 100 [mm], and machining time is 2 [h] 37 [min] 40 [sec], while number of points is 195752. For milling with emulsion length of cutting is 188 [m] 794 [mm], machining time is 2 [h] 38 [min] 14 [sec], and number of points is 193986.

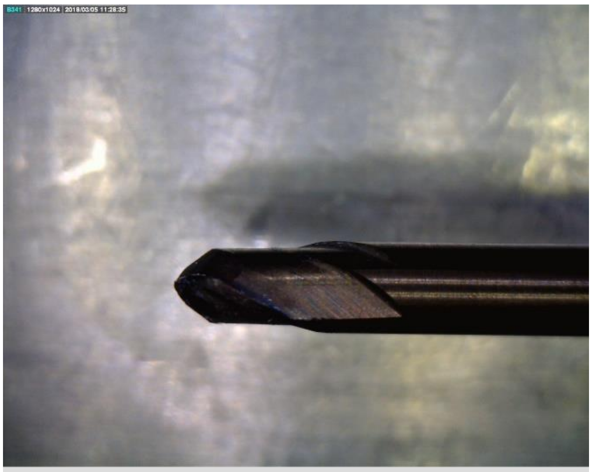
There is a difference in toolpath between milling without emulsion and milling with emulsion of 694 [mm].

3.1 AISI 316L Milling

Milling without emulsion is conducted with burr number 1 air, mass 7.4602 [g]. Controller position of z-axes is +63.723 [mm] at start. Machine work is stopped after 15 minutes because burr started to overheat, despite the air pressure of 6 bars. Controller in z position is +63.722 [mm] for ending.

For tool number one which was used for milling AISI 316L without emulsion, there was a small amount of mass loss, which was 0.0004 g. Toolwear is minimum, as well as mass loss. Figure 6 - 8 shows tool wear after milling.





Source: Pictures taken in Laboratory for Metallographic Analysis at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture

Figure 6 - 8: Steel part (or fragment) that got magnetized during the cutting processes, and got on magnetic sensors on machine

For milling with emulsion, burr 2 is used, mass 7.4648 [g]. Controller started in position of z axis +63.697 [mm], and ended in position of z axis 63.647 [mm], after 2 [h] 44 [min] 50.2 [s]. Machined measured tool wear 0.050 [mm].

3.2 42CrCm4V Milling

Milling without emulsion is conducted with burr 3 air, mass 7.4592 [g]. Controller position of z-axes is +63.733 [mm] for start. Machine work is 2 [h] 45 [min] 14.06 [s]. Controller position of z axis is 63.721 [mm] for ending. Machined measured tool wear 0.012 [mm]. Burr 4 (7.4507 [g]) is used for wet milling, with controller z position +63.577 [mm]. After machine work which lasted 2 [h] 44 [min] 49.74 [s], position of z axis is measured at +63.622 [mm]. Machined measured tool wear 0.045 [mm].

3.3 S235JR Milling

Milling without emulsion is conducted with burr 5, mass 7.4402 [g], with controller z position +63.499 [mm] at start. Machine milled for 2 [h] 45 [min] 13.46 [s], after which controller had position z= + 63.630 [mm]. Machine measured tool wear at 0.149 [mm].

Wet milling is conducted with burr number 6, mass 7.4547 [g]. Controller measured position of z axis at +63.580 [mm] for starting position, and after milling work which lasted 2 [h] 44 [min] 49.68 [s], ending position measured was +63.630 [mm]. Machine measured tool wear to be 0.050 [mm].

Figure bellow shows steel during milling and steel that got magnetized during the cutting processes, and got on magnetic sensors on machine.

Source: Made by author made in milling centre in Croatia

Figure 9 - 10: Steel part (or fragment) that got magnetized during the cutting processes, and got on magnetic sensors on machine

4 CONCLUSION

Tool wear is minimum, as mass loss used for testing, because of short time of toolpath used in this experiment. In that interval, however, it is possible to make preliminary testing and observe behavior of different stainless steels relevant to shipbuilding industry. Milling lasted for 158 minutes for given toolpath. Manufacturer suggests tool life up to 400 minutes maximum.

AISI 316L cannot be milled properly without emulsion with given parameters, but with emulsion it had very good results, with tool wear of only 0.050 [mm].

42CrCm4V had good results for both wet and dry milling, with small amount of magnetic pieces during the dry milling. Material had slightly better surface quality with emulsion, but tool wear was 0.012 [mm] during the dry milling, and increased to 0,045 [mm] during the wet milling. S235JR steel had good response to both wet and dry milling, but surface got magnetic during the milling without emulsion which affected magnetic sensors. During the wet process, better results were shown. For dry milling, tool wear measured was 0.149 [mm], and 0.050 [mm] for wet milling. Surface quality was worse for dry milling. For all materials, milling with emulsion gave better results on surface quality, but for 42CrCm4V tool wear showed better results without emulsion. Tool had problem with overheating or with magnetic pieces of steel during the milling without emulsion, but tool wear was almost the same for all three materials for wet milling which implicates hardness did not had effect on tool wear. During the testing without emulsion, tool life showed better results for harder materials. Further research should include the use of up-to-date models and methods for high speed milling process tool life optimization regarding steel materials analyzed in this paper.

ACKNOWLEDGMENTS

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RAPID SOFTWARE DRIVEN DESIGN OF ARM BASED EMBEDDED SHIPBORNE COMMUNICATION DEVICE

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ABSTRACT

This paper presents the details and experiences gained in software driven design of the shipborne communication device. Prior to codesign techniques emerged in 1990's the traditional embedded design methodology involved problem specification, separate hardware and software specification, and integration and the system test as the final step in the embedded device design. Such an approach can potentially lead to numerous iterations and increased cost of the development cycle because some tests cannot be performed without fully functioning software. Codesign techniques, on the other hand, involve steps such as co-specification, co-synthesis and co-verification of hardware and software. Furthermore, it is well known that when designing embedded device the most working hours are spent on software design. However, nowadays there is a large number of freely-available software tools and libraries available which greatly facilitate the software design. Therefore, it is suitable time for new paradigm shift where design of hardware is completely dictated by the design of software and the design of hardware is simply the matter of selecting proper components available on the market. In this paper we present an example of software and hardware design of ship's communication device using this software driven design strategy. By the end of this paper, it will be shown that such an approach not only decreases the possibility of design errors but it allows rapid prototype design, as well.

Keywords: embedded design, hardware-software codesign, software driven design, shipborne embedded device, ARM technology

1 INTRODUCTION

An embedded system is the special purpose computer system used for single purpose, such as domestic appliance, parking car counting device or a smart phone. Embedded system can even be the subsystem of the larger system such as medical device or a number of embedded systems can be interconnected such as in shipborne communication system.

Prior to codesign techniques the traditional embedded design methodology involved problem specification, separate hardware and software specification, and finally the integration and the system test. Such approach did not allow, for example, early fault identification of the system's architecture. Furthermore, some hardware tests could not be performed without fully functioning software. This led to potentially many iterations of hardware development until the product is in the final production stage.

In early 1990's the hardware/software codesign emerged as a new discipline for embedded system design [1]. Because of the technological advances an adoption of codesign techniques became the necessary tool for embedded system companies. Codesign techniques involve steps such as cospecification, which is a common specification that specifies both hardware and software components. Other steps in codesign are cosynthesis and coverification where software and hardware is tested simultenously to verify both hardware and software components.

In the embedded system design the larger portion of time is allocated to the development of software than it is to the design of the hardware. Furthermore, the software design tend to be more complicated then hardware design because of the required functionality. This is especially true when GUI (graphical user interface) design is required. The hardware design, in most cases, relies simply on selecting the appropriate components to achieve software design requirements. In today's IC market the electronic component manufacturers provide IC's with almost any standard functionality.

Furthermore, nowadays, there is a large number of software tools available and variety of code libraries and code elements that can be reused. Thus, the right combination of software tools can potentially lead to rapid development of product and could lead to better product in terms of reliability and quality. The question that really needs to be answered here is what components (IC's) do support the software components and libraries?

For the afore mentioned reasons, instead of codesign technique, in this paper we present the software driven embedded design of shipborne communication system. We define the software driven embedded design as the design methodology that combines the hardware and software in such way that software requirements dictate the final decision on the hardware components.

2 COMMUNICATION SYTEM REQUIREMENTS AND DESIGN

In maritime design of shipborne communication device many considerations that are related to the operating environment of the device had to be taken into account. For example, the display of the device had to support low light conditions such as in engine room and it had to be visible while exposed to direct sunlight. Because the engine room is noisy environment the care had to be taken in order to discriminate the human voice from the environment sounds. The design had to be electrically and mechanically robust in order to support conditions with increased salinity and temperature. Moreover, because of the cost constraint relatively inexpensive display is used and user interface (UI) system called µWin was developed to support such non-standard display. At the same time the system had to encrypt/decrypt large number of UDP packets while simultaneously processing microphone input and speaker output. For all these reasons, the software design in this case is order of magnitude more complicated than hardware design. Therefore, we have decided to take the software driven approach in our development which in turn dictates the hardware development.

2.1 Functional Requirements on the Ship's Communication Device

The functional concept of the shipborne communication device is shown in Figure 1. At the core of the embedded system there is a CPU powerfull enough to deliver the desired level of functinality. Because the device might be installed outside of ship's chambers, one of the important requirements is that display should be visible in sunlight conditions, therefore, limiting the choice of displays to OLED technology.

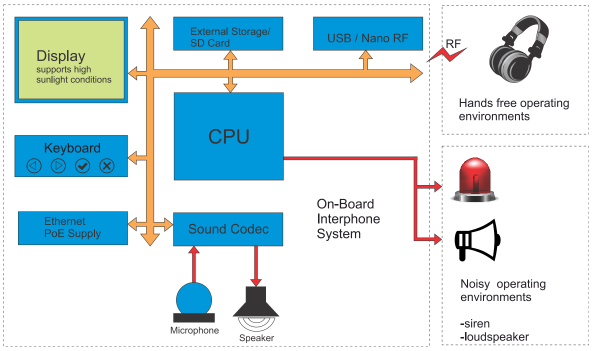

Figure 1: The functional layout of the communication device

The device is intended to be connected to ship's LAN network which offers an opportunity to simplfy the device's power suystem and the installation of the device by utilizing ethernet's PoE (Power over Ethernet) capability. This approach effectively eliminated the need for device's batteries, for wall electric power socket and for device's power supply circutry.

Because the communication device is intended to operate in noisy and dark environment of the engine room there are several considerations to take into account: first in order to enhance the visibility of display in the engine room conditions the additional requirement for the display is to have back-light functionality. Second, because of noisy environment and because the engineers in engine room should operate the device hands-free we have added wireless USB-Nano headphones with built-in noise cancellation. Third, again because of the noisy and dark engine room environment we have decided to add siren to visualy alert the crew, and the possibility of external loud speaker for those occasions when ship's captain or officer need to speak to several crew members at once.

The network layer is another important aspect to consider since the communication device is intended to operate as VoIP (Voice over IP) device which is connected via LAN to ship's communication central. Furthermore, because the requirement for the device is to support one-to-one conversation, one-to-many conversation, group conversations and conference calls each of these functionalities had to be carefully implemented. Related to this, since the communication device is currently installed on operating ships the special care had to be taken about the network security and packet encryption.

Finally, it was our intent to make the device user friendly and flexible and to allow some degree of user's customability. This means that to some degree and with ship's officer permission, the crew members are allowed to change ring tones, the layout of certain menus, to add other crew members to phone book and similar and to play the background music. All this information is stored on SD card which serves two purposed: first the crew's customization information is stored on SD card and second it allows the software updates since the parts of the operating system and software is stored on SD card. Furthermore, in the unlikely event of device's fault some important service data is stored on SD card which allows the service engineers to inspect this data and to detect the cause of the fault.

2.2 Software System Layout

The general layout of software components for ship’s interphone system design is shown in Fig.(2) where software components are shown in top-down order according to the level of complexity and interdependency. Hardware is mentioned simply to clarify the necessity of hardware abstraction layer (HAL) which is the software component, in most cases, available from CPU manufacturer. Because of the situation on the market, our goal was to reuse the code components which are freely available from various sources. Because one of the constraints of the project was to reduce the cost, we decided to use Free RTOS because we only needed support for minimal threading model. Furthermore, the minimum version of Free RTOS takes only 86 bytes of RAM, therefore too advanced CPU should not be required.

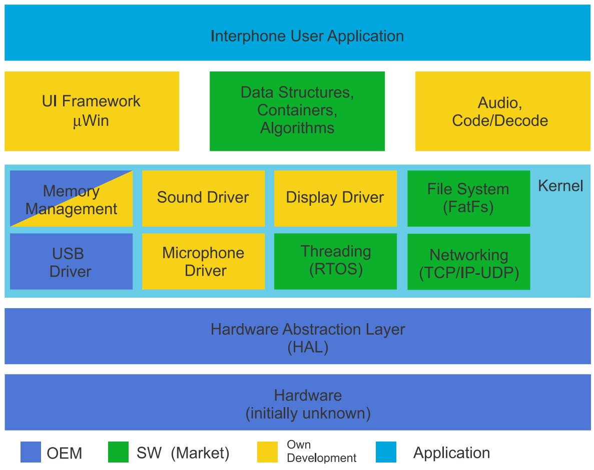

Figure 2: The layout of software components of embedded interphone design. Free software available from different sources is marked with green color

In the design of software components there is a need for standard data structures, containers and algorithms such as lists, queues, stacks, trees and networks. This is especially true in GUI design where menu's, drop-down lists are placed in tree structures. Thus, in order to expedite the production of ship's intercom system the natural choice to support these structure was STL. The standard template library (STL) is the set of ready-to-use templatized standard algorithms, containers and functionalities [2] and in order for STL to work the programming language must be C++. This placed another restriction on the choice of CPU, that is, the processor that was at the core of our embedded communication system design had to be selected with the aim to support C++ programming language. Since nowadays most of the ARM processors support GCC for ARM which is C++ compiler, the natural choice of CPU was the one that supports ARM technology.

In Figure (2) the schematic representation of the software system is shown where the parts that come from original equipment manufacturer (OEM) are shown in porple color, software components that are freely available from the market are shown in green color and software components that were missing and needed in-house development are marked with yellow color. On top of previously mentioned software layers comes the application layer which is responsible for integration and control of all these components and for user interface and ship's intercom functionality. The Figure (2) was created after market analysis which software components are freely available and easy to integrate into ship's intercom system and one of its purposes is to serve as guideline for later hardware component selection.

Thus, after analysis, the following software components had to be developed to ensure the intended functionality of the communication device:

- Microphone driver - the driver that converts analog microphone sound signals to digital signals with acceptable sampling frequency and with enough quantisation levels to ensure the audio quality. Furthermore, to ensure the voice quality the device is required to have two microphones for stereo sound.
- Sound driver - this is two channel stereo driver which is responsible for reproduction of voice audio at range of audio frequencies.
- Display driver - displays the characters on the screen at desired pixel location, displays the rudimental 2D graphics such as lines, circles, rectangles and round rectangles and allows the bitmap drawing. In addition it regulates the level of backlight.
- Memory managment - since for small embedded systems the available RAM is limited resource one of the main concerns was to avoid memory fragmentation that naturally occurs when memory is allocated dynamically. Memory fragmentation was completely eliminated by employing some special memory management algorithms.
- Audio Code/Decode - this driver is responsible for decoding encrypted audio that comes from LAN network and to provide the audio data to sound driver at required playback frequency. Furthermore, it codes the data from microphone and it prepares and encrypts the data packets for transmission over the LAN network.
- UI Framework (µWin) - this driver is essentialy the windows management system similar to windows management system on commercial operating systems such as MS Windows. Its main task is to maintain z-order, perform windows clipping, windows drawing by implementing painter's algorithm and to respond to external events such as keyboard or inbound call.

Due to large number of tasks that are required to be performed simultaneosly the processor to be selected is required to support the large number of DMA (Direct Memory Access) channels. If the large number of DMA channels are supported in hardware then the processor core would be releved of tasks such as: copying the buffers to audio playback ship, copying the data from microphone to audio buffer, LAN packet retrieval, writing buffers to display and similar. For example, if DMA is used then the task of drawing the pixel to the display is reduced to the task of writing the data to designated memory area used for DMA access to display.

Finally, the user interaction with keyboard is intended to be implemented via standard interrupt mechanism available on all modern processors.

3 HARDWARE COMPONENT SELECTION

Due to software requirements and analysis presented in previous section the natural choice for core processor is processor based on ARM technology. The ARM technology is the set of processor architecture guidelines that are provided by Arm Holdings Ltd. in order to unify processor architecture and instruction sets across various processor manufacturers [3]. The instruction set unification came in the form of Thumb and Thumb-2 instruction sets [4]. This approach guarantees the code compatibility and reusability on processors that come from different manufacturers and these guidelines are issued almost yearly. Most of the main processor manufacturers have adopted this standard and nowdays it is estimated that majority of processors on the market support ARM technology which evaluates to about 15 billion units sold only in 2015 [5]. This means that nowadays the ARM technology is present in most of the mobile phones (especially those based on Android), tablets, television sets, computers, home appliances and similar.

One interesting consequence of this architecture unification is that the compiler tools are unified as well. For example, GCC for ARM is freely available compiler for ARM and it was used in this project for software development. Furthermore, the debugging and programming of ARM processors was unified as well. In the old days, the code developer for microprocessor, in order to program effectively had to buy an expensive processor emulator for particular microprocessor device and then develop and debug the code on that emulator (for example with Keil µVision). Then the developer had to use chip programator device (which also could be expensive) to program that particular microprocessor chip. The need for this emulation software was effectively eliminated with the emergence of ARM technology becase ARM technology provides simple unified hardware interface for programming and debugging called JTAG interface. The hardware debugging removed the need for expensive emulator software because all the debugging, setting break points, following the code flow is now done in hardware. The task of GUI debugger is now to simply follow the code flow and to communicate via JTAG interface. This allowed for free ARM debuggers such as System Workbench for STM32 which are au par with commercial counterparts such as Keil µVision. Additionaly, because the GCC for ARM was chosen as the compiler tool of choice the access for code and standard algorithm libraries such as STL is guaranteed. All of these reasons amounted to decision that processor based on ARM technology is our processor of choice.

Before the emergence of ARM technology the microprocessors came in two flavors: central processing units (CPU's) and microcontrollers [6]. The purpose of the CPU is to execute program code and to communicate with peripherials such as USB, RS232, A/D or D/A module, etc [7]. On the other hand, microcontrollers are small devices which were able to execute the code, however, microcontrollers had peripherials integrated, as well [8,9]. This means that on the single chip both CPU and peripherials such as USB, RS232 were integrated together. For this reason, the microcontrollers are referred to as SoC or system on chip. Of course, this integration of CPU and peripherials came at the price of lower CPU processing capabilities and the intent of the microcontroller is to operate in small embedded devices such as home appliances.

With the emergence of ARM technology the need for microcontrollers was recognized and this gave birth to ARM Cortex M microprocessors. The Cortex M series of ARM microprocessors are packed with peripherials such as: LAN, CAN, RS232, IrDa, A/D, D/A, USB 2.0, USB 3.0, TFT display support, SD card interface, CCD camera interface and similar. The first Cortex M was Cortex M-0 while most modern ARM Cortex M microprocessor are designated as ARM Cortex M-7.

Since our communication device was designed with the intent to be relatively cheap ARM Cortex M series was natural choice for device's development because it allows to reduce the number of other electronic components (i.e. for USB and LAN communications etc.). At the time of device's design (2015) an award winning STM32F4 processor caught our attention: it was 32bit ARM Cortex M4 processor, packed with various pheripherials and with the full range of freely available software ecosystem such as peripherial drivers graphics drivers and similar. Its DMA system was very simple to set up by simply designating the region of memory used for DMA and, furthermore, almost all peripherial devices could be connected to DMA (such as microphone, sound codec, graphic display, LAN, USB). This alleviates the processing burden from microprocessor allowing it to spend the most of the processing time executing application stack (GUI, user requests etc.). On top of this, STM32F4 is equipped with floating point unit, runs at 180 MHz and is equipped with DSP instruction set, hardware calendar (required to display device's time) and had remarkable 225 DMIPS instruction throughoutput.

Once the core CPU for ship's communication device was selected using the software criteria the remaining hardware components had to be chosen. This was relatively straightforward task, for example, the chosen sound codec was stereo codec WM8731 from Wolfson microelectronics. The chip came with integrated headphone driver, stereo output to speakers and stereo input from microphone. Since one of the requirements for software sound and microphone driver was programmable sampling/playback rate WM8731 was the codec of the choice because it supported this functionality in hardware for audio sampling frequencies from 8kHz to 96kHz. With WM8731 the sampling rate can be set simply by setting apropriate chip's register. Furthermore, one of the requirements for communication device was to have the mute button. Again, WM8731was chip of choice because muting is controlled by register and the task of muting/unmuting is reduced to set or clear appropriate bit in the register. Furthermore, WM8731 works seamesly with SMT32F4 DMA buffers using I2S (Inter-IC sound) which is supported in hardware by STM32F4 microprocessor. The microphone's used were electret condeser microphone CMR-2747PB-A coupled to low noise audio amplifier MCP6021 in order to match the microphone output impedance, therefore, minimizing the signal loss from microphone.

Another important point in hardware development of the ship's communication device was interfacing LAN to STM32F4. Although STM32F4 provides ethernet interface we still had to adjust electrical levels of ethernet signalling in order for core processor to receive and send UDP packets required for VoIP. This was achieved with DP83848 ethernet transciever from Texas Instruments, the chip which adapts the physical level of LAN signals to the expected signal levels from core processor which are expected to be at 3.3V.

Furthermore, because the communication device was expected to operate in harsh environment, that is, increased temperature in the engine room and in cold environments if placed on outside areas of the ship the military grade components were selected to ensure device's functionality in harsh environments. The final product, the PCB of which is shown in Fig. (3), was tested in climate chambers and for water-tightness under increased pressure conditions.

4 CONCLUSION

In this paper we have presented the design process of ship's communication device which was almost completely driven by the software. By designing the software functionalities first and by making use of ARM technology we were able to start the software design process long before the electronic components of the device were selected. The advantage of such design process is that the waiting time for hardware component acquisition and assembly is eleminated and this time is allocated into software design process which takes significantly more time than the hardware design. Once the core processor was selected to meet the requirements of the software design the choice of other components was dictated mostly by the core processor (which again was chosen by software) and software requirements. This approach allowed us to start software development cycle before-hand and therefore reduce overall product design time. The approach of software design first was greatly supported by the availability of free software components and it would probably not be possible in 90's and 80's. Finally, the cost of the design in terms of the equipment and in terms of developer software tools was significantly reduced by choosing freely available software tools and by choosing appropriate technologies.

Figure 3: Finished PCB artwork of ship's communcation device

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MONTE CARLO SIMULATION IN RAILWAY DEMAND FORECASTING

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ABSTRACT

Liberalized railway market implies the necessity of railway undertakings and infrastructure managers to focus on users' needs and demand forecasting. However, railway market is a dynamic category, both by volume and by structure, with the permanent demand and supply changes. Demand structure for the railway passenger and freight services is subject to change under the influence of various factors, therefore railways companies have to constantly adapt to the changes that have occurred and direct its business orientation to changes in demand. Process of railway demand forecasting including uncertainty itself, therefore it is needed to use simulation models. Traditional model of railway demand forecasting uncertainty is based on developing of three case scenarios: base, optimistic and pessimistic, for the input variable risks assessment. This paper emphasizes the possibility of using Monte Carlo simulation in order to optimize railway demand planning process for the case of the Railways of the Federation of Bosnia and Herzegovina.

Keywords: Railway, demand, Monte Carlo simulation, risk assessment

1 INTRODUCTION

The main objective of this paper is to emphasize the possibilities of Monte Carlo method in railway demand forecasting process minimizing the risks of uncertainties. In order to achieve defined objective, this paper has been structured through several chapters. The first part is giving the theoretical overview of railway service specificities and railway demand influencing factors for passenger and freight railway transport. In the second part there have been analyzed the demand forecasting methods. Monte Carlo basics principles and proposed forecasting model of railway traffic demand and Case Study dealing with its effectiveness in railway demand forecasting are summarized in third part and fourth part, respectively.

2 RAILWAY SERVICES DEMAND CHARACTERISTICS AND SPECIFICITIES

Generaly, the demand for transport services is distinguished by specifics and characteristics coparing with the other proucts demand. In th basics of railway services demand there are certain needs of the users. The basic characteristic of the needs for railway transport is their non-autonomy, what arises from the fact that moving of goods and people from one place to another as a rule is never the goal by itself (Kolarić, 2007). The most important characteristics of this demand are the strict time and spatial determination. The time determination of the railway demand means that the needs for the spatial movement of people and goods occur at strictly specific moments, what is often the case that the need for transportation, expressed through an effective demand at a given moment, will not be in the next. Strict linking of the demand for transport services for specific moments or time intervals is valid both in passenger and freight traffic and it is more pronounced in the transport of people than in the transport of goods. (Kolarić, 2007). The time unevenness of the railway demand is one of its further important characteristics. It is expressed as during one day, as well as other time intervals. The spatiall determination of the demand for railway transport services is even more expressed than the time one. The needs for railway transportation and the demand based on them are always expressed through a request for moving goods and people between strictly defined spatial origin and destinations points. The spatial determination of the demand for railway services implies that this demand is always expressed on a specific railway relations. Spatial unevenness is also a significant feature of the demand for transport, what is manifested in the absence of symmetrical two-way flows of both freight and passengers, what is the result of varying intensities, as well as the different structures of return flows of goods and passengers. The above stated spatial determination, leads to the fact that the demand for railway transport on a particular route implies demand. The railway demand research and analysis process also includes the use of aggregate sizes of transport demand, a variety of degree of comprehensiveness such as: (a) the demand for transport services at the level of individual territorial units; (b) demand for transport services at the level of individual traffic branches; (c) demand for the transport of services at the level of specific transportation companies (Novaković, 1999).

2.1 Identification of rail demand factors

The above highlighted character of the demand for railway transport services is significantly determined by numerous factors. In identification of railway demand, based on (Novaković, 1999), determinates of demand for transport services are contained in those factors that determine the volume of transport needs for freight and passengers.

2.1.1 *Freight railway demand factors*

The railway freight market is mainly determined by the factors of economic development, and the basic influence on railway freight demand, beside of many, (Kolarić, 2007) has apostrophes following factors:

1. Economic development and structural changes in demand for transport services;
2. Territorial division of the economy; and
3. Traffic-geographical position in international traffic.

Distribution of manufacturing and consumer centers in the gravity area of railway lines determines the directions of transport, relations and freight flows, and the structure of freight on concrete transport directions require an appropriate mobile capacites. Distribution of production and consumer's regions determines essential components of the railway market giving the core content of the railway company business policy.

The area on which the sources of railway demand are formed presents the place where transport needs arise. Each railway relation as established connections between different areas is treated as a special traffic market, because the traffic service in the basis is "changing the place of the goods (people or goods) ie. overcoming the space between the place of production and the place consumption" (Kolarić, 2007). For each railway relations, the railway company has to know the scope of demand and its structure. Constantly adjusting railway transport capacity to the dynamics of the volume of passengers and the volume and type of freight, and demand structure of these flows on these relations as weel, is the basic issue for railway companies in order to offer the capacity structure for the satisfying transport needs.

2.1.2 *Passengers railway demand factors*

The need for passenger transportation is determined by a number of factors, which determine demand in railway passenger transport. The general passenger demand factors (Novaković, 1999) are valid for railway passenger traffic, too:

1. Number and territorial population distribution - The total number of inhabitants is the basic factor that determines the volume of needs for transportation of passengers in the market area. By territorial distribution of the population by spatial units, defines the territorial structure of the needs and demands for the transport of passengers;
2. Economic and social structure of the population - The national income policy is a factor in the formation of demand in railway passenger traffic. The larger share of national income allocated for personal consumption will result in a larger volume of total demand. The standard of living and the ability to meet the diverse needs of the individuals is determined by the amount of their available income. Consumer income is a direct determinant of demand.
3. Demographic characteristics of the population - The different demographic categories of the population also exhibit different transport intensities, and
4. Agglomeration tendencies - The agglomeration tendencies of the population are of significance for the analysis and assessment of the volume of future needs and the need for transport of passengers. This factor has to be especially appreciated in the assessment of needs and needs in underdeveloped areas.

3 RAILWAY DEMAND FORECASTING PRINCIPLES AND TECHNIQUES

In the contemporary market conditions, the supply of railway companies is determined by the future needs and demands of their services users. Therefore forecasting the demand is a critical input to railway management and planning activities. In order to adjust supply to railway transport demand reliable forecasts are based on demand model. Demand model establishes a possible causal relationship between the subject of forecasting process (number of passenger or freight trains on a railway line) and the influencing factors (GDP, quality of service, travel times, prices, etc.). After determining the causalities and checking for statistical and logical validity, model can be used for forecast of railway demand in future (Milenković, 2016). The best source of customized inputs in a forecast derives from a detailed railway market assessment, its customers, services portfolio and railway traffic volumes.

3.1 Forecasting principles

Forecasting is an inherently uncertain activity simply because past experience can be only a hint about future performance. Thus, even the most sophisticated forecasters find that the actual results are often higher or lower than their predictions. Although forecasting is a challenging task, the production of more dependable railway traffic forecasts can be guided by a set of principles that have been judged to be effective (Chapter3, 2010):

- Understanding the issues and events driving the forecasts and to communicate with users regarding the nature of the forecasts;
- Sound judgment and impartiality of the forecasting process should be maintained through the forecasts process;
- Using of the most reliable and correct and solid traffic current data basis;
- Using the most appropriate forecasting methodology and technique for different traffic component due to data availability;
- Ensuring the internal and external consistency through the forecasting process for input variables and forecast adjustments, and
- Identification of uncertainties the forecasts.

3.2 Common Forecasting Techniques

Forecasting methods used for railway demand modeling can include both quantitative data and qualitative observations. Qualitative forecasting techniques are often subjective in nature and require judgment of experts. These techniques are often used in situations where there is little or no historical data: market surveys, historical analogy, Delphi method, personal and panel insight (Milenković, 2016). The more appropriate quantitative forecasting methods are typically based on the available past data The most common quantitative techniques include a simple growth rate model, time series, and an econometric approach (Chapter3, 2010). These models can be specified at the individual railway line level, at a service level, or at a domestic/international railway service level. The models can also be combined with a market share forecast.

However, any demand forecasting has one primary disadvantage as that of any other method of predicting the future – there is no absolute certainty about the future. Any unforeseen factors may influence on forecast usability, regardless of the quality of its data. (Milenković, 2016).

3.3 Risk assessment in forecasting process

The risk analysis is systematic use of available information to determine how often specified events[1] may occur events and the magnitude of their consequences. The risks originate from the stochastic nature of the input variables. A reliable risk analysis should identify pitfalls and uncover new opportunities. Risk analysis can be performed qualitatively or quantitatively. Qualitative risk analysis generally involves assessing a situation by instinct. Quantitative risk analysis attempts to assign numeric values to risks, either by using empirical data or by quantifying qualitative assessments (http://www.palisade.com/risk/risk_analysis.asp).

The steps to identify the model assumptions are described below (Cambridge Systematics, 2016). Each step in the risk analysis requires thorough evaluation to ensure key risk factors understood and addressed appropriately.

Table 1: Eight steps Risk analysis approach

Approach	Step	Description
Identification of risk variables	1	Risk factors identification
	2	Risk variables determination
	3	Narrow down to key risk variables
Developing risk variables range and distributions	4	Developing the range for each variable
	5	Developing distributions and correlations for each variables
Implement risk analysis	6	Run the model to obtain data points
	7	Creating of regression model
	8	Perform Monte Carlo simulation

Source: based on (Cambridge Systematics, 2016)

A leading form of quantitative risk analysis, Monte Carlo simulation produces a single probability distribution of output variable, based on the risk profile for all relevant “risky” variables.

4 IDENTIFICATION OF MONTE CARLO SIMULATION METHOD STEPS

The idea of the Monte Carlo simulation method is quite simple. Instead of describing random phenomena using analytical dependencies, it is conducting modeling of random events using a procedure that gives a random result. In one experiment, one realization of a random occurrence is obtained. If the experiment is repeated many times, providing statistical material - a collection of random events that can be processed by the usual methods of mathematical statistics (Čičak, 2003). Monte Carlo simulation is a type of simulation that relies on repeated random sampling and statistical analysis to compute the results. This method of simulation is very closely related to random experiments, experiments for which the specific result is not known in advance. In this context, Monte Carlo simulation can be considered as a methodical way of doing so-called *what-if* analysis (Raychaudhuri, 2008). Finally, Monte Carlo method is based on generation of multiple trails in order to determine the expected value of random variable provided ba the mathematical model:

$$P\{\left|\frac{1}{N}\sum_N \xi - \mu\right|\}<\frac{3\sigma}{\sqrt{N}} = 99{,}8\% \qquad (1)$$

where is:

$\varepsilon = \frac{3\sigma}{\sqrt{N}}$ - total estimation (forecasting) error, σ - standard deviation, N -is the number of simulations.

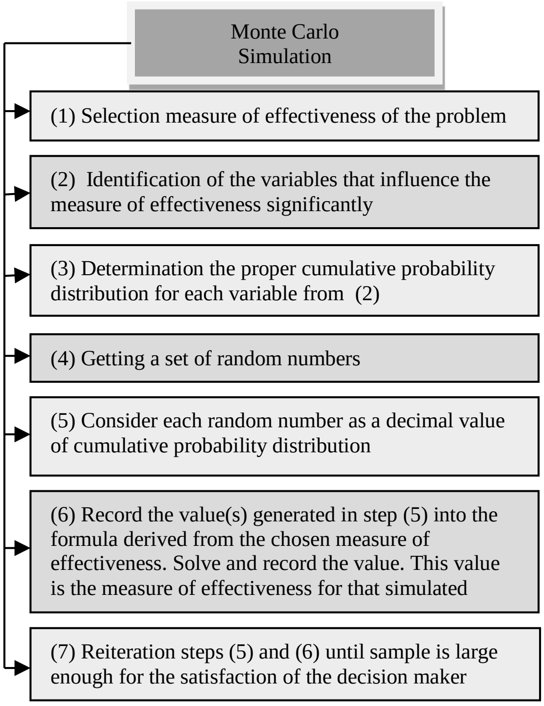
The accuracy of the Monte Carlo model increases depending on the coefficient $1 / \sqrt{N}$, and twice the accuracy requires four times the number of simulations that can be time-consuming. Cumulative distribution function (CDF) is useful for representing the probability of meeting the desired output variable.

Often such a procedure is simpler than an attempt to construct an analytical model and explore the dependence between model parameters. Monte Carlo simulation is a better alternative compared to other methods as it leads to error bounds on the estimated values (Sak, 2017).

The following steps shown in Figure 2 are typically performed for the Monte Carlo simulation.

Monte Carlo simulation starts with developing a deterministic model as real or the base case scenario of the input variables value. Mathematical relationships use the values of the input variables and transform them into the desired output as a measure of effectiveness.

[1] Risks are typically defined as negative uncertain event or condition, or the probability or threat of quantifiable damage, injury, liability, loss, or any other negative occurrence that is caused by external or internal vulnerabilities, and that may be avoided through preemptive action.



Source: (http://www.icaiknowledgegateway.org).

Figure 1: Steps in Monte Carlo simulation

Determination the proper cumulative probability distribution for each variable from (2) giving the risk components to the model. This step needs historical data for the input variables. In the step (4), as the core step of Monte Carlo simulation, after identifying probability distribution, random variable generation is provided from these distributions. One set of random numbers, consisting of one value for each of the input variables, will be used in the deterministic model, to provide one set of output values. Repeating this process by generating more sets of random numbers, one for each input distribution, resulting in recording different sets of possible output values. Analysis and decision making after collected a sample of output values in from the simulation, allows performing statistical analysis on those values. This step (7) provides statistical confidence for the decisions which might be made after running the simulation (Raychaudhuri, 2008). Application of the Monte Carlo method in railway traffic

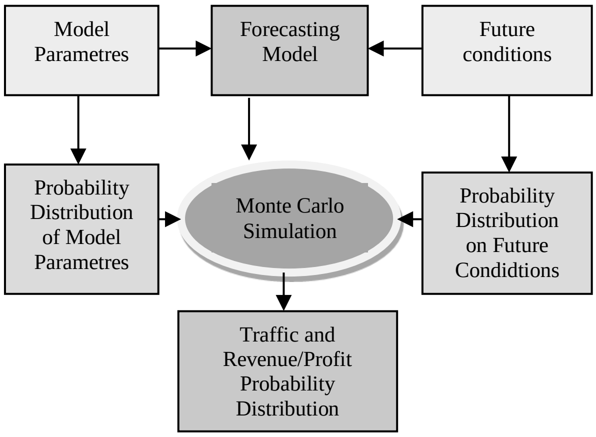
In the railway traffic, the Monte Carlo method can be applied in following operation (Čičak, 2003):

- Modeling the arrival, handling and departure of trains;
- Modeling the station operation processes, as:
    - determining the current values of the parameters,
    - input stream,
    - duration of basic maneuvering operations,
    - supplementary operations on the shunting ,
    - technical and commercial inspection of the composition,
    - the process of accumulating a car,
    - final formation of the train composition, and
    - modeling the interaction of technological operations with each other.

SNCF[2] used Monte Carlo method to investigate the second category of risk, for traffic demand and revenue forecasts, as well as capital and operating expenditures (Pradayrol, 2017).

4.1 Developing Monte Carlo railway demand forecasting model

Figure 1 show railway traffic demand forecasting analysis used to support quantitative risk analysis.



Source: based on (Adler, 2014)

Figure 2: Forecasting model of railway traffic demand

The forecasting model of railway traffic demand is simplified model defined by (Adler, 2014). Probability distributions can be developed for all of these uncertain factors. The railway demand forecasting model can be "synthesized" then be (Sak, 2017) in a Monte Carlo simulation in order to generate distributions of the outputs of interest. It is supposed that the railway demand is a normally distributed with the fix distribution by setting the 95% confidence limits on distribution LSL and USL[3].

The results of the Monte Carlo simulation in probability distributions have to determine the relative contribution of each risk factor on demand, revenue and railway traffic volumes.

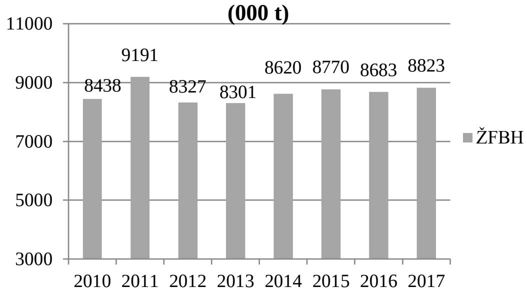
5 CASE STUDY

The Case Study has been conducted for the Railways of Federation of Bosnia and Herzegovina[4]

[2] The Société nationale des chemins de fer français is France's national state-owned railway company.
[3] LSL-lower specification limits; USL-upper specification limits
[4] Railway companies in Bosnia and Hercegovina: Railways of the Federation of Bosnia and Herzegovina (ŽFBH) and Railways of Republic of Srpska (ŽRS)

5.1 Analysis of the market performances of the railway sector in B&H

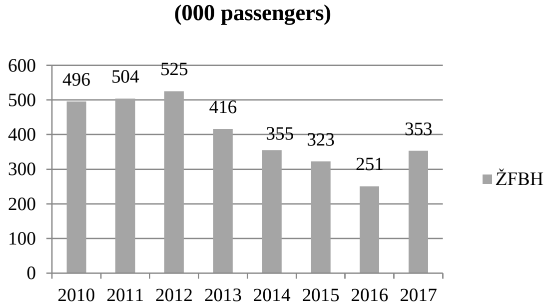
Based on the realized operational performances of the railway sector in B&H, on the total network of lines in the length of only 1,017 km, it is obvious that freight transport dominates recording 14 million tons of transported goods and less than million passengers (Figure 3 and Figure 4, respectively).



Source: (ŽFBH, 2018)

Figure 3: Freight demand distribution

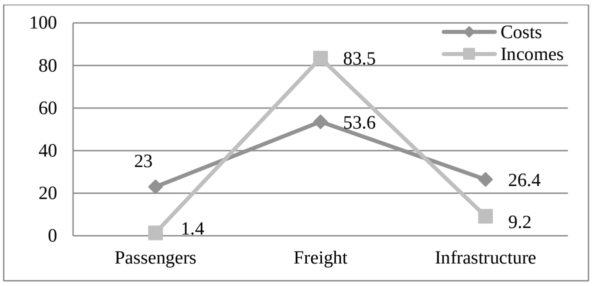
It is evident permanently declining trend in the volume of passengers demand.



Source: (ŽFBH, 2018)

Figure 4: Passengers demand distribution

Such indicators point to the conclusion that the low quality and portfolio of railway services implies weakening of the competitive position and reduced market share of railways on the B&H transport market from year to year.



Source: (WB, 2016)

Figure 5: ŽFBH transport demand, costs and incomes relationship(2014)

As a result of transported volumes in 2014, total operating costs amounted of 103.1mil.KM and realized incomes in amount of 94.1 for passengers, freight and infrastructure (Figure 5).

5.2 ŽFBH simulation model developing

According to the framework model presented in Figure 2 and preliminary research of railway transport market, there has been developed Monte Carlo railway freight demand forecasting model[5].

Table 2: ŽFBH Monte Carlo simulation model

INPUT DEFINING	STEP1			
Price per tone (KM/t)	Triangular	min	mode	max
Market size (t)	Triangular	min	mode	max
Operating costs (KM)	Triangular	min	mode	max
OUTPUTS DEFINING	STEP 2			
Demand (t)	Normal	LSL	USL	μ, σ
Market share (%)	Normal	LSL	USL	μ, σ
Total profit (KM)	Normal	LSL	USL	μ, σ
SIMULATION RUNNING	STEP 3			
Histogram creation				
Cumulative distribution function (CDF)				
Risk assessment				

Source: Authors

For the Monte Carlo simulation running has been used STATISTICA v.10 Software (Figure 6).

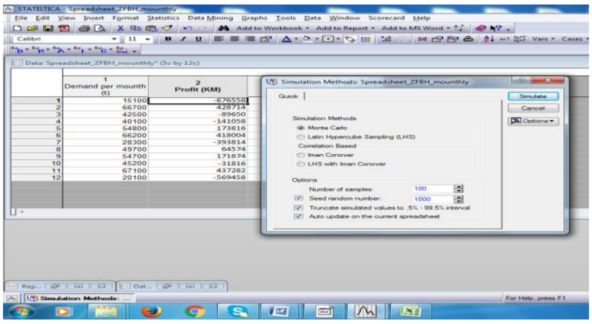
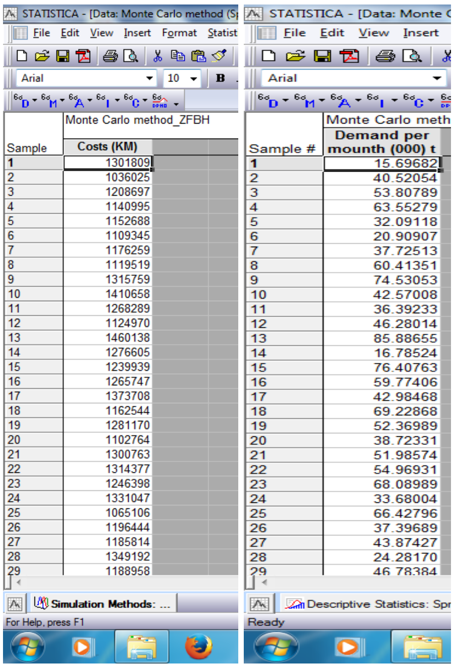


Figure 6: STATISTICA v.10 user simulation interface

[5] Passenger transport is not the scope of this paper, due to the specific poor conditions of the railway passenger transport in B&H it would be neded deeper analysis.

Figures below are presentation of the Monte Carlo simulation of the railway freight demand on monthly base for the case of the iron finished products on the relation Zenica-Ploče.



Sample	Costs (KM)	Sample #	Demand per mounth (000) t
1	1301809	1	15.69682
2	1036025	2	40.52054
3	1208697	3	53.80789
4	1140995	4	63.55279
5	1152688	5	32.09118
6	1109345	6	20.90907
7	1176259	7	37.72513
8	1119519	8	60.41351
9	1315759	9	74.53053
10	1410658	10	42.57008
11	1268289	11	36.39233
12	1124970	12	46.28014
13	1460138	13	85.88655
14	1276605	14	16.78524
15	1239939	15	76.40763
16	1265747	16	59.77406
17	1373708	17	42.98468
18	1162544	18	69.22868
19	1281170	19	52.36989
20	1102764	20	38.72331
21	1300763	21	51.98574
22	1314377	22	54.96931
23	1246398	23	68.08989
24	1331047	24	33.68004
25	1065106	25	66.42796
26	1196444	26	37.39689
27	1185814	27	43.87427
28	1349192	28	24.28170
29	1188958	29	46.78384

Figure 7: Random values of defined variables

The simulation has been run for the sample of thousand iterations for each defined variables of ŽFBH demand simulation model (Figure 7).

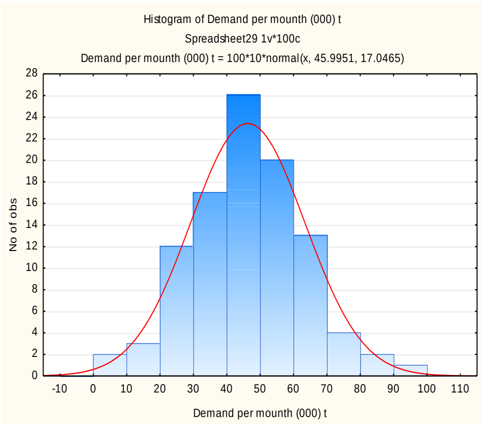


Figure 8a: Results of Monte Carlo simulation

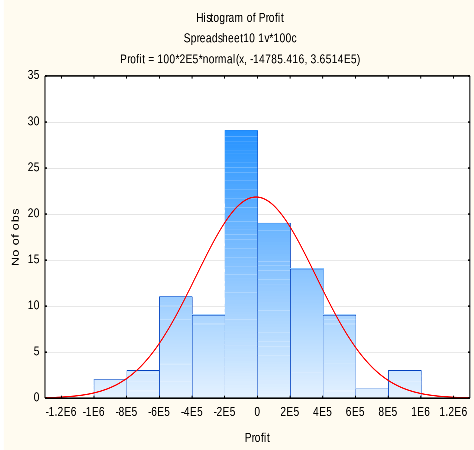


Figure 8b: Results of Monte Carlo simulation

It has been simulated the case of demand forecasting presented in volume of transported iron finished products on the relation Zenica-Ploče, in order to determine profitability if the price is 21,42 KM/t.

In order to make a progress with demand risk analysis in practice, simulated forecasting results have given the answer what is the probability that the planned demand for next mount will be profitable. Cumulative distribution function (Figure 9) presenting the probability of desired variables values achievement.

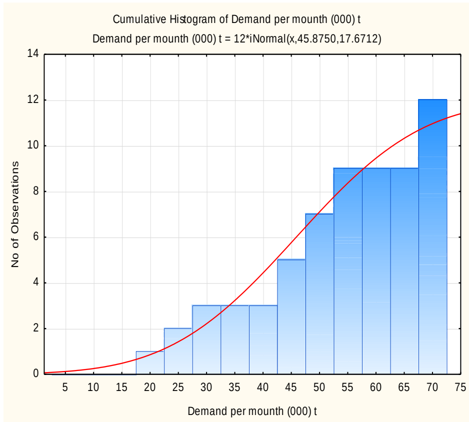


Figure 9: Cumulative distribution of demand

In this Case Study, probability that the demand higher than 49.7 (000) t, is 42%. The demand les of this amount will not result with the profit at the price of 21.42 KM/t.

6 CONCLUSION

When it is necessary to make a forecast or decision in a situation where there is significant uncertainty about the values of some variables in the future, it is not recommended to take the average value of a variable, but rather a random distribution. Unlike the historical method of forecasting with limited number of scenarios, Monte Carlo can generate an infinite number of scenarios and test many possible events, and its simulation results can be used to obtain expected values for what-if analysis. The potential weakness of this method is also the risk of a model arising from the wrong assumptions about variables models and the stochastic process on which it is based. Proposed model of Monte Carlo simulation for the

Railways of Federation of Bosnia and Herzegovina (ŽFBH) has shown the possibility and significance of Monte Carlo method applaying in railway demand forecasting, in order to consider their bussines planning policy in terms of overall profitability. In the upcoming structural changes of railway transport market in Bosnia and Herzegovina and in the region of Western Balkans countries, will arise the importance of railway demand forecasting models based on scientific quantitative methods, as Monte Carlo ensurig that the risks and ucercetainties of demand forecasting are well managed.

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THE INTERNATIONAL CONVENTION FOR THE CONTROL AND MANAGEMENT OF SHIPS' BALLAST WATER AND SEDIMENTS-RELATED DEFICIENCIS FOUND BY PARIS MOU AUTHORITIES

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ABSTRACT

The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) was adopted in February 2004 to prevent damage to the ecosystems, human health issues and economic losses caused by introduction of invasive aquatic species. The development and adoption of the Guidelines and the guidance documents enabled its uniform implementation and it entered into force in September 2017. A successful enforcement of the provisions of the BWM Convention depends on the involvement of the ship-owners, flag States and port State authorities. The role of the Port State Control (PSC) is to verify compliance with the requirements of the BWM Convention. This paper analyses the BMW Convention-related deficiencies found on ships inspected in areas under the jurisdiction of the Paris MoU from September 2017 until January 2018 to detect which problems arise and to propose corresponding measures.

Keywords: The International Convention for the Control and Management of Ships` Ballast Water and Sediments, Port State Control, Paris-MoU

1 INTRODUCTION

The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) entered into force in September 2017 ("International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM)," n.d.).The main goal of the BWM Convention is to prevent the spread of noxious aquatic organisms. Therefore, under the BWM Convention all ships in international traffic are required to manage their ballast water and sediments to ensure compliance with Regulation D-1 and eventually (defined by the ship's International Oil Pollution Prevention Certificate (OIPP)) with regulation D-2. Due to number of challenges related to installation of Ballast Water Management Systems (BWMS) many ship-owners postponed installation for five additional years by de-harmonization of OIPP (Hasanspahić & Zec, 2017).

The Port State Control (PSC) plays a major role in the elimination of substandard ships in order to improve maritime safety and protect marine environment (Cariou & Wolff, 2015). For example, after a PSC inspection the number of reported deficiencies during next inspection is reduced significantly, as indicated by an analysis of Swedish Maritime Administration activities for the period from 1996 until 2001 (Cariou, Mejia, & Wolff, 2008). Therefore, it can be anticipated that the PSC enforcement will contribute to achieving of the goals of the BWM Convention.

The majority of the PSCs worldwide have grouped together under 9 regional memorandums of understanding (henceforth MoU) (Bang & Jang, 2012). Among them the Paris MoU is the oldest and most established. It consists of 27 participating maritime Administrations, 26 European coastal States and Canada. Hence, for a preliminary assessment of PSC activities related to the BWM Convention we have looked into deficiencies recorded under the Paris MoU from date of the BWM Convention´s entry into force until 31 December 2017.

The remainder of the article is organized as follows. The second section concisely describes the PSC activities related to the BMW Convention. The third section analyses deficiencies with respect to the defective items, ship type and age, flag State and port State. The conclusions are presented in the final section.

2 PORT STATE CONTROL ENFORCEMENT OF THE BWM CONVENTION

An IMO document Guidelines for Port State Control under the BWM Convention, adopted in 2014 ("MEPC.252(67).pdf," n.d.) prescribes a tiered approach to the ship's inspection. Therefore, procedure is divided in four stages: an initial inspection, more detailed inspection, sampling and detailed analysis. The initial inspection focuses on documentation and checking if the designated officer has been appointed. If a vessel is of 400 GT or above, an International Ballast Water Management Certificate (IBWMC), provided by flag State, or Statement of Compliance, in cases when flag State is not a party must be on board. Additionally, the following documents must be on board: an approved Ballast Water Management Plan (BWMP), which includes compliance with D-1, D-2 or exception/exemption regime; a Ballast Water Record Book (BWRB), which should contain the details of any ballast water operation, especially those necessary to meet performance standards. If the BWMS is installed (once the ship is subject to D-2 or before) Port State Control Officer (PSCO) may ask to check Type Approval Certificate. During initial inspection overall condition of the relevant equipment is checked visually.

More detailed inspection is performed if PSCO provides clear grounds for proceeding, such as missing, not valid or expired documents, discrepancy between entries in the BWRB and situation on board, master´s or crew´s lack of knowledge. When carrying out more detailed inspection, the PSCO may check whether BWMP is followed, whether changes of structure, equipment, fittings, arrangements or material associated with the BWMP since the last survey have been made, and whether BWMS operate properly.

An indicative sampling can be performed to prove (non-)compliance. A detailed analysis is carried out if necessary. Sampling and analyses methodology and gear should be properly selected to avoid over- and under-sampling the organism concentration and species diversity (Gollasch & David, 2017). Due to numerousness of available methods and competences of designated staff problems with uniformity of inspections can be anticipated.

Detention by the PSC may result from the following deficiencies: absence of an IBWMC; absence of a BWMP; absence of a BWRB; indication that the ship or its equipment does not correspond substantially with the particulars of the IBWMC and BWMP; absence, serious deterioration or failure of proper operation of equipment required under the BWMP; the designated officers or crew are not familiar with essential ballast water management procedures including the operation of BWMS and all associated BWMS equipment; no ballast water management procedures have been implemented on board; no designated officer has been nominated; the ship has not complied with the BWMP for management and treatment of ballast water; result of non-compliance by sampling; or ballast water has been discharged other than in accordance with the regulations of the BWM Convention. The list is non-exhaustive and other deficiencies, if evaluated as serious by inspector, can lead to detention.

3 ANALYSIS OF DEFICIENCIES

To find out how implementation of the BWM Convention started regarding PSC activities in areas under The Paris MoU, inspection database is surveyed (“Inspection Search | Paris MoU,” n.d.). Out of 27 member States of the Paris MoU 15 ratified the BMW Convention and their Port State authorities are entitled to conduct inspections: Belgium, Canada, Croatia, Denmark, Finland, France, Germany, Greece, Malta, the Netherlands, Norway, Portugal, the Russian Federation, Spain, and Sweden (“Status of Conventions,” n.d.). The member States of the Paris MoU that have not ratified the BWM Convention are: Bulgaria, Cyprus, Estonia, Iceland, Ireland, Italy, Latvia, Lithuania, Poland, Romania, Slovenia and the United Kingdom.

In the period from 8 September 2017 until 31 December 2017, 3641 ships were inspected and 118 detained by PSCOs in States who ratified the BWM Convention. 63 ships that were subjected to initial (8), expanded (14) and more detailed (41) inspections had deficiencies related to the BMW Convention (BMW deficiencies henceforth). During those inspections 434 deficiencies in total were observed, and 17% were BMW deficiencies. Those 74 deficiencies are listed in the reports using 10 deficiencies codes. As seen from Table 1 deficiencies were most frequently (33.8%) related to BWRB, with remarks that BWRB is missing, not properly filled, incorrect or entries are missing.

Table 1: The BWM Convention-related deficiencies recorded in the Paris MoU region, 8 September 2017-31 December 2017

Defective item	Code	Number of Deficiencies	Comments
Ballast Water Management Plan	14801	18	Not approved, no updated, incorrect, missing
Ballast Water Record Book	14802	25	Not properly filled, incorrect, entries missing, missing
Construction dates applicable for BWM	14803	0	
Ballast Water Exchange	14804	20	Not as required, missing
Sediment removal and disposal	14805	0	
Crew Training and familiarization	14806	7	Lack of familiarity
Conditions for exemptions	14809	0	
Water Discharge violation in port	14810	3	Not as required
Ballast Water Management System	14811	0	
Other (BWM)	14899	1	

Source: authors based on data from the Paris MoU Database

https://www.parismou.org/inspection search/inspection-search

Ballast water exchange (27%) also seems to be an important issue according to data. It could be that it was not performed properly or, in the case of avoidance due to justified reasons, properly explained. Similarly to BWRB, in some cases (24.3%) BWMP was missing, or it was not approved, not updated or incorrect.

PSCOs decided to detain 6 out of 63 inspected ships. However, although they had detainable BWM deficiencies, such as absence of a BWMP or absence of a BWRB, they were not marked as a ground for detention. It is interesting to note that some of the inspected ships were not detained at all, although detainable BMW deficiencies (for example lack of familiarity, missing of BWMP or BWRB, inappropriate discharge of ballast water) were reported. It can be supposed that due to the early phase of the implementation, PSCOs decided not to detain the ships. Potentially important information is that 8 ships had only BWM deficiencies, indicating that otherwise satisfactory ships were not properly prepared for the BMW implementation.

The targeting of ships is based on a Ship Risk Profile, SRP, which is recalculated daily. It is dependent on generic (type and age of ships, performance of ship's flag, performance of the recognized organization, performance of the company that is holder of Document of Compliance) and historic (number of deficiencies, number of detentions) parameters. Therefore it is interesting to check if data on BWM deficiencies can influence SRP. Concerning ship type (Table 2), the most prominent are bulk carriers and general cargo ships, reflecting widely acknowledged fact that among substandard ships those ship types are represented mostly.

Table 2: Number of ships with the BWM Convention-related deficiencies recorded in the Paris MoU region, 8 September 2017-31 December 2017, by ship type

Ship type	Number of ships
General Cargo	10
Bulk Carrier	16
Refrigerated Cargo	1
Container Ship	6
Chemical Tanker	10
Oil Tanker	12
Ro-Ro Cargo	2
Gas Carrier	1
Other	5

Source: authors based on data from the Paris MoU Database https://www.parismou.org/inspection search/inspection-search

Data on ships´ age (Table 3) reveal that majority of ships with deficiencies are older ships, also in an accordance with previous experience.

Table 3: Number of ships with the BWM Convention-related deficiencies recorded in the Paris MoU region, 8 September 2017-31 December 2017 by ship`s age

Ship´s age (years)	Number of ships
0-5	7
5-10	17
10-20	31
> 20	8

Source: authors based on data from the Paris MoU Database https://www.parismou.org/inspection search/inspection-search

The Paris MoU White (quality flags), Grey and Black (flags with a poor performance) Lists of flag States are formed based on the total number of inspections and detentions over a 3-year rolling period for flags with at least 30 inspections in the period ("White, Grey and Black List | Paris MoU," n.d.). It is interesting that 93.7% of ships with BWM deficiencies fly a white listed flag (Table 4). Thus it could be expected that data about BWM deficiencies will affect the PSC targeting and eventually contribute to the improvement of performance regarding preventing pollution by ballast waters and sediments.

Table 4: Number of ships with the BWM Convention-related deficiencies recorded in the Paris MoU region, 8 September 2017-31 December 2017, by flag State

Flag State	Number of ships
White list	
Antigua*	2
Bahamas*	1
Bahrain	1
Barbados*	1
Cayman Islands	1
China	1
Comoros	1
Cyprus	3
Denmark*	1
Faroe Islands	3
Finland*	1
Gibraltar	2
Greece*	1
Hong Kong	1
Isle of Man, UK	1
Italy	1
Liberia*	5
Luxemburg	1
Malta*	6
Marshall Island*	10
Netherlands*	2
Panama*	7
Portugal*	2
Singapore*	3
United Kingdom	1
United States	1
Grey list	
Poland	1
Black list	
Cook Island*	1
Moldova	1

*States which ratified the BWM Convention

Source: authors based on data from the Paris MoU Database https://www.parismou.org/inspection search/inspection-search

Furthermore, out of 29 flag States, 14 ratified the BMW Convention. Therefore it could be assumed that more effort must be put worldwide into familiarization with its requirements.

A harmonized approach to treatment of ships is necessary to obtain desirable results of PSC activities. Data in Table 5 show that only in 10 out of 15 port States BWM deficiencies were observed.

Table 5: Number of ships with the BWM Convention-related deficiencies recorded in the Paris MoU region, 8 September 2017-31 December 2017, by port State

Port State	Number of ships
Spain	14
Netherlands	24
Russian	3
Germany	7
Greece	6
France	4
Canada	1
Malta	1
Sweden	2
Denmark	1

Source: authors based on data from the Paris MoU Database https://www.parismou.org/inspection search/inspection-search

Moreover, as can be seen from Table 5, the number of inspected ships with recorded BWM deficiencies is significantly higher in Spain and Netherlands in comparison with other port States. There are many possible explanations for such heterogeneous distribution: features of the ships calling in different ports, differences in the manner inspections are done, level of competences of PSCOs.

4 CONCLUSIONS

A preliminary survey of the PSC activities carried out in the Paris MoU area from the September 8th 2017 until January 2018 shows that 1.7% of inspected ships had deficiencies related to requirements of the BMW Convention. Although the fraction of the ships with recorded BMW deficiencies is low, types of deficiencies and related comments recorded for otherwise adequate ships indicate that additional efforts must be put into familiarization with its provisions.

An analysis of the number of ships with BWM deficiencies inspected in different port States suggests that there is a need to thoroughly investigate a level of differences across the port States, especially since further problems with uniformity of inspections are expected once when compliance with D-2 will be checked.

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VIBRATION DIAGNOSTICS OF MARINE GAS TURBINE ENGINES

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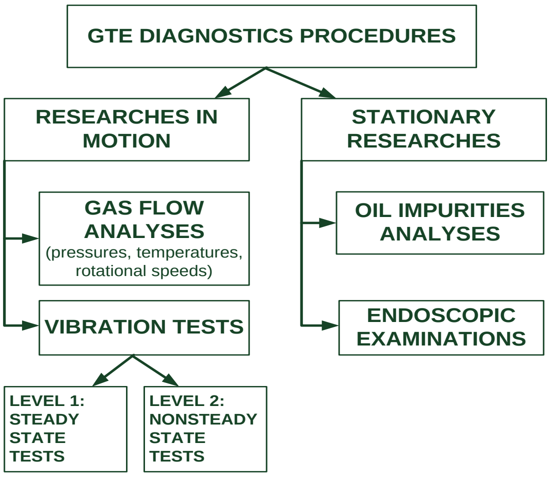
ABSTRACT

Operation of marine gas turbine engines (GTE) involves three interdependent processes, ie genesis, diagnosis and prognosis of the engines technical condition. Manufacturers equip gas turbines with monitoring systems and prepare some manuals for the user to facilitate the operation of engines (Baragan, 2001). Poor knowledge about the causes of the failure may lead to incorrect diagnosis and prognosis of operation. The GTE diagnostics is an essential element of the proper operation and this technical activity should be considered as a multi-symptom process. Vibrational tests are one of many diagnostic tools, but their effectiveness and validity depends to a large extent on the analysis of two or more diagnostics symptoms confirming failure or wear. The paper presents a branch of the diagnostic system prepared for the Polish Navy, based on vibration analysis and other dynamic parameters which allow to evaluate the technical condition of the turbine engine rotor system. The gas turbine engines LM 2500 type are an example of such system. The paper presents diagnostics methods in steady and non-steady states. Finally, it is presented the analysis of trends of sensitive diagnostic symptoms.

Keywords: GTE, vibration, rotor system, diagnostics, trend

1 INTRODUCTION

Diagnostics of the gas turbines has a long history, which mainly results from their first application, what was aviation. The reliability requirements for airplanes have always had the highest priority. The marine GTE are liable to automate and measure gas- dynamic parameters, which makes them easy to diagnose. Currently, the biggest problem for an off-line type diagnosing are knowledge of the detailed construction and physical parameters of materials. Engines producers treat the turbine construction secretly, what makes diagnostics a difficult task. The gas turbine engines diagnostic system prepared for Polish Navy, was launched in 1994 and it has supervised nearly 36 engines of 7 types (Charchalis i Grządziela, 2001). The Figure 1 presents a scheme of the diagnostics system.



Source: own research

Figure 1: The scheme of diagnostic system of GTE used by Polish Navy.

The vibroacoustic tests are divided into 2 levels, i.e. tests in steady state and non-steady states. The steady-state tests are carried out for all operational engine loads, and the limited values of diagnostics parameter are obtained from the producer's manuals or as effect of own tests. During the tests, general vibroactivity are evaluated by analyzing the results with the standards eg ISO 10816 or ISO 2372. The analyses of the research results also led to the implementation of dimensionless symptoms of the evaluation of the rotors' unbalance, which are S1 and S2 parameters (in the following, the paper the both parameters have been described). The steady state tests can be carried out with or without triggering of signals.

Diagnostic tests in non-stationary states are performed during the deceleration process up to stoppage of the engine rotor (Downham E., 1971). Such test has suppressed of dynamic disturbances of working processes in the burning chambers, what allows for analysis of changes in vibration and dynamic parameters in terms of rotor unbalance, bearing wear, gas-flow passage contamination, local resonances, critical speeds, etc. The second level of researches are performed with triggering rotors speeds due to the use of Order tracking procedures (Krzyworzeka P., 2007).

2 THEORETICAL BACKGROUND

The rotors systems of the marine GTE operate on the atmosphere impure by salt and gas deposits. Practically all GTE rotors have a dynamic unbalancing coming from technological errors or operational reasons. Forces acted on the bearings of rotors systems have different values and phases. The vibration measurement should be done at least two gauges with triggering of signals. Depending on the rotors vibration modes, the number of energetically significant harmonics will be at least 2 or 3. The values of subsequent harmonics and the changes in the values of their ratios in the deceleration process are physically eligible symptoms for the unbalance rotors investigation. Phase analyzes in initial unbalance identification are not necessary due to the use of averaging values of vibration signals. Triggering of optical signals are mainly used for Order tracking procedures and for identifying the imbalance from the failure of one or a few rotor blades.

Theoretical considerations assume that GTE rotors behave like flexible one. Their movement is a composite of two circular motions: the motion of the rotor around its own deflection line and the motion of this line around the rotor axis called the concurrency precession. When increasing the rotational speed of the rotor, for example during engine start-up, there is an increase in the radius of the eccentricity circle e and the angular change between the line of centrifugal force and the direction of shaft deformation. The radial force acting in the direction of deformation is balanced by the elastic force and the tangential force of the precession track is partially balanced by the resistance of motion, thanks to which the shaft rotates in a circle with the radius e. The tangent force reaches the maximum value at the critical speed. Such a method of analysis practically concerns rotor machines from the power industry, i.e. high-power steam turbines (Song, 1998). Unbalance analyzes for marine GTE are usually performed as for a rigid rotor analysis. This is determined by the higher rigidity of the rotor and the use of ball and / or spherical roller bearings. Essentially, this means that the first stage of research is to assess the vibroactivity of the machine in relation to the producer of limits or another standard. If the measured signal reached warning level than the gas-flow passage of the GTE should be cleaned as a first procedure. The next step is vibration analysis for the purpose of examine the unbalance of the rotor.

The GTE rotor at supercritical rotational speeds causes the self-centering effect of the rotor shaft due to the direction of the centrifugal force (Irretie H., 1998). The centrifugal force is phased in relation to the tangential force by an angle in the range of $90^0 < \varphi_0 < 180^0$. Thus, the analysis of vibration signals measured on the rotor struts provides information about the amplitude and phase. As the rotor speed increases, the angle φ_0 will also increase as well and the amplitude of the vibrations will decrease in relation to the critical amplitude for $\omega = \omega_{CR}$. The rotor with only the residual unbalance will have a constant ratio of the values of its harmonics and the value of the first harmonic amplitude will increase with the increase of the rotational speed. The increase in the value of the vibration amplitude of the first harmonic does not only depend on the centrifugal force because it is reduced by the influence of changes in the angle φ_0, which increases phase shifting the tangent force vector. This reasoning algorithm enables the analysis of the ratio of subsequent harmonic values as symptoms of an increase in unbalance greater than residuals.

The implementation of diagnostic models to diagnostic data base is highly desirable because it allows to predict the response of the rotor-bearing system in the domains of amplitudes, frequencies and phases as a symptom of virtual damage. The schematic of the diagnostic model is shown in Figure 2.

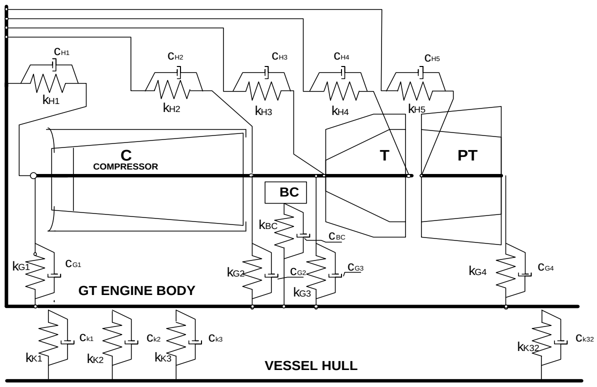


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Figure 2: Axi – symmetric lumped mass inertia model of the GTE rotors, where C – compressor, T – turbine, PT – power turbine (Grządziela, 2002)**.**

Movement parameters of discrete model have been found by solution of following equation:

$$\boldsymbol{M}\ddot{x} + \boldsymbol{C}(x,\dot{x})\dot{x} + \boldsymbol{K}(x,\dot{x})x = \boldsymbol{F}(t) \quad (1)$$

where: $\boldsymbol{K}$ – matrix of structure's stiffness, $\boldsymbol{C}$ – matrix of structure's damping, $\boldsymbol{M}$ – matrix of structure's inertia, $\boldsymbol{F}$ – vector of forces and moments, $x, \dot{x}, \ddot{x}$ – displacement and their derivatives (velocity and acceleration)

The application of the diagnostic model for the evaluation of the GTE healthy conditions is very difficult due to the individual characteristics of the engine, similar to vibration fingerprints. Furthermore, a simulation model of the GTE rotor presents the deflection of the rotor while the vibrations are measured on the bearings, eg on struts. Practically it means the need to tune the model in all domains, it has many practical limitations in diagnostics and this can lead to matching errors. The main task of the dynamic model is virtual verification of accepted diagnoses (Charchalis i Grządziela, 2001).

3 METHODS FOR MEASURING VIBRATIONS OF THE GTE ROTORS

The O.H. Perry class frigate are equipped with COGAG propulsion system, which consists of 2 gas turbines LM 2500 types. The propulsion system is monitored by the on-line system, however, it analysis only I harmonics values and triggering of gas generator rotor's speed (GG) and power turbine rotor's speed (PT). The off-line diagnostics system consists of Bruel & Kjaer PULSE system and 4 accelerometers B&K 4514 type. Triggering signals are recorded from optical sensors of the monitoring system on-line (Grządziela, 2002). Due to the high temperature of the power turbine case detailed analyzes of signals measured at the PT did not yield satisfactory results. The results indicated too high value of standard deviation of results for the same measurement procedures and in the same engine technical condition. It was a reason that off-line diagnostic system is focused only on vibrational diagnostics of the compressor rotors. Accelerometers are mounted on over the struts to the upper case of the compressor. The location of the sensor mounting is shown in Figure 3. The assembly method is shown in Figure 4.

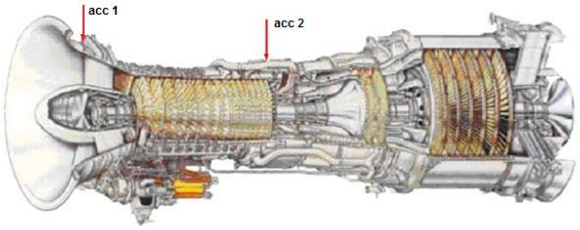

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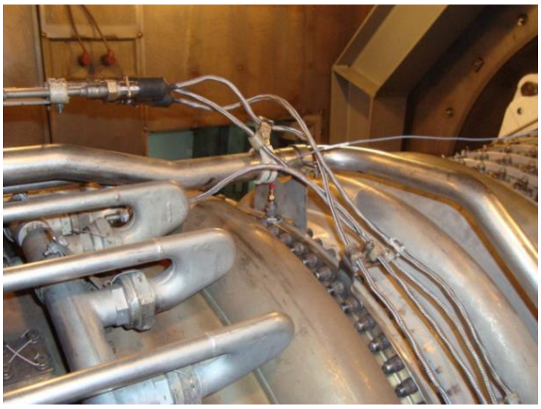
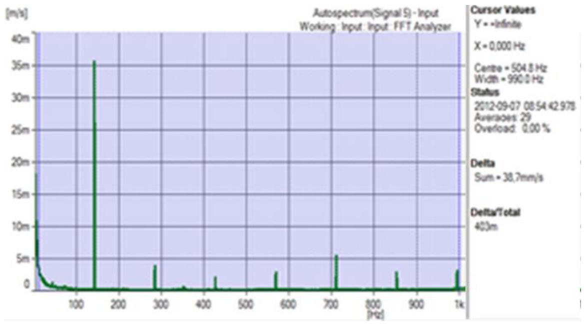
Figure 3: Locations of accelerometers over bearings for GTE LM 2500 type vibration measurements.



Source: own research

Figure 4: The assembly method of accelerometers.

The basic analyzes of vibration diagnostic parameters are changes in the values of the following three harmonics of the compressor in the function of operational speed for all driving modes of the propulsion system and delta root mean square values of vibration velocity for the range 2Hz - 1 kHz (band filter) - Figure 5.



Source: own research

Figure 5: The spectrum of vibration at nGG=9000 rpm.

Trends of first three harmonics and dimensionless parameters S1 and S2 are analyzed as well. During the tests, acceptable limits of all vibration parameters were established (Charchalis i Grządziela, 2001). The analyzed ratios of subsequent harmonics as dimensionless parameters S1 and S2 are performed, as follows:

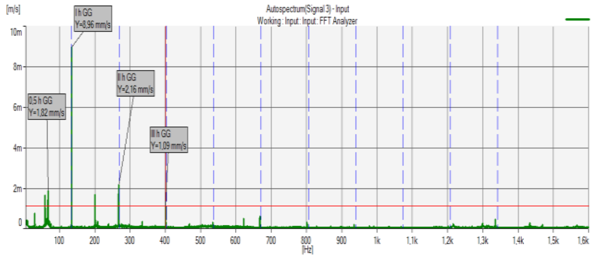
S1 - ratio of the values root mean square of vibration velocity amplitude of a compressor rotor (1st harmonic to 2nd harmonic),

S2 - ratio of the values root mean square of vibration velocity amplitude of a compressor rotor (1st harmonic to 3rd harmonic) - figure 6.

The minimum values of symptoms S1 and S2 for rotational speed GG = 7000 rpm and more for LM 2500 type engines were determined as follows:

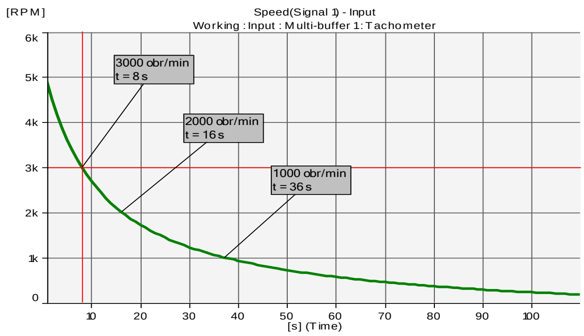
- the minimum value of S1 (GG) = 1,5,
- the minimum value of S2 (GG) = 2.5.

The third type of diagnostic symptoms is the deceleration time analysis of the GG rotor during the engine stoppage. The procedure consists in keeping a constant rotational speed of the GG rotor at 5000 rpm and then stopping the engine and measuring the time until the rotor reaches successively speeds of 3000, 2000 and 1000 rpm. These time parameters determine the condition of the rotor bearings (increase frictional resistance) as well as the increase of rotors inertia resulting from its impurities (increase in the moment of inertia). An example of the analysis result is presented in Figure 7.



Source: own research

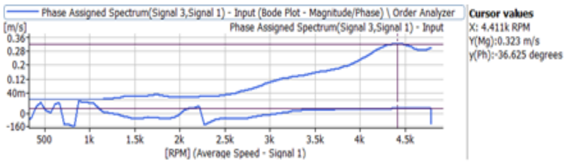
Figure 6: The Gas Generator (GG) structure of vibration harmonics.



Source: own research

Figure 7: The time signal performance of compressor rotor at run-down process of GTE.

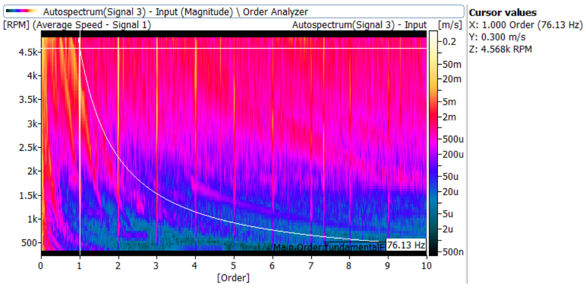
Although all decelerated periods of time are recorded and analyzed, but the most sensitive is the third period time of GG from 5000 rpm to 1000 rpm. Changes in the technical condition of the bearing system and the impurity gas flow passage of the GTE indicate the best sensitivity of such symptom. The analysis of changes in the value of the vibration velocity amplitude makes it possible to make the deceleration performances of both rotors of GTE similar to a fingerprint Figure 8. The acceptable limit time for deceleration from 5000 to 1000 rpm was established at 32 seconds.



Source: own research

Figure 8: The vibration velocity amplitude performance of compressor rotor at deceleration process of GTE.

The Order tracking analysis is next diagnostic procedure used at the GTE stoppage process (Pedersen T.F., 2006). Analysis of the orders structure enables fast and accurate identification of new resonances appear during rotor deceleration - Figure 9. The tests performed during the engine stopping ensure no interference from combustion processes, and other rotating rotors. The identification of new resonances consists in determining the harmonic values and background vibrations of the spectrum, which was also observed.



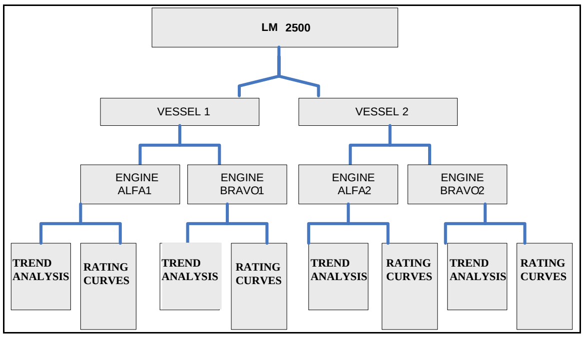
Source: own research

Figure 9: The Order tracking performance of compressor rotor at deceleration of GG rotor.

4 TREND ANALYSIS OF SYMPTOMS

The concept of trend is significant for proper interpretation and application of technical analysis. The purpose of applying the majority of instruments among all technical analysis tools is related to the current trend - mainly the goal is to identify the direction but also the moment of reversing the trend (Rzadkowski, 2009). The analysis of the vibroacoustic symptoms trends have been conducted in the Polish Navy for many years. The first analyzes concerned recorded vibration signals from operational documentation to determine the extent of changes in vibration parameters before the maintenance process. The off-line system has adopted the necessary simplifications in which the healthy condition of GTE after maintenance process or overhaul corresponds to the technical condition of the brand new engine. This procedure was necessary due to the small number of objects studied.

An active database, called ANALIZA, which analyzed vibration parameters was prepared and launched whose task are to archive and statistical analysis of measured data. The database is of an open type and it enables implementation new statistical tools. The organization of the database structure is shown in Figure 10.



Source: own research

Figure 10: The organizational of the ANALIZA database.

Diagnostic tests of LM 2500 engines were conducted in 2009 - 2015. Vibration tests were carried out on 6 Gas Generators and number of measurements were 187. All measurements consisted of tests on Idle load - nGG = 5000 rpm and on other loads, i.e. nGG = 6000, 7000, 8,000 and 9,000 rpm. Total were performed 143 deceleration tests and 112 Order tracking analyses.

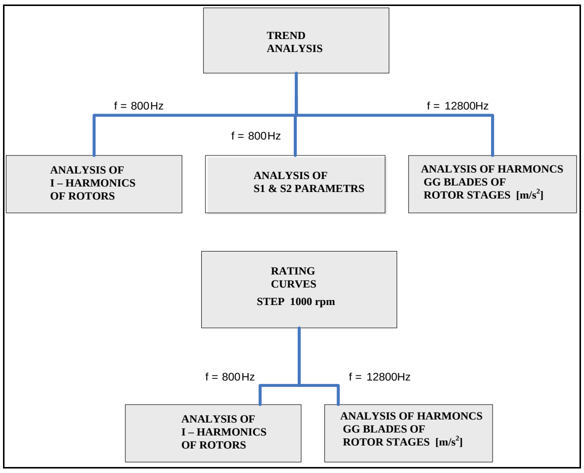
Vibration diagnostic symptoms have been classified into 4 groups, which are analyzed separately and after that together. The occurrence of 2 or more symptoms identifying the same fault implies warning signal for the diagnostic team. The structure of vibration diagnostics symptoms presents Table1.

Table 1: Group structure of diagnostics symptoms for GG rotor.

Group	Diagnostics symptoms
1	I harmonic GG/GG [mm/s], I harmonic GG/PT [mm/s], RMS from 2Hz – 1 kHz band [mm/s]
2	S1 GG [-], S2 GG [-],
3	The time signal performance of compressor rotor at deceleration process of GTE [sec]
4	Resonance identification in Order tracking spectrum

Source: own research

The next procedure of trend analysis is focused on developing the velocity of vibration parameters performances in steady state conditions. Analyzes are performed for the following rotational speeds of compressors rotor nGG = 5000, 6000, 7000, 8000 and 9000 rpm. Structure of this part of the database is presented in Figure 11.



Source: own research

Figure 11: The organizational structure of rating curves and trend analysis.

The vibration diagnostic system of the propulsion system during operation of the engine monitors the vibrations of GG / GG, GG / PT, PT / GG and PT / PT, where AA / BB means respectively AA / - I-st harmonic of GG or PT rotors and / BB - location of the accelerometers, on GG or on PT. Regarding the procedure of off-line tests, the measurements were taken on all GTE. Optical triggering of signals have been synchronized with the on-board monitoring systems. The aim of the research was to determine the trend of changes in the values of GG / GG symptoms. The results of the analyses the I-st harmonic of GG /GG from all test of six Gas Generators for the rotational speed of rotors nGG = 9000 rpm are presented in Figure 12. The postulate of statistical analysis was that the coefficient of the determination R^2 is limited for diagnostics of the trends. The theoretical definition of the coefficient of the determination defining the total sum of squares as:

$$M_{TOT} = \sum_I (y_i - \bar{y})^2, \tag{2}$$

and the regression sum of squares as:

$$M_{RG} = \sum_i (f_i - \bar{y})^2, \tag{3}$$

and next the sum of squares of residuals as follow:

$$M_{RS} = \sum_i (y_i - f_i)^2 = \sum_i e_i^2, \tag{4}$$

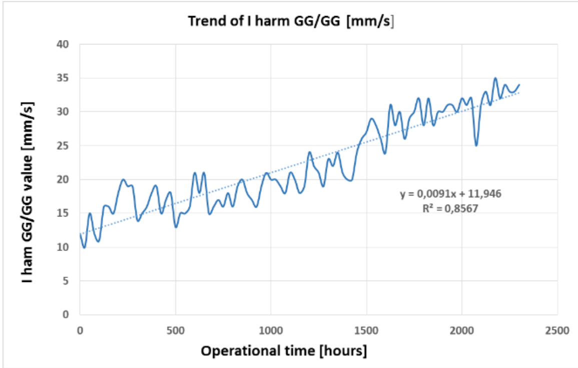
then the general definition of the coefficient of determination is:

$$R^2 = 1 - \frac{M_{RS}}{M_{TOT}}. \tag{5}$$

where: $\bar{y}$ - is the mean of the measured symptom, f_i - a predicted value of the symptom.

The coefficient of the determination provides a measure of how well recorded symptoms are replicated by the mathematical model, based on the proportion of total variation of results accounted by the model.

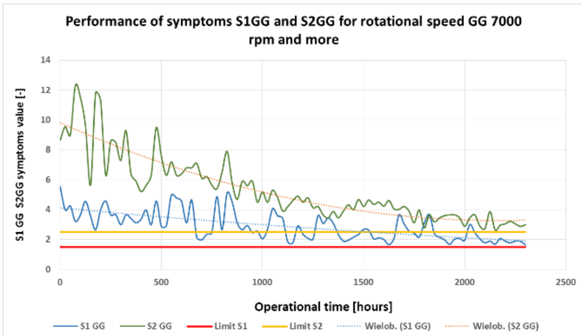
It was establised that the minimum value of R^2 should not be less than 0.85. Positive results were obtained for GG/GG symptom measured at nGG = 9000 rpm. For lower values of rotational speed of the GG rotors, the obtained R^2 were in the range of 0.72 - 0.81 and results were not analyzed as unambiguous diagnostic symptoms. The acceptable value of I-st harmonic of GG rotor was defined as A_V= 40 mm/s.



Source: own research

Figure 12: The trend of I-st harmonics of GG/GG symptoms at nGG=9000 rpm.

The test of I -st harmonics are a useful tool to determine the unbalancing of rotors as using triggering of signals can identify the damaged rotor blade. However such tool has two basic limitations. First of all, it identifies only simple unbalances resulting from damage to one or few blades. Diagnostic analysis of only the I-st harmonic of the rotor is not sensitive to the indication of damage such as gas flow passages pollution or oil leaks into the rotors casing. Such errors are clear observed by following the symptoms of S1 and S2. The increasing the values of subsequent harmonics, even if the value of I-st of harmonic is constant, indicates the occurrence of momentary unbalance. An example of analysis of symptom trends S1GG and S2GG is shown in Figure 13.

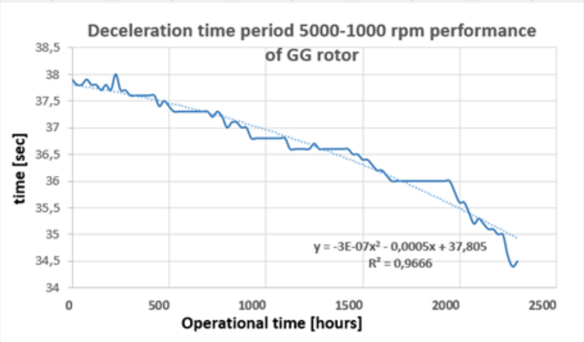


Source: own research

Figure 13: The trend analyses of S1GG and S2GG symptoms at nGG=7000 rpm and more.

The last group of analyzed symptoms as trends are the deceleration time period's performances from 5000 to 1000 rpm of GG rotor. Consumption wear of the rotor - bearing system should be considered as three groups of typical failures. The first group is rubbing the blades with a lower or/and upper case of the gas generator. This phenomenon has an acoustic nature and it is not necessary to apply advanced diagnostic tools to recognize it. The problem is usually quickly identified by the technical staff.

The second group is the salinity or contamination of hydrocarbons on blades and channels in the gas flow passage. The decreasing of the aerodynamic cross-section in the compressor causes an increase in air flow resistance and, therefore, faster braking of the rotor in the stoppage process. The effect is to increase the deceleration of the rotor. The last group of defects is the wear of the bearing system. The frictional wear of rolling bearings is already manifesting in the initial phase the increase in rolling resistance and thus the reduction of the period time from 5000 to 1000 rpm. The example of trend periods time deceleration 5000-1000 rpm performance of GG rotor is presented on Figure 14.



Source: own research

Figure 14: The example of trend deceleration time period 5000-1000 rpm performance of GG rotor

Observation of such symptom is much more effective than vibration testing of the bearing system. Certainty of the diagnosis is enhanced by the observation of increasing temperature of the lubricating oil behind the bearings as well. (Charchalis i Grządziela, 2001) The statistical analysis of time changes during the engine stoppage is done similarly to the first harmonic analysis, using equations (2) - (5).

5 CONCLUSIONS

The off-line diagnostic method allows for rational use of time of use when the engines are in the advanced wear process or after the next overhaul. The tests confirmed by the results of engine inspections confirm the sensitivity of the vibration symptoms presented.

The research allowed to accumulate a significant number of results from the database, which increases the efficiency of diagnose and forecasts for marine engines. The presented results indicate the following conclusions:

1. the proposed diagnostic method for the evaluation of rotor systems as non-invasive does not require the ship to be switched off from use for time of measurements,

2. implementation of the vibration diagnostic method as a multi-symptom element allows for highly probable and early detection of typical damage,

3. periodic tests of the trend of diagnostic parameters allow to assess the suitability of the engine for further use.

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DETERMINATION YSTAD NEW OUTER PORT PARAMETERS FOR RO-PAX FERRIES OF 230 METER LENGTH BY USE OF REAL TIME SIMULATION METHOD

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ABSTRACT

The increasing sizes of ships determine the interest in modification the already existing ports and terminals. Simulation models allow analysing the possible modernization variants. The paper presents all stages of real time simulation researches for determination of optimal parameters of newly design outer port in Ystad in Sweden for next generation of 230 meters length Ro-Pax ferries. The simulations was conducted with use of full mission simulator according to own methodology of port design. Study results delivered navigational guidelines for designing the new outer port with two ferry quays, turning place and approach channel in Ystad Port.

Keywords: Model of ships manoeuvring, navigation safety, designing of ferry terminals, real time simulation

1 INTRODUCTION

The port of Ystad is medium sized harbour with good facilities mostly for handling passengers and roro cargo. Maritime University of Szczecin (MUS) team since 2005 have been engaged in Ystad Port modernisations realising several simulation studies [Report, 2008; Gucma, 2009].

Figure 1: Current dimensions of waterways, infrastructure, and navigational marking inside the Ystad outer port

The navigation approach to port of Ystad (Fig. 1) from the SW is made by the marked navigational canal of 130 meters width. The need of modernisation come from narrow inner port and lack of ferry berths inside and growing competition from Trelleborg Port, where such modernization is currently ongoing. Second trigger is constant increase of Ro-Pax ferries size in Baltic Sea. The most important aim of Ystad port modernisation is to provide access to the port by ferries up to 210m length and enable future port development in the future to serve ships of 230m length [Report, 2017]. The modernisation is scheduled in two stages:

- Stage 1: creation of berths no 7 and no 8 (depth H=8.85m), creation of turning place (depth H=9.35m) and significant modernizations of outer breakwater together with new 150m width approach channel (Fig.2).
- Stage 2: creation of additional 4 berths and moving all port to the outer port.

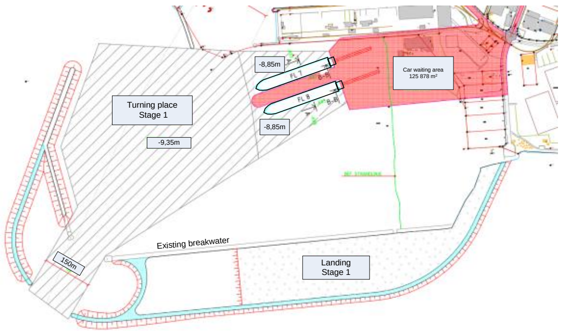

Figure 2: Proposed changes in berths and breakwater arrangements in Port of Ystad (stage 1 only)

2 THE MATHEMATICAL MODELS OF SHIPS, PORT, AND ENVIRONMENT CONDITIONS

In order to perform researches the mathematical models

of Ro-Pax ferry manoeuvring for Ystad Port was designed and implemented in the Kongsberg Polaris simulator. The model of ships manoeuvring dynamics used in the Polaris simulator in terms of mathematics and programming is one of the most innovative solutions in the field. Ship model called *Ystad230* represents future ferry for Baltic Sea is assumed as maximal for outer Ystad Port. The model of this ferry was created on the base of Polferries owner preliminary design. The general arrangement is presented in Fig. 3. and Tab.1. The ferry is characterised by large windage area (almost 6.5 thousand square metres) and relatively small engine and tunnel thrusters power in compare to existing Baltic Sea ferries. Predicted maximal lateral wind speed for the ferry for port manoeuvring is 15m/s.

Table 1: Ferry main parameters used in simulations

Parameter	Ystad230
Length overall	Lc=230m
Breadth	B=31.8m
Draft	T=6.3m
Lateral windage area	Fny=6,400 m^2
Total engine power	P=2x9.000 kW
Propellers	2x CPP inward
Bow thruster power	Pttb=2x2,300 kW
Stern thruster power	Ptta=1,500 kW
Rudder	Becker 45 deg.
Max. transverse wind for static surge	vk= 15 m/s

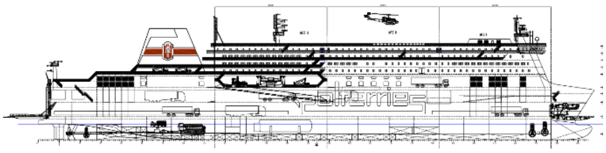

Figure 3: General arrangement of predesign as the base for Ystad230 model

The procedure of model creation is presented in [Artyszuk 2005]. It embraces several steps of tuning model parameters to real manoeuvring data. In case of non-existing ships, like in presented study, the large database of Ro-Pax ferries (more than 15 ferries of different size) created in MUS was applied to achieve extrapolated results. The specific model output as performance during turn is presented in Fig. 4.

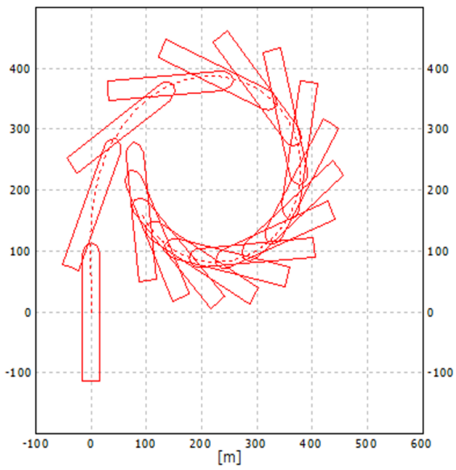

Figure 4: Example turning circle tests of Ro-Pax Ystad230 (starting at 12kn, 35 deg, time 480s, ship contour 30s, speed 3kn, drift angle 20 deg.)

The navigational and ship handling Polaris simulator, connected to the K-Pos dynamic positioning system from Kongsberg Maritime AS applied in this study is presented in Fig.5. The simulator setup consist of model of ship in 6DOF, 3D model of visual situation in port, model of bathymetry, navigational markings, and environmental conditions such as wind and current and waves. Such setup was validated by chosen captains according to validation procedures of real time simulation setups [Gucma, 2005].

Figure 5: Full Mission bridge of the navigational/ship-handling simulator at MTEC (Marine Traffic Engineering Centre)

3 THE METHOD OF NAVIGATIONAL SAFETY ASSESSMENT BY MEANS OF STATISTICAL MODELS

The simulations are usually performed in different meteorological conditions. In each set of conditions, there is adequate number of trials executed by real ferry captains. After simulations, each trial is processed statistically in order to obtain probability density function of ship's maximum distances from the centre of the waterway and accident probability calculation in given conditions. Later on, the safe water area can be obtained and plotted on the area map with consideration of previously setup admissible risk level [PIANC 2014, Iribarren 1999, Savenije 1996].

The vessel can safely navigate only in such an area where each point satisfies the depth requirement. If this is the case, the area is referred to as the safe navigable area. The vessel carrying out a manoeuvre in a navigable area sweeps a certain area determined by the subsequent positions of the vessel. The parameters of that area have a random character and depend on a number of various factors [Gucma, 2018]. The area calculated at a certain level of confidence is called a safe manoeuvring area SMA (Fig. 6).

In single series of simulation trials, the several ships paths (two-dimensional area, which occupies the ship in a single passage) can be obtained which depends on the number of performed experiments. Statistical processing of the simulation results allows determining the statistical parameters necessary to determine safe manoeuvring area.

The characteristic values for the examined waterway are areas occupied by ships determined at the level of (Fig. 5.):

- maximum,
- average,
- as given confidence level (assumed as SMA) or with use of risk concept.

Analysis of simulations results, leads to determination of horizontal safe manoeuvring area parameters. In simulation tests, these parameters are determined based on width of the ship's traffic lane, which is the area occupied by a single, ship during performing specific manoeuvre. Ships traffic lane (so called PATH) is defined for given, specific ship and manoeuvre, whereas safe manoeuvring area (SMA) is a term given to the different ships and manoeuvres. In the Fig. 6 it is shown that safe manoeuvring area exceeds available water area (AWA) and enters danger area (D) what results in necessity of introducing changes (like dredging works) to avoid accidents (Fig. 6).

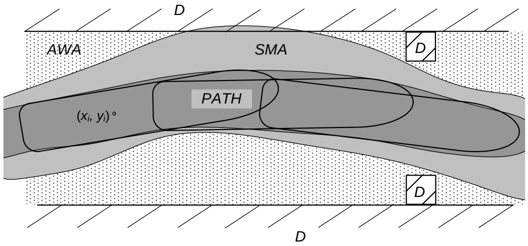

Figure 6: Definition of the ideas connected with horizontal areas taken by ships (legend: PATH- 2D lane of single ship, AWA- available water area, SMA- safe manoeuvre area on the required confidence level, D – navigation danger, obstacle)

Safe manoeuvring area is the area in which the probability of collision of the ship with the edge and/or the bottom, is on the assumed, high level (usually adopted as 95% or 99%). Risk concept could be also consider and used for defining the SMA [Gucma, 2018]. Condition of safe navigation shall fulfil dependency:

$$d_{i\alpha} \leq D_i \tag{1}$$

where:

- D_i – width i-th point of the waterway at the bottom for safe depth,
- $d_{i\alpha}$ – width of safe manoeuvring area on defined confidence level (1 - α).

It should be noticed that general population with infinite number are all possible simulation trials of particular ship on the water area at the same hydrometeorological conditions. Whereas, sample will be the series of simulation trials conducted appropriate number of times at the same conditions. The width of the safe manoeuvring area of the ship is the range that contain specified as a percentage part (fraction) of the population general. It can be defined accordingly to dependency that takes advantage with range of confidence term (Fig. 7):

$$d_{i\alpha} = m_{di} + k_\alpha \sigma_{pi} + k_\alpha \sigma_{li} \tag{2}$$

where:

$$m_{di} = m_{pi} - m_{li} \tag{3}$$

where:

- $d_{i\alpha}$ – width of the safe manoeuvring area at i-th point of the waterway defined on the confidence level $(1 - \alpha)$;
- m_{di} – mean of the safe manoeuvring area width;
- k_α – factor dependent on fraction of general population p, which should be taken into estimation (like: assumed as $k = 1{,}96$ for $p = 1 - \alpha = 0{,}95$);
- m_{li}, m_{pi} – mean from maximum distance of ship's points to the left from i-th point of the waterway;
- σ_{li}, σ_{pi} – standard deviations of maximum distance of ship's points to the left from i-th point of the waterway;
- $d_{il\alpha}$, $d_{ip\alpha}$ – width of the right and the left safe manoeuvre area at i-th point of the waterway at defined confidence level $(1 - \alpha)$.

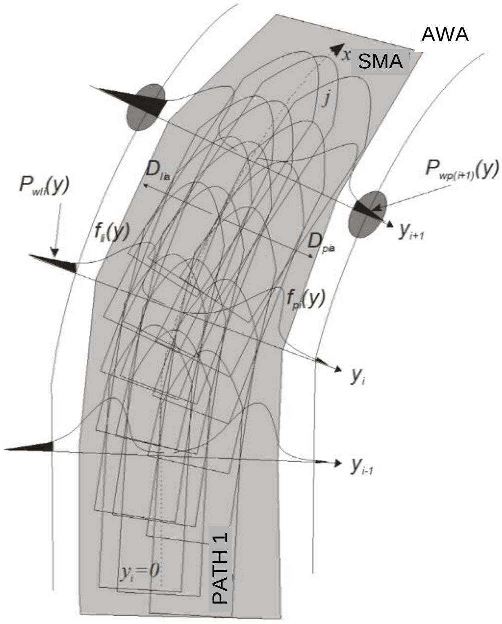

Figure 7: Method of defining the safe manoeuvre area SMA on given level of confidence and the probability of collision with obstacles located on the edge of waterway

4 THE SIMULATION PLANNING, EXECUTION, AND RESULTS ANALYSIS

Simulation researches are based on performance of manoeuvring trial series (inbound/outbound) of significant number for detailed variants. These scenarios determines given problem. Comparing of results for each variant is done with use of navigational safety criteria. General simulation researches assumptions were here as follows:

- In researches maximum wind speed was assumed as 15m/s and 17m/s (7°B covers 13.9m/s to 17.2m/s) for Ystad230 respectively. The wind was determined in several preliminary manoeuvres by experts with use of simulator.
- Several worst wind conditions have been taken into consideration for turning and mooring and departures:
  - wind: E as most frequent wind unfavourable for approach to the port;
  - wind: W as most frequent wind unfavourable for approach to the port.
- All manoeuvres have been performed without tugs service.
- 10 simulation runs have been performed in series (some were excluded during statistical processing).

- The total number of simulation series for *Ystad230* was 5;
- Since the minimum number of trials in given series was 10 the total number of trials (manoeuvres) performed for *Ystad230* was more then 50;
- Each captain has been performed maximum 3 runs in each series. In researches, 7 regular and 5 additional (during simulator commissioning) captains have been performing simulations.

Analysis of simulation results is made usually based on several navigational safety criteria such as for example:

1. Manoeuvring area widths (horizontal safe manoeuvring area);
2. Underkeel clearance (vertical safe area);
3. Energy induced in contact point with berth structures;
4. Velocities of propeller bottom stream;
5. Speed of ferry on entrance and inside;

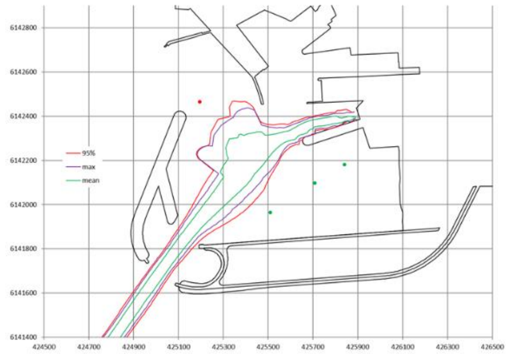

Figure 8: Safe manoeuvring areas for scenario no 8. Entrance of *Ystad230* to Berth no 7 and approach to port. Wind W 15 m/s.

In this study, the criterion 1 was applied for design of waterways and turning basin. Additionally the criterion 3 was applied for design of fenders and criterion 5 for creating the operational guidelines for ferries.

The statistical processing methodology presented in previous part was used for each of 5 series for *Ystad230* model. The example results which presents 2D manoeuvring area of future Ystad port is presented in Fig. 8. Results from all 5 series were used to determine optimal area of turning place and approach channel together with berthing energy and navigational operational conditions (Fig. 9).

5 CONCLUSIONS

Presented complex study could be used for creating guidelines of port modernisation, operational limitations and for risk assessment of selected water areas.

The paper presents also the basic methodology for statistical data processing of data possessed from simulation experiments. Such methodology could be used also to analyse the empirical results for example obtained by the AIS system.

The study results showed that nowadays the simulation method is only available to design of safe water areas for ships manoeuvring and for defining its operational conditions.

There are several detailed conclusions related to conditions of safe manoeuvring of ferry model *Ystad230* in modernised Port of Ystad [Report 2017]. Most important are as follows:

1. Safe navigation for analysed model of *Ystad230* could be performed in winds from any sectors of force up to 15m/s.
2. Top, western part of the piers shall be covered with appropriate siding fenders for frequent operational use during manoeuvres.
3. Turning place should be shaped as presented in Fig. 9.
4. Navigational marking as presented in Fig. 9 shall be installed.
5. Approach channel of width 130m increasing up to 150m in entrance is considered as safe for even extreme port operations.
6. Fenders of minimal absorbing energy should be equal to E=400kNm should be applied to protect berthing.
7. Speed in inner port should be less than 10 knots.
8. The extensive manoeuvres should be avoided when the ferry passing the outer breakwater.

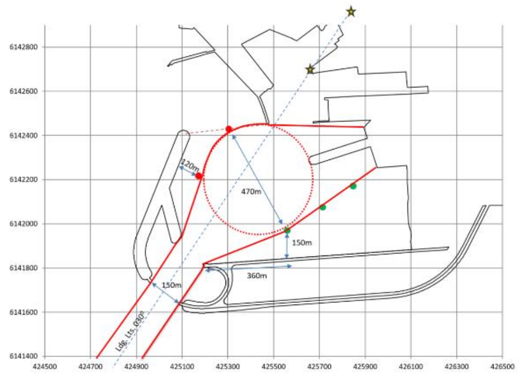

Figure 9: Proposed layout of waterways and turning basin for future ferries

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INTERMODAL TRANSPORTATION COSTS

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ABSTRACT

This paper reveals with empirical case data how the maritime-based short sea shipping costs aggregate in export industry. The authors had the possibility to utilize invoice data of the delivered orders. The data contains the information of logistics costs from the mill located in a Nordic country to two customers located in two different countries in the Mediterranean region. This study shows that micro level data may reveal interesting perspectives of the logistics costs research tradition.

Keywords: intermodal transport, logistics cost, export industry

1 INTRODUCTION

Long transport routes including short sea shipping can be a challenge for the export industry. Serving customers located far from the manufacturing unit increases delivery time and also costs. Porter (1990) described in his diamond model the essential elements to competitiveness of industries (see also Krugman 2017; Aiginger 2006). They all addressed the importance of flexible logistics functions. The aim of this study is to present intermodal logistics components and their costs from a mill to end customers. The integration of manufacturing and logistics are essential topics for an export dependent industry (Huemer 2012; Pagh and Cooper 1998). Eckhardt and Rantala (2012) address that efficient logistics make globalization possible, offering methods to transport raw materials and end products. On average, logistics costs constitute a considerable proportion of operating costs, often more than 10 per cent of the company's turnover (Engblom et. al 2012). Hämäläinen (2011) presented in his study that in the Nordic paper industry the share of logistics costs from the turnover varies significantly depending on how far customers are located from the mill. In total, logistics costs can be up to 20% of the turnover on customer level. Bulk products need heavy and expensive machinery during transportation and transfers.

Manufacturing companies in Nordic countries utilize heavily intermodal transport functions to get their products to the customer. Usually, Short Sea Shipping (SSS) connections operate according to scheduled timetables from the Nordic ports. In a continuous production environment, like in the paper industry, dispatching, shipping and logistics have an essential role. Because, in reality, daily export deliveries are not possible, there is a need for warehouses along the transport routes in export countries. In multimodal logistics handling, every stage increases costs variously and depending on the nature of logistics phase, e.g. port handling and lifting, land and sea transportation or warehousing.

Large bulk companies produce thousands of tons of products monthly to the market and this supply chain requires accurate coordination and communication with third party transport operators. Openness of information and utilizing the best practices could support improvements and development of logistics from the remote areas to the end customers. Anderson and van Wincoop (2004) note that it is difficult to measure the real trade costs generated from deliveries between countries. This paper tries to make a small contribution to this deficiency. Earlier Hämäläinen (2011) utilized case data from an export company to reveal this well-known problem in transport logistics research. Davis and Weinstein (1999) and Krugman (1991) have claimed that location and freight transport costs have an obvious matter when companies make investments decisions. Connections to markets must be taken into account when location decisions are made.

Main topics of this paper are: 1) Expose foreign deliveries with detailed invoice-based transport data. 2) Reveal variations in logistics data during the transport process. 3) Provide information on how short sea shipping together with port handling impacts the delivery costs. 4) Analyse whether the delivery volumes and logistics costs have any correlation. These four points are important topics when intermodal transport is exposed (see e.g. Albornoz et al. 2016). According to Martincus et al. (2014) heterogeneity can arise from reasons like market knowledge, effectiveness of logistics chain and from delivery accuracy. These all indicate that the complexity of the supply chain is possible to uncover with the help of very accurate case data.

The structure of this paper is as follows: Some of the theoretical aspects concerning port and shipping that gave ideas to compose this paper are presented in Section 2. In Section 3, we reveal how research data was acquired and we present the research methods used in this paper. The findings based on case empiric data are presented with several figures in Section 4. Discussion, conclusions and managerial deductions are addressed in Section 5. Ideas for future research drawn from this study are presented in section 6.

2 BACKGROUND OF PORT AND SHIPPING BOUND LOGISTICS

Nordic countries have developed efficient integration of remote area connections, maritime transport and port handling services. Twrdy et al. (2012) point out that ports are important part of supply chains and that today whole supply chains compete among themselves, not just ports. Usually a maritime transport system covers ports, logistics operators and vessels, which link export and import ports. Connections from the manufacturing unit to the port are operated by either trucks or rolling stock. When manufacturing is running 24/7, this demands very detailed logistics planning and continuous freight flows from the site to consignees. Álvarez-SanJaime et al. (2013) emphasize that the shipping companies hold market power and enjoy economies of scale. Vaghi and Lucietti (2016) analyzed with a case study that by speeding up formalities, it is possible to gain a significant amount of potential in ports. They used very detailed company-based data to reveal these improvement potentials. Integrated value chain with logistics service providers helps create the product or service that is required by the customer (Porter 1985). Partly due to Porter's ideas, companies started to increase outsourcing especially the activities in which the organization does not have a clear competitive advantage, like ex-mill logistics activities. They also note that the rapidly developed and expanded information and communication technology brought a new era to controlling, managing, and improving the flow of deliveries from suppliers to end users (Christopher 2005). Increase in deliveries and trade flows increase a need to develop clever algorithms to handle logistics information flows. A multimodal maritime freight transport includes loading at the port, transportation from its origin to its destination, including a sequence of at least two transportation modes, the transfer from one mode to the next being performed at an intermodal terminal (Crainic and Kim 2007). Anderson and Van Wincoop (2004) remind that transport expenses are a fundamental part of trade costs. Results of many studies show that service quality, like the frequency of services, may have an impact on freight rates (Wilmsmeier et al. 2006; Martinez-Zarzoso and Nowak-Lehmann 2007). In Nordic countries the service frequency is a challenge due to the SSS transport routes. Shipping lines operate weekly or sometimes 2–3 times per week depending on the port and freight volumes. Wang et al. (2016) emphasize the importance of port connectivity to the entire logistics chain of maritime transport and that it is a cost-efficient way to facilitate international trade. Because of long logistics routes from Nordic countries, warehouses in the export countries act as service centers for local customers increasing inventory levels and binding extra capital (see Langevin et al. 1996). Wang and Cheng (2009) have exposed that the inventory cost function can be unified into a common expression for various batching schemes. Daganzo and Newell (1985) and Daganzo (2004) state that transportation costs are generally understood to be a function of the travel distance. Tang et al. (2011) exposed with empirical data that port efficiency is the most important factor in acquiring new and keeping the existing customers. The important role of ports in transport and supply chains has been examined in many studies, see e.g. Pallis et al. 2011; Notteboom et al. 2013. Robinson (2002) pointed out that ports serve as an essential element in the value-driven chain systems connecting businesses together.

For export industry ports are a part of a value-driven chain system and due to cost-efficiency of sea transport, it is hard or even impossible to replace ports with other logistics systems (Robinson 2002). Bichou and Gray (2004) argue that ports are an essential component of integrated supply chains (also Marlow and Paixao 2003). Configurations of shipping routes and networks provide a direct assessment of port connectivity, representing a port's competitiveness (Low et al. 2009). Tran (2011) points out that the selection of a port is based upon the minimization of the overall cost of the cargo's journey. Freight logistics developers have used clustering to understand the geographic distribution of demand and simplify logistics operations (Cao and Glover 2010; Sharman and Roorda 2011; Singh et al. 2007; Qiong et al. 2011). There are arguments that competition has moved from competition between firms towards competition achieved through practical logistics chain management (e.g., Ketchen and Hult 2007). Efficient logistics certainly support a manufacturer to operate in a more profitable way in the international business environment. However, operating in a global market may also increase the uncertainty in the company's operations (Bhatnagar and Viswanathan (2000) and Bhutta et al. (2003). Long transport routes may lead to increased inventories and longer delivery times of freight transport and bond capital. Researchers note that location of an industry naturally has an impact on the success and survival of a production unit. Carbone and Martino (2003) emphasize the importance of a common platform among both the logistics systems and the cargo handling systems to create synergies and to combine the interests of all actors. Pettit and Beresford (2009) remind about the change of ports' roles towards vertically integrated logistics services during last years. Integration of logistics services offers an essential method for continuous bulk manufacturing to stay in international business even for companies located far from market like the Nordic paper industry.

3 RESEARCH DATA

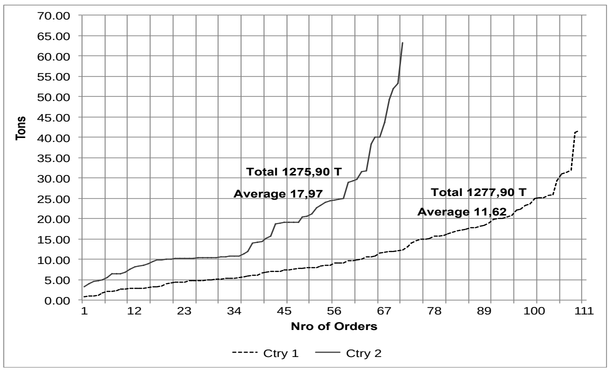
Logistics research has long traditions and roots in industry location questions. When making an analysis of the logistics and transport, the crucial matter is to receive reliable data (Martinez-Zarzoso and Suarez-Burguet 2005). Official statistical data (e.g. International Monetary Fund) as a source for logistics research may be too unreliable (Baier and Bergstrand 2001; Limão and Venables 2001; Hummels and Lugovskyy 2006). Hummels (2007) points out that exact transport data are available only in few countries in their open official statistics. Firm-level data on transport costs are not available (e.g. Bernard et al. 2006). Goffin et al. (2006) indicate that the buyer–supplier relationships should be revealed according to their industrial contexts.

Research material for this study is received from the integrated cost management system (see e.g. Hämäläinen, 2011; Hämäläinen et al. 2017) and this confidential data was converted for research purposes. The data comes from a paper mill that relies on the multimodal logistics chain that consists of transfers by truck to port and from ship port by truck to the end customer. Because the customers are located in different regions and countries, this increases the variety of logistics chain between markets. As the data is from a bulk industry it may bring some contributions to research of bulk industry in which continuous 24/7 production and logistics is a normal function.

The data includes invoice information from the deliveries to two countries located far from the mill in the Mediterranean Sea region. The data covers June 2009. Both of these countries are rather important markets for the mill. The mill sold paper products nearly 15,000 tons annually to both countries, which makes round 1,300 tons per month. In total, there were 186 deliveries during this sample period. We removed 2 deliveries from both country data, because information of invoice data in was not proper. These were probably so called test deliveries that were not priced and transport information was incomplete and insufficient. So, in total, we could utilize 71 invoiced deliveries from one country and 111 deliveries from another country, which is 182 deliveries altogether. These invoices contained detailed logistics data after the mill warehouse: total transport costs, delivered tons, transport to port and port handling costs, the part of maritime costs of transport costs, land transport from export port to consignee/warehouse and domestic and export warehousing costs. The mill was running, producing and delivering paper products as usual during 2009. The logistics data was moved to Excel spreadsheet and analysed there together with countries in separate columns. Martinez-Zarzoso and Suarez-Burguet (2005) point out that many studies address that firm-level, reliable logistics cost information is only rarely available for research purposes. With this case data, we also wanted to expose the characteristics of variations between the deliveries to these countries. In the following section, we will show rarely revealed features of logistics functions, costs and their behaviour in the export logistics environment with the help of our detailed data.

4 FINDINGS

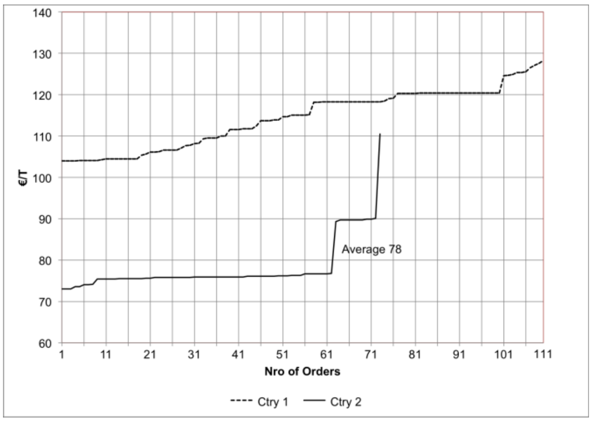
In this section, we will try to contribute to logistics research discussions with detailed empirical data. We highlight the logistics costs during the transport from the mill to export countries based on empirical data. The data contained 182 deliveries and these are presented in Figure 1. It presents the distribution from largest to smallest and total tonnage and average amount during the research period. The distribution is relatively normal between delivered volumes and the orders are divided quite evenly. However, the delivery volumes to Country 1 are smaller. Country 1 is closer to the mill and this addresses that closer location may result in smaller deliveries but the deliveries may take place more often. During the research period, delivered tons in total are nearly the same, but to Country 1 there were 111 orders, 11,62 tons on average and to Country 2 there were 71 deliveries and the average amount nearly 18 tons per order. When single orders are from a few tons up to 50 tons, there can be between 15,000 and 30,000 international shipping annually in a mill that produces 500,000 tons annually. The amount of deliveries emphasizes the role of continuously flowing logistics for paper and other industries producing high volumes of saleable products.



Source: authors

Figure 1: Distribution of the orders in tons. Source: authors.

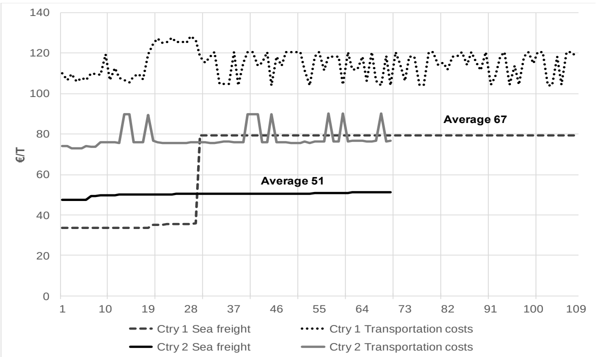
The interesting thing is that the total transport costs from the mill to the end customer vary relatively little as Figure 2 highlights. Hummels et al. (2009) support this finding; export costs vary endogenously with trade and adoption of new transport technology. Figure 2 indicates that in Country 1 the transportation costs vary between 105 €/T and 130 €/T and, on average, the costs are 114 €/T. This country is located closer to the mill than Country 2. Logistics costs were approximately 75 €/T to a large extent in the case of Country 2 (flat starting of the line), but in the highest case close to 100 €/T. Calculated average for Country 2 is 78 €/T. As Figure 2 highlights, there can be some expensive deviations in transportation. The data did not reveal the reasons for these costly transports. Both countries are behind the SSS and therefore the transport prices are rather easy to estimate because freight owners usually have long-term agreements with shipping companies due to large and regular freight volumes. The vessels usually visit export ports weekly or sometimes more often. In the port of import, the packages are transported directly to customers or stored to warehouses and later delivered to destinations.



Source: authors

Figure 2: Total transport costs €/T of the orders

Sea freight is an essential and obligatory transport mode for Nordic mills. Figure 3 addresses the sea freight costs in euro per ton compared with total transport costs. Both country data is sorted by sea freight costs. The sea freight costs of all deliveries were nearly the same to the country 2, averagely 51 €/T. This addresses that all the deliveries were transported along the same shipping route between export and import port. The picture shows that there are some variations, especially in other than sea freights. Sea freight costs to Country 1 were twofold. Firstly, sea freight costs were rather small, a little under 40 €/T in 28 cases. In these deliveries, the other logistics costs fill the rest of the costs. In the 100 cases to Country 1, the sea freight costs are 80 €/T. The other logistics costs are land transports, port handling and warehousing, and in all of the cases the total transport costs vary between 105 and 120 €/T. Port handling is an important and essential part of logistic chain. Freight is transported to port and at the port, the cargo is handled carefully and packed in to the specific cargo vessels.

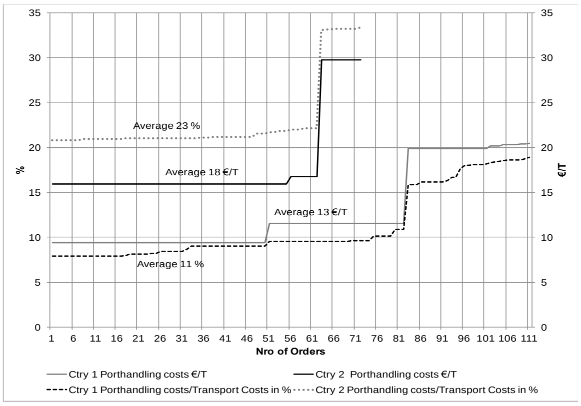


Source: authors

Figure 3: Sea freight costs and total transport costs of the orders €/T

Figure 4 shows the port handling costs and their share of total transport costs in per cent. These values are obtained by dividing the total port handling costs in euro with the total transport costs in euro. At the export port, the handling costs are the same for both markets. The variation rises when the vessels arrive at import ports, where the differences in handling costs arise. In Country 2, the total port handling costs, on average, are nearly one fourth of total transport costs. In Country 1, on average, the port handling costs are only 11 per cent of the total costs.

Figure 4 addresses that average values tell very little about the logistics costs. Also, in the case of building a mathematical model to report logistics costs, the variation pointed out by Figure 4 should be built into the systems. The total maritime bound logistics costs as an important modal in supply chain are presented in Figure 5. The total maritime bound transport costs to Country 1 are 80 €/T on average, and the share of these costs of the total transportation costs are 70 % on average. But there is a significant variation in the share of maritime bound costs of total logistics costs starting from 45 €/T and ending up to 85 €/T. The route planning of deliveries is very important. The freight owner should find the best, cost-efficient route for each delivery. Maritime bound logistics costs to Country 2, which is a longer sea route away, are on average 68 €/T and the average share of total costs is very high at 87 €/T. Because this market is a long sea route away, it fills out major part of all logistics costs. Figure 5 addresses the impact of long sea route to the total costs. The variation is smaller and, obviously, the logistics costs can be estimated more accurately due to the significant impact of one modal. It is rather astonishing that there is trade between Nordic mills and these regions even when the burden of transport costs is so heavy. The transport information is rarely presented at this accuracy before. Case based logistics costs data has its benefits in giving a researcher an opportunity to look into the logistics world.



Source: authors

Figure 4: Port handling costs and share of transport costs

Finally, the authors wanted to test if there were any correlations between delivered tons and transport costs in €/T. Very few studies have been conducted of this phenomenon earlier (see e.g. Hämäläinen 2011). Figure 6 reveals a correlation between delivered tonnage volumes and costs in €/T. In Country 1, there is a strong negative correlation (calculated with Excel-spreadsheet). When tonnage volumes rise, the actual transport costs per ton decrease, although there is also significant variation between deliveries. The transport costs understandably vary because packages are delivered to different places in the target country. Country 1 is also closer and the delivered volumes per order are nearly a half a size compared to the second country. In theory, it could be vice versa, i.e. when a country is closer the volumes are smaller, but of course this depends on the shipping routes and intense of traffic between export and import port. The correlation in Country 2 is much smaller and also negative. The authors calculated the correlation of all deliveries together and correlation was -0,34. The negative correlation indicates that companies get logistics services cheaper in €/T when delivering more tons in the same order. The delivery volumes are naturally dependent on how much customers order. A break-even point exists when the order volume is so small that the invoiced price does not cover the expensive transport.

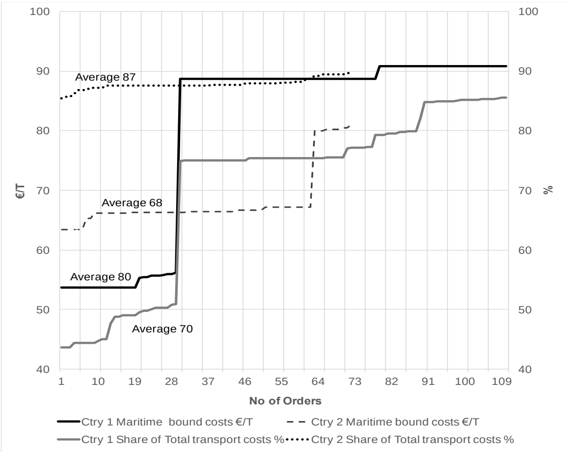


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Figure 5: Maritime related costs and share of transportation costs

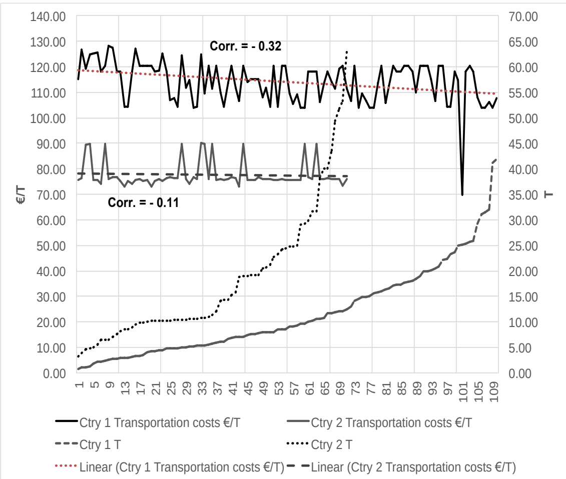

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Figure 6: Correlation of transport costs €/T with delivered tons to customers

In this section, the authors revealed a piece of logistics operations and their costs and delivery environment with empirical figures. The figures addressed that in different markets the delivered volumes, logistics rates and behavior of the whole supply chain is unique. In the end, the cost differences reveal the variety on real life transport chain. Large companies in Nordic countries need efficient logistics, although it can be very costly for them. Due to expensive transport competition, a company must be secured with other means, like economically efficient business and operation models.

5 DISCUSSION AND CONCLUSIONS

Export bulk industry that runs around the clock needs a lot of predictable logistics services to stay in business. In many industry sectors, like in paper industry, the price competition is high and consumption is decreasing due to the digitalization of society and business. The authors of this paper wanted to contribute to the logistics research tradition with empirical numbers. The data (182 invoices in total) of our study was obtained from a large company's records of June 2009. The data included detailed cost and delivery data of orders to Mediterranean countries a long sea transport route away. We were not able to show how logistics impact on the margins of the orders, i.e. customer profitability. Hämäläinen (2011) has earlier addressed that logistics has a clear impact on profitability and it varies between market areas. We may imagine that it is the same in this case to some extent. One purpose of this study was to make a small contribution and managerial implications to the logistics discussion in form of cost analysis. An intermodal supply chain adds costs in every step and, unfortunately, from freight owners' points of view, the shipping companies have a strong negotiation position when rates are stated. This study shows that sea freight has a fundamental role in cost accumulation. Because the research data covers invoice data from one company and from a short period, it is an obvious limitation and extrapolations based on these findings should be done cautiously. As a summary, the authors point out that intermodal logistics is highly complicated system, especially in situations where volumes are high and transport routes are long. Both freight owners and customers expect reliable service partners, predictability, cost efficiency, flexibility in case of obligatory changes and safety in everyday operations.

6 FUTURE RESEARCH

All logistics researchers are aware of the difficulty to acquire firm based export data. Future research could focus more on finding reliable empirical data and together with mathematical modelling make tests based on this case data. Also route modelling with real costs could be interesting topic to reveal.

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CHARGING INFRASTRUCTURE CHALLENGES AND POLICY SUPPORT IN SELECTED COUNTRIES OF DANUBE REGION

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ABSTRACT

This paper addresses eMobility policy in relation to charging infrastructure challenges in selected countries of the Danube region. Introduction of eMobility into everyday lives of citizens is one of the highest priorities of the European Union (EU). One of major EU strategies for dealing with greenhouse gas emissions, climate changes and dependency on fossil fuels in transport is deployment of electric vehicles (EVs), which present a clean and effective alternative to conventional vehicles with internal combustion engine (ICE). In order to trigger mass adoption of EVs, the availability of charging infrastructure needs to surpass the demand for it. Interdependency between the availability of charging infrastructure and the uptake of EVs is tackled on political level with deployment of policies stimulating planning and/or funding of charging infrastructure. While all member countries of the EU are committed to implement joint EU policies and directives, approaches to their implementation differ. These differences stem from diverse baseline circumstances of countries, notably in terms of already available charging infrastructure and the level of acceptance of eMobility in general public.

Within EU funded project "Electric, Electronic and Green Transport Systems – eGUTS" policies on eMobility in countries of the Danube region have been analyzed together with current levels of charging infrastructure development. It can be noted that, irrelevant to level of economic development, charging infrastructure network is not fully developed in any of the studied countries of the Danube region. The levels of development of charging infrastructure to some extent correlate to levels of economic development with northern countries having more developed charging infrastructure network as south-eastern countries. Within the article, the relations between adopted eMobility policies and levels of development of charging infrastructure is examined.

Keywords: eMobilty, eMobility Policies, charging infrastructure, electric vehicles, Danube region

1 INTRODUCTION

Electric vehicles have been around for more than hundred years with the first mass-produced electric vehicles appearing in America in the early 1900s. For various reasons electric cars failed to gain public acceptance and road transport market was, and still is, dominated by vehicles with internal combustion engines (ICE). With advanced understanding of negative impacts of transport's emissions on the environment and its contribution to climate changes, electrification of transport (electro mobility) has become a priority. With the electrification of road transport greenhouse gas emissions, air pollution as well as fossil fuel dependency can be significantly reduced.

As the sector of road transport is of particular importance in the EU, for it is directly contributing to almost a fifth of the EU's greenhouse gas emissions while employing 5 million Europeans, Europe's answer to above challenges is an irreversible shift to low-emission mobility in terms of carbon and air pollutants. The ambition is clear: by mid-century, greenhouse gas emissions from transport will need to be at least 60% lower than in 1990 and be firmly on the path towards zero. Emissions of air pollutants from transport that harm our health need to be drastically reduced without delay (European Commission, 2016). To reach this goal, EU wide mass deployment of electric vehicles (EVs) is advocated. However EVs' adoption is not progressing as fast as called for. While significant progress for overcoming battery technology limitations and high battery cost, as the obstacles to wide spread adoption (Egbue & Long, 2012), has been made, the interdependency between the availability of public charging infrastructure and the uptake of EVs by customers is one of the major barriers in present time.

The results of a survey conducted by Lieven (2015) show that the installation of a charging network on freeways is an absolute necessity and is completely independent from the average mileage driven per day. Through this, missing charging facilities and, in particular, a missing charging network on freeways caused the strongest dissatisfaction.

More interestingly, Lieven's survey has revealed that consumers do not highly value road tax exemptions and that free use of bus/fast lanes and downtown parking are neither expected nor perceived as reasonably attractive. It can be assumed that for anyone interested in EVs, a respective acquisition is out of question as long as the existence of an adequate charging infrastructure is not guaranteed. Lieven concludes that the charging network is the bottleneck, and the argument that EVs with a limited range are well-suited for the majority of drivers does not hold. Thus, the charging network is a must-have to avoid range anxiety (Lieven, 2015).

This interdependency between charging infrastructure and uptake of EVs was acknowledged by the Council of the European Union stating: "Creating a sufficient network of recharging and refuelling stations is considered crucial in order to drive consumer demand for vehicles powered by "clean fuel", such as electricity, hydrogen and natural gas, and to encourage manufacturers to develop such vehicles and to sell them at competitive prices. Currently the use of clean fuel is being held back by the high cost of vehicles, low demand and the lack of infrastructure. In this vicious circle, refuelling stations are not being built because there are not enough vehicles. Vehicles are not sold at competitive prices because there is not enough demand. Consumers do not buy the vehicles because they are expensive and the stations are not there." (Council of the European Union., 2014). The problem is seen not only for electricity, but for all kinds of alternative fuels including hydrogen, compressed natural gas (CNG), and liquefied petroleum gas (LPG) (Wirges, 2016). In order to stimulate faster market uptake of EVs and other vehicles using alternative fuels, countries have adopted a mix of policies and measures ranging from financial incentives for vehicle purchase, tax exemptions and, more importantly, for charging infrastructure development.

In this article policies related to charging infrastructure and current state of charging infrastructure in selected countries of Danube region are investigated.

2 POLICIES RELATED TO ELECTRIC CHARGING INFRASTRUCTURE

2.1 EU Policy framework

Before discussing policy initiatives related to charging infrastructure, it is important to explain the hierarchy of policies on different levels. Hierarchically, there is the level of global agreements, e.g. through the International Energy Agency (IEA), which can drive innovation, collaboration and dissemination by a focus on standards and voluntary agreements, realise a policy focus on areas with some impetus funding for research, workshops, training etc. There is then the level of integrated markets (European Union, with mandatory standards around emissions for vehicles, urban air pollution, labelling and information); further, there is the national (EU member state) level, which also has legislation, policy, financial instruments, R&D and demonstration programmes. Then there is the regional and not least there is the local level which again has extra policies. EV policy is indeed a multi-level policy game, where policy makers continuously have to take into account and operate within frameworks and actions set elsewhere. Governance is nested, which is to say that national level cannot be seen separate from the EU level, nor can the regional and local level be seen as disconnected from the national/Federal or international one in terms of investment, competition, standards (including for charging infrastructure), (Steen, Schelven, Kotter, & Deventer, 2015).

The basics strategic documents of the EU regarding transport and low emission vehicles are the 2020 Energy and Climate Policy Framework and the 2011 Transport White Paper. The 2020 Energy and Climate Policy Framework has set three goals, 20% greenhouse gases (GHG) emissions reduction compared to 1990, 20% EU primary energy to be renewable and a 20% improvement in energy efficiency. The 2011 Transport White Paper is a long-term vision of transport development until 2050. One of the most important targets of the Paper is the need to cut CO2 and pollutant emissions to improve air quality particularly in cities. Favouring electric vehicles is the Clean Vehicle Directive that mandates public procurers to consider fuel consumption, CO2, and pollutant emissions when purchasing road transport vehicles, giving them various options to do so.

The most important strategy for faster introduction of electric vehicles is the European Alternative Fuels Strategy and the accompanying Directive on the deployment of alternative fuels infrastructure. The strategy deals with all modes of transport with requirements for the development of alternative fuels infrastructure, common technical specifications, consumer acceptance and technological development, including advanced biofuel production in to increase the uptake of low emission vehicles, among them also electric vehicles. The Directive specifies required coverage and timing by which specific infrastructure for different modes must be put in place, development of harmonized EU-wide standards for recharging points for electric vehicles and refuelling points for natural gas (LNG, CNG) and hydrogen, and the provision of consistent and clear consumer information (eGUTS project, 2017).

2.2 Policies in selected countries of Danube region

The implementation of the above mentioned directives into strategic documents and national legislation of EU member states resulted in various national and regional policies and measures. Overview of adopted policies shown in figure below.

	AT	HR	CZ	HU	RO	SK	SI	RS	ME
Infrastructure Incentives	-	-	-	-	✓	-	-	-	-
Local Incentives	✓	-	-	✓	-	-	-	-	-
Purchase Subsidies	✓	-	-	-	✓	✓	✓	-	-
Registration Tax Benefits	✓	✓	✓	✓	✓	✓	✓	-	-
Ownership Tax Benefits	✓	-	✓	✓	✓	-	✓	-	-
Company Tax Benefits	✓	-	-	✓	-	-	-	-	-
VAT Benefits	✓	-	-	-	-	-	-	-	-
Other Financial Benefits	-	-	-	-	-	-	-	-	-

Source: (EAFO, 2018)

Figure 1: Incentives & Legislation in analysed countries

As shown in Figure , all analysed EU member countries have implemented registration tax benefits while implementation of other policies vary. On the other hand it is obvious that Serbia and Montenegro are lagging behind. As this overview gives only general information on implemented polices, more detailed review per country is given below (eGUTS project, 2017).

Austria: direct subsidies by various authorities for electro mobility are available. The federal Ministry of Transport, Innovation, and Technology (BMVIT) is responsible for planning, financing, and establishing infrastructure for eMobility. EMobility promotions started in 2002 with subsidies on national level and, in 2008 on regional level. In 2012 the federal government adopted a national implementation plan “Electromobility in and from Austria” which specifies 65 measures for promoting clean vehicles and sustainable transport (EAFO, 2018). Different programmes are deploying diverse sets of measures, ranging from incentives for charging infrastructure, e-vehicles, car sharing, research and innovations to education and awareness raising. To mention just The Electric Mobility Model Regions Program aiming for progressive installation of charging infrastructure, supply of renewable energy, and development of new business and mobility models. In Austria strong dependency between growth of new e-vehicles and enlargement of charging station network is notable.

Croatia: since joining the EU in 2014, activities related to eMobility were intensified but the backlog caused by previous inactivity, is still evident. First subsidies for e-vehicle procurement were introduced only in 2014. Only in April 2017 the Government of the Republic of Croatia has adopted the decision on the National framework for the implementation of alternative fuel vehicles. National framework specifies total number of charging stations in Croatia while also requiring availability of charging station in 50 km range on national highways and in all cities above 20,000 inhabitants.

Czech Republic: several strategic documents with direct impacts on eMobility were adopted. National Action Plan Clean Mobility, as one of the more important for development of eMobility, was adopted in 2015 and specifies measures and requirements for the construction of charging stations in the period of 2020-2030.

Hungary: in 2015 the Jedlik Plan was adopted in order to stimulate uptake of eMobility. As part of the Jedlik Plan, business associations are stimulated to locate charging points on private properties with public access.

Romania: the Green Charging infrastructure program for development of charging infrastructure network was deployed at the end of 2016. Within the programme financial incentives are given to territorial units, public institutions and economic operators in order to erect 6,000 charging stations in Romania. This programme is complemented by Rabla Plus programme granting incentives for procurement of electric and hybrid vehicles.

Slovakia: in 2015 Strategy on development of electric mobility in the Slovak Republic was ratified. It specifies 18 measures supporting eMobility (including tax exemptions, incentives etc). However, the legislation on charging infrastructure construction, as the major obstacle, remains in place.

Slovenia: several strategic documents were adopted, among them Transport Development Strategy of the Republic of Slovenia and Resolution on the National Programme for the Development of Transport in the Republic of Slovenia until 2030. In 2016 Slovenian Alternative fuels strategy was adopted, specifying sets of measures for each alternative fuel. Priority is given to measures that establish a charging infrastructure for electric vehicles and for vehicles using compressed and liquefied natural gas. But more importantly grants for eMobility were already available since 2011 through Slovenian Environmental Public Fund. The grants were not absorbed completely in 2011 and 2013, but since 2014 onwards all available funds were absorbed.

Serbia: no existing policy initiatives regarding eMobility were identified.

Montenegro: no legislation, policies or official initiatives in terms of introducing electric charging stations for electric vehicles exist.

We can conclude that that majority of policies regarding eMobility were adopted from 2014 onwards in majority of analysed countries with exception of Austria, where active policy on eMobility was deployed in 2002 already. Different intensity levels of eMobility policies are reflected in current state of charging infrastructure discussed hereinafter.

3 EXISTING CHARGING INFRASTRUCTURE IN SELECTED COUNTRIES OF DANUBE REGION

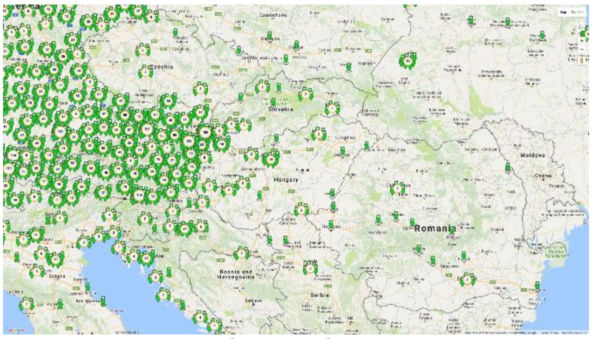
As discussed above charging infrastructure is especially important for overcoming range anxiety. In order to stimulate use of EVs the availability of charging stations needs to surpass the demand for it (eGUTS project, 2017). This is especially true for urban areas as in sub-urban and rural areas EV owners usually charge vehicles overnight using existing outlets in their homes. In urban areas EVs need to rely in much higher rate on publicly accessible charging locations. Easy access, technical characteristics and the spatial setup of EV charging infrastructure in urban areas are crucial for strengthening the EV adoption in mass market. (eGUTS project, 2017). The number of charging positions and the number of registered plug-in electric vehicles (PEV) per position in selected countries of the Danube region is shown in Table while situation in each country is further discussed in subchapters. The term charging position means a recharging point capable of charging one electric vehicle at a time; this includes the power supply, plug and the space to park the car (EAFO, 2018).

Table 1: Number of charging positions and number of plug-in electric vehicles (PEV) per position

Danube countries	Number of charging positions	PEV per position
Austria	3,706	5
Croatia	436	6
Czech Republic	684	3
Hungary	272	7
Romania	114	7
Slovakia	443	2
Slovenia	495	2
Serbia[1]	4	-
Monte Negro	0	-

Source:(EAFO, 2018)

The density of electric charging network is shown in Figure 2.



Source: https://ev-charging.com

Figure 2: Charging station network in Danube region with focus on analysed countries

It is evident that north-eastern part of the region has the densest network of charging infrastructure while the situation in the southern and eastern part is not favourable for eMobility. Situation in each country is depicted below.

3.1 Austria

Austria is well developed in terms of eMobility and, at the moment, the demand for charging infrastructure still surpasses the demand although number of registered EVs is increasing. The charging infrastructure includes a nationwide high-speed charging network SMATRICS with more than 400 charging points located about every 60 km along motorways and in urban centres together with SMATRICS app that allows charging even to non-customers. (SMATRICS GmbH & Co KG, 2018).

Focusing on Vienna, as the largest city in Austria, we can determine that eMobility is seen as an important part of transport network. Already in 2016, the community of Vienna elaborated a concept for an urban e-charging network to include more than 1,000 charging stations. The implementation of the charging stations in Vienna depends on the increase of e-vehicles. This means that there is a direct connection between the numbers of e-Vehicles and the implementation of charging stations (eGUTS project, 2017). Similarly, all Austrian provinces are very active in promoting eMobility, for nearly all towns and communities there is an e-charging finder installed where e-vehicle customers can find their preferred charging station.

3.2 Croatia

Charging infrastructure in Croatia has experienced a dramatic increase in the number of charging stations in the last 6 years. The first official launch of an open to public charging station was on the 2nd of July 2011 in Zagreb. After that event, the largest Croatian electric company HEP started to develop their own programme, HEP ELEN, installing charging stations in all regions of Croatia. Company Hrvatski Telekom followed and is the largest operator on the Croatian market today, with a total of 90 charging stations (eGUTS project, 2017).

Based on the latest data, there are 436 charging positions currently installed in Croatia. Out of the 436 charging positions, only 55 are high power (>22 kW) charging positions. Besides that, there are 5 Tesla superchargers that are located on one charging point (EAFO, 2018).

3.3 Czech Republic

The first charging station in the Czech Republic was installed in the town of Desná on 28 April 2007. The station was equipped with a standard industrial outlet 400V, 32A and the consumption could be paid through a text message. The public and non-public infrastructure has developed significantly since then (eGUTS project, 2017).

According to the latest data, there are 684 charging positions currently installed in Czech Republic. Out of the 436 charging positions, 225 are high power (>22 kW) charging positions. 22 charging positions in Czech Republic are also Tesla superchargers (EAFO, 2018).

3.4 Hungary

The charging network in Hungary is still to be developed in order to achieve that an electric vehicle can reach every part of the country. In Hungary currently there are only 272 charging points available for the public (EAFO, 2018), with many charging points located in or around capitol city Budapest. In long-term a high number of new charging

[1] Data source https://ev-charging.com/at/en

stations are required to make electric vehicles a real alternative (eGUTS project, 2017).

3.5 Romania

Number of EVs in Romania is on the rise, in 2016 the sales of hybrid cars rose by 88,7% year to-year whereas the sales of electric cars went up by 129,4% compared to the same period in 2015. Due to different programs (like RABLA plus) it is estimated that in 2017 the numbers of electric vehicles will increase considerably compared to the previous years. Alongside increased sales of EVs the number of charging stations in Romania has increased, predominantly in larger urban areas of Romania (Bucharest, Timisoara, Cluj-Napoca) (eGUTS project, 2017).

At the moment there are only 114 charging positions in Romania. Only 19 charging positions are high power (> 22 kW). There are none Tesla superchargers in Romania at the moment (EAFO, 2018).

3.6 Slovakia

In Slovakia, a private company GreenWay operates the most comprehensive network of public electric vehicle charging stations in Slovakia. Greenway fast charging stations are conveniently located near the motorway and highway exits and roads in Slovakia, 15 fast charging stations are located on the route Bratislava and Košice (eGUTS project, 2017).

According to the latest data, there are 443 charging positions in Slovakia altogether. 96 out of 443 are high power charging positions and there are also 10 Tesla superchargers in Slovakia (EAFO, 2018).

3.7 Slovenia

In Slovenia electric cars are still in minority, compared to classic internal combustion type of cars. Nevertheless, the charging network is well developed with 495 electric charging positions. 348 have the nominal charging power lower than 22 kW and 147 have the nominal charging power higher than 22 kW. 42 charging positions are Type-2AC, 44 ChaDeMo, 41 CCS and there are also 18 Tesla super chargers (EAFO, 2018).

3.8 Serbia

In Serbia publicly available electric charging infrastructure is very scarce, 2 stations in Belgrade, one in Backi Petrovac and one in Subotica (KELAG, 2018). In addition, several hotels in Belgrade have installed chargers. Due to lack of public charging infrastructure, EVs are usually charged at private charging points (usually household outlets)

3.9 Montenegro

No publicly available charging infrastructure exists and there are no official initiatives in terms of introducing electric charging stations for electric vehicles within urban areas.

4 ADOPTED EMOBILITY POLICIES AND LEVELS OF DEVELOPMENT OF CHARGING INFRASTRUCTURE

Danube region countries do not differ only in economic and charging infrastructure development levels, but also in levels of intensity with which they adopted eMobility policies. With comparative analysis and consideration of GDP, number of charging positions, adopted policies and financial initiatives for eMobility, we can summarize main disparities among countries.

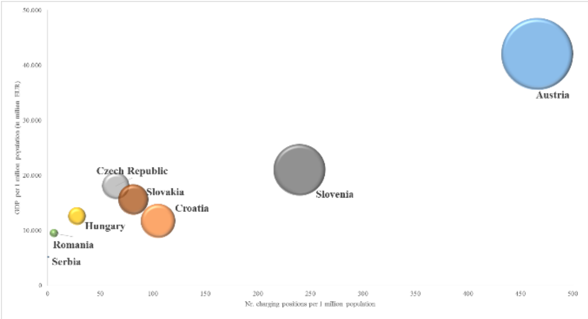
As the country with the highest GDP per capita among selected Danube countries (Table), Austria also has the highest number of total charging positions. This does not change even by the normalization of GDP and number of charging positions to common scale (population 1 million). After normalization of baseline data some changes of countries' positions occur – Slovenia moves to second place before Czech Republic and Hungary and Croatia change positions. Exploring further, it is evident that identical positioning of the countries appears considering GDP per capita and number of charging positions per million inhabitants. We can furthermore notice that countries with lowest GDP (Serbia, Montenegro) are also performing very poorly in terms of implementation of charging positions.

Table 2: The countries position before and after normalizing data

	Baseline data		Normalized data	
Danube countries	GDP per capita	Total nr. of charging positions	GDP per 1 million population	Nr. of charging positions per 1 million population
Austria	1	1	1	1
Czech Republic	3	2	3	3
Slovenia	2	3	2	2
Slovakia	4	4	4	4
Croatia	6	5	6	6
Hungary	5	6	5	5
Romania	7	7	7	7
Serbia	9	8	9	9
Monte Negro	8	9	8	8

Source: Eurostat 2017, (EAFO, 2018)

Taking into consideration GDP per capita and number of charging positions per 1 million of inhabitants a significant gap between Austria, Slovenia and other analysed countries of Danube region is revealed (Figure). There is a significant gap between Austria and Slovenia, both in terms of GDP and number of charging positions, followed by another gap between Slovenia and a cluster of other countries.



Source: (Eurostat, 2018), (EAFO, 2018)

Figure 3: Number of charging station towards GDP (per 1 million population)

The existing gap between countries in terms of charging infrastructure, can be in part explained with good set of policies and financial initiatives for eMobility in place in Austria and Slovenia. Austria provides financial initiatives for different types of charging stations and access to the federal funding for electric cars and for promoting private charging infrastructure. Austria has managed to establish a strong federal, state and municipal policy and funding system providing direct subsidies to the electro mobility resulting in dense network of charging stations. Slovenia has, in its Transport development strategy, given special attention to the development of charging infrastructure for alternative fuels. It has set minimal mandatory infrastructure coverage for electricity and other alternative fuels and has provided funding mechanism and measures in forms of non-refundable financial incentives for the purchase of electric vehicles and loans for development of the network of charging stations for end users, legal entities and local government together with tax reliefs. Combination of these measures stimulate not only industry and governments, but also consumers to purchase and use electric vehicles and with that expanding market share of EV (eGUTS project, 2017).

Outline of policies in other analysed countries might reveal reasons for limited performance - in Czech Republic several incentives for acquisition of vehicles or charging stations (including all alternative fuels such as CNG and LPG) are in place but there is no support program solely dedicated to electric vehicles and electric charging infrastructure. In Slovakia the development of the eMobility was mainly driven by the private sector with national authorities taking somewhat passive role. Only recently (in 2016) eMobility was addressed in national policy and effects still remain to be seen. In Hungry currently 272 public charging stations are available (EAFO, 2018), a few thousand more charging points would be required to make electric vehicles a real alternative. Although there are some resources committed to establishing charging stations, the regulation and law referring developments and investments of eMobility are still at an early stage (eGUTS project, 2017). In Croatia tax reliefs and purchase subsides are in place and as result Croatia has recorded high growth of electric vehicles.

In case of Serbia and Montenegro, we have found almost no policies for eMobility, financial initiatives or measures stimulating deployment of EVs, the same is true for charging infrastructure. Lack of standards and regulation is evident in both countries which might explain lack of charging infrastructure in both countries.

5 CONCLUSIONS

Through examination of existing charging infrastructure for electric vehicles, adopted eMobility policies and GDP in selected countries of the Danube region we have found out that north-eastern part of the region has the densest network of charging infrastructure while the situation in the southern and eastern part is not favourable for eMobility. The levels of adopted eMobility policies differ in analysed countries, with the exception of Serbia and Montenegro with very limited or no policies. The major difference, with regard to policies, is notable in the time of policy adoption. With exception of Austria, all other countries have adopted eMobility policies relatively recently and the effects are yet to be seen.

More interestingly, a connection between GDP and charging infrastructure development seems to exist. As shown, Austria and Slovenia have well adopted eMobility policies and funding mechanisms, that encourage the development of charging infrastructure, but more importantly these two countries also have the highest GDP per capita among analysed Danube countries. Austria is, both in terms of GDP and in charging infrastructure development, far ahead of other countries. Slovenia is about half way in terms of GDP and charging infrastructure if compared to Austria, while other countries are lagging behind. Performing the worst are Serbia and Montenegro with no policies to support eMobility, underdeveloped charging infrastructure and very low GDP.

Comparative analysis has revealed how important it is for the countries not only to state clearly the eMobility goals in their strategies and national political programs, but also to provide appropriate financial initiatives to consumers, industry and local government to encourage eMobility. However sufficient funds need to be available which seems to depend strongly on the GDP of the country in question.

Further research of GDP levels and development of alternative fuels' charging infrastructure in different countries could determine if correlation between the two exists.

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TRANSPORT VOCABULARY IN A COMPREHENSIVE MODERN BUSINESS DICTIONARY: ENGLISH-SLOVENE

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ABSTRACT

This article deals with transport vocabulary as it is presented in Veliki moderni poslovni slovar: angleško-slovenski = A Comprehensive Modern Business Dictionary: English-Slovene by Lidija Šega. Since its publication in the year 1997, this dictionary has been the most comprehensive English-Slovene paper dictionary for the Slovene users of Business English. Transport business is a specific field of business therefore A Comprehensive Modern Business Dictionary: English-Slovene contains a large English transport vocabulary with Slovene translation equivalents. This dictionary was published in comprehensive and pocket paper editions. Since it is not available online, the students of transport technology and logistics have so far hardly ever consulted this dictionary when studying Professional English. A Comprehensive Modern Business Dictionary: English-Slovene is out of stock now and one could only use it in a reference library. One of the main advantages of this dictionary is that it contains a prominent archive of Slovene translation equivalents for a lot of specific English vocabulary used in transport business. Therefore, the linguistic features of the English entries that are marked with the field label trans are presented in this article. Unfortunately, over the last twenty years the print dictionary has never been updated, revised or electronically published either on CD-ROM or online. The aim of this analytical presentation of transport vocabulary from A Comprehensive Modern Business Dictionary: English-Slovene is thus to provide basic guidelines for the compilation of a new modern online Transport Dictionary: English-Slovene that could be easily updated, revised and standardized by linguistics experts and field specialists.

Keywords: transport vocabulary, transport logistics, business dictionary, English-Slovene, Veliki moderni poslovni slovar: angleško-slovenski = A Comprehensive Modern Business Dictionary: English-Slovene

1 INTRODUCTION

Due to the growth of transport business and logistics, there is considerable interest in compiling and standardizing professional traffic and transport logistics vocabulary comprising English professional words and phrases with their Slovene translation equivalents. This paper thus presents transport vocabulary which has been extracted from Lidija Šega's *Veliki moderni poslovni slovar: angleško-slovenski = A Comprehensive Modern Business Dictionary: English-Slovene*, published in Ljubljana by Cankarjeva založba in 1997. Over the last twenty years, this has been the most comprehensive English-Slovene business dictionary, and a part of its vocabulary was marked with the field label TRANS for TRANSPORT.

In Slovenia, since then no other English-Slovene business dictionary has been published either in print or in electronic edition or online. Before Lidija Šega's *A Comprehensive Modern Business Dictionary: English-Slovene*, a Slovene translation of Peter H. Collin's *Business Dictionary* was published in Ljubljana in 1995 by DZS, and its translator was Majda Ažman-Bizovičar. Peter Collin's *Business Dictionary* was one of the many sources in the process of preparation of the *A Comprehensive Modern Business Dictionary: English-Slovene* by Lidija Šega. Due to the success of the comprehensive edition, a pocket edition of Lidija Šega's dictionary was published in 2001 with the title *Mali moderni poslovni slovar: angleško-slovenski = A Compact Modern Business Dictionary: English-Slovene*. However, until now no Slovene-English business dictionary has been published in Slovenia, although a trilingual business dictionary offering Slovene expressions as first headwords was printed in Klagenfurt – Celovec, Austria, by Mohorjeva = Hermagoras in 2005 with the title *Trijezični poslovni slovar: slovensko-nemško-angleški = Wirtschaftswörterbuch: slowenisch-deutsch-englisch*. The dictionary was compiled by Vekoslav Potočnik and Charles Gledhill, and was designed as a study aid for students of the Bilingual Federal Commercial Academy in Klagenfurt – Celovec.

Regarding specific traffic and transport vocabulary, the Faculty of Civil Engineering of the University of Maribor published Metka Brkan's *Angleško-slovenski prometni slovar = English-Slovene Dictionary of Traffic and Transportation* in 2006. This dictionary was compiled as a study aid for students of traffic engineering at the Maribor Faculty of Civil Engineering. Considering the faculty's study program, the selected vocabulary focuses on land transport, i.e. mainly on road and rail transport, and comprises traffic and transport vocabulary from the construction and engineering perspectives. Among the numerous references, the author of the dictionary named the following English-Slovene dictionary sources:

- Oxford-Duden-Cankarjeva založba Angleško-slovenski slikovni slovar (1989)
- Angleški in francoski slikovni slovar (1989)
- Veliki slovensko-angleško-nemško-italijanski slovar (1994)
- Glosar za statistiko transporta (2004)

- Slovensko-angleški slovar (1990/1997)
- Veliki angleško-slovenski slovar (1978/1997)
- Veliki angleško-slovenski slovar Oxford (2005/2006)

From the dictionary titles on the list it could be noticed that almost all available English-Slovene general and picture dictionaries were consulted in the process of compilation. The only exceptions are smaller English-Slovene school dictionaries that are not on the list of references. It could also be confirmed that Lidija Šega's *A Comprehensive Modern Business Dictionary: English-Slovene* and other English-Slovene business dictionaries were not consulted and considered as sources in the process of compilation of this dictionary, since the author's emphasis was understandably on traffic engineering, and not on transport business or on transport logistics.

Obviously, among printed dictionary sources there is a gap regarding the professional vocabulary of transport business. This paper therefore addresses the following research questions:

- Which transport vocabulary is included in A Comprehensive Modern Business Dictionary: English-Slovene?
- How could transport vocabulary from *A Comprehensive Modern Business Dictionary: English-Slovene* be made available for transport logistics professionals?

The purpose of this study is therefore to extract transport vocabulary from the English-Slovene most comprehensive business dictionary and to analyze the results.

At the moment there is no comprehensive English-Slovene specialized dual-field dictionary available either in print or online that could well serve as a study aid for transport technology and logistics. Fortunately, Slovene students of maritime studies have a possibility to use the dictionary *Slovenska pomorska terminologija = Slovene Maritime Terminology* compiled as a BSc thesis by Rok Sorta in 2003. It has been available in pdf format on the website *Slovarji in drugi pripomočki za prevajalce* for several years now, and in 2017 it was also published in print by Osminka & Co.

Termania, a joint dictionary website for online and digitalized dictionaries, does not provide an English-Slovene and Slovene-English transport or logistics dictionary, thus students and transport logistics professionals can help themselves by consulting *Evroterm*, a multilingual terminology database on the internet when searching for specialized English-Slovene or Slovene-English equivalents. The *Evroterm* platform was created for technical translators, and is still one of the most reliable online sources for specialized bilingual English-Slovene and Slovene-English translation searches.

Some specific transport and logistics glossaries are accessible on the internet links listed in specific sections of the website *Slovarji in drugi pripomočki za prevajalce – Evroterm = Dictionaries and Other Aids for Translators – Evroterm*, available on the *Evroterm* homepage. In these sections with specific transport and logistics glossaries, terms have to be looked up on different lists of words or in books in pdf format, or on different websites. Evidently, no dictionary platform with transport technology and logistics terminology has so far been created as a hub for both fields of industry and study, thus an online dictionary for transport technology and logistics professionals could really be very useful.

This paper therefore presents a sample from basic transport vocabulary that comprises a selection of English transport terms and Slovene translation equivalents from *A Comprehensive Modern Business Dictionary: English-Slovene.* When compiling her dictionary Lidija Šega, who is also a translator, consulted more than 50 specialized dictionaries and more than 50 glossaries that helped her to make a good wordlist and to find or suggest most appropriate translation equivalents. When dealing with transport terms, she chose vocabulary with emphasis on transport business and transport logistics. At the end, this paper offers suggestions for the compilation of a new digital transport logistics dictionary.

The existing online glossaries and dictionaries should also be analyzed and consulted as sources later on in the process of compilation of a new transport logistics dictionary. However, the focus of this paper is on the most comprehensive English-Slovene business dictionary which is not available online.

2 METHODOLOGY

In *A Comprehensive Modern Business Dictionary: English-Slovene* the entry terms designated with the TRANS label occur sometimes as headwords and predominantly as word combinations presented as run-on entries of the corresponding dictionary article.

The research was done by looking for TRANS field labels used after headwords, run-on entries (e.g. derived phrases), and run-in entries (e.g. citations as examples of usage) in *A Comprehensive Modern Business Dictionary: English-Slovene*. The whole dictionary comprises about 80,000 entries with their translation equivalents. It has to be pointed out that entries are not only headwords that are printed in bold type at the beginning of dictionary articles. According to dictionary entry counting (Landau 2001: 109–114) also any other defined parts of speech of the headword, inflected forms, run-on derivatives, idioms, variants of entries and words in lists count as entries.

3 RESULTS

3.1 Structure

The entry articles in *A Comprehensive Modern Business Dictionary: English-Slovene* are printed in two columns of text with deliberately organized structure on 933 pages with layout size of 15 cm x 25 cm. The text was read through in search of TRANS field labels. By looking at the hits with the TRANS field label in *A Comprehensive Modern Business Dictionary: English-Slovene* it became obvious that the majority of word combinations are printed in the dictionary A–Z part at more than one place, e.g. forwarding agent occurs under A for agent and under F for forwarding.

In *A Comprehensive Modern Business Dictionary: English-Slovene*, specialized vocabulary is mainly presented in word combinations, and these are listed in sections after the general English entry in the position of headword. Word combinations are alphabetically listed after each general English section in a specific order. In the first section after the general section there are word combinations with the entry word at the front. This is followed by the section with word combinations where the entry word is used in the position of a postmodifier, the third section is normally the section with the entry word in prepositional phrases, and finally the derivatives are presented in separate sections.

By means of this structure the users of this paper dictionary are able to find word combinations fast, since they occur at almost every initial letter of almost any constituent word of a specific word combination. The search within the dictionary article is also made easy by separate sections. Some users reported that this was clearly an advantage for this comprehensive dictionary, although the drawback was definitely the inflated size of the dictionary which made the book to be used mainly as a desk manual.

By skimming the text of the dictionary it became noticeable that transport field labels occur on average 2.,6 times per page, from 0 to 21 times per page at maximum. Transport terms are therefore one of the main constituent parts of business vocabulary, since transport logistics is clearly one of the constituent fields of transport business.

Since transport logistics terms merge with general business terms, it is very difficult to set distinct boundaries between professional transport and general business vocabulary. Sometimes the field label TRANS is not used, probably by mistake, such as in the entry article: arrival notice obvestilo (špediterja) o prispetju (pošiljke). In some cases a supplementary explanation dealing with transport is added, e.g. in the entry article: adjustment of a claim KOM rešitev reklamacije zlasti če je škoda krita s transportnim zavarovanjem. It is evident that such entries could also be regarded as pertaining to transport vocabulary.

Boundaries between different fields of vocabulary definitely present a linguistic challenge, as transport is part of not only business but also general vocabulary. Many times transport terms could be found also in the field of commercial or financial vocabulary that is marked with the field labels KOM and FIN or with the field label ZAV for insurance vocabulary, e.g. railway express agency KOM, TRANS, AM železniška špedicija za ekspresne pošiljke; gross adventure FIN, TRANS posojilo proti zastavi ladje in/ali tovora and
cargo policy TRANS, ZAV zavarovalna polica za tovor, polica transportnega zavarovanja.

In addition, transport vocabulary is also marked with other labels such as EKON for economy, e.g. abandonment of a railway EKON, TRANS opustitev železniške proge; JUR for law, e.g. air charter party JUR, KOM pogodba o zakupu letala; TUR for tourism, free (baggage) allowance TRANS, TUR dovoljena prtljaga brez doplačila.

3.2 Transport Logistics Vocabulary

In the sample from the initial part of the dictionary letter A there are word combinations which are here sorted as main entries according to the initial letter of the word combination. Just in few cases, the entries are listed as headwords of their own dictionary articles, e.g. aboard, address, advice, ahead.

aboard TRANS *prisl* na krovu, na letalu, v avtu: *The goods are aboard.* Blago je vkrcano/naloženo. **II** *predl* na, v v zvezi z ladjo, letalom, vlakom go aboard (a ship/bus/train/plane) vkrcati se (na ladjo), vstopiti (v avtobus/na vlak/v letalo): *All aboard (for London)!* Potniki (za London), vstopite! take goods aboard vkrcati blago, naložiti blago

acceptance trials TRANS poskusna vožnja ladje pred predajo lastniku

access road TRANS dovoz, dovozna cesta/pot

accident to conveyance TRANS, ZAV nezgoda transportnega sredstva

accommodation road TRANS lokalna cesta, dovozna pot

accommodation train TRANS lokalni vlak

accompanied baggage/luggage TRANS spremljajoča prtljaga prtljaga, ki potuje skupaj s potniki

accompanying documents/papers KOM, TRANS spremni dokumenti

ad valorem freight KOM, TRANS tovornina (določena) po vrednosti blaga

address commission TRANS, KOM provizija ladjarskemu posredniku

return address KOM, TRANS naslov pošiljatelja
adjustment of a claim KOM rešitev reklamacije, zlasti če je škoda krita s transportnim zavarovanjem

advance charge TRANS vnaprej plačani prevozni stroški

advance freight TRANS *kr* a.f. vnaprej plačana tovornina

advanced rate KOM, TRANS povišana/višja tarifa (za prevoz)

gross adventure FIN, TRANS posojilo proti zastavi ladje in/ali tovora

advice KOM, TRANS aviza, napoved

advice of delivery TRANS obvestilo pošte o prispetju priporočene pošiljke

advice of dispatch KOM, TRANS obvestilo (tujega) dobavitelja/špediterja o odpremi

advice note KOM, TRANS aviza, obvestilo o odpremi, obvestilo o prispetju (blaga)

advice of shipment KOM, TRANS obvestilo (tujega) dobavitelja/špediterja o odpremi advise *gl* KOM, TRANS avizirati

aerocab *sam* TRANS aviotaksi

aeroplane *sam* TRANS, BR letalo

heavy transport cargo aeroplane transportno letalo

affix the leads KOM, TRANS zaplombirati, zapreti s plombo

affreight *gl* KOM, TRANS zakupiti tovorno ladjo

affreightment *sam* **1** KOM konosament, ladijski tovorni list, nakladnica
2 JUR, TRANS ladjarska pogodba, pogodba o zakupu ladje

afloat TRANS ploven ladja, plavajoč

after arrival TRANS *kr* a.a. po prispetju

forwarding agency TRANS špedicija

railway express agency KOM, TRANS, AM železniška špedicija za ekspresne pošiljke

shipping agency TRANS pomorska agencija; TRANS špedicija

forwarding agent KOM, TRANS špediter

goods agent KOM, TRANS špediter

shipping agent KOM, TRANS, AM špediter

transit agent KOM, TRANS vmesni špediter

transport agent KOM, TRANS špediter

aggregated shipment TRANS zbirna odprema, zbirnik

ahead *prisl* TRANS naprej: *Full speed/steam ahead!* S polno paro naprej!
ahead only TRANS zavijanje prepovedano, obvezno naravnost

4 DISCUSSION AND CONCLUSION

The selected sample of the wordlist of transport terms from the letter A of *A Comprehensive Modern Business Dictionary: English-Slovene* illustrates that the dictionary comprises a high number of transport and transport logistics words and word combinations which could be very useful for transport logistics professionals.

The main problem is that this vocabulary is now available only in paper form published in 1997, and now is out of print. As a result, the digital users are not able to consult transport and transport logistics terms printed in this dictionary.

In comparison with Metka Brkan's Angleško-slovenski prometni slovar = English-Slovene Dictionary of Traffic and Transportation, the selected samples show that A Comprehensive Modern Business Dictionary: English-Slovene offers much vocabulary that is used in transport logistics, and thus it would be very useful if it were widely available.

After twenty years from its compilation, also the transport logistics vocabulary needs thorough revision by logistics professionals, so that the Slovene users could find suggestions for modern standardized translation equivalents of the English business terms.

Nonetheless, *A Comprehensive Modern Business Dictionary: English-Slovene* is still one of the most reliable sources when checking the meaning and translation equivalents of transport logistics terms. Thus it could be one of the basic sources when compiling a new transport logistics dictionary. Of course, the terms from the existing dictionaries do not suffice. A new transport logistics dictionary should be prepared as a project involving different coordinated partners.

In a new transport logistics dictionary, new English and Slovene texts dealing with transport logistics should be compiled from a corpus, so that new expressions could be presented in new contexts. The dictionary should be available from English into Slovene and vice versa.

Transport logistics is a rapidly growing field of industry therefore new processes and services are constantly being improved and developed, and new words and word combinations are simply the result of this process. One of the main tasks of professional language specialists therefore is to observe and follow the process by documenting and presenting new expressions as dictionary entries on the world wide web so that they can be available to the majority of users.

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INVESTIGATING SCENARIOS FOR FREIGHT TRAFFIC IN THE EASTERN SICILY PORT SYSTEM

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ABSTRACT

Ports are crucial nodes of economic development for their regions, providing not only sea access but also acting as key facilitators of global trade. Their performances are nowadays largely depending on the offer of tailored services to operators and the optimization of port operations, with particular reference on the quality of cargo-handling and the time spent by the ship at the terminal.

The objective of this paper is to identify a methodological approach to propose effective strategies to improve port operations, without increasing the size of the urban areas dedicated to port activities, with a focus on the evaluation of port terminal capacity. In order to achieve this objective, an application to the case study of the Eastern Sicily port system has been performed, involving the ports of the cities of Catania and Augusta and by processing data concerning Ro-Ro freight traffic. Data have been acquired from the port authority and from the main terminal and logistic operators, in order to conduct an analysis of terminal operation efficiency making specific reference to Ro-Ro traffic and dedicated terminal spaces.

Results coming from the analysis allow the construction of a framework of the current state of the Eastern Sicily port system and the proposal for short and long-term approaches of different planning scenarios for the two ports that are part of the system.

Keywords: Transport planning, Port optimization, Port-city relations

1 INTRODUCTION

Ports can be considered the main hub for freight handling; they have significantly changed their function and the activities that take place within them, moving from simple landings to commercial centers, through which the big cities started their ascent, exploiting the huge quantities of goods they could dispose of. Historically, cities were born around the ports; then there was a contemporary development between urban areas and port areas, up to a detachment of the latter in search of larger spaces, often distant from the urban context. Port areas are in fact affected by significant traffic flows from and towards the port causing several externalities greatly influencing the functionality of both the port and the city. The large scale of the handled freight traffic is commonly causing negative externalities such as air and noise pollution. Closeness between ports and cities leads to the fact that ports can be considered responsible for the attractiveness and the livability of the close residential area; this leads to take into consideration a social and sustainable perspective when actions are taken (Hall, 2007).

Nowadays, ports have evolved into a logistics and industrial sectors with national and worldwide significance (Cetin & Cerit, 2010); the huge increase in the movement of freight and road transport, often causes an insufficient sizing of terminal spaces and generates attempts to expand into urban areas. Port spaces must consequently be carefully managed so that port congestion can be reduced to a minimum and, in case of an increase in trades, guarantee that arrivals and departures can be hosted by the terminal.

The relationship between ports and cities, therefore, requires careful regulation that can allow continuous coordination between the various neighboring areas. In this regard, legislation comes into play, in different ways in the various countries, that moves, especially in recent years, towards the determination of a complementary coexistence of neighboring ports, which very often have found themselves competing with each other.

In this paper a methodological approach is identified in order to propose effective strategies to improve port operations with a particular reference on the analyze the terminal capacity.

The reminder of the paper is organized as follows. This first chapter contains an introduction on the evolution of Italian policies on port management and the actual legal structure. In the second chapter a framework of the methodology used is described. The third chapter illustrates the Case study on the Eastern Sicily port system and the evaluation of port terminal efficiency. Finally, in the last part of the paper strategies and recommendation for the improvement of Ro-Ro traffic efficiency in port operations are presented.

1.1 Italian policy and legal framework

Before 2016, Italian ports were managed by Port Authorities, regulators of the entrepreneurial activities carried out in the port, as well as managers of state property; those bodies defined a major change and revolution in the State-port relationship, greatly reducing public intervention in the port sector, leaving greater freedom to private companies with the possibility to operate according to the logic of the market and of competition. In July 2016 a new ministerial decree was approved, introducing three key points. a bureaucratic simplification; a reorganization of ports in Port System Authorities; a new governance model. Fifteen Port System Authorities take over the 57 national ports, chosen as strategic decision-making centers with offices in major cities and in the ports considered the most important by the European Community. The Management Committee is led by a president expert in transport and port economics and with extensive decision-making powers. He is chosen by the Minister of Infrastructures and Transport in agreement with the Region or the Regions concerned by the System Authority. It is worthwhile to underline that when one authority can address planning and operation of more ports there is the chance to increase the opportunity of optimization and performance improvement.

2 METHODOLOGICAL APPROACH

To achieve the objective mentioned in previous section, the methodological approach for this study has been designed and presented in the form of flow chart as shown in Figure 1.

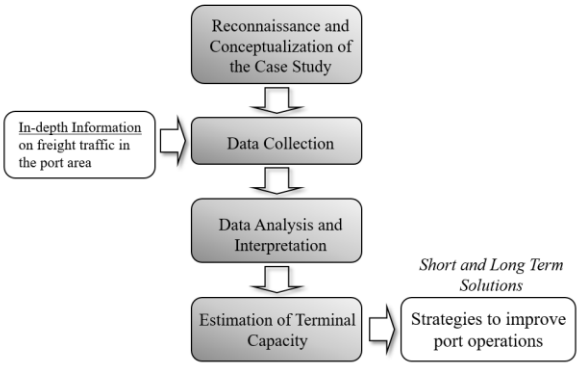


Figure 1: Devised Methodology for the study

As can be seen from this figure, a recognition on the state of affairs was made to realize a conceptualization of the case study.

Subsequently, the data collection was realized. To conduct a wider and detailed analysis of traffic studies, in-depth information on freight traffic in the port area were considered for the data analysis and interpretation.

Finally, these results have been utilized in developing long term strategies/recommendation.

3 CASE STUDY

3.1 Territorial framework

The Eastern Sicily port system is a public authority with the institutional purpose of managing and organizing goods and services in its port area, coordinating the activities of the ports of Catania and Augusta.

Catania is a medium-sized city of about 300.000 inhabitants, located in the south of Italy. The city extends through an area of about 183 km^2 and it has a population density of 1.754,54 inhabitants/km^2. It is part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania (Ignaccolo et al., 2017).

The Port of Catania (Figure 2) according to national classification is an international commercial seaport; it stretches in north-south direction with the entrance facing south. The main characteristics of the port are given by its geographical position, the high degree of accessibility and the proximity of the airport, the railway station and the inland terminal.

Source: http://www.porto.catania.it/porto-di-catania/

Figure 2: Port of Catania

3.2 Analysis of Freight Traffic Data

With reference to the traffic freight relating to the port of Catania, the Port Authority produces both monthly and annual statistics, which show that there has been a noticeable increase in the commercial activity of the port in last years, especially due to Ro-Ro traffic.

From an analysis of available data by the Port Authority, it is possible to examine, from a numerical (Table 1) and graphic (Figure 3) point of view, the trend of vessels' arrivals and departures towards the port of Catania, in the last fifteen years.

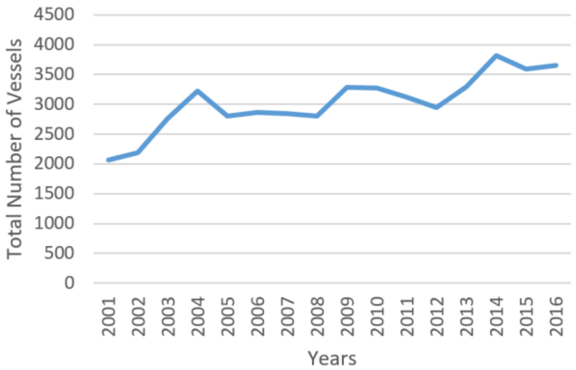
From 2001 to 2016, there is the evidence of a significant increase in both vessels departing and arriving towards the port of Catania, with a 76% growth rate.

More specifically, considering only the Ro-Ro traffic component, it is possible to note the variations of these trades (in terms of tons), as shown in Table 2.

Table 1: Number of arrivals and departures of the port of Catania, 2001-2016

Year	Arrivals	Departures	Total	Annual percentage difference
2001	1031	1038	2069	-0,19%
2002	1090	1100	2190	5,85%
2003	1382	1382	2764	26,21%
2004	1611	1610	3221	16,53%
2005	1402	1402	2804	-12,95%
2006	1432	1432	2864	2,14%
2007	1422	1422	2844	-0,70%
2008	1400	1400	2800	-1,55%
2009	1641	1641	3282	17,21%
2010	1636	1633	3269	-0,40%
2011	1563	1562	3125	-4,41%
2012	1475	1474	2949	-5,63%
2013	1649	1647	3296	11,77%
2014	1909	1908	3817	15,81%
2015	1797	1798	3595	-5,82%
2016	1824	1825	3649	1,50%

Source: Catania Port Authority



Source: Port Authority of Catania

Figure 3: Trend of vessels' arrivals and departures from/to port of Catania, 2001-2016

Table 2: Ro-Ro arrivals and departures [tons] from/to port of Catania, 2001-2016

Year	Arrivals	Departures	Total	Annual percentage difference
2001	1141373	522263	1.663.636	3,67%
2002	1.182.270	595.298	1.777.569	6,85%
2003	1.860.860	1.265.217	3.126.077	75,86%
2004	2.210.550	1.852.485	4.063.035	29,97%
2005	1.638.696	1.078.342	2.717.037	-33,13%
2006	1.613.674	1.119.290	2.732.963	0,59%
2007	1.776.257	1.268.282	3.044.538	11,40%
2008	2.058.714	1.330.240	3.388.954	11,31%
2009	2.212.323	1.327.364	3.539.688	4,45%
2010	2.522.393	1.608.875	4.131.269	16,71%
2011	2.677.159	1.803.391	4.480.549	8,45%
2012	2.601.846	1.624.781	4.226.628	-5,67%
2013	3.155.463	1.989.989	5.145.452	21,74%
2014	3.748.859	2.331.430	6.080.289	18,17%
2015	4.274.337	2.353.022	6.627.358	9,00%
2016	4.218.608	2.799.502	7.018.110	5,90%

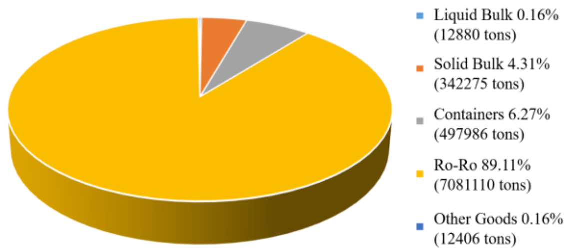
Source: Catania Port Authority

In this case, the quantity of goods handled in the port terminal of Catania through Ro-Ro traffic have increased by even 322% in 2016 compared to 2001 (Figure 4).

Source: Port Authority of Catania

Figure 4: Trend of Ro-Ro traffic [tons] from/to port of Catania, 2001-2016

Taking into account the latest available data, it is possible to define the different percentages of freight traffic components, as it possible to see in Figure 5:



Source: Port Authority of Catania

Figure 5: Percentages of freight traffic components of port of Catania, 2016

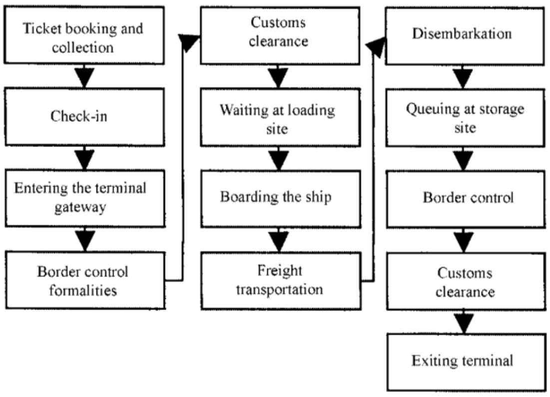
It is noticeable that, in addition to being constantly increasing, Ro-Ro traffic represents for the terminal the highest rate of freight traffic component, with about 90% of total traffic.

For this reason, as discussed in the next paragraph, it has been realized an analysis of Ro-Ro terminal efficiency of the Port of Catania. It will be based on the study of Maksimavièius (2004), that through indexes and relations, allows to understand if the spaces used for CTU in the Ro-Ro terminal of Catania, are actually sufficient or if it is already in crisis.

3.3 Issues due to terminal capacity

Ro-Ro represents for the port of Catania the highest rate of freight traffic, with about 90% of total and it is constantly increasing. The Ro-Ro commercial area of the port has recently been expanded through the construction, of a new terminal, finished in the 2015, called *Nuova Darsena*. The area is divided into five parts, each of 15000 m^2. The two companies *Tirrenia* and *Cartour* manage 1/5 each of the area, while the remaining 3/5, equivalent to 45,000 m^2, are managed by *Grimaldi Group*, an Italian ship owning company based in Naples operating both in the passenger sector (cruise ferries) and cargo. The *Grimaldi Group* has created an international network of about 20 terminals for handling rolling cargoes, containers and general cargo. In particular, the terminal in Catania managed by *Grimaldi Group* can host a maximum of 450 semitrailers positioned in a herringbone pattern, which are loaded on ships of about 200 seats, whose destinations are Salerno, Genoa, Livorno, Ravenna, Brindisi. In the port of Catania, ships that can moor at the same time are at most five, of which four with aft ramp and one with a side ramp. The operations of loading and unloading of the ships by the *Grimaldi Group* last approximately 10 hours, thanks to the use of about ten *DugMaster* trailers, achieving from 35 to 40 movements per hour.

Based on an in-depth interview conducted with *Grimaldi Group* operator, one of the main critical issues emerged which regards the size of their Ro-Ro terminal in the Port of Catania, even though the recent opening of *Nuova Darsena*. Starting from this consideration, a study of capacity of the terminal and the port's border facility has been conducted through a methodology developed by Ričardas Maksimavičius (2004), aiming at the optimization of terminal operation efficiency with different capacity calculation for each facility of the scheme of cargo transportation by Ro-Ro ship (Figure 6).



Source: Maksimavičius, 2004

Figure 6: Freight transportation by Ro-Ro ships

As far as customs operations are concerned, the terminal of *Grimaldi Group* at port of Catania does not receive goods directly from abroad, so there are no custom controls and only gateway analysis should be conducted.

For the application of this methodology we must first define the number of gateways of the terminal and the time necessary to realize the entire process of unloading the single Cargo Transport Unit (CTU) in minutes, so that the general intensity of the CTU processing at the gateway can be obtained.

In this case, considering that the port of Catania has a single gateway G and that the time of discharge of the CTU (t_{apt}) is usually between 5 and 10 minutes

$$\mu = G/t_{apt} = 1/9 = 0{,}11 \quad (1)$$

assuming a t_{apt} time of 9 minutes.

The arrival process of CTUs at the terminal gateway is assumed according to the Poisson law with intensity λ=0,104. The processing time of the CTU is considered negative exponentially distributed, provided that during the normal operation of the gateway the workload of the gateway $\varphi = \lambda/\mu$ must not exceed 1.

$$\varphi = \lambda/\mu = 0{,}104/0{,}11 = 0{,}937 < 1 \quad (2)$$

Where λ was obtained as the ratio between the number of CTUs departing daily and the time.

Moreover, the minimum number of gateways ($G_{min)}$ to estimate the flow of CTU is equal to:

$$G_{min} = \lambda t_{apt} = 0{,}104 \cdot 9 = 0{,}93 \quad (3)$$

Otherwise the reliability of the terminal is insufficient and not all the CTUs can be accepted.

So the average queue time outside the terminal gateway W and the average entry time to the gateway for CTU W_e are:

$$W_e = \frac{\varphi}{(1-\varphi)\mu} = 135 \text{ s} \quad (4)$$

$$W = W_e + t_{apt} = 144 \text{ s} \quad (5)$$

With the condition that W≤ T, where T is the relative time (time for CTU check-in and loading):

$$G^2 - \lambda t_{apt} G - \frac{\lambda t_{apt}^2}{T - t_{apt}} \geq 0 \rightarrow T = 122{,}625 \text{ s} \quad (6)$$

Since the W≤T condition is not verified, the average queue time outside the gateway is excessive.

The average number of CTUs waiting outside the thermal gateway Pq and the average number of CTUs in a row for each gateway in this case coincide and are both equal to 15:

Thus, the steps to a gateway and the terminal export platforms must be designed based on the average number of CTUs waiting outside the Pq terminal gateway and the average number of CTUs aligned in a single Lq gateway.

The allowable number of CTUs Ss (max), which can use the storage site depends on:

- The time of arrival of the ship at the terminal ti;
- Number of CTUs disembarking from each docked ship i;
- Average storage time at a terminal site, t;

Part of CTUs using parking at the terminal, is.

Considering that the percentage of CTU remaining in the terminal following the landing i_s about 90% of the total CTU and that the number i_j of CTU that use the terminal is equal to about 600, we have:

$$S_s(max) = \sum_j i_s i_j = 540 \quad (7)$$

Therefore, considering that the terminal in question has 450 γ_r spaces for CTUs:

$$n_r = \sum \gamma_r / \sum S_i = 0{,}83 \quad (8)$$

A value of n_r less than 1 means that the terminal spaces are not sufficient for handling the current Ro-Ro traffic.

4 STRATEGIES TO IMPROVE PORT OPERATIONS

In this section, some practices to improve operations in the port of Catania, accommodating growing volumes of Ro-Ro cargo, are presented.

As already stated in section 3.1, the Eastern Sicily Port system coordinates the activities of the ports of Catania and Augusta. The port of Augusta (Figure 7) is included in the TEN-T "CORE" NETWORK Networks as a Strategic Port of the European Union for its barycentric position along the international traffic routes. It is the largest natural harbor in the lower Mediterranean area, where there is an important industrial center; it includes a petroleum port, a commercial port, a military base and a port/city with two docks.

Source: https://www.adspmaresiciliaorientale.it/porto-di-augusta/

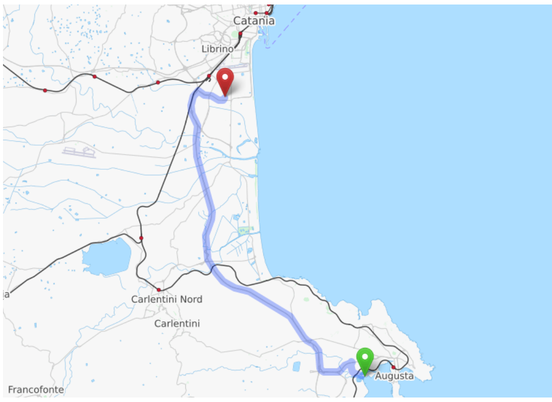
Figure 7: Port of Augusta

In the view of building collaborative relationships with the municipality in which the port operates and finding common ground with surrounding businesses and neighboring ports, three main strategies, their strengths and their challenges are illustrated in this study:

1. A reassignment of Ro-Ro traffic to other ports, with a particular focus on Port of Augusta;
2. An improvement in the use of existing structures;
3. The introduction of technological and operation innovations.

4.1 Reassignment of Ro-Ro traffic to other ports

This section explores the possibility to exploit the spaces of the port of Augusta, which are currently under-utilized, taking into consideration two possible long-term proposals. The first one deals with the extension of the route by sea, with arrival of the vessels at the port of Augusta and the connection between Augusta and Catania by road transport. In this configuration (Figure 8), the increase of distance by road is equivalent to about 45 km, while the distance covered by ship increases of about 18.6 miles.



Source: Openstreetmap

Figure 8: Augusta Catania

The main challenge of this proposal is that, although the increase in travel time might seem not significant, it is very important to evaluate the costs supported by the companies and operators. The construction of a new interport and a commercial and industrial area located close to Augusta could reduce the externalities generated by such dislocation of trades.

The second proposal regards the extension of the route by sea, with arrival of the ship to the port of Augusta and connection Augusta-Catania by rail.

Before 2010 the Bicocca railway logistic terminal (Figure 9), in the industrial area of Catania, operated with four intermodal trains a day, mainly directed to Milan, Bologna, Padua and Vicenza. Nowadays, this movement has been reduced to a single train per day.

Figure 9: Bicocca Terminal

Currently, the railway network project within the port of Augusta has not yet been started. The project includes pick-up and delivery tracks in the port area. The connection between the station and the tracks of the port beam will be entirely electrified and centralized to make entry and exit operations faster and easier.

Each train will have a length of about 400 meters, consisting of 24 wagons and each of the wagons can accommodate 2 CTUs, for a total of 48 CTUs for trains. A journey to be completed has a length of about 40 km, with single-track electrified lines and tunnels of sufficient height for the passage of codified C22 CTUs. Lowered load, can reach up to C45 CTUs.

The main challenges of this proposal are that for loading and unloading of the CTUs inside the terminal and at destination specific mobile cranes must be used, circulating between the docks and between the port warehouses or lift trucks. Moreover, it can't be considered a door-to-door service, so the cost of the road transport used to reach the destination of goods from the train station in Catania should be added.

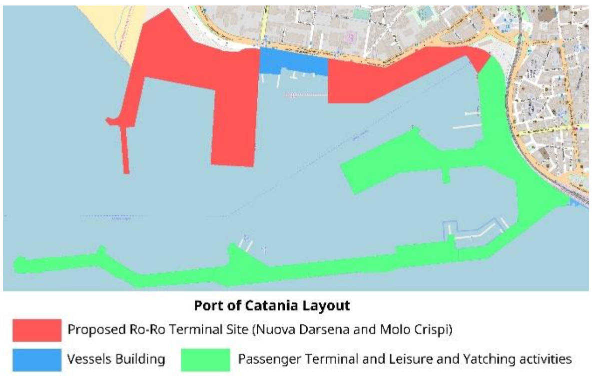
4.2 Improvement in the use of existing structures

At the current state of the Port of Catania (Figure 10), the Ro-Ro freight traffic is fully located in correspondence of the *Nuova Darsena* and *Molo di Mezzogiorno* areas. At the right of *Molo di Mezzogiorno* there is an area for vessels-building, called *Zona Cantieri*; *Molo Crispi* area is indeed occupied by container traffic. The area going from *Porto Vecchio* to *Molo Levante* is occupied by passenger terminal and leisure and yatching activities.

The solution proposed in this section refers to the use of *Molo Crispi* for Ro-Ro traffic, which would mean an additional space of 32.000 mq and two further docks for the arrival of vessels (Figure 11). The main challenge of this proposal would be the shift of container traffic to Augusta Port, due to the same evidences found in section 4.1.

Source: https://www.adspmaresiciliaorientale.it/porto-di-catania/

Figure 10: Actual Port of Catania Layout



Source: Elaboration of Figure 10

Figure 11: New Port of Catania Layout

4.3 Technological and operation innovations

Among the strategies to improve port operations, in both national and European context, the aspect related to technological and operation innovations represents a sector in constant development and being improved.

The recent spread of information and telecommunications technologies and their application to the transport sector has allowed the development of systems capable of "intelligently" addressing the mobility problems in their entirety, named for this reason Intelligent Transport Systems (ITS) (Torrisi, 2017).

In this view, ITS constitute an element capable of significantly shaping the future of multimodal logistics and in particular sea port operations, achieving a reduction of terminal operation's times, of accidents and the impact on the environment.

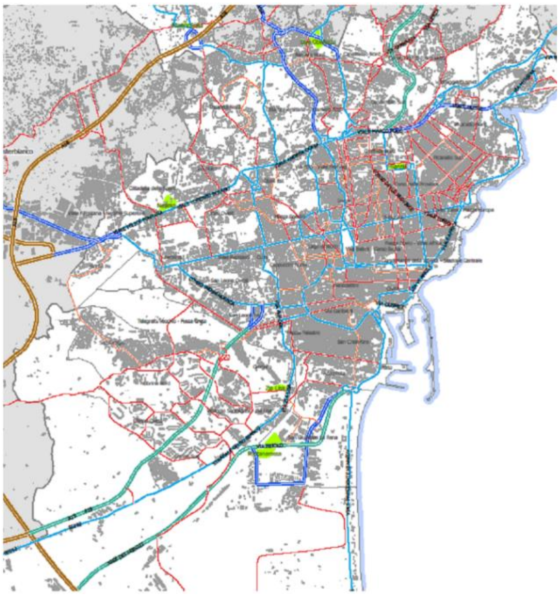
The applications supported by the use of ITS technologies implemented in port areas relate to some specific aspects, such as: daily operation plan, bulk collection, haulage unloading, vehicle track and trace (GPS), collection tickets control (Mondragon et al., 2012).

The growing complexity of multimodal logistics operations in ports and in particular specific features of the port terminal of Catania mostly related to the interdependencies between sea transportation and road haulage represent a strong case for considering the efficient use ITS technologies.

In fact, in order to ensure and enhance safety and security and to simplify administrative and customs procedures, it would be advisable to develop electronic logistics management systems applied for supporting daily operations and optimizing the current use of the terminal.

Moreover, ITS also concern real-time control, based on real-time data, which ultimately affects risk and resiliency factors of port terminal operations. In this regards, consideration could be given to using available data from a traffic monitoring system consisting of a network of radar sensors installed within the urban area of Catania (Torrisi et al., 2016). The traffic monitored area is broadly represented by the white coloured portion of the territory, whereas the grey portion identifies the neighbouring municipalities, which are not included (Figure 12).

This system could represent an excellent tool through which it is possible to obtain real-time traffic data (more details can be found in Torrisi et al., 2017a and Torrisi et al., 2017b) useful in carrying out more detailed mobility analyzes around to the port area.



Source: Torrisi et al., 2016

Figure 12: Traffic monitored area of Catania

This would allow to understand the inter-relationships between the Ro-Ro terminal traffic and urban mobility, since the port of Catania, given its location, it is characterized by a strong port-city relationship.

In the future, from the perspective of a modern logistics chain, almost all of terminal operators and road haulage companies will benefit from services available in such "intelligent networks" to make more efficient handling cargo inside the port and more generally the port terminal operations.

5 CONCLUSION

Ports play an important role in regions economic development and their planning and management are crucial aspects for achieving good standards in freight transport. The role acquired by ports has generated in recent year a huge increase in the movement of freight traffic and road transport, often causing an insufficient sizing of port terminal spaces and several social and environmental externalities.

Based on this premises, in this paper a methodological approach was identified in order to propose effective strategies to improve port operations, with a focus on the analysis of the terminal capacity.

The Eastern Sicily port system and specifically the ports of Catania was examined and, through in-depth analysis of freight traffic and operation, the port efficiency was evaluated making specific reference to Ro-Ro traffic and dedicated terminal spaces. Despite the recent works for the extension of the *Nuova Darsena* area, according to data acquired from the port authority and from the main terminal and logistic operators, it has been deduced that the terminal spaces are not sufficient. Therefore, a methodology to evaluate ro-ro terminal capacity has been applied in order to verify such evidence. These results have led to the proposal of different strategies to improve port operations, both in the short and in the long term, fostering the harmonization with Port of Augusta in the view of the recently introduced Port Authority System framework. Such strategies concern the increase of terminal capacity through the improvement of existing infrastructures; the reassignment of traffic to other ports in order to reduce the demand; and finally the implementation of technological and operation innovations primarily based on the use of ITS technologies. The first findings of this study might be adapted to the application to similar context and pave the way to the development of other intervention strategies to foster progress port operation.

Future research could address the analysis of further scenarios of improved port efficiency, encouraging a more comprehensive view orientated to the promotion of social, environmental and economic sustainability.

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INTEGRATED COASTAL ZONE MANAGEMENT IN THE REPUBLIC OF CROATIA

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ABSTRACT

The main part of this paper is dedicated to the Integrated Coastal Zone Management, its definition, description of the procedures, the legal frameworks and goals. Integrated development management unifies the methods of physical, environmental, social and economic planning. Integrated coastal zone management should be carried out in a coordinated manner, both at national and international level. In the 1970s began the history of coastal zone management in the region, when the Program for development of the United Nations launched a project focusing on tourism: Upper and Southern Adriatic. These projects are considered to be the basis of integrated planning and management of the Croatian coast. In Croatia, there is a need for an ecosystem approach (Maritime Spatial Planning - MSP), in order to achieve a balanced strategy of environmentally sustainable use of natural resources.

Keywords: coastal zone, integrated management, procedures, legal framework, the Republic of Croatia

1 INTRODUCTION

The coast is usually defined as a place where water, land and air meet, and the coastal area as the land and sea bordering the shoreline. The coastline enables determining the boundaries easily and there are no controversies concerning that, unlike discussions concerning the transverse axis entering into the depth of coastal areas. The water and underwater boundary of the maritime domain are defined by international maritime laws, whereas the land section of the maritime domain is still subject to imprecise criteria when determining boundaries (Olsen, 2000). The maritime domain and coastal zone comprise a complex system and its management requires an integrated approach by all subjects having an impact on the respective area. Integrated management implies a flexible management process with the aim of achieving sustainable development. It can be defined as the preservation of resource quantity and quality, not only for current needs, but also for future generations.

After the Rio Declaration (Declaration on Environment and Development, adopted in 1992, consisting of 27 principles important for sustainable development) and the Kyoto Protocol (a protocol relating to the Convention, with the main point of setting obligatory targets for reducing greenhouse gas emissions), the phrase sustainable development became common. The focus of sustainable development is a symbiotic relationship between the economy, environment and social progress. Sustainability is multidimensional and comprises economic sustainability, which in turn refers to autonomous subsistence. It is focused on increasing resources and optimal allocation, in order to meet human needs, environmental sustainability, involving the long-term survival of the natural environment and socio-cultural sustainability (http://www.ucc.ie/research/crc/papers/ICZM_Report.pdf).

The legal and policy documents at the EU level have been adopted for various sources of pollution and danger to marine environment (oil pollution, hazardous substances, the issue of municipal waste, eutrophication, reduction of biodiversity, habitat destruction, and maritime transport). They prevent contamination and lead to the creation of strategic and political models. However, at the EU level, there is no single document on protection of the marine environment which would include all important elements (Barić Punda, 2008).

Integrated management provides policy guidelines and procedures for determining objectives and priorities. This leads to a perspective and multi-sectoral approach that takes into account all sectoral and stakeholders' interests. According to Cummins (2016) the main principles of ICZM as defined by the EU are:

1. Adoption of certain views of interrelated problems;
2. Making decisions based on recent data and information;
3. Taking into account natural influences;

4. Inclusion of all stakeholders and all relevant sections of public administration;
5. The use of a series of instruments (laws, plans, economic instruments, information campaigns, voluntary agreements, promotion of good practices, etc.) for coastal zone management.

Guidelines and the European Union's strategy for environmental protection are:

1. The European Spatial Development Perspective (ESDP) which is a set of policy guidelines aiming to improve cooperation between sectoral policies. It involves an intergovernmental document of an indicative nature which is not binding, but the goals remain current as they closely relate to the objectives of the Europe 2020 strategy.
2. The European strategy for smart, sustainable and inclusive growth (Europe 2020) proposed in early 2010 was initiated as an EU strategy for smart, sustainable and inclusive growth. The strategy was developed in partnership between the EU and its Member States. It includes five main interrelated objectives which the EU must achieve by 2020 in the areas of employment, research and development, climate change and energy, education, combating poverty and social exclusion.
3. Blue Growth is a strategy for sustainable development of the marine and maritime domain. It forms the maritime dimension of the Europe 2020 strategy, providing clear indications in creating smart, sustainable and inclusive growth and employment opportunities. In the document, the Commission describes the existing measures upon which the Member States support blue economy, and identifies five specific areas that have special development potential: maritime and coastal tourism, green energy, marine mineral resources, aquaculture and blue biotechnology with the aim of harmonizing economic, social and environmental aspects.

2 ICZM PROCESS

Integrated Coastal Zone Management (ICZM) is defined as a dynamic process involving sustainable management and the use of coastal areas. Integrated management refers to integral and complex approach, sustainable development of coastal areas, and there are several types of integration to distinguish (Cicin Sain et al., 1998). They are based on the hierarchy of relevant administrative authorities, from the aspect of management, sectors of activity in coastal areas, cooperation between science and management, cooperation between official political bodies and non-governmental organizations, and economic entities, cooperation between regions, countries and economic associations.

One of the basic functions of management is setting objectives that are clearly defined and understandable because ambiguous can create misunderstanding and erroneous guidelines, which may result in conflicts. The objectives of integrated coastal zone management can be determined as general or individual, wider or narrower ones. The main objectives of ICZM are the utilisation of resources in terms of the receptive capacity of the resource base, restoration of damaged resources for traditional or new uses, preservation of coastal ecosystems, the mitigation of risks with respect to particularly sensitive resources, encouraging compliant activities. The function of integrated coastal zone management includes planning, proper use of coastal zones, environmental protection and conservation of biodiversity, maintaining the general safety against disasters caused due to the direct consequences of improper management.

Decision-makers may be at the local, regional, county or state level, depending on the geographic area of the process. It begins with the drafting of a document that provides an overview of the problems to be solved, the urgency, the restrictions of the current sectoral approach, the overall improvements that ICZM would bring in the current situation (Cicin Sain et al., 1998). The key is to present the proposal as an opportunity to strengthen interaction, and not as a threat to existing structures. Integrated management analyses the implications of the onset of inconsistencies and conflicts in internal relationships between natural processes and human activities, while proposing and promoting relations and reconciliation between different activities.

The implementation of ICZM has phases and models according to which it is implemented. One of the models is made up of five stages. The first stage is the initiation, problem identification and situation analysis, followed by planning. It also includes data collection, policy development and decision making. This is followed by the formal acceptance, funds sourcing and implementation, i.e. implementation which includes plan execution, action and maintenance. Finally, there are evaluation and validation. The stages are cyclical and each comprises tasks as part of a stage. Parts are different due to the geographical, social, economic, cultural or political background. The second phase includes planning and data collection, with the purpose to identify and support the proposals of decision-makers in establishing a continuous and integrated coastal and marine area (http://www.ucc.ie/research/crc/papers/ICZM_Report.pdf).

The program must be accepted by decision makers. The third phase consists of formal acceptance and securing of funds. There are two possibilities for financing integrated coastal zone management. One is the state budget, and the second is funding from participating institutions. Interest in the process of integrated coastal zone management can be encouraged among local authorities through the decentralisation of funds and granting greater autonomy. According to Cicin Sain (1998), mechanisms for financing ICZM include partnership between public and private sector (including risky ventures between local communities and the private sector), private sector funds (co-financing users of coastal areas), investment funds (investment opportunity), institutional arrangements, legal arrangements (conventions, laws, proclamations), financial arrangements (allocation of funds for covering costs).

The success of ICZM depends on a thorough preparation and proper monitoring system. A proper monitoring system must cover the entire area of interest and should include greater spectrum, including social (nationality, quality of life), economic (personal income, number of industrial companies, traffic between two regions), ecological (number of individual plants, the 'health' of the population, number of fruits), and physical part (location of the coastline, depth of channel, etc.). Maritime zoning and spatial planning are seen as a comprehensive process based on the ecosystem approach. It is implemented at multiple, national and regional level. Maritime area planning, along with land planning, is one of the prerequisites for successful ICZM. Ideally, the land and sea area are subject for joint planning, but the marine section is not developed as the land area. (Kordelj-De Vill et al., 2013).

3 ICZM IN CROATIA

The Adriatic Sea, islands and coastal areas are ecologically sensitive Croatian natural resources. There are 1244 islands, islets, reefs and rocks outcrops, with the coastal area occupying 22% of the territory of the Republic of Croatia along which is 25.6% of the population (411000 inhabitants). There are approximately 400 towns and cities along 700 km of coastline. Four of the six largest cities are located in coastal areas, of which Split and Rijeka are the largest. The main economic activities are tourism, maritime transport, fisheries. Irrational spending and lack of water in coastal areas and islands (during the summer), can affect the quality of the environment (Kordelj-De Vill et al., 2013).

The coastal area is the national interest of the country and the Constitution stresses that the sea, coastline and islands are to receive special protection due to the interest they pose. Development pressures on coastal and marine ecosystems and protected areas are numerous, but the most important are: intensive coastal urbanisation; aquaculture and mariculture; land and maritime transport; utility infrastructure; industrial production; transmission lines and electrocution; air transport; hunting of wild animals; collection of terrestrial plants, fungi and terrestrial invertebrates; fishing; the collecting of other marine organisms; the introduction of alien and invasive species; effects of climate change; recreational activities; contamination from liquid, solid and sea waste, air pollution; light pollution; noise pollution; forest fires; construction of dams and the use of freshwater ecosystems. These pressures do not have the same effect, but it is the synergic effect of numerous factors that provide an influence greater than the sum of individual disturbances. According to the Environmental Protection Agency, pressures that most threaten the Adriatic are damage to the landscape, reduction of value of agricultural and/or forest soils, overfishing, jeopardizing of cultural heritage and traditional way of life of island communities. The main disadvantages are the lack of vision in coastal development, non-existence of integrating the coastal land and sea in planning documents, insufficient sectoral integration and vertical coordination, overlapping powers in the management of coastal resources, lack of trust in institutions, inadequate professional capacities for undertaking ICZM and insufficient participation of stakeholders (Olsen, 2000).

One of the management tools for Integrated Coastal Zone Management is the strategic environmental assessment. According to the Croatian legislation it is required for most of the strategies and programs. There are advantages and disadvantages of implementing a strategic environmental assessment as a component of coastal zone management. The Strategic Environmental Assessment (SEA) is defined as a procedure for assessing major environmental impacts (Sorensen, 1993). It is necessary in creating a basis for promoting sustainable development, by summing requirements for environmental protection, strategies, and plans. Strategic Environmental Assessment must be proactive, transparent in all decision-making processes and enable public participation in the process. The further development of the Republic of Croatia requires implementation of the integrated planning and management of coastal areas (Katavić et al., 2015).

The history of coastal zone management began in 1970 when the Program for development of the United Nations launched a project focusing on tourism: Upper and Southern Adriatic. These projects are considered to be the basis of integrated planning and management of the Croatian coast. Adriatic III was launched under the same institution in 1978 and gives the basis of integrated planning and management of Croatian coastal zone. Unfortunately, implementation of an integrated coastal zone management failed because decisions on various projects were made without a proper assessment, at the local and also the national level.

In March 2013, the European Commission prepared a draft of the Directive Establishing a Framework for Maritime Spatial Planning and Integrated Coastal Management, where Member States are obliged to draw up national management strategies for coastal zones that are to be bound to the Commission's Recommendation on Integrated Coastal Zone Management of 2002 (2002/413/EC) and the ICZM Protocol. Based on this Directive, the Commission proposes the joint development of two processes - Integrated Coastal Zone Management ICZM and the planning of marine areas (Vladušić, 2009). Croatia has committed itself in adopting the Act on Ratification of the Protocol on Integrated Coastal Zone Management (ICZM) of 2013, to integrate spatial and economic planning as well as protection of the environment. Croatia has accepted the international obligation to undertake spatial planning in its coastal areas, as well as environment and nature protection, cultural heritage protection and a policy of sustainable development of the coastal economy. Although the protocol can be characterised as a compromise in certain provisions, it requires vertical and horizontal coordination of all stakeholders in coastal development management, and effective coordination of parties to the Protocol. However, determining the land borders requires adhering to the criteria of political acceptability, administrative feasibility and the potential threat to coastal ecosystems.

4 CONCLUSION

The coastal area is the national interest of the country and the Constitution stresses that the sea, coastline and islands are to receive special protection due to the interest they represent. The sectoral approach cannot provide an adequate solution because of its dependence of human activities and resources. The only solution for improvement is in integrated development management, where spatial planning is one of the key elements. There is a need for an ecosystem approach (Maritime Spatial Planning - MSP), in order to reduce conflicts presented by interest groups. It is of great importance to achieve a balanced strategy of environmentally sustainable use of natural resources, which can be attained by preserving biodiversity. There should also be the institutional mechanism to harmonize different activities that affect our coastal area and its resources. Achieving this goal requires effective management, establishing and maintaining the best method of utilisation and sustainable levels of development and activities in coastal areas. Islands which are unique in Croatia require a high degree of integrated coastal management. This management understands existence of sectoral policies, enforcement mechanism and environmental impact assessment procedures.

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CONSUMPTION AND ACTIVITIES OF TOURISTS IN CRUISE TOURISM IN THE REPUBLIC OF CROATIA - CASE STUDY OF PORT OF ROVINJ

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ABSTRACT

Cruise tourism is a type of tourism that is rapidly evolving around the world and makes one of the bases of development for many countries, including the Republic of Croatia. In this scientific paper, the activities of cruising tourists and their consumption in the destination Rovinj will be analyzed. At the same time the aim of the paper is to determine the overall impact of cruise tourism on the economic aspects of each destination and to show the dynamics of this form of tourism. The research was based on collecting primary data through a personal interview with tourists in the surroundings of Rovinj destination. The socio-demographic profile of the passengers was interrogated, as well as the basic information about the passengers, their activity and consumption in the destinations, and the degree of satisfaction with the elements of the offer. One of the objectives of the research was to determine the correlation between individual segments of consumption in the destination. The results of the research carried out in this scientific paper indicate the overall satisfaction of tourists in certain segments such as maintaining the city and its surroundings, hospitality and providing tourist information. However, at the same time, the results point to the need for improvement and additional investment in the destination, in all segments, from the port area to city sights and communal infrastructure. Furthermore, the research results enable the segmentation of the markets of cruising tourists in the country, determining the main advantages and disadvantages of the tourist offer of Rovinj and determining the characteristics of the cruise tourism.

Keywords: Cruise Tourism, Port of Rovinj, Tourist's Consumption

1 INTRODUCTION

The cruise tourism is very significant for the Republic of Croatia and it is developing quickly, forming the basis for development of tourism in general. Cruise tourism is very significant, since cruise ships are considered floating hotels that bring tourists on daily basis, affecting a destination directly, by direct spending on souvenirs, refreshments etc., and indirectly, by creating new workplaces in the activities connected to cruise tourism. In Croatia, international cruise tourism may be organized in ports open for public transport (ports of special or international importance, county and local ports). About twenty public ports with various intensity of visits are included in international cruise tourism in Croatia, from the largest ones, such as Split, Rijeka, Dubrovnik etc., followed by county ports, including Rovinj, which is elaborated in detail in this paper, and other ports such as Pula, Korčula, Mali Lošinj etc., to the small, local ports, such as ports on Lopud, Mljet, Šipan, etc. (Gračan & Zadel, 2013, p. 51)

Tourism in general, with cruise tourism as a part thereof, makes significant, direct contribution to GDP, and it amounted to USD 2,306.0 billion (3.1 % of GDP) in 2016. It is expected to increase by 3.8 % in 2017, amounting to USD 2,394.2 billion. The above said is primarily reflected by the economic activity created by industries such as hotels, travel agencies, airline companies and other passenger transport services. However, that also includes, for example, the activities of restaurants and recreational industries, directly supported by tourists. Tourism as an economic activity plays a significant role in Croatia, and its share in the economy exceeds the world average, amounting to 18 % of GDP.

For the purposes of this scientific paper, a survey was performed among 138 cruise ship passengers at the destination of Rovinj in 2014, and primary information were collected via personal interviews. The basic content of the research includes social and demographic profile of the passengers, the activities that the passengers participated in Rovinj, and their attitudes towards the offer, i.e. the level of satisfaction with the elements of the offer.

2 RESEARCH RESULTS

In 2016 in Croatia, there were 825 cruises by foreign ships with 1,092,199 passengers, who stayed in Croatia for 1,813 days. Compared to the same period of 2015, the number of cruises increased by 7.4 %, and the number of passengers who entered the Republic of Croatia in that manner increased by 4.2 %. The total number of days the ships stayed in the same period grew by 15.9 % (Croatian Bureau of Statistics, 2017). By comparing the data from 2014, it can be said that the number of cruises in 2016 increased by 17.02 %, while the number of passengers grew by 6.92 % (Croatian Bureau of Statistics, 2015).

2.1 Social and demographic properties and tourist activities at the destination of Rovinj

According to the research results, it was concluded that the largest number of cruise ship tourists comes from the United States of America and Germany. Furthermore, there are also tourists from Canada, Brazil, New Zealand, and South Africa, and tourists from various European countries who, in total, are the most numerous. Concerning the age structure, the most cruise ship tourists are middle-aged, i.e. more than 70% of the participants in the survey were older than 50. Almost 13% of the interviewees were between 41 – 50 years of age, and only 10% were younger than 40.

Taking into consideration that most tourists consider ships, especially the big ones, their primary destination of a cruise, the ports of docking become secondary destinations. In those ports, as a rule, only a certain number of passengers and crew disembark and temporarily stay on dry land. The research results showed that 89% of the interviewees spent the average of 1 – 6 hours at the destination of Rovinj. Only 5% of the interviewees spent 6 – 12 hours at the destination, and the remaining of 6% did not disembark at all. The above said also depends on the average time that the cruise ship spends in the port. Furthermore, 94% of the interviewees visited and explored the destination while the ship was docked in the port, while 4% participated in organized excursions outside the destination. It is important to note that most tourists who go on organized excursions outside the destination are the tourists staying at the destination for more than 6 hours; however, it is not an exclusive precondition. To conclude, very few tourists staying at the destination of Rovinj for less than 6 hours go on organized excursions outside the destination, and 67% of the interviewees returned to the cruise ship before that time, which leaves the destination with the room for development and introduction of new contents which shall keep the tourists out of the ship for longer, and as a consequence encourage increased spending.

2.2 Tourist spending at the destination of Rovinj

Tourism rapidly changes economic and social image of a country and tourist phenomenon, such as cruises, has already been transformed in a serious social and economic activity. The cruise tourism enables charging natural activities and other available resources, while tourism inspires, directly and indirectly, the development of numerous economic branches and activities. The above said results in more workplaces, creating additional income, increasing the standard, decreasing emigration and encourages improvement of public utility equipment, country's balance of payment, domestic product and national income (Perić & Oršulić, 2011, p. 222).

Tourist spending at the destination is the most significant research element of this paper, and special attention was paid to the same. According to the World Travel and Tourism Council, the passengers in maritime cruises spend 30% less than stationary guests, which provides each destination with the chance to improve its tourist offer. However, the marketing concept of cruise tourism is based on implementation of the contents of the receptive cruising country in the offered package. It makes it clear that the cruising company needs not take care of sustainable and responsible spending of the receptive country resources, because when it loses its market value, the cruising company shall change its route, changing also the ports it takes its guests to (Šerić & Režić, 2014, p. 3).

Table 1: Total and average spending by interviewees per category

Number of responses	% of passengers spending money	Total spending (EUR)	Average spending (EUR)	Min	Number of responses	% of passengers spending money	Total spending (EUR)
Souvenirs	69	47 %	1 540.00	22.32	5	65.00	10.55
Clothes and accessories	28	19 %	904.00	32.29	10	100.00	6.19
Domestic food and alcoholic drinks	33	22.6 %	885.00	26.82	3	75.00	6.06
Refreshments	84	57 %	734.00	8.95	1	100.00	5.03
Transportation (taxi, bicycles, motorcycles)	12	8.2 %	205.00	17.08	8	35.00	1.40
Entertainment	21	14.4 %	400.00	19.05	10	70.00	2.74
Postcards	31	21 %	111.50	3.60	0.5	10.00	0.76
Museum tickets	3	2 %	17.00	5.67	3	7.00	0.12
Organized sightseeing	5	3.4 %	115.00	23.00	15	40.00	0.79
Other	1	0.00 %	10.00	10.00	0	10.00	0.07
TOTAL			4 921.50	16.85			33.71

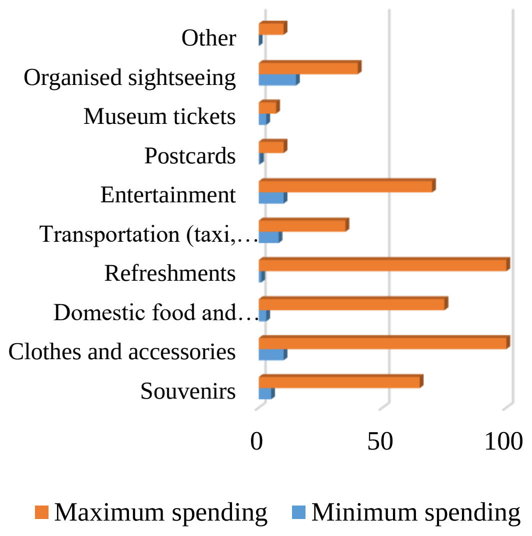
Source: Processed by authors based on the performed survey

The above table displays the spending patterns of the interviewees according to ten different categories, and presents the number of answers per specific categories, the total spending per category, average spending in each category, minimum and maximum spending and average spending per interviewee.

The total spending by passengers on cruise ships amounted to EUR 4,921.50, and most of that amount was spent on souvenirs (EUR 1,540.00), clothes and accessories (EUR 904.00) and buying domestic food and alcoholic drinks (EUR 885.00). Furthermore, the total average spending of all cruise ship passengers at the destination of Rovinj in the observed period amounted to EUR 33.71. That money was, on average, mostly spent on clothes and accessories (EUR 32.29), organized sightseeing (EUR 23.00) and buying souvenirs (EUR 22.32). By analyzing average spending per interviewee, the conclusion is that tourists mostly spend money on souvenirs, EUR 10.55 on average, while the overall average spending at the destination of Rovinj amounts to EUR 33.71.

All income and effects of marine cruises to the economy of a destination are observed through various economic data and through their influence to GDP, employment or unemployment, increase of salaries, and statistics of population and workforce. Direct effects created by tourists at a destination influence employment and salaries in the sector providing goods and services. Direct jobs that are created generate spending and income in other sectors of goods and services, since the employees spend their income on other goods and services, which again creates new jobs and new workplaces.

In order to see the tourist spending in more detail, minimum and maximum spending was analyzed in each category giving detailed results displayed in the range on the following figure.



Source: Processed by authors based on the performed survey

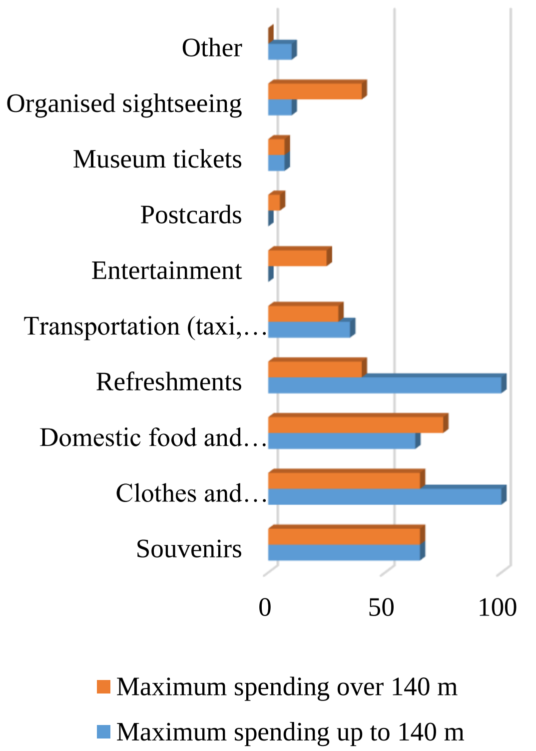
Figure 1: Minimum and maximum spending by passengers per categories (in EUR)

As is clear from the figure, the spending range for e.g. souvenirs amounts to EUR 5 – 65, the range for clothes and accessories is somewhat greater EUR 10 – 100, as well as for refreshments, from EUR 1 – 100. The said parameters depend on the market prices of each category, but also on the readiness of tourist to spend money.

Furthermore, the analysis was made pursuant to the group of interviewees per size of the cruise ship, i.e. it was analyzed whether the interviewees spend more if they stayed on larger cruise ships. In order to enable analysis, the cruise ships were divided into three sizes, and depending on the length of the ship, the accommodation capacity differs:

- Ships up to 100 m long
- Ships from 100 to 140 m long
- Ships from 140 to 200 m long

Since few interviewees were from ships up to 100 m long, their statistical indicators cannot be considered representative. Therefore, only tourists from medium-sized and large cruise ships were taken into consideration. Average spending per individual item is displayed in the figure below.



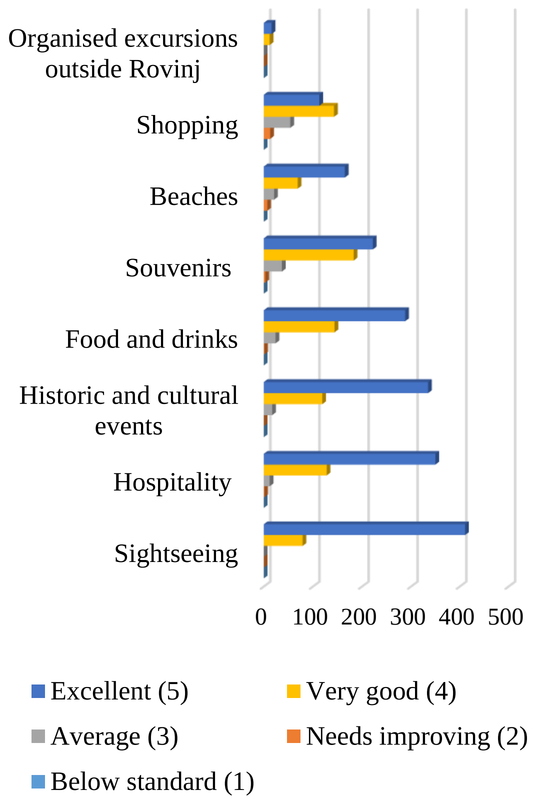
Source: Processed by authors based on the performed survey

Figure 2: Minimum and maximum spending by passengers per categories (in EUR)

It can be concluded from the previous figure that there are no significant differences in spending by cruise ship tourists from ships of different sizes. Most of spending refers to refreshments (from EUR 40-100), and clothes and accessories (from EUR 65-100). Furthermore, approximately EUR 75 is spent on domestic alcoholic drinks and food on big cruise ships, and EUR 63 on medium sized cruise ships. However, there is significant difference in organized sightseeing, in which the interviewees from large cruise ships participate more often. The above said is connected to longer stays of large ships in the port, compared to smaller cruise ships, which also confirms the conclusion by the Tourism Institute that the average spending per person is proportionate to the length of stay at the destination, i.e. that the average spending per person increases with the increase of the length of stay at the destination (Institut za turizam, 2008, p. 9).

2.3 Satisfaction with the destination and recommendations for further development

The total satisfaction with the destination of Rovinj within the survey included the levels of experience in different categories, such as sightseeing, hospitality, historic and cultural events, food and drinks, souvenirs, shopping, organized excursions outside Rovinj, etc. The research results are displayed in the following figure.



Source: Processed by authors based on the performed survey

Figure 3: Level of satisfaction at the destination of Rovinj

The level of satisfaction in almost all categories is high, although there is a tendency to improve shopping in the city, the appearance and facilities of the beaches, and the possibility of purchasing souvenirs and their diversity. Furthermore, average grades were calculated by statistic calculations for each category, which is clear from the following table.

Table 2: Satisfaction of tourists with the destination of Rovinj expressed by average grades

Category	Average grade	Category	Average grade
Sightseeing	4.86	Port	4.74
Shopping	4.30	Tourist information	4.62
Historic and cultural events	4.65	Land transport	4.20
Beaches	4.66	Welcome	4.46
Hospitality	4.58	Duration of docking	4.40
Food and drinks	4.59	Knowledge of language	4.44
Organized excursions outside Rovinj	4.75	Tourist signalization	4.37
Souvenirs	4.37	Kindness of hosts	4.65
Other	5.00	Maintenance of the town and the surrounding area	4.68

Source: Processed by authors based on the performed survey

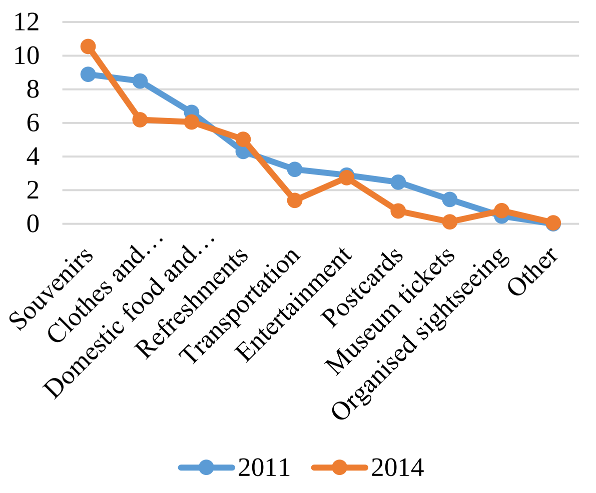
The overall satisfaction of tourists got high grades, and the results may be considered satisfactory, especially when it comes to sightseeing of the town, organized excursions, port appearance, the and functionality and maintenance of the town and the surrounding area. However, the results indicate that land transport, tourist signalization and knowledge of languages by the local population needs improving, and therefore they need to be improved also for the purpose of developing cruise tourism at the destination of Rovinj. The cruise tourism at the Croatian coast of the Adriatic, which is the third largest in the Mediterranean, is partially based on the development of ports for reception of cruise ships. The ports for reception of large cruise ships make indisputably good business, achieving high financial results. However, as can be seen from the previous results, there is room for development and improvement in certain segments, both in the offer and in the infrastructure and superstructure of the destination.

3 COMPARISON OF RESEARCH FROM 2011 AND 2014

Cruise ship tourists were also interviewed in 2011, and below are the results compared to the results from 2014.

Most of the passengers from 2011 were from Great Britain and the United States of America, while in 2014 tourists from Germany and the United States of America prevailed, although most tourists in both surveys were from European countries. Furthermore, most of cruise ship tourists were middle-aged, both in 2011 and in 2014. Namely, more than 70 % of the interviewees were older than 50.

Spending is the element of utmost significance for the observed destination, and comparison of average spending per interviewee, according to ten different categories in 2011 and in 2014, is presented in the following figure.



Source: Processed by authors based on the performed survey
Figure 4: Comparison of average spending per interviewee in 2011 and 2014

The total spending amounted to EUR 38.87 in 2011, while it dropped to EUR 16.85 in 2014, which is not positive for the destination of Rovinj, since the same or increased spending by tourists is expected year after year. Souvenirs were what that the interviewees spent most on in both 2011 (EUR 8.89) and in 2014 (EUR 10.55). Furthermore, the money spent per interviewee on clothes and accessories amounted to, on average, EUR 8.50 in 2011 and EUR 6.15 in 2014. In the category of organized sightseeing, the least average spending per interviewee was noticed, EUR 0.47 in 2011, and EUR 0.79 in 2014. One of the reasons for that is the fact that passengers who usually go on such excursions outside the destination are the passengers who stay at the destination for more than 6 hours.

4 CONCLUSION

Cruise tourism, as one of the three basic types of nautical tourism, has been continuously developing at a high rate both on the world market and on the Croatian market; therefore, it is necessary to take into consideration the tourists visiting the destination in order to bring the offer in compliance with their demand. The research conducted and analyses performed indicate the tourists are mostly satisfied with the observed destination of Rovinj, and their overall satisfaction received a high grade. Most cruise ship tourists in Rovinj in the observed 2014 were from Germany and the United States of America, and more than 70 % of the interviewees were older than 50. The total spending of interviewees amounted to EUR 4,921.50, while the average spending per interviewee amounted to EUR 33.71. The cruise tourism creates direct income to the destination of its docking, presented in spending of tourists on souvenirs, refreshments, clothes, accessories etc. Furthermore, there are indirect effects as well, such as creating new jobs in the economic activities connected to the cruise tourism, and creating income in other sectors, since employees spend their income to other goods and services. All of the above contributes to the increase of the destination standard, decrease of emigration of the population, and encourages the increase of the domestic product and national income.

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"I JUST DIDN'T THINK IT WAS GOING TO SINK": SNYCHRONOUS CORPUS ANALYSIS OF PRONOUNS USED WITH REFERENCE TO SHIPS

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ABSTRACT

The use of the personal pronoun 'she' with reference to ships has been historically established in maritime language for many centuries. In 2002, however, the Lloyd's List, a daily newsletter published in London on shipping issues since 1734, decided to abandon this traditional practice and has since then referred to ships with the neutral pronoun 'it'. The paper will use qualitative and quantitative synchronous corpus analysis to explore the use of the feminine pronoun 'she' ('her') and the neutral pronoun 'it' ('its') with reference to ships in texts published by the online magazine *The Motorship* in 2010 and in 2017-18. Given the dynamic and variable nature of language, it is expected that the traditional use of 'she' ('her') has been replaced by the use of the neutral 'it' ('its') in most contexts but that the traditional form still has not entirely disappeared from written maritime language.

Keywords: Ship, pronouns, synchronous corpus analysis, *The Motorship*

1 INTRODUCTION

The reasons why ships have traditionally been referred to using the feminine pronoun 'she' are not very clear and have been lost in the meanders of history. According to some theories, this depends on the feminine gender of the Latin word for ship, *navis*. More romantically bent theories claim that ships reminded seafarers of important women in their lives or the feeling of being protected in their mothers' wombs. Others might say that the function of the ship, like that of the mother, is to contain. Possibly, female names and thus the use of the pronoun 'she' were used to invoke goddesses to help seafarers navigate through the perils of oceans. Even today some shipping companies are preserving the tradition of giving their ships mostly female names. For example, seven out of eight E-class container ships of the Maersk company have been given female names (Emma, Estelle, Eleonora, Evelyn, Ebba, Elly, Edith), the only exception being Eugen, which can actually be a feminine or masculine name.

As defined by the Oxford English Dictionary (OED; http://www.oed.com), the personal pronoun 'she' can be used to refer to an inanimate object when what it denotes is personified or traditionally treated as female. Thus, 'she' has been conventionally used to refer to boats or ships but this use is, according to the OED, now to be considered colloquial or regional. The Collins dictionary (https://www.collinsdictionary.com) does not limit the use of 'she' to regional and colloquial contexts but rather to professional communities, and states that it is often used to refer to ships or boats by those who sail frequently. Finally, the American Merriam-Webster (https://www.merriam-webster.com) links the use of 'she' to refer to inanimate objects with personification, in other words, using it for objects considered feminine. However, in its Learner's Dictionary format, the Merriam-Webster adds that this use of 'she' is to be considered somewhat old-fashioned.

The four conventions that constitute the pillars of the international regulatory framework of the maritime industry all use the neuter pronoun 'it' with reference to ships, as is corroborated by the following examples:

- International Convention for the Prevention of Pollution from Ships: "/…/ the Party carrying out the inspection shall take such steps as will ensure that the ship shall not sail until **it** can proceed to sea without presenting an unreasonable threat of harm to the marine environment." (International Maritime Organization, 1978, 8)
- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers: "A Party may afford a ship which is entitled to fly its flag the benefits of the nearcoastal voyage provisions of the Convention when **it** is regularly engaged off the coast of a non-Party on near-coastal voyages as defined by the Party." (International Maritime Organization, 1995, 24)[1]
- Maritime Labour Convention: "A maritime labour certificate, complemented by a declaration of maritime labour compliance, shall constitute prima facie evidence that the ship has been duly inspected by the Member whose flag **it** flies /…/" (International Labour Conference, 2006, 73)
- International Convention for the Safety of Life at Sea: "The survey shall be such as to ensure that the ship, as regards the structure /…/ is in satisfactory condition and is fit for the service for which **it** is intended, and that it complies with the requirements of the present regulations and of the laws, decrees, orders and regulations promulgated as a result

[1] The author is aware of recent amendments to some among the listed conventions. These versions of the texts were used because they are available online in the electronic format and thus searchable.

thereof by the Administration." (International Maritime Organization, 2009, 18)

Among other conventions of the International Maritime Organization, the International Convention on Loadlines from 1966 and the International Convention on Tonnage Measurement of Ships from 1969 also use the neutral pronoun 'it:

- International Convention on Loadlines: "Any such ship shall, however, comply with safety requirements, which, in the opinion of that Administration, are adequate for the service for which **it** is intended and are such as to ensure the overall safety of the ship and which are acceptable to the governments of the States to be visited by the ship." (International Maritime Organization, 1966, 9)
- International Convention on Tonnage Measurement of Ships: "The privileges of the present Convention may not be claimed in favour of any ship unless **it** holds a valid certificate under the Convention." (International Maritime Organization, 1969, 5)

Interestingly, the International Regulations for Preventing Collisions at Sea use the feminine pronoun 'she': "When a vessel is in any doubt as to whether she is overtaking another, **she** shall assume that this is the case and act accordingly." (International Maritime Organization, 1972, 25)

Authors of maritime fiction or prose that depicts imaginary or real events and people from the maritime world are, for the very nature of their writings, freer to decide which of the two pronouns their will prefer to use. The following is an excerpt from Joseph Conrad's Youth, a short story on a young sailor's first maritime journey to the East: "The ship also was old. **Her** name was the Judea. Queer name, isn't it? **She** belonged to a man Wilmer, Wilcox—some name like that; but he has been bankrupt and dead these twenty years or more, and his name don't matter. **She** had been laid up in Shadwell basin for ever so long. You can imagine **her** state. **She** was all rust, dust, grime—soot aloft, dirt on deck. To me it was like coming out of a palace into a ruined cottage. **She** was about 400 tons, had a primitive windlass, wooden latches to the doors, not a bit of brass about **her**, and a big square stern."

Approximately fifteen years ago, the Lloyd's List, a journal on shipping news with a tradition almost 300 years long, decided to abandon the use of 'she' to refer to ships in order to modernise the language used by their authors and make it in line with that used by other news agencies (Hibberd & Woolcock, 2002). Given that the dictionaries mentioned earlier limit the use of 'she' to colloquial or regional contexts, most international conventions prefer the neutral pronoun 'it', and the Lloyd's List has officially abandoned the use of 'she', the aim of this paper is to establish whether the feminine pronoun 'she' has entirely disappeared from use in the maritime sector or whether its use with reference to ships has survived in texts targeting the professional audience of the maritime industry.

The research questions that this paper addresses are:

- Are the pronouns used with reference to vessels found among the keywords in the specialised corpus as compared to the British National Corpus?
- What is the frequency in use of feminine or neutral pronouns with reference to ships in the specialised corpus?
- Has the frequency of feminine or neutral pronouns used with reference to ships changed in the last decade?

2 METHODOLOGY

A specialised corpus that contains 108 texts from two volumes of the online journal *The Motorship* was first created in Microsoft Office Word for Windows. The headquarters of *The Motorship* are located in Fareham, UK, and the magazine regularly publishes opinions and news related to the maritime industry. The news subsection is divided into news on ballast water management, conferences, equipment, fuels and oils, historical reviews, industry news, LNG, people on the move, propulsion, regulation, repair and conversion, ships and yards, and ships of note. All texts were derived from the subsection on the news on ships and yards. This subsection was selected because it was expected that it would contain numerous references to vessels and thus pronouns that are used to refer to them.

The specialised corpus consists of two subcorpora. The first subcorpus represents 36 texts that were published in the Ships & Yards subsection of *The Motorship* in the year 2010, which is when the journal started publishing content on ships and yards online. The second subcorpus contains 72 texts containing news on ships and yards published from 1 January, 2017, through 20 February, 2018. This time frame was chosen to include data as recent as possible, which would enable the identification of changing trends in relation to the use of pronouns used with reference to ships. Data for both subcorpora are presented in Table 1.

Table 1: Corpus data (*The Motorship*, Ships & Yards)

	2010	2017-18
Number of texts	36	72
Number of types	26,370	47,039

As data presented in Table 1 show, the 2010 subcorpus contains 26,370 types while the 2017-18 subcorpus is larger and contains 47,039 types (in other words, the total number of words that occur in each of the two subcorpora). All texts were accessed online in electronic format. Corpus construction took approximately two hours.

3 RESULTS

The first research question aims to establish whether the pronouns used with reference to vessels can be found among the keywords in the specialised corpus as compared to the British National Corpus, which represents a wide-cross section of current British English.

AntConc 3.5.2. was the main application used to build the wordlist and extract the keywords. Any word that was found to appear in the specialised corpus significantly more often (at the level of p=0.000) than in the referential corpus was considered "key". The purpose of this step of analysis was to find whether the pronouns that can be used with reference to vessels (she, her, it, its) are used statistically significantly more often in the specialised corpus than in the referential corpus. The rank, frequency, and keyness of the keywords from the 2010 ($p<0.0004$) and 2017-18 ($p<0.0003$) subcorpora ranked by effect size are presented in Tables 2 and 3 respectively.

Table 2: Keywords in the 2010 subcorpus

2010				
Rank	Freq	Key-ness	p	Word
1	4	20.67	0.0003	genset
2	4	20.67	0.0003	newbuild
3	4	20.67	0.0003	skysails

Table 3: Keywords in the 2017-18 subcorpus

2017-18				
Rank	Freq	Key-ness	p	Word
1	6	24.63	0.0002	azipod
2	5	20.53	0.0002	containership
3	5	20.53	0.0002	cruiseships
4	5	20.53	0.0002	easymax
5	6	24.63	0.0002	gensets
6	6	24.63	0.0002	handysize
7	6	24.63	0.0002	roro
8	5	20.53	0.0002	seaspan
9	6	24.63	0.0002	ship-management
10	5	20.53	0.0002	tweendeck

In the 2010 subcorpus, no keyword has the effect size of $p<0.0003$ and thus the three words with the effect size of $p<0.0004$ are presented in Table 2. Below each among these keywords is presented in an example taken from the 2010 subcorpus.

E1 (2010): … auxiliary power is afforded by three main **gensets** with D2842 prime movers from MAN Truck & Bus.

E2 (2010): The new class notations can be assigned to both **newbuilds** and vessels in service in conjunction with propeller shaft withdrawal.

E3 (2010): The **SkySails** kite system is one of the four core technologies that should make E-MAXair the 'greenest tanker in the world'.

In the 2017-18 subcorpus, ten words were found with $p<0.0003$. The first three are presented in examples taken from the 2017-18 subcorpus.

E4 (2017-18): They will be powered by two **Azipod** D units each, for polar conditions …

E5 (2017-18): … a series of **containerships** optimised for transits through the expanded Panama Canal has made its debut in the liner trade between Europe and South America.

E6 (2017-18): The central focus on the high value-added sectors of **cruiseship** and naval construction is elemental to the whole.

Next, the keywords lists were checked for the presence of the personal pronouns that can be used with reference to ships, more specifically 'it' (and its) and 'she' (and her). The rank, frequency, and keyness of these pronouns in the 2010 and 2017-18 subcorpora ranked by effect size are shown in Tables 4 and 5 respectively.

Table 4: 'It', 'its', 'she', and 'her' in the 2010 subcorpus

2010				
Rank	Freq	Keyness	p	Word
574	9	40.17	0.0007	her
220	23	110.72	0.0017	she
522	75	377.28	0.0055	its
524	94	475.12	0.0069	it

Table 5: 'It', 'its', 'she', and 'her' in the 2017-18 subcorpus

2010				
Rank	Freq	Keyness	p	Word
236	8	26.84	0.0003	she
671	18	66.33	0.0007	her
612	151	608.48	0.0061	it
				its

The data shown in Tables 4 and 5 indicate that the pronoun 'she' was used 23 times in the 2010 subcorpus and eight times in the 2017-18 subcorpus. Its keyness level dropped from 110.72 to 26.84. Two examples, one from the 2010 subcorpus and another from the 2017-18 subcorpus, are presented below.

E7 (2010): The vessel will still do an equally good, if not better, job as existing intermediate tonnage and will have ice class 1A. **She** will, of course, be built in accordance with the Stena MAX concept regarding redundancy, safety and large cargo intake on a shallow draught.

E8 (2017-18): Furuvik's sister vessel, the 7,700 DWAT Cymbidium, is currently in build. When completed in October **she** will be deployed in Mediterranean waters.

'Her' as the objective form of the pronoun 'she' was used nine times in the 2010 subcorpus and 18 times in the 2017-18 subcorpus. The keyness level slightly increased from 40.17 to 66.33. Two examples, one from the 2010 subcorpus and another from the 2017-18 subcorpus, are presented below.

E8 (2010): BG Diamond picked up **her** regular schedule in Rotterdam on January 18 following a positioning voyage from China …

E9 (2017-18): American Pride and **her** three sisters plus the preceding quartet for Crowley each embody the MT50 class …

The analysis of the pronoun 'it' and is objective case 'its' with reference to vessels first had to disambiguate between the uses of this pronoun with reference to other inanimate objects, as the one shown in the following example:

E10 (2010): Meanwhile, Viking Ocean Cruises already has Cathelco ICCP systems installed on six of **its** latest ships ordered from Fincantieri. It has now ordered a further two sister vessels from the Italian builder …

In this case, ‘its’ refers Viking Ocean Cruisers and not a vessel. As a result, a qualitative analysis of all sentences from both subcorpora that contain the pronoun ‘it’ or ‘its’ was made. The results are presented in Table 6 for the 2010 subcorpus and Table 7 for the 2017-18 subcorpus.

Table 6: Number of occurrences of the pronoun ‘it’ (‘its’) used with reference to vessels or other inanimate objects in the 2010 subcorpus

	2010		
	Vessels	Other inanimate object	Total
It	15	79	94
Its	19	56	75
Total	34	135	169

Table 7: Number of occurrences of the pronoun ‘it’ (‘its’) used with reference to vessels or other inanimate objects in the 2017-18 subcorpus

	2017-18		
	Vessels	Other inanimate object	Total
It	14	137	151
Its	9	161	170
Total	23	298	321

It was found that in the 2010 subcorpus ‘it’ was used to refer to vessels 15 times whereas in 79 other occurrences this pronoun was used to refer to other inanimate objects. Two examples of ‘it’ from the 2010 corpus used to refer to vessels are presented below.

E11 (2010): L’Hydroptère is an 18m long by 23m wide trimaran that rides on foils at speed and **it** has recently set a world record under sail at 51.6 knots.

E12 (2010): Towage and salvage specialist Multraship successfully brought the 1,258 dwt, St Vincent & Grenadine-flag general cargo vessel ‘Janina’ to safety after **it** was holed by a fishing vessel while at anchor at Buitenbanken, near Rotterdam.

In the 2010 subcorpus, ‘its’ was used to refer to vessels 19 times while 56 uses referred to other inanimate objects. Two examples of ‘its’ used to refer to vessels are presented below:

E13 (2010): With **its** engines running on LNG the vessel is said to produce 35-40% less CO2 than a conventional vessel of comparable size, 90% less NOx, no SOx and 99% fewer particles, and all this without using catalytic converters!

E14 (2010): The approval from DNV confirms that the Höegh LNG FPSO design complies with all rules and regulations and that there are no obstacles to **its** construction.

Similarly, in the 2017-18 subcorpus 'it' was used to refer to vessels 14 times while the other 137 occurrences of 'it' referred to other inanimate objects. Two examples of 'it' used to refer to vessels from the 2017-18 subcorpus are presented below.

E15 (2017-18): The vessel, designed by Norwegian design company Marin Teknikk, will be 176m long in total, making **it** the longest vessel to date to be built at the Kleven yard in Ulsteinvik.

E16 (2017-18): **It** is the third Hurtugruten ferry to call recently, following the 16,140gt explorer post ship Trollfjord and sister Midnatsol.

Moreover, in the 2017-18 subcorpus 'its' was used with reference to vessels nine times while the majority of uses (161) referred to other inanimate objects. Two examples of 'its' used with reference to vessels in the 2017-18 subcorpus can be found below.

E17 (2017-18): Just completed by GDD has been /…/ offshore cable and support ship Endeavor. **Its** propulsion system comprises two TH1500MZ bow Azimuth thrusters, two TH1000MKLR retractable Azimuth thrusters and one 56TT800ML tunnel thruster.

E18 (2017-18): The concept is one of imbuing a vessel with the ability to return to port by **its** own power after suffering a fire, flood or fault, while still affording passengers a certain level of habitability, comfort and sustenance, reducing the likelihood or need for evacuation.

An interesting choice was made by the author in the example presented below. Although ‘its’ is used in the first subordinate clause (its transit), the personal pronoun ‘she’ and not the neutral ‘it’ is used in the main clause (she docked).

E19 (2017-18): After completing **its** transit into the Caribbean Sea through the new Agua Clara Locks, **she** docked at Manzanillo International Terminal in Panama before proceeding to the Dominican Republic and across the North Atlantic to northwest Europe.

The last research question in this study explores whether the frequency of use of personal and neutral pronouns with reference to ships changed between 2010 and 2017-18, which are the time periods that the two subcorpora covered. Based on the data presented in Tables 6 and 7, no conclusive claim can be made regarding changes in the frequency of use of either the personal pronoun ‘she’ (and its form ‘her’) or neutral pronoun ‘it’ (and its form ‘its’) with reference to vessels.

4 DISCUSSION AND CONCLUSION

The general objective of this paper was to establish whether the feminine ‘she’ is presently still used with reference to ships, and to identify any changing trends in relation to the use of personal and neutral pronouns with reference to ships through time.

The analysis has shown at what seems to be an entirely arbitrary choice between ‘it’ (‘its’) and ‘she’ (‘her’) with reference to ships. If most international conventions published by the International Maritime Organization consistently use the neutral pronoun irrespective of the time frame in which they were published (43 years passed between the publication of the International Convention on Loadlines in 1966 and the 2009 version of the International Convention for the Safety of Life at Sea). The only exception to this rule seems to be the 1972 Convention on the International Regulations for Preventing Collisions at Sea in which 'she' is consistently used.

In the 2010 specialised subcorpus, both examined pronouns and their forms can be found in the keywords list. This indicates that they are used in this subcorpus statistically significantly more often than in the referential British National Corpus. The same finding applies to the 2017-18 specialised subcorpus with one exception: 'its' as a form of the neutral pronoun 'it' does not meet the effect size level of $p<0.000$ set for this study.

A disambiguation between uses of the pronoun 'it' (and 'its') with reference to other inanimate objects on one hand and ships on the other has shown that most occurrences of this neutral pronoun are not linked to ships. If this is taken into account, then we can see that the numbers of occurrences of 'it' versus 'she' with reference to ships in the 2010 subcorpus reaches similar levels (15 occurrences of 'it' versus 23 occurrences of 'she', and 19 occurrences of 'its' versus nine occurrences of 'her'). Similarly, in the 2017-18 subcorpus 'it' was used to refer to ships 14 times versus eight occurrences of 'she' whereas 'its' was used nine times versus 18 occurrences of 'her'.

Based on these findings it cannot be claimed that the frequency of occurrence of personal or neutral pronouns with reference to ships in the selected texts has significantly changed in the last decade(s). The choice whether to use 'she' ('her') or 'it' ('its') therefore seems to be entirely arbitrary and depending on the writer's personal preferences.

This study has only touched upon the uses of personal and neutral pronouns with reference to ships in two volumes of a single online journal that specializes in providing maritime news to the professional community. In order to reach conclusive results, other (written and spoken) genres would have to be subject to a comprehensive quantitative and qualitative analysis.

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THE ROLE OF REGIONAL ELECTRONIC NAVIGATIONAL CHARTS COORDINATING CENTERS IN THE PROVISION OF ENC SERVICES

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ABSTRACT

Electronic Navigational Charts (ENCs) have a very important role in modern maritime navigation. Their development and application on ships directly contributes to maritime traffic safety. The International hydrographic organization (IHO) has developed a whole series of ENC standards. Regional Electronic Nautical Charts Coordinating Centers (RENCs) have important role in the process of implementation of these standards. The RENCs are non-profit government services. They are operated on behalf of national hydrographic offices. To date, two RENCs – PRIMAR and IC-ENC, are in operation. The main role of RENC is to participate in the IHO data protection scheme. RENCs among other things, carry out the activities of collection, distribution and update of the ENCs. They maintain ENC databases and their updates. ENC cells and updates are available to end users through the network of authorized distributors. Although, a number of nations still distribute their ENCs individually either through individually appointed chart data suppliers or directly, many national hydrographic offices send their products to RENCs for the collection and distribution. The paper analyzes the organization and activities of RENCs within the IHO data protection scheme. The advantages and disadvantages of the scheme are considered with special emphasis on the solutions related to the whole process of using ENCs.

Keywords: Electronic Navigational Chart, RENC, Data protection scheme, Chart updates

1 INTRODUCTION

One of the most important activities of IHO and national hydrographic offices (HOs) in the last two decades is the development of a complete system for production, quality control, distribution, maintenance and data protection of ENCs. After the initial enthusiasm connected to the development and use of ENCs within the Electronic Chart Display and Information System (ECDIS) it has been noticed that there are many issues that needs to be resolved within the entire system. This paper discusses current approach to organization, activities and role of RENCs in the provision of ENC services. RENCs have been established in order to ensure successful and safe use of ENC within ECDIS and ECS. IHO has developed WEND principles that represents a common worldwide network of ENC datasets. RENCs are non-profit governmental entities that represent a link between the HOs. They perform the tasks of collection, validation, quality control, organization, distribution and protection of ENC data on a worldwide basis. The paper discusses all above mentioned tasks with a particular emphasis on the data validation and protection. These tasks are performed in a standardized manner, enabling end users the availability of verified and reliable official ENCs and HOs the ability to check the status and improve the quality of their products. RENCs also working on updating and organizing the distribution of ENCs. Updating is based on the collection of updates from HOs and their validation. Validated updates are delivered to end-users through a network of authorized distributors. This method allows end-users carrying up to date charts in accordance with the provisions of the Safety of Life at Sea (SOLAS) Convention. RENCs have developed two different distribution models, enabling the availability of ENC services worldwide. This paper analyzes the possibilities and limitations of these models.

2 THE ORIGIN OF THE REGIONAL ELECTRONIC NAUTICAL CHARTS COORDINATING CENTERS

RENC is an organizational entity where IHO Member States have established cooperation amongst each other to guarantee a world-wide consistent level of high quality data, and for bringing about coordinated services with official ENCs and updates to them [14]. This official definition emerges that RENC can be established by two or more HOs from the IHO member states. The definition also sets the basic scope of tasks for RENCs. These tasks are connected to quality assurance of products and services in order to provide availability and updating of official ENCs.

Conceptually, RENC has emerged within the framework of Worldwide Electronic Navigational Chart Database (WEND) principles of the IHO [21]. IHO has developed the WEND concept because of the need to establish a unified system that will define the overall objectives and the necessary principles required to produce and make ENCs available worldwide [5]. This meant that it was necessary to develop a set of worldwide standards that would regulate all issues related to the development of ENCs which will be used within ECDIS. IHO has developed these standards and harmonized them with the provisions of the SOLAS Convention and the requirements of the IMO Performance Standards for ECDIS. One of the cornerstones of WEND concept is that national HOs produce ENCs and their updates, while a separate entity/entities under the auspices of the IHO are working on issues connected to cooperation in order to ensure worldwide uniformity and availability of ENCs. IHO has developed WEND principles[1] from this concept, which, among other issues, also defines the role of RENCs in order to meet requirements of Chapter V of the SOLAS Convention and also the requirements of IMO and IHO for the successful application of ECDIS on ships. At the Norwegian Hydrographic Service (NHS) suggestion a worldwide Electronic Chart Center (ECC) has been established in Norway [1]. ECC plays a significant role in the sense of establishment and development of PRIMAR RENC by ensuring its technical operability and development of the ENC database. IHO WEND Committee has developed a conceptual model for data flow and organizational relationships for the purposes of ECDIS [1]. According to this model HOs produced ENCs and deliver them to the RENCs. RENCs organize database, perform validation, data protection, and ensure access of ENC to distributors. Distributors deliver these cells to end-users. In 1995 ECC in Norway embarked on a joint venture with the British Admiralty, which is the basis for the work of the RENC Northern Europe since then [5]. In late 1998, the RENC/NE established itself as the European ENC Coordinating Centre and adopted PRIMAR as the global brand name for its services [5]. PRIMAR was officially opened in 1999, as the first RENC in the world. After three years of its work, it has been concluded that appropriate changes are required in order to increase level of commercialization of ENCs with the aim to improve work on the distribution activities of them. It has been proposed to establish two RENCs [18]. PRIMAR was reorganized in 2002. At the same year the United Kingdom International Centre for ENCs (IC-ENC) was established. So, two RENCs, PRIMAR and IC-ENC are currently operational. Coordination between these two RENCs was formalized by establishing IC-ENC and PRIMAR Cooperation Committee (IPCC). In 2011 the IPCC has risen in RENC Harmonization Subgroup (RHSG) [22]. RHSG operates within the IHO WEND Working Group. Its scope, which has been agreed by the member nations of both existing RENCs, is to develop the most appropriate RENC structure for the IHO to achieve the WEND vision [22]. In this way, an appropriate institutional co-operation between the two RENCs under the auspices of IHO was achieved.

3 PRIMAR RENC

The PRIMAR is a non-profit governmental service operated by the NHS [20] on cost recovery basis and connected to ECC. The NHS hosted PRIMAR and provide technical support, while the ECC provide technical operability and administering ENC database. Its headquarters is in Stavanger, Kingdom of Norway. It was founded by 12 HOs (Belgium, Denmark, Finland, France, Germany, The Netherlands, Norway, Poland, Portugal, Spain, Sweden and the United Kingdom) [1]. Part of the member states that founded PRIMAR 2002 went to the new IC-ENC RENC. Current PRIMAR members are Albania, Croatia, Estonia, Finland, France, Georgia, Iran, Latvia, Lithuania, Montenegro, Mozambique, Norway, Poland, Russia, Sweden, Ukraine and Vietnam [20].

3.1 Organization of PRIMAR RENC

PRIMAR as an organization consists of relatively small number of employees, governing body and working groups. Employees ensure the continuous functioning of RENC, while governing body administering the organization. Members of the governing body and working groups shall be given by the Member States.

The PRIMAR RENC consists of:

- Advisory Committee,
- Strategic Working Group,
- Financial Working Group,
- Marketing Working Group and
- Technical Working Group [20].

The main governing body is PRIMAR Advisory Committee (PAC). The members through PAC controls PRIMAR. PAC provides guidance and advice on the RENC operation and exchange opinions on related topics of mutual interest [13]. The PAC meets once a year and decisions are made by consensus. Decisions can be made on strategy issues, technical issues (tools for ENC quality control, non-navigation services, etc.), marketing issues (pricing and distribution models, etc.), information, communication and financial issues (cost and revenue sharing, etc.) [13]. PAC is chaired by a representative from a member nation and this position is rotated amongst the members [20]. Working groups are subordinated bodies of PAC. PRIMAR ENC Service (distribution of ENCs and updates) is delivered via international network of authorized distributors. PRIMAR receives the data (ENC cells and updates) from its member states, other countries and organizations which participate in distribution agreements. Other countries which participate in distribution agreements currently are Canada, China, Hong Kong, India, Indonesia, Japan, Singapore and South Korea

[1] WEND Principles are defined in IHO Resolution K 2.19, which is part of the official publication of IHO M-3: Resolutions of the International Hydrographic Organization

[21]. PRIMAR also distributes data from countries that are members of the IC-ENC RENC [21].

3.2 Activities of PRIMAR RENC

The core services of PRIMAR are:

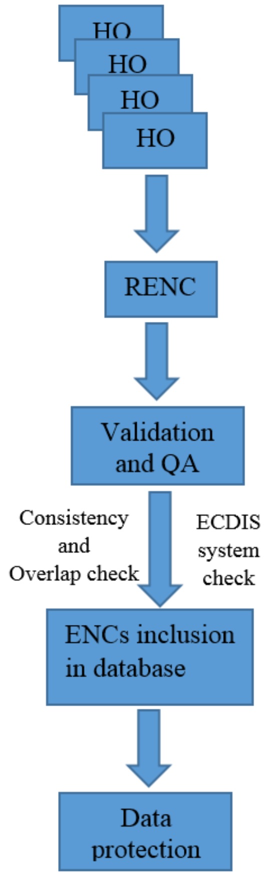
- Administration and signing of agreements,
- ENC production support,
- ENC Validation and Quality Assurance services,
- ENC data protection,
- Maintenance of PRIMAR ENC database,
- ENC distribution,
- Revenue management and
- ENC updates [19].

3.2.1 Administration, signing of agreements and ENC production support

The service of administration and signing of agreements for an administrative management of RENC, conclusion of bilateral agreements between HOs and NHS for RENC cooperation, licensing agreements, distributor agreements, navy supplier agreements and national agreements. The agreements covers all technical and legal issues connected to relations between PRIMAR and HOs (PRIMAR members and licensing partners), PRIMAR and distributors, and between PRIMAR and navies (navy supplier agreements for delivering of ENCs to the nation's own navy and/or coast guard under national discretion). The PRIMAR has no agreements with end users. ENC production support includes support from PRIMAR to HOs in all issues related to meet requirements of quality assurance of the ENCs in order to meet IHO standards and customer requirements.

3.2.2 ENC Validation, quality assurance and data protection

All ENC cells received by PRIMAR pass through validation and quality control processes. Validation is carried out to determine whether ENC cells are aligned with the corresponding IHO Standards. The validation process is carried out using specially designed computer tools. For the purposes of validation PRIMAR uses Validation Report Checker (VRC), Overlap checker, the S57 Advisor, dKart Inspector and ENC Analyzer. Each ENC must be upload into the PRIMAR database. The uploading is performing under Virtual PRIMAR Network (VPN). After that, a validation process started together with the quality control process. Validation is a formal process that consists of certain steps. It is performed using special tools. Within the validation, ENC cell consistency is going to be checked, which means that it is necessary to determine if there are vertical and horizontal inconsistencies of cell, in accordance with IHO S-65 and IHO S-57 (Use of the Object Catalogue) [20]. Figure 1 represents the concept of connections between elements for ENC approval.



Source: Authors

Figure 1: Concept of connections between elements for ENC approval

ENCs can be compared vertically, so that the content of two ENC cells can be viewed simultaneously [20]. At the same time, the ENC display will provide access to object/attribute information for the ENC cells being checked [20]. When choosing to check for horizontal inconsistency, the ENC border areas of two neighboring countries can be compared [20]. This step is checked using the internally developed software VRC [13]. The next step is overlap check. This step includes checking whether this cell overlaps with other cells (within the same navigational purpose) from the producing country and neighboring countries. The next step is data quality check in accordance with IHO Standard S-57. Then the cell is going to be converted into readable format. The last step is ECDIS system check. ENC cell is checked in two different ECDIS of different manufacturers [20]. Updates also pass through validation and quality control process as well as ENC cells. PRIMAR keep a database of all the inconsistencies and errors with the aim to inform the ENC cell manufacturer (HO) of inconsistencies and errors. Only the cells that successfully pass the entire validation and quality control process will be included in the PRIMAR database and available to end users. HOs have the ability to check their own cell status within VPN. Prior to release in commercial use, it is necessary to protect ENC cell. PRIMAR manages data protection (digital signatures and encryption) in accordance with the IHO standards S-63 Editions 1.0 and 1.1 on behalf of its member states [20]. ECC and UKHO were the original contributing organizations patented the Data Protection Scheme. IHO has accepted the scheme and include it in the Standard S-63 [15]. PRIMAR uses this Data Protection Scheme for the purpose of prevent copyright infringement and data piracy. According to the Data Protection Scheme, PRIMAR is one of the Data Servers, meaning that it is authorized to issue Cell Permit and Digital Signature for ENC-a, so that Data Clients, with valid user permits, can decrypt ENC data [15]. The purpose of this system is that only authorized end-user have the ability to decrypt the protected ENC cells (for which it has been approved) at the authorized ECDIS and with the ability of that ECDIS to verify the authenticity of the ENC cell. This is achieved by a complex asymmetric cryptography system by using the S-63 digital signature.

3.2.3 Maintenance of database, ENC distribution and revenue management

The PRIMAR database consists of ENCs from PRIMAR RENC member nations, from the IC-ENC RENC and from nations having license agreement with NHS [20]. The PRIMAR ENC database is continuously updated [20]. New data are continuously and promptly released for the benefit of online users, with CDs always provided for backup [20]. As of September 2017, the PRIMAR ENC database consist of more than 15 400 ENCs from 60 different nations [20]. PRIMAR database management allows a member nation to access its own data at any time by using VPN [19]. ENC distribution is carried out only through a network of authorized distributors. PRIMAR does not work directly with end-users of ENCs. Standard distributor agreement allows all PRIMAR distributors to resell encrypted ENC data from PRIMAR [13]. PRIMAR performs Revenue Management, which means that it manages all aspects of sales reporting, invoicing and revenue collection process on behalf of its member nations. PRIMAR has developed a whole range of services that enable 24/7 access to data in order to improve and simplify the use of services. One of these services is the system of ENC distribution named Pay as You Sail Service (PAYS). The PAYS has been developed in mutual coordination between PRIMAR and IC-ENC. PAYS enables on-line orders of only those ENCs that will be used for a particular passage.

3.2.4 ENC updates

The process of ENC updates is carried out in accordance with IHO standard S-63. This means that HOs submit updates to PRIMAR. PRIMAR encrypts these updates and prevent unauthorized use or changes in updates. The updates are organized and issued on a weekly basis. The updates are distributed through the Base CD and Weekly update CD. The Base CD is issued several times a year. The Weekly update CD is not released in the week when Base CD issued. In order to end-users meet the requirements of the SOLAS Chapter V, distributors (when selling ENC cells) have to provide them with the latest Base CD and Weekly update CD. The organization of update files prevent end-users from entering non-sequential corrections. This means that all previous ENC cell updates must be pre-entered before the last update is entered into this cell. By the end of 2017, PRIMAR has stopped providing distribution of updates in a CD form. Since then, PRIMAR continues to notify users about new updates and allows them direct download of these updates from the PRIMAR official web sites. The user registration is performed through the Chart Catalogue application. The application allows the ordering of ENCs and the registration of individual users (licensees) for which a unique user permit must be specified (composed of 28 alphanumerical marks). After the activation of order, the system automatically generates Cell permit for each individual ECDIS. Distributors deliver Cell permit to end-users. Each ECDIS is uniquely designated by its own user permit, which is used for registration of ECDIS in a unique ENC data protection system, in accordance with the IHO standard S-63. End-users receive appropriate keys (ENC permit) from distributors which enable them to decrypt databases (for which they have licenses) on their ECDIS.

4 IC-ENC RENC

In 2002, a number of European HOs split off PRIMAR and set up the IC-ENC, operated by the UKHO [24]. It is operated on a not-for-profit basis. The IC-ENC headquarters is in Taunton, UK. HOs of the UK, the Netherlands, Spain, Portugal and Germany founded the IC-ENC [17]. Since its establishment, the number of members has increased significantly. Currently there are 42 members of IC-ENC [9], of which Mozambique and Russia are at the same time PRIMAR members. IC-ENC has a slightly different structure than PRIMAR. It consists of employees and other bodies. Employees are general manager, and a team of cartographers, geographic information officers and other specialists [17].

4.1 Organization of IC-ENC

The IC-ENC operational structure consists of:

- Steering Committee (SC),
- Technical Experts Working Group (TEWG),
- Commercial Working Group (CWG),
- IC-ENC Headquarters (IC-ENC HQ) and
- Regional Offices (ROs) [4].

The SC is main governing body of organization. It consists of representatives of the IC-ENC member states. The SC meets on annual basis and its purpose is to oversee the operation of IC-ENC and provide strategic direction [17]. The SC oversees the work of its appointed working groups [4]. These groups are tasked to help with the technical and commercial work of IC-ENC and its participating nations [4]. The TEWG meets twice yearly and is responsible for setting standards that lead to the harmonization of data from the HOs [4]. It considers all aspects of data management, validation and usability of ENCs. The CWG assess, recommends and reviews issues related to ENC distribution, costs and revenues [4]. In order to promote Regional Offices Concept IC -ENC has been established three ROs (IC-ENC Australia, IC-ENC Latin America and IC-ENC North America) [10]. The ROs are a separate business units within the hosted HOs.[2] The main activities of the ROs are validation of regional data, collation the ENCs that have passed validation and supplies them to IC-ENC HQ for the distribution [11]. Validation of regional data is performed by trained personnel by using the same standards, software and working procedure as the IC-ENC HQ [11].

4.2 Activities of IC-ENC

- The core services of IC-ENC are:
- Independent ENC validation,
- ENC Production support,
- ENC Distribution and
- ENC Revenue management [7].

4.2.1 ENC validation and production support

Validation is performed on almost identical principles and with the same purpose as in PRIMAR RENC. All ENC cells received by IC-ENC are passing through the validation and quality control process. IC-ENC registers each ENC in order of receipt into its internal database and performs some initial checks [3]. The working practices set out the validation procedures, which include conformance to S-57 and S-58 IHO standards, vertical and horizontal consistency, and assessment of ENC display on ECDIS [23]. IC-ENC checks an ENC's data structure against both S-57 and S-58 standards, and also its data content by making a visual assessment [23]. IC-ENC uses validation software tools to assist in the validation of each ENC, including Jeppesen's dKart Inspector, and SevenCs' ENC Designer and ENC Analyzer [3]. The next steps in the validation process are visual assessment and other checks. This involves data assessing at the boundaries of adjoining ENCs that have identical compilation scales, and assessing data against larger and smaller-scaled ENCs which overlap it [3]. The purpose of this check is to identify any gaps or overlaps between adjoining cells within the same and different navigational purpose of ENC cells [23]. These checks are necessary in order to avoid serious problems for the users of ECDIS [23]. The data consistency and coverage between adjacent ENCs is generally checked using dKart Inspector and ENC Designer [3]. A visual assessment is made of the vertical and horizontal consistency of the ENCs in the area. This is done by accounting for the purpose of the ENC, voyage routes, prominent navigation features and so on [23]. All issues found are cross-checked on three different ECDISs to assess their impact on the mariner [3]. The assessment includes checking the clarity, consistency, application of SCAMIN (density of features when zooming in and out), and general usability of the ENC [23]. Additional checks include the assessment of datum, compilation scales, additional word and picture files, and CATZOC[3] suitability [23]. If any errors and inconsistencies are discovered during validation process, appropriate messages are generated. In this case the HO, producer of ENC cell will be informed by IC-ENC. The validation process ends with the issuance of the Validation report. Only the cell that passed validation process will be accepted for release. Each IC-ENC office conducts a full and independent validation to all ENC data before it is released to the market in accordance with the IC-ENC validation policy and procedures [16]. Updates also pass through validation and quality control process as well as ENC cells. IC-ENC ROs submitted validated ENCs and Updates to the IC-ENC HQ. IC-ENC supports HOs in the production of ENC cells. These tasks include the support of HOs in the entire process of production of ENC cells, technical support by the staff of IC-ENC to HOs, program support in terms of the use of appropriate software tools, the use of data from on-line IC-ENC Errors Database and technical support from the TEWG through technical advices and guidance provided to HOs.

4.2.2 ENC distribution and revenue management

The distribution of ENC cells is performed through the network of Value Added Resellers (VARs) and authorized distributors. IC-ENC as well as PRIMAR has no direct distribution to end-users. IC-ENC collates all the relevant ENC and Update files into an Exchange Set and securely sends ENCs and Updates to the VARs [3]. IC-ENC HQ delivers validated but unencrypted cells to the VARs weekly. VARs have access to the IC-ENC File Transfer Protocol (FTP) site and are able to download the latest Exchange Set from IC-ENC every week using standard Business to Business (B2B)[4] secure file transfer methods [4]. VARs deliver these cells and updates to distributors. Distributors are working with end-users. Current IC-ENC VARs are The United Kingdom Admiralty Vector Chart Service (AVCS), the Kelvin Hughes ChartCo, ChartWorld International, C-MAP, DATEMA, Maris As, NAVTOR and PRIMAR [8]. In the system of distribution of ENCs, the role of VARs is to participate in the IHO Data Protection Scheme as The Data Server, which means they are responsible for ENC encryption and distribution in accordance with the procedures defined by the IHO standard S-63. VARs issue licenses (a set of ENC Permit files) so that the Data Clients will be able to decrypt and use ENCS in the ECDIS. This organization of the distribution system is simpler than the one used by the PRIMAR. It enables distributors to develop more flexible solutions in that segment. This means that distributors can develop their own set of services and distribution methodology, according to their business policy and user needs.[5] IC-ENC manages all aspects of the VARs sales

[2] IC-ENC Australia is hosted by the Australian Hydrographic Service. IC-ENC Latin America is hosted by the Brazilian Directorate of Hydrography and Navigation. IC-ENC North America is hosted by the US NOAA. See more in [10].

[3] Category Zones of Confidence (CATZOC) is the official categorization for the accuracy of data presented on the nautical charts. CATZOCs had been developed by the IHO.

[4] B2B is one of the methods for the distribution of services. This method is used by both RENCs.

[5] For example, C-MAP has developed its own tailored service with various distribution options. These options are Flat Fee, Open ENC, Fixed Fee (PAYS), Dynamic Licensing and Direct Licensing. See more at [2].

reporting, auditing, invoicing and revenue collection process. An itemized sales report is provided on a quarterly basis to each member HO, and the revenue generated from these sales is then paid accordingly to each member by IC-ENC [12].

5 ANALYSIS OF CURRENT RENCS MODEL ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of existing models of data protection and distribution of ENCs can be viewed through the role RENCs, aspects related to HOs and end-users. The existing organization and activities of RENCs is compliant with relevant IHO standards and WEND Principles. RENCs play an extremely important role in the IHO data protection system. In this sense, it is necessary to emphasize the role PRIMAR, who was the first to apply this system. RENCs fully implemented standards of data protection, validation and quality control. This enables end-users to safely and authorized use the up-to-date ENCs, thereby complying with the provisions of Chapter V SOLAS Convention. Validation, quality control, ENCs and Updates check carried out by qualified RENCs personnel by using modern standardized computer tools as well as standardized procedures. The development of special services such as PAYS, Chart Catalogues, VPN, B2B, Web Map Service, and others, simplifies and speeds up the procurement process. The availability of ENC databases via internet enables HOs to check their own ENCs status at any time. Both RENCs play an extremely important role in the technical development of ENCs by participating in their own, their common and working groups of the IHO, thus directly contributing to the improvement of ENCs quality. Also, one of the most significant segments is the harmonization of HOs activities in the production of ENCs in order to avoid existing gaps, overlaps and inequity in the density of data presented on ENCs within the same navigational purpose for the ENCs of the one particular HO and neighboring HOs. This problem makes significant difficulties when using ECDIS. Although both RENCs emphasizing numerous benefits of the membership, the most significant advantages in the technical sense are improvement of data quality and consistency through independent data validation and quality control via standardized procedures and full implementation of the Data Protection Scheme in accordance with relevant IHO standards. A large number of HOs want to be an RENC member because the membership providing access to a larger market allowing them to get the widest possible distribution. On that way RENCs allows the HOs to focus on their core business – performing hydrographic surveys and production of nautical charts containing reliable and up-to-date hydrographic data, regarding their responsibility for the accuracy and reliability of data displayed on their ENCs. Furthermore, HOs are exempt from carrying out complex tasks of data protection, and all issues connected to ENC distribution. The advantages for shipping companies (that representing end-users) are that they can only purchase quality controlled and updated ENCs from the authorized distributors. The role of RENCs is that shipping companies sign agreements for procurement and updating of ENCs only with authorized distributors. There is no need to sign the agreement with any single HO (in case if it is a RENC member or licensed partner). This distribution principle reduces administration and speeds up the process. It is also important that end-users receive only secured data, thus avoiding the possibility of any use of unofficial or unreliable data. The disadvantages of the existing model can be considered through the existence of only two RENCs and a limited number of distributors, which in some way limits the development of the ENCs distribution market and the pricing policies. In some new decentralized distribution model it is likely to reduce ENCs prices.

6 CONCLUSION

RENCs are one of the most important components of the system that allows the distribution and use of official ENC data. The existing RENCs have a lot of similarities but some differences in terms of organization and scope of work. It is common for them to be non-profit government agencies that enable coordination and cooperation of HOs based on WEND principles. Both RENCs do not work directly with end-users. Each RENC collects the official ENCs and updates from HOs. Then validates, collates, and quality assures them according to standardized procedures. Only those ENCs that pass this process are included in the PRIMAR or VARs database and become available to end-users through the network of authorized distributors. This way allows end-users to carry out official and up-to-date charts. RENCs have a different operating systems and distribution models. PRIMAR performs the ENCs data protection prior to their inclusion in its own database, while the IC-ENC leaves these tasks to the VARs. IC-ENC develops ROs network, which performs collection, validation and quality control tasks. Although the RENCs are competing organizations they have established mechanisms for cooperation in order to improve ENC coverage. Thus, both RENCs play an extremely important role in the quality management and distribution of official ENCs. Both RENCs are developing new services available through the Internet. These services allow easy, fast, continuous and secure access to distributors, HOs, governmental and private agencies and ships.

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PORT OF KOPER FIGHTING THE GROWTH OF SHIPS AND TRYING TO ACCOMMODATE LARGE CONTAINER VESSELS USING A LASER-RANGING SYSTEM

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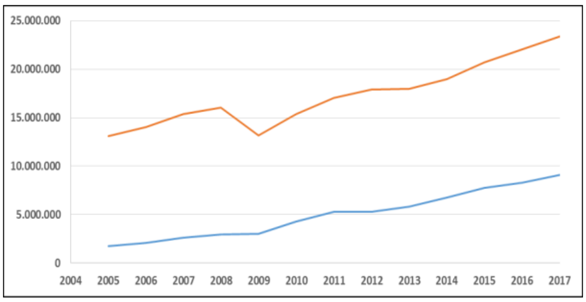
ABSTRACT

The tendency of commercial ships getting bigger and better does not always benefit everyone involved in maritime business. More precisely, ships are getting "finer" shaped hulls so as to be able to carry more and sail faster, since time in maritime business is of crucial importance. The problem is that ports are lagging behind the progress which ships are making. There aren't many newly built ports and the ones that are operating a longer time, such as the Port of Koper may face difficulties berthing largest container vessels. When the port started to operate it was obvious that the rails for ship to shore cranes were as near the edge of the pier as possible, but nowadays as the ships are more "V" shaped that is becoming a problem. Many accidents happen when the ship hits the structure of the crane at its maximum breadth. That's why pilots and tug boat operators are facing many difficulties berthing large vessels. To increase safety of the ship and port structures in the Port of Koper special care is given to the controlled berthing using a laser docking system and observing real-time measurements. The laser-ranging system and measurements taken with it are described in the paper.

Keywords: Port of Koper, container terminal, laser docking system, vessel berthing, berthing parameters

1 INTRODUCTION

All ports, not only Port of Koper, are encountering the same problem. They are having a hard time adapting to constant ship growth. Although ships are already under high emission pressure, it must be understood that with bigger ships and higher fuel consumption the amount of cargo also rises. Comparing marine transport with road transport carrying the same amount of cargo, it can be clearly seen that marine transport is more efficient and environmentally friendly. That is why ports have to adapt to the so called "Scale Enlargement" to keep the business running [4]. Otherwise other ports in the vicinity would overtake less adapted ones.



Source: (Luka Koper, 2018)

Figure 1: Increase in container (Blue line) and total cargo (Orange line) in previous years

Fig. 1 shows the annual increase of cargo in number of containers and total amount of cargo throughput in tones which makes clear that the Port of Koper did managed to adapt to the ship growth with certain measures [3]. In the Port of Koper, a specific channel leads to the container terminal; it is quite narrow and bent on one side. It had to be dredged already, and to further increase safety some leading lights, lasers and AToNs were also installed. A challenging task is to berth a 310 m long container vessel on a barely 600 m of operative coast after close passing of Ro-Ro and passenger ships, berthing on the other side. The implementation of a laser ranging system was a good solution, contributing to safer and more controlled docking. This system is in fact more frequent in tanker ship berthing due to the required safety measures, but it was more than welcome in this situation where fenders were not fit to absorb the berthing energy of a large container vessel at "high" berthing velocity.

In this paper the laser ranging system, implemented at the container terminal will be presented and results of berthing some Panamax container vessels will be explained.

2 SHIP ENERGY AND BERTHING

The last two actions on the ship's journey are getting it safely into shelter, in this case into the cannel of the port and then safely approach the berth and moor. As already mentioned in the introduction, the channel leading to the container terminal in the Port of Koper is a bit specific. Pilots have to guide the ship at the right angle, avoiding the shallow part of the channel on the south side. As mentioned, leading lights, lasers and AToNs help pilots to perform the task as needed. In the case of container vessels nowadays sizes, in Koper there are no problems with draught, which is permitted to 14.5 m with 0.5 m of under keel clearance (UKC). For the pilots with some experience with the channel of Koper, the dangers they face are the unpredictable winds. The area is known for the "Burja" (bora), a north-east wind which can blow with more than 25 m/s. By Beaufort scale that is approximately 8 - 9. And it can get even worse, because the wind blows in gusts. In such cases ships have to enter the channel at higher velocity, which makes them more vulnerable to the wind due to the exposed longitudinal area above the water line. For such cases, by Brolsma's Curves, ports are divided in five types depending on navigation conditions [6]. It is specified at which velocity ships at a given displacement should enter certain ports and berth. Fender design is based on Brolsma curves as well. Later at Beckett Rankine they published a study on those curves concluding that the curves were determined merely through experiences and estimations, rather than on statistical data. After the finding, that Brolsma's curves do not fit the modern vessels' berthing, in 2013 Japanese researchers Seigi Yamse et. all concluded with a study on more than 2500 ships berthing all over the world that their results do not match Brolsma's [7]. One of the most important conclusions is that winds blowing under 10 m/s do not increase the berthing velocity. At winds under 10 m/s the berthing velocity depends solely on the mass of the ship, its velocity and port assistance. They also found that there is no need to divide ports and berthing velocities into five groups; they divided berthing velocities into two types instead, based on operator's experience and environmental conditions.

Table 1: Berthing velocities categorized by Seigi Yamse et. all

	Group A	Group B
Average	3.9 – 5.4 cm/s	6.7 – 9.3 cm/s
95% Confidence Value	7.7 – 11.3 cm/s	14.1 – 16.9 cm/s
99% Confidence Value	9.4 – 16.0 cm/s	19.3 – 23.8 cm/s

Source: (S. Yamse, S. Ueda, T. Okada, A. Arai, K. Shimizu, 2014)

From the Chapter 3, where laser measurements of berthing are presented, it is clear, that berthing velocities in Port of Koper are much lower even than the velocities in group A. This established circumstance further supports the use of laser ranging - systems. The necessity to reduce berthing velocities came from inappropriate fenders for the largest ships and the vicinity of STS crane rails that needed special care in berthing, so as not to lead to any accidents. The existing fenders in the Port of Koper are calculated to absorb a maximum of 560 kNm abnormal energy each. To understand what this means let us explain the theory behind berthing energy. A ship in motion has kinetic energy. Where:

m – the mass of the ship

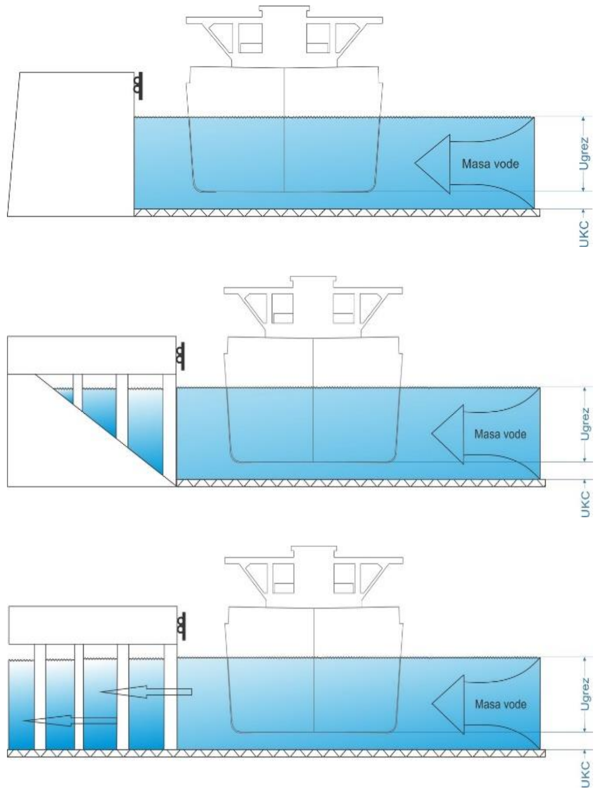
v – represents ship's velocity

$$E_K = \frac{1}{2} \times m \times v^2 \tag{1}$$

From the equation it can be seen that the kinetic energy increases with the square of the velocity, since we can not influence the displacement or mass of the ship on the sea. So, the only way to berth large container vessels in Koper was to reduce their berthing velocity. But this isn't all that regards berthing energy; there are four coefficient which either decrease or increase berthing energy [2].

$$E_K = \frac{1}{2} \times m \times v^2 \times C_C \times C_M \times C_S \times C_E \tag{2}$$

C_C – Is the coefficient of berth configuration



Source: (Authors)

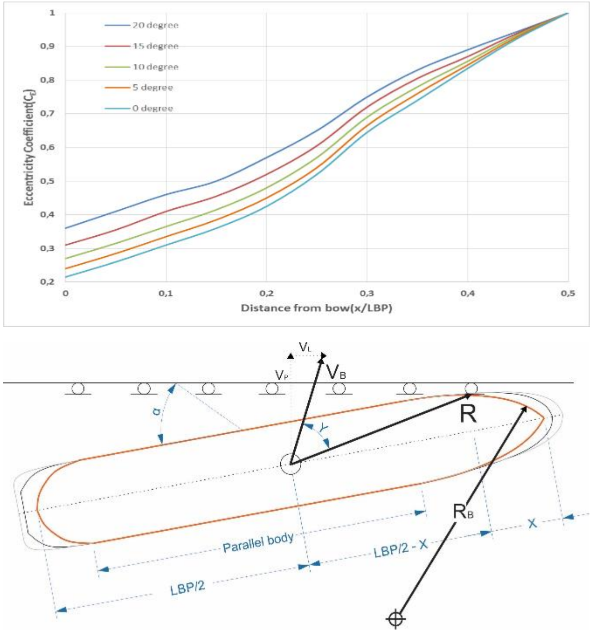
Figure 2: Types of pears

The solidly built pier at the top of figure 2 does not allow any water to be displaced through or under it and with small enough UKC and parallel ship berthing, water has nowhere to escape, contributing to coefficient numbers lower than 1 and decreasing total berthing energy. As for the open pier at the bottom of figure 2, water has all the space to escape to the other side so that the coefficient is 1.

C_M – Is the coefficient of added mass, while a moving ship is dragging some of the water with it, at a certain point as the ship tries to stop, and that water can push it a little bit further, increasing total berthing energy. The coefficient can be calculated using the dedicated PIANC equations [5].

C_S – Is the coefficient of softness. Fenders are made from softer or harder rubber and when a force is applied onto them, they tend to deform. The same happens with a ship's hull and so a part of the energy is transferred back to the ship and some goes into fender deformation, contributing to a slight decrease of berthing energy [1].

C_E – Is the coefficient of eccentricity. The ship doesn't always make contact fully parallel to the pier. Under normal conditions ships always berth with ⅓ or ¼ of length at the bow. At impact the ship than rotates around the point of impact and some of the energy is used to align the stern. The eccentricity coefficient can be determined using the chart in figure 3 or precisely calculated based on few parameters shown by figure 3.



Source: (Authors)

Figure 3: Eccentricity coefficient

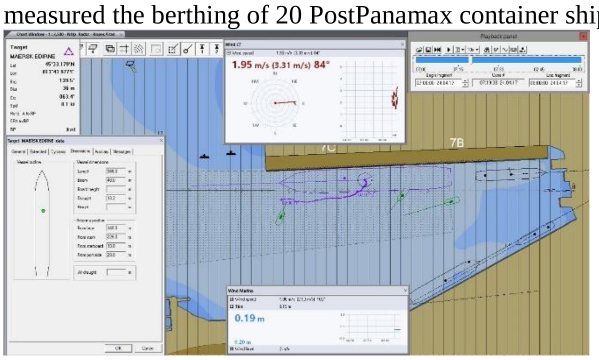
Based on displacement, velocity and those coefficients we can determine the berthing energy which fenders will have to absorb. But since safety is of the utmost importance in maritime commerce, we also have to include some safety factors. They are determined by the type of the ship; since tankers, cruise ships and ferries represent more danger to the environment and human lives they have higher safety standards to meet. In the case of container vessels, the safety factor ranges around 1.5. This means that the so called "normal" berthing energy, calculated with equation 2 is increased by this factor and the new energy is called "abnormal" berthing energy.

3 OBSERVATIONS AND MEASUREMENTS OF BERTHING IN PORT OF KOPER

In this chapter we present an example of berthing one of the largest container ships which was berthed at the Port of Koper. In December 2016 MSC Paloma with capacity of 14,000 TEU berthed in Koper. With 200,000 ton displacement and 9 cm/s (which is the lowest approach velocity according to the Japanese study) the ship would hit fenders with approximately 1200 kNm. With that velocity, due to PIANC regulations Paloma's berthing would require twice as much energy absorption as the Port of Koper fenders can provide (560 kNm).

To avoid the costs of buying new fenders a tailored solution was proposed. The first thing to do was to reduce berthing velocity. To do so, pilots had to be specially educated and trained on nautical simulators, since maneuverability of a ship of this size is extremely reduced with such low velocity. The maneuverability thus solely depends on tug boat assistance. The next possible measure to take was to berth the ship as parallel as possible to the pier. This reduces berthing energy since it is distributed among a series of fenders and not only on too few of them; this was achieved by berthing at recommended 5 ° angles [8].

Using a laser-ranging and laser docking system in conjunction with metocean data we have observed and measured the berthing of 20 PostPanamax container ships.



Source: (Authors)

Figure 4: Container terminal basin layout at Koper

In the figure 4 there is the container vessel "Maersk Edirne" which berthed in Koper on 24 April 2017. Berthing parameters are also presented in figure 5. From the top side of the figure 4 it can be seen that it berthed almost parallel to the pier; in fact, it hit the fenders at an angle of 0.5 ° with its bow. The ship was oriented in the opposite direction it usually would be, that is to fit between two STS crane booms with its superstructure. The approach velocity at which it hit the fenders was 0.9 cm/s. Based on those parameters the berthing energy of the Maersk Edirne was only 25 kNm, which is barely 5 % of the energy fenders in Koper are designed for.

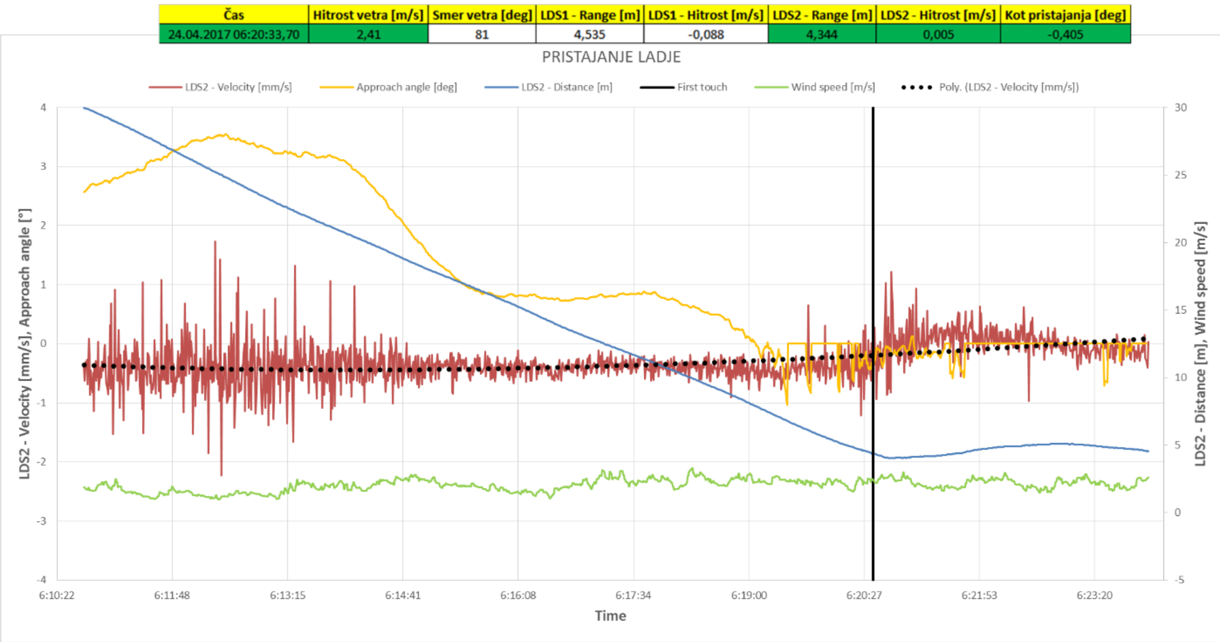


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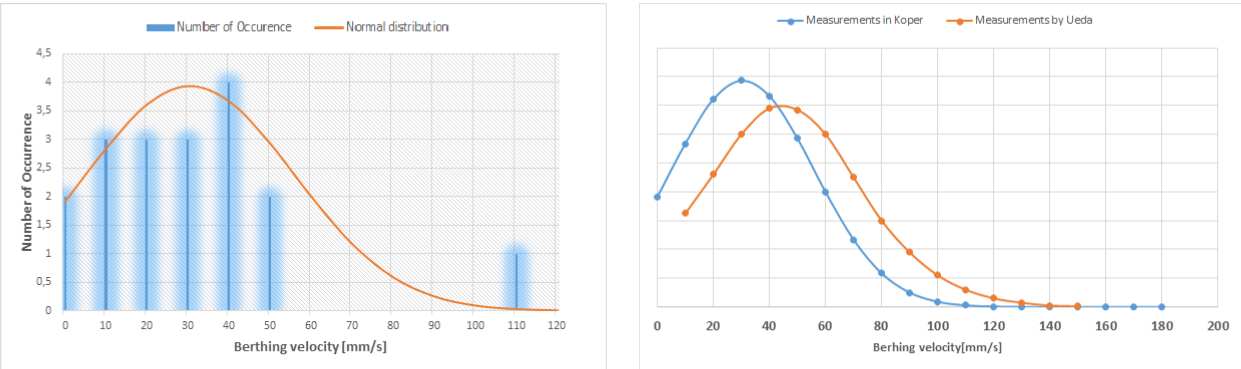
Figure 5: Berthing of Maersk Edirne using laser docking system



Source: (Authors)

Figure 6: Normal distribution of berthing velocities with number of occurrence and comparison to Japanese study

In figure 6, there is a normal distribution of berthing velocities compared to those the Japanese researchers suggested [7]. It can be seen that our approach velocities are approximately 1 cm/s lower. This was because measurements of two berthings were very close to 0 cm/s.

Table 2 presents more statistical data on berthing velocity, approach angle and wind speed. Since Japanese researchers determined that winds under 10 m/s do not additionally affect berthing in this time of the year - from April to June - there were no such problems in our case. Approach angles are also very small meaning that ships are being berthed as parallel as possible, decreasing total berthing energy.

Regarding berthing velocities, we can say that with an average of 3 cm/s we reduced total berthing energy almost to the minimum. And with 9 cm/s with 99 % confidence level we are still at the lower limit for group A berthing velocities taken from the Japanese researchers.

Table 2: Statistical result of berthing velocity, approach angle and wind speed

	Average berthing velocity	Average approach angle	Average wind speed
Average	3.049	0.478	2.866
Standard deviation	2.537	0.767	1.826
68% Confidence level	4.241	0.839	3.725
95% Confidence level	7.209	1.736	5.862
99% Confidence level	8.959	2.264	7.122

Source: (Authors)

4 CONCLUSION

This paper was written to present one of the problems we are facing in Port of Koper with ongoing ship scale enlargement. In previous years, some other measure took place that would allow the port to accommodate large container vessels. Dredging of the channel and extension of a pier made that possible. In Koper we are still facing some spatial problems regarding the width of the channel. Upgrading the pilots' knowledge by adopting new technologies is inevitable. On this point it can also be said that we have very few to no accidents regarding navigation and berthing. But ships are developing too fast, leaving the port a little bit behind. As a solution, it was necessary for us to a system of laser docking. With this system pilots can check the exact velocity and position of the ship in relation to the pier. With this system, from the results in Chapter 3, it can be seen that we have managed to decrease berthing velocities to the minimum as well as berthing angles, contributing not only to lower berthing energy but also to the lower wear of fenders and other structures in the port. By getting really good results from the use of the system at the container terminal, it was decided that a similar system will be integrated at other terminals as well.

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THE IMPACT OF THE INFRASTRUCTURE CHANGE ON THE QUALITY OF PUBLIC PASSENGER TRANSPORT: CASES FROM THE COASTAL-KARST REGION

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ABSTRACT

The article tries to analyse the impact of some infrastructure changes on the quality of public passenger transport in the Coastal-Karst (Obalno-kraška) statistical region of Republic of Slovenia. Consideration of relevant statistical data show that the Coastal region is one of the most important touristic and recreational destination in Slovenia and that the usage and quality of public passenger transport in Slovenia is under the average of the European Union. Some interesting existing situation on the intercity bus line Koper – Piran are taken into consideration and some solutions are prepared. Realizing proposed solution could shorten the travel time of the line.

Keywords: Public passenger transport, mobility, intercity mobility, level of service, impact of infrastructure change, sustainable urban mobility plans

1 INTRODUCTION

A modern society is based on a well-developed mobility which influences its economic and social development directly. Public transportation has to follow the needs of the people and with relevant development try to compete with personal transport.

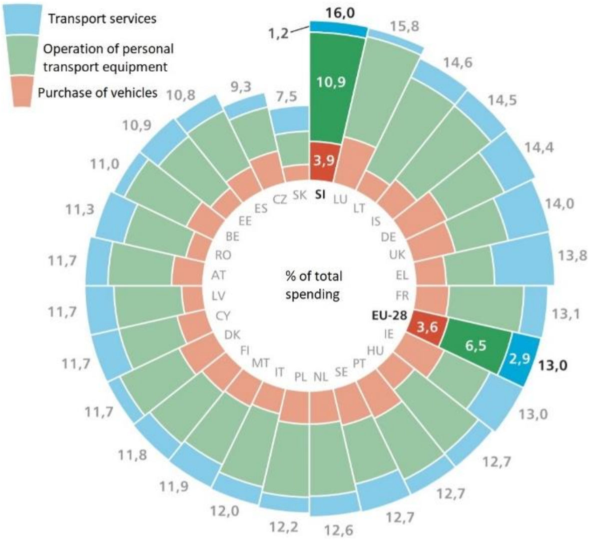
The basic inputs that we need to plan a well-functioning public transportation are good travelling matrices (where people live, work, study, where they want to visit tourist attractions, etc.), the amount of passengers (also tourists) and available and relevant infrastructure (routes, stations, etc.).

Slovenian Coastal-Karst region is a part of Republic of Slovenia, European Union as well. The most important characteristic is that the region is the most developed touristic and recreational region with some important touristic destination are located (Koper, Izola, Piran, Portorož, etc.). Mentioned mean that the number of people (which could be possible travellers) is in season time important bigger like outside the season.

The Coastal-Karst statistical region comprises seven municipalities, four of them are situated at the coast, three of them are situated in the area where public passenger intercity line Koper – Piran is. Those municipalities are: Municipality of Koper/Capodistria – with more than 51,000 inhabitants with city of Koper which has more than 25,000 inhabitants, Municipality of Izola/Isola with about 16,000 inhabitants (Izola itself has around 11,300 inhabitants) and Municipality of Piran/Pirano with almost 18,000 inhabitants (cities: Piran – almost 4,000 inhabitants, Portorož almost 3,000 and Lucija with more than 6,000 inhabitants). The area of mentioned three municipalities is fully interconnected what mean that important connections between the economic, social, cultural activities in region exist. For all three coastal municipalities is valid that the number of people, older than 65 years, increased in the last couple of years.[29] ("Statistical Office of the Republic of Slovenia," 2018)

To make the estimation of quality and usage of public passenger transport in Slovenia some statistical data were used. Comparison about expenditure of householders in transport service between 28 European countries shows that the average Slovenian family spends the highest amount of their income on personal mobility (Figure 1); which come to 4.4 % more than the average of EU-28, just for the operation of personal transport equipment. Only 7.5 % of their income goes for transport services and the rest (92.5 %) goes for the operation of personal transport equipment and for the purchase of vehicles.

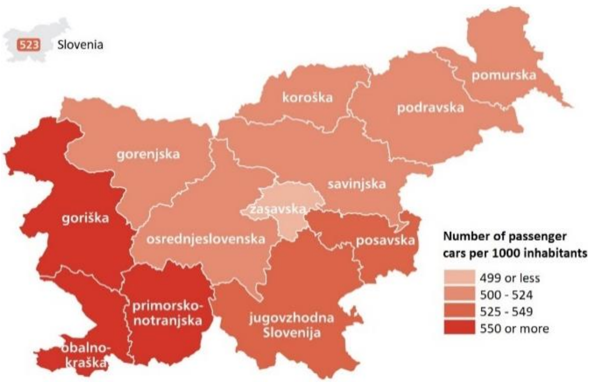
[29] Statistical data on 1.1.2017



Source: (Košar, 2017)

Figure 1: Share of household expenditure on transport services across countries (EU-28, 2015)

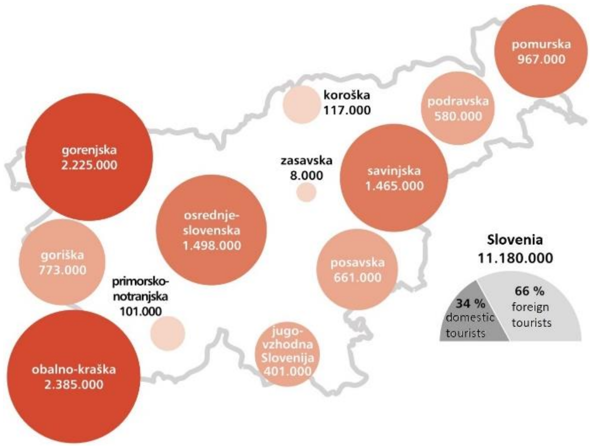
Nowadays people want to be flexible and to travel as directly from A to B as possible to save on time. The amount of the road traffic in Slovenia is increasing, especially because of the flexible and more comfortable personal transport. Figure 2 shows that south western Slovenia has higher motorization than the rest of the country.



Source: (Košar, 2017)

Figure 2: Registered passenger cars per 1000 inhabitants by statistical regions of Slovenia, 2015

As it mentioned, the Coastal-Karst region has the highest amount of tourists along all Slovenian statistical regions, which is increasing since 2010. Especially in the summers that causes a lot of traffic and traffic jams.



Source: (Statistical_Office_of_the_Republic_of_Slovenia, 2017)

Figure 3: Tourist overnight stays, statistical regions, Slovenia, 2016

Most tourist overnight stays were registered in Municipality of Piran (14%), followed by Municipality of Ljubljana with 11%. (Marc, 2017)

These are only a few facts that show us the current situation in the region, to which the public transportation provider and the competent authorities should be adapt.

Delivered service quality of public passenger transport is (usually) measured with different quality criterions that belong to one of eight categories of criterions:

- availability,
- accessibility,
- information,
- time,
- customer care,
- comfort,
- security and
- environmental impact. ("SIST EN 13816:2003, Transportation - Logistics and services - Public passenger transport - Service quality definition, targeting and measurement," 2003)

Analysing each of mentioned category show, that public passenger transport in the Coastal-Karst region should be improved. The needs of improvement are evident. In the article the impact of the infrastructure changes especially on travelling times will be analysed.

1.1 Impact of sustainable mobility plans into infrastructure changes

Sustainable urban mobility plans (SUMP) represent the basis documents for planning the relevant measures with the important impact to sustainable urban mobility. The action plans in the document are defined based on relevant public mobility data, relevant policy decisions and they were checked in public. SUMPs were made across the European Union and also in several Slovenian municipalities (should) foresee improvements in:

- public transport,
- walking and cycling,
- intermodality,

- urban road safety,
- road transport (flowing and stationary),
- urban logistics,
- mobility management,
- intelligent transport systems. ("The SUMP concept," 2018)

The documents (SUMPs) of three coastal municipalities (Koper, Izola and Piran) were taken into consideration. The improvements in the public passenger transportation, especially those that have to do with infrastructure have the special interest. All three municipalities published their SUMPs in 2017. Each municipality structured their mobility plan differently (public passenger transport is second, third or fourth strategic pillar in different documents), although the importance of all pillars should be the same. Some of infrastructure improvements, novitiates or plans are listed here:

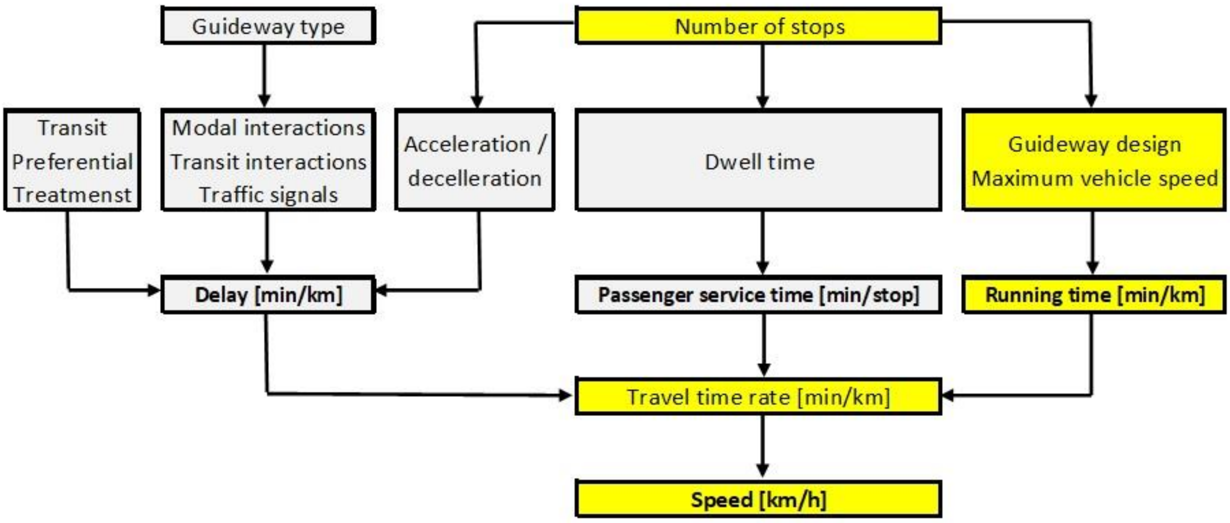
1. The SUMP of Municipality of Koper include:
   - implementation of two P+R (park and ride) systems and one P+R+W (park and ride or walk) system (till 2025),
   - public transportation line by the sea,
   - passenger terminal (till 2025),
   - renovation of the railway station Koper (till 2027),
   - light rail (till 2030). (Harpha Sea, 2017)
2. The SUMP of Municipality of Izola include:
   - new bus stop at Prešernova street,
   - some improvements of the existing bus stops,
   - the possibility study of implementation of multimodal centre,
   - the possibility study of implementation of urban passenger bus transport,
   - the possibility study of implementation of maritime passenger transport
   - and light rail. Light rail from Trieste (Italy) to Umag (Croatia) would connect Slovenian coast cities. (MK Projekt, 2017)
3. The SUMP of Municipality of Piran include:
   - renovation of existing and construction of new bus stops till 2022 (new bus-stops will be constructed especially in the villages in the hinterland),
   - construction of a parking for tourist buses till 2022. (Lineal, 2017)

We can conclude that all three mobility plans foresee at least a couple of infrastructure improvements in the public passenger transport. In some cases, municipalities foresee wider interactions with the neighbouring municipalities or even countries (for example in case of light rail).

1.2 Infrastructure elements

In general, each public transportation line has its static and dynamic elements. Static or structural elements are: line, terminals, bus stops, bus stations, the length of the line and the distances between the bus stops and/or stations. Dynamic or functional elements of the public transportation line are: the number of vehicles, duration of each cycle, vehicle flow/ride frequency and interval. (D. Sever, 2014)

Mentioned elements have an impact on different characteristics of public passenger service. Only factors that influence the speed were taken into consideration. The factors that influence the speed of the public passenger transport are coloured with yellow, are more connected with our case study (Figure 4).



Source: (Kittelson & Associates, 2013)

Figure 4: Factors influencing transit speed

The article focuses on static infrastructure elements of the line that influences on running time especially by guideway design.

2 PUBLIC PASSENGER TRANSPORT IN THE COASTAL-KARST REGION

2.1 Intercity line Koper - Piran

Local public transport operator in the mentioned area is Arriva Dolenjska in Primorska d.o.o. (Arriva). Some other operators (Izletnik Celje d.o.o., Avrigo d.o.o. and Avtobusni promet Murska Sobota d.d.) connect the coastal cities once or twice per (working) day as a part of a longer lines (for example: Celje – Lucija, Lendava/Murska Sobota – Piran). Travelling by bus is the only available public transportation mode. ("The portal of the public passenger transport," 2018)

There are 45 connections per direction per working day from the main station in Koper to the main station in Piran, operated by a local transport provider Arriva. Most of the intercity rides include (all) 18 bus stops. The travelling time of a "typical" route from first to last station takes anywhere from 46 to 50 minutes. Travelling time on line Koper – Piran from the last bus stop in Koper (Koper Tržnica / Koper Soča) (19 km) lasts 40 minutes according to the timetable. According to the timetable season or peak – hours have little influence on travel time. There are only about 5 rides, which last less, and are part of a longer line: those from the line Ljubljana – Piran and those from the line Trieste – Piran. ("Arriva," 2018) The length of travel time is too long as observed by both; the customers and the management viewpoint. One of the challenges the transport provider faces is to shorten it.

Analysing the route between Koper and Piran we find out some locations where the waste of time happens:

- One of the biggest wastes of time is to leave the expressway and drive through the centre of Izola. While Koper and Piran have an urban transport, Izola does not.
- Secondary wastes of time are two loops that needs to be driven each time by each bus on the line because of two bus stops: Strunjan and Portorož.
- Involved parties (subjects) should solve the complex questions that involve the way of integration of Lucija and Piran in the line; "Which location of the station should be the main bus station (Lucija or Piran)?" and "Should be Lucija and Piran connected by intercity line a s well?".

Travelling times that have to do with the current bus line and the possible variants of the intercity line Koper – Piran are on the Figure 9.

Further on this document we will show some possible solutions and also one, which was made in the past.

2.2 Avoiding driving through the centre of Izola

One of the biggest losses of time on the line Koper – Piran for someone who wants to travel from first to the last station is driving through the centre of Izola. The most elegant solution would be to implement a new bus stop near expressway H6. The mentioned expressway was finished and is in use since 2015. The new bus stop could be frequently connected at least with the existing bus stops within Izola by an urban passenger transport, which would need to be established by Municipality of Izola (Izola is the only one of three mentioned municipalities that still does not have any urban passenger transport). The SUMP of Municipality of Izola has planned to conduct a study for implementing urban passenger bus transport.

According to the "Rules on bus stop stations" it is not allowed to construct a bus stop right next to the motorways or expressways. ("Pravilnik o avtobusnih postajališčih (Uradni list RS, št. 106/11) / Rules on bus stop stations," 2011) One of suggestions is to build a bus stop or bus station near the exit Izola, where could be also an intermodal terminal.

2.3 Bus stops in Portorož and in Strunjan

As shown next, the line Koper – Piran (and vice-versa) has two stops (small loops) which represent waste of time:

- the first is in Portorož and
- the second one in Strunjan.

Especially in the cold part of the year, when the number of tourists is low, it is often only about losing the time because there is no one who would enter or leave the bus. Sometimes the passengers who did not checked the direction board of the bus or did not see the way the bus is coming from are confused about the direction of the bus. In such case the drivers inform those passengers. The chance that two buses will meet and one will have to wait for the other is doubled. To avoid those loops, bus stop should be built by the roads.

2.3.1 The bus stop (loop) in Portorož

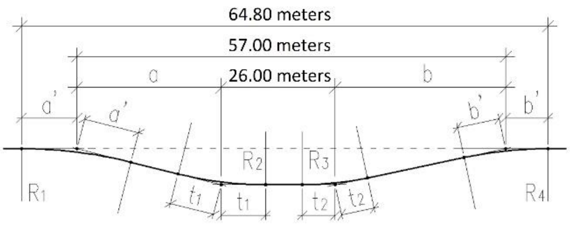
The bus stop "Portorož" is used for intercity and urban public passenger lines and for the tourist buses as well. The problem of the bus stop "Portorož" is not only its loop (location) – Figure 5. Existing bus stop "Portorož" does not have any covered waiting area and also not any denivelated platform (bus stop kerb). Municipality of Piran (which is responsible for the maintenance of the road that goes through Portorož) wants to renovate it soon.

Source: ("Geopedia," 2018)

Figure 5: The loop in Portorož with possible solution

Instead of a couple of parking lots on each side of the road, there is a chance to construct bus stop. On the other hand, there is also a chance to provide some parking lots on the area where the bus stop is nowadays – even though the nowadays bus stop could be used for tourist buses only.

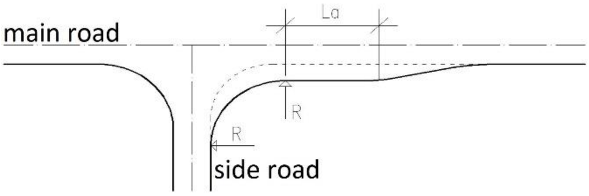
There is a chance and a need to construct a bus stop for the length of two buses between intersections in direction Lucija – Piran. On the other side of the road there is already built space which could be used as a bus stop. The speed limit in our case/study area is 30 km/h, which is our input for the lengths of bus stop parameters/elements (L', L and L_a - L_a < L < L') – Figure 6.



Source: ("Pravilnik o avtobusnih postajališčih (Uradni list RS, št. 106/11) / Rules on bus stop stations," 2011)

Figure 6: Horizontal technical elements of the bus stop

In our case bus stop could be located also right after the intersection (as shown in the Figure 7).



Source: ("Pravilnik o avtobusnih postajališčih (Uradni list RS, št. 106/11) / Rules on bus stop stations," 2011)

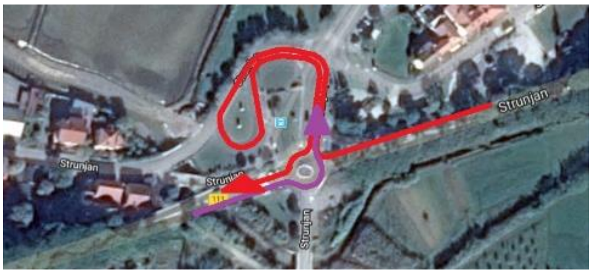
Figure 7: Bus stop right after the intersection

Mentioned solution would be even better for saving space because there is another intersection after less than 100 meters. By paragraph five of article 11 the bus stop should be located at least 20 meters before lanes (in our case we have extra added right turn lane). ("Pravilnik o avtobusnih postajališčih (Uradni list RS, št. 106/11) / Rules on bus stop stations," 2011)

2.3.2 The bus stop (loop) in Strunjan

The second loop (Figure 8) is next to the main road no. 111 that leads from Izola to Sečovlje (from the end of the two-lane expressway in Izola to the border with Croatia in the total length of 15.560 km). The road no. 111 belongs to the main roads II – G2 by Decree on the classification of national roads. ("Uredba o kategorizaciji državnih cest (Uradni list RS, št. 102/12, 35/15, 38/15, 78/15, 21/16, 52/16, 64/16, 41/17 in 63/17) / Decree on the classification of national roads," 2012)

The loop has (as it was in the case of Portorož) one bus stop for the passengers in both directions.



Source: ("Google Maps," 2018)

Figure 8: The loop in Strunjan

On the both sides of the road no. 111 in the mentioned area there is a tree-line of pinuses, which are protected and belongs to the natural monument. It would be difficult to construct bus stops on both sides, because it would be necessary to cut down some trees.

According to the "Rules on bus stop stations" (paragraph four of article 6) it is allowed to implement bus stop on the main or regional roads (by classification of national roads) under two conditions:

- annual average daily traffic (AADT) does not cross 10,000 vehicles per day,
- the amount of daily made stops by bus is lower than 20. ("Pravilnik o avtobusnih postajališčih (Uradni list RS, št. 106/11) / Rules on bus stop stations," 2011)

Let's take a look at the data for our specific situation. The mentioned road no. 111 has four automatically counters. The annual average daily traffic is shown in the table 1.

Table 1: Annual average daily traffic on the road 111 by the automatic counters

Number and name of the counting point	Type of the automatic counter	Data from year 2016 (average annual daily traffic, all vehicles)
13 Izolska obvoznica	QLTC8	18,635
901 Belveder	QLTC8	22,443
10 Seča	QLD6	10,271
500 MP Sečovlje	QLTC8	5,365

Source: (Slovenian_Infrastructure_Agency, 2018)

The closest counter to the Strunjan bus stop is Belveder (counter no. 901), with AADT more than 22,000 vehicles per day, which means that there is no option for the bus stop on that road.

To avoid the loop at least when there is no passenger(s), the possible solution is to use intelligent transportation system for this specific situation. One option is that camera would detect waiting passengers; another is that the waiting passenger would need to push the button or do something to inform the driver that she or he is waiting for a bus. There is also a weakness of the system: it is not possible to not know in which way the passenger wants to travel. To solve this, we could set for example more buttons that waiting passengers would need to push. The question is how people would adopt to the system with button / buttons, because it is not common way for the public registered transport lines.

2.4 Closure of the coastal road between Koper and Izola

Another example of impact of the infrastructure change on the quality of public passenger transport is closure of a coastal road between the towns of Koper and Izola. A section was closed for motorized traffic in March 2017.

Before the closure of a coastal road the following decision makers; Municipality of Izola, Municipality of Koper, Ministry of Infrastructure, DARS (Motorway Company in the Republic of Slovenia) and Arriva (transportation provider) were discussing (also) the options/alternatives for the public transport lines. Some of them figured out that:

- It is not proper to redirect lines via Semedela / Žusterna suburb and via hospital Izola (driving up to a steep hill and down is energetic wasteful, it would prolong driving time and cause damage to the area and its' inhabitants because of several lines that would lead through densely populated area).
- In case of driving through the tunnel (expressway H6) there were questions that have to do with safety because of maximum allowed speed on that road (it was 110 km/h) – according to the article 47 of the Road Traffic Rules Act it is not allowed to drive more than 60 km/h in case there are standing passengers. ("Zakon o pravilih cestnega prometa (Uradni list RS, št. 82/13 – uradno prečiščeno besedilo, 69/17 – popr., 68/16, 54/17 in 3/18 – odl. US) / Road Traffic Rules Act,") Mentioned speeds (60 km/h and 110 km/h) are too different to provide adequate security.

They decide to redirect all the lines through the tunnel (expressway H6) and to reduce the maximum possible speed on that road to 100 km/h. They also allowed driving non-vignette on that section.

The lines between Koper and Izola were minimum possible corrected. The bus stops "Koper Semedela K", "Koper Žusterna" and "Koper pristan" are not a part of the intercity transport line Koper – Piran anymore and the rest of them stayed the same.

The closure of the mentioned section of the coastal road influenced also on the public passenger urban transport in Koper. The line 5 (Koper Brolo-Žusterna-Markovec-Žusterna-Koper Brolo) and line 6 (Potniški terminal-Žusterna-Markovec-Žusterna-Potniški terminal) were changed at least two times after the closure of the coastal road.

The people living in the affected area (Žusterna suburb area) needs nowadays to come by an urban line to the bus stop Koper Soča first if they want to continue their journey in direction to Piran by a public transport. The transport provider (Arriva) claim that there are no complaints of passengers to the existing regime – they accepted the change and adopted to it.

3 THE IMPACT OF THE INFRASTRUCTURE CHANGES ON THE QUALITY OF INTERCITY BUS LINE KOPER – PIRAN

Only quality parameter "time of service" was taken into consideration. The travelling time by bus on the intercity bus line Koper – Piran is estimated by provider information from bus stop Koper Soča to Piran as 40-41 minutes (existing route).

The impact of proposed solutions was estimated based on self-measurement of time needed to be spared by driving a personal car from bus stop "Koper Soča" to bus station "Piran". The measurement was made using Google navigation tools. The representation of the traveling times would be more realistic if we had made measurements of time a bus needs to complete the journey.

The results are presented in Figure 9.

			driven by	
			car*	bus
(not) avoiding	**From "A" to "B" by two different routes**	lenght [km]	traveling time [min]	
Izola, Lucija and Portorož	**from bus stop "Koper Soča" to bus stop "Piran"**			
	current bus line without Strunjan loop	18,9	30-35	40-41
	ideal line	15,8	17	
		saving up to	**18**	
Izola	**from expressway exit Izola to Belvedere**			
	use of registered public passenger transport line through the city center of Izola	4,1	9	
	use of expressway (H6) and main road II (111)	4,2	3	
		saving up to	**6**	
Lucija	**from bus stop "Strunjan" to bus stop "Portorož "**			
	use of registered public passenger transport line	5,3	10	14-15
	use of registered public passenger transport line**	3,1	5	6
		saving up to	**7**	**8-9**
Lucija and Portorož	**from bus stop/roundabout "Valeta" to bus stop "Bernardin K"**			
	use of registered public passenger transport line	6,2	13	
	use of Koprska cesta, Belokriška cesta and Cesta rabskih žrtev	3	4	
		saving up to	**9**	

* no stops, no traffic jams
** only as a part of a line "Ljubljana AP - Piran" (loss of time by driving back to bus stop "Portorož")

Sources: ("Google Maps," 2018), ("Arriva," 2018)

Figure 9: Relations between time needed driving a bus on existing and on "improved" route

It is easy to see that usage of in previous chapters mentioned solution could spare about 13 to 18 min or up to 44 % of driving time on the existing route.

The Figure 9 represents some options of the bus line Koper – Piran. It is not necessary to redirect all the rides to only one of those variants.

In case of avoiding Izola, that city needs an urban passenger transport which would be frequently connected to the new bus stop (or bus station) near the expressway. The location of the new bus stop/station could be an intermodal passenger terminal, which would join not only intercity and urban bus passenger transport, but also personal transport by car (park and ride system) and by bikes (secured bicycle parking) and even light rail which is predicted in the SUMPs.

Avoiding only Lucija or Lucija and Portorož within the line Koper – Piran, this solution would only be possible with a very good intercity lines and integration of different lines.

Additional loss of time on part of the line between Lucija and Piran is generated by intercity buses stoping by almost all bus stops that are in use for the urban passenger transport in this area.

However, all mentioned options in Figure 9 come out of different line options (and also different lengths of the line) which brings to different number and location of bus stops and different distances between them. These are infrastructure changes that influence measured quality parameter (traveling time) directly.

4 CONCLUSIONS

The only line that we analysed is the line Koper – Piran as it is one of the most important public transportation lines in the region.

By changing the static elements of the public transportation line we influence on travel time which is not the only factor that influences on travel time; for example, one way to reduce the traveling times is also to encourage people to buy tickets in advance. If we would check more quality criteria, we would find even more possible improvements.

Possible improvements that were identified have to do with the locations of the existing bus stops in Strunjan and Portorož and with possible new bus stop (or station) in Izola. Several variants of routes that exclude some existing bus stops on the line Koper – Piran were also under scrutiny.

The proposed SUMPs that the coastal municipalities have accepted are written on giving a bigger and more important role to the public passenger transportation. Some proposals in the SUMPs would also solve the aforementioned problems; for example, adding some other public transportation modes to the existing offer. The light rail, which is mentioned in the SUMPs as well, would be good contribution to the existing modes. Great tourist attraction would be an option to travel by sea or even by cableway.

Changes in public transport should be done not only when there is must for them (like in case of a closure of the coastal road) but also when there is recognized a sense or need of change.

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MARITIME ZONE SURVEILLANCE WITH VIDEO CAMERAS

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ABSTRACT

The growing risks of crime, terrorism, danger to the environment and safety of traffic are becoming increasingly important. Hence, the more frequent use of surveillance systems. The solution is often a combination of AIS and radar, although problems might occur if the AIS device malfunctions, if objects are non-AIS, and due to the radar's EM emissions unsuitable for biological organisms (human beings included). Difficulties in the video surveillance of maritime zone, ports and marines are discussed in the paper. The main topic is the discussion of datasets for traffic surveillance at sea in a variety of unfavorable weather conditions, like fog, rain, and haze. Further problems are gradual and/or sudden illumination variations (sun motion, clouds), motion changes (camera jitter due to wind or vibrations), modifications of the background geometry (anchored boats), sudden background changes (naturally occurring and boat-generated waves on the sea surface, and all sorts of waste materials floating on sea surface), reflections, shadows, wakes, foam, speckles in the water, horizon detection, etc.

Keywords: Video surveillance, maritime traffic, low visibility, difficult weather conditions, port security

1 INTRODUCTION

Traffic video surveillance is plagued by a wide variety of issues tackled in a number of references. However, references dealing with water surfaces, not to mentioned maritime zone surveillance, are scarce.

Visual surveillance in ports is addressed in [1]. Vessels are detected by an optimal trade-off filter, which distinguishes vessel types as defined in the e-NOAD database. Although the proposed system gives good results, the type of cameras used are not mentioned. Long range high resolution cameras are more suitable for maritime zone surveillance, but too expensive, while classic video cameras have a very limited range. Higher resolution results in better algorithm input, but is computationally more expensive.

A software based on multi-sensor input is presented in [2]. It uses IR sensors to increase the accuracy of automated object detection in the maritime environment.

Complex dynamic scenes are discussed in [3]. Although there was no explicit maritime zone surveillance, it addresses some important problems occurring at sea. The problem of detection of moving objects is treated as the complement of saliency detection. The algorithm classifies non-silent pixels as background.

IR surveillance of shallow waters based on buoys is presented in [4]. The reported true positive detection rate was around 90% (5 km detection range). However, IR-able sensors are more expensive than visual, and buoys are moving objects (anchored, but moving due to waves, currents, winds in the limited range), which aggravates object detection (camera jitter and motion compensation).

Problems in maritime surveillance are addressed in [5]. It specifically tackles the problem of reflections, shadows (caused by: boats, buildings, birds, etc.), wakes. Wakes are dealt with in the optic flow framework, and shadows and reflections by converting color space from RGB to HSV. It is based on the OpenCV framework.

The results of motion detection in road traffic are addressed in [6], with special focus on different weather conditions. It is interesting, because such conditions are also problematic at sea.

Horizon detection, dynamic background modelling, the presence of small objects on distant backgrounds, illumination effects, and other problems are discussed in [7] for marine environments. Problems analyzed are also: cluttered horizon, haze and the absence of line features, glint and absence of line features, vegetation forming edges, haze due to wake, ships forming edges on the horizon line. It illustrates the problems that must be taken into account in maritime zone surveillance.

High vision applications have to be aware of maritime situations. They are more than image processing. Maritime situation awareness is discussed in [8]. It utilizes many sensors, sensor fusion and computational intelligence. The presented algorithm uses AIS data, radar, sonar, NIR, and visible spectra to form input to the computational block. Even so, it can lose correspondences. Then, fuzzy logic is applied.

An innovative maritime surveillance system based on IR spectrum is presented in [9].

Challenges in ground truth evaluation are discussed in [10]. It is concluded that new benchmark sets are necessary for multi-target scenes.

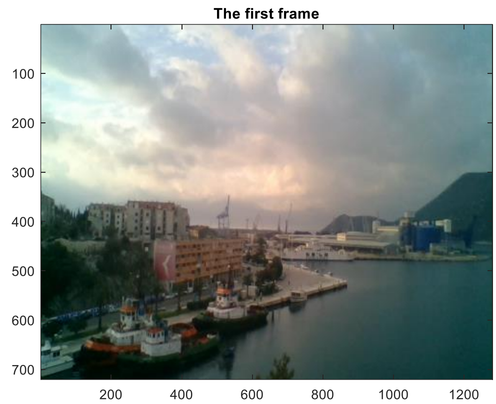
This brief overview shows the many problems of maritime zone surveillance. It also shows how important it is to develop reference datasets for such problems and the reason why the "Establishment of reference database for studying the influence of weather conditions on marine video surveillance" project was accepted by the Maritime Faculty of the University of Split. The application of algorithms developed for such surveillance can range from security, safety and collision avoidance to ecology and nautical tourism, etc.

In this paper we will attempt to illustrate the problems and possibilities relating to ground truth determination, which could be used for the establishment of reference datasets for maritime zone surveillance in different weather conditions.

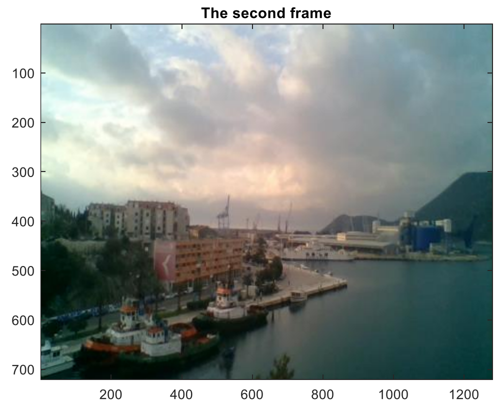
2 PROBLEMS AND TOOLS IN GROUND TRUTH DETERMINATION

The process of establishment of any given reference video dataset includes two unavoidable steps: video capture and the establishment of ground truth in every frame. But there is no easy, fast, and reliable way to mark the ground truth. Ground truth is obvious to human beings, but marking every pixel in the frame is problematic. Hence, an automated or half-automated method would be immensely helpful.

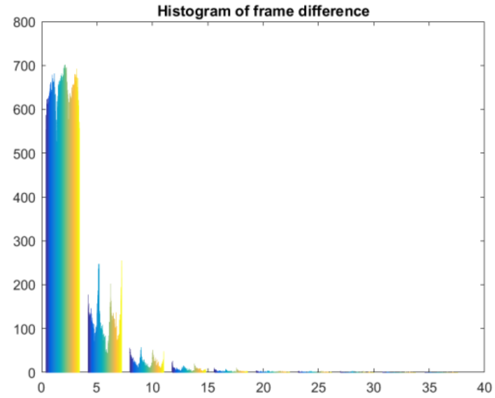
Figure 1 shows why this is not an easy problem. It shows two, mostly identical frames. By simple differencing, almost everything would be black (but it is not, see Fig. 1.d). However, the histogram and the result of differencing show otherwise due to illumination variations (see [11, 12, 13]).



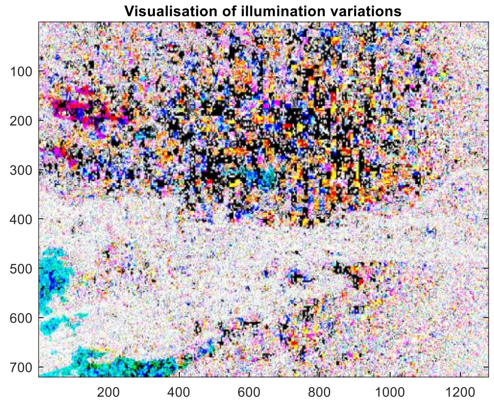
a)



b)



c)



d)

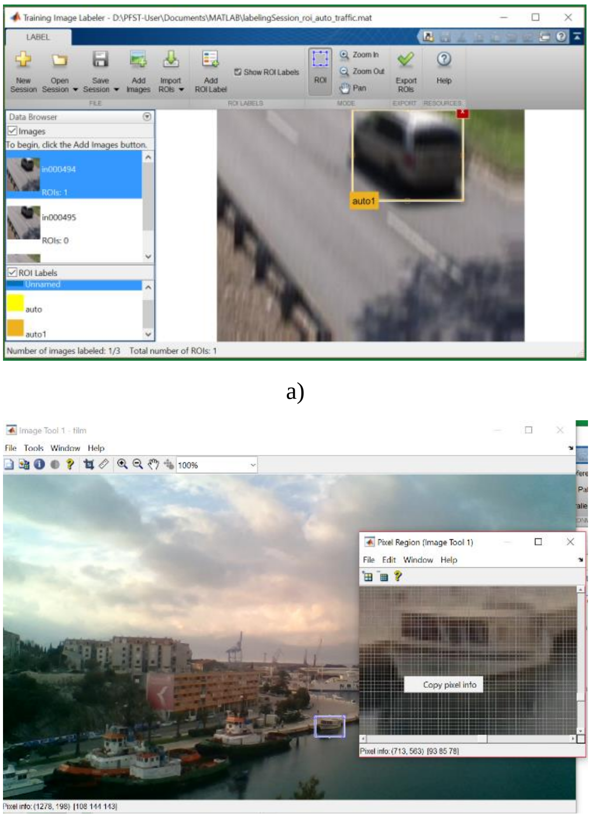
Source: Authors.

Figure 1: Port of Ploče (Croatia) in cloudy weather - a) the first frame, b) the second consecutive frame, c) histogram of the frame difference, d) frame difference

Matlab incorporates several ways to help in determination of the ground truth. One way to facilitate the process of ground truth determination is to use the Matlab training tool - the Image Labeler. The second way is to try to adapt the Classification Learner App for video processing. This is an advanced way based on learning, with definite potential for future usage. The third way is to use the "imtool" app.

The fourth way is to train a cascade object detector to detect objects from scenes. Finally, in Matlab 2017, the "Ground Truth Labeler App" [14] is introduced as part of a specialized toolbox (Automated Driving System). However, all of these methods are flawed.

The fourth method has an obvious flaw: it requires all types of vessels to be in the database. The first and the third method result in rectangular objects (pixel windows), which is usually not the case in practice. Hence, they could be used to narrow image parts that should be carefully and manually "fine tuned" in order to obtain the precise ground truth. The second method should be considerably modified to obtain the desired results. Unfortunately, we were unable to test the fifth method, because we do not have the license to use that specific toolbox.



a)

b)

Source: Authors.

Figure 2: Example of operation - a) Matlab “Image Labeler”, b) Matlab “Image Tool”

The standard approach to benchmark establishment is to classify the image pixels into white areas (moving objects) and black areas (background). However, that is insufficient, because there are, as mentioned above, many interesting phenomena which could occur, such as shadows, which are interesting in outdoor surveillance. Shadows are changes in the image which are moving with a moving object, and can, technically, be considered foreground. However, they extend the motion area and aggravate measuring objects and feature extraction. When exact object extraction is important, shadows are unwanted changes in frames difference, which should not be taken into account. The waving tree effect is also an unwanted foreground, but is not connected to the motion object. Hence, many new datasets also consist of one or more grey levels, which marks the area of special interest for the issue covered.

Since we wanted to create a new benchmark set, deciding what to take into consideration was relevant. There are several important aspects which need to be defined before engaging in any extensive work on the benchmark (reference dataset). In modern development the following needs to be defined:

- the purpose it serves (as a way to test: advanced deep learning algorithm tests capable of distinguishing between moving sea surface objects and moving objects on land, or standard motion segmentation)
- the specifics of the problem which should be specially marked with gray levels
- the output (ROI coordinates, ROI pixel window in the output image, gray or black and white image (motion mask))?

3 RESULTS AND DISCUSSION

The purpose of developing a new benchmark (dataset) is to have a dataset, which can be used to test new algorithms for maritime zone surveillance by video cameras (possible long range and preferably high resolution). Cameras are placed on land, with a view of the desired scene (zone). The items from the previous section illustrate that the purpose of the mentioned project is to segment moving vessels at sea (both small and large). Specifics that could be important in determining potential risks (in some tested algorithm, not in the ground truth generation!) are shadows, the waving tree effect, clouds, which should be discarded from consideration, and wakes, foam, and speckles in the water. Waving tree effect should not be included in the correct motion mask. Effects that are false positives and should be of interest (and it could be useful to use gray tones) are wakes, foam and speckles in the water, which should definitely be identified as motions by motion detection algorithms, but as undesired motions. Shadows should also have their gray tone. Finally, the answer to the third item is that gray images in the bitmap format are the desired ground truth output.

The project is divided into several stages:

- Choice of surveillance zones,
- Recording of video sequences,
- Ground truth marking in every frame,
- Publication of the benchmark set.

Surveillance zones, which should be chosen, depend on the purpose. It could be marine or port, but it could also be a wider zone with dense traffic. Video surveillance could be important in maritime traffic safety when dealing with mixed traffic, such as combination of ships with and without AIS.

The second stage is to record video sequences. It is preferable to use the same camera position under different weather conditions. In this time-limited project, it is important to record as many interesting scenes as possible. The recorded sequences will be publicly available on the Internet.

Ground truth will be establish for several sequences due to time and personal limitations. The goal is to obtain sequences and ground truth for the same scene under different characteristic weather conditions. Other sequences will be left for future research and projects.

It would be preferable to use advanced marking of moving objects, marked with coordinates. Since we use Matlab, research teams which are not compatible, could not use a novel benchmark set. Hence, it is also useful to establish ground truth of gray images, not just vectors.

Figure 3 illustrates an example of ground truth for a frame from Figure 1.

Figure 3: Example of the ground truth of frame 1 from Figure 1

Figure 3 shows motion mask for one small moving vessel out of AIS – a boat. Motion on land is discarded, since it is of no interest for maritime traffic analysis. However, it is only a black and white type of output. Hence, shadow is added to the boat's silhouette.

4 CONCLUSIONS

There are a number of problems in ground truth establishment in a maritime zone. Some aspects are discussed, while other are merely mentioned. Tools for ground truth labeling and identification are discussed.

This paper also explains the motivation for hard work on the scientific project "Establishment of reference database for studying the influence of weather conditions on marine video surveillance". Anticipated project duration is two years. The paper provides an overview of problems faced by the project, to be dealt with in future research.

ACKNOWLEDGMENTS

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UNMANNED VEHICLE SYSTEMS IN HYDROGRAPHIC SURVEY - NEW OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Nowadays, there is many performance of unmanned vehicle systems (UVS). The movement or navigation of these systems may operate with various degrees of autonomy: either under remote control by a human operator, or fully or intermittently autonomously, by on-board computers. Some of those systems are used in hydrographic survey as following:

1. Unmanned aerial vehicle (UAV), commonly known as a drone is an aircraft without a human pilot aboard;
2. Unmanned surface vehicles (USV) is vehicle that operate on the surface of the water (watercraft) without a crew;
3. Remotely operated underwater vehicle (ROV) is a tethered underwater mobile device.

Each of these types of vehicles may have equipment for positioning (usually Global Navigation Satellite System - GNSS), Systems for platform stabilization (Inertial Navigation Systems - INS with Inertial Measurement Unit - IMU) and equipment for hydrographic survey (echo sounder for vessels or underwater vehicles; multispectral camera or LIDAR for drones). Many hydrographic offices increasingly have used such vehicles for hydrographic survey in recent years and there are efficient and inexpensive versions of equipment for hydrographic and bathymetric survey.

In addition to the listed types of vehicles, the use of satellites as a relatively new depth determination method will be presented in this paper (Satellite Derived Bathymetry - SDB).

The paper will present and summarize techniques and methods used for hydrographic survey, comparative advantages and disadvantages of each system. Results will be compared with conventional survey and International Hydrographic Organization (IHO) standards for hydrographic surveys S-44.

Keywords: unmanned vehicle systems, hydrographic survey, IHO S-44

1 INTRODUCTION

It is very well known fact in the world hydrographic community that the Moon's surface is better mapped than the Earth's seabed. Sea depth data was by far the most expensive spatial data. Systematic bathymetric survey with satisfactory data accuracy was recorded only near the coast or depth area up to 200 meters (continental shelf).

Many national and international initiatives have tried to present proposal to find methods and techniques to prevail this discouraged reality.

In such an atmosphere the NIPPON FOUNDATION – GEBCO Seabed 2030 Project, which plans to map 100% of the world's ocean seabed by 2030, will be an enormous challenge to create a complete high-resolution digital bathymetry image of the oceans and seas (https://seabed2030.gebco.net/).

Taking into considerations up today standard hydrographic methods and techniques of survey, many scientists and hydrographers proposed a few recommendations to fulfill ambitious challenges of mapping the entire oceans and seas by 2030 (https://www.hydrointernational.com/magazine/november-december-2017):

1. To develop new methods of data collection instead to build a massive new fleet of research vessels;
2. To dedicate a bigger workforce to the post-processing of the resulting vast amount of data as well as to data management;
3. To continue with improving sensors technology.

It should also be noted that hydrographic equipment manufacturers are also competing in finding new, simpler and cheaper "vehicles" equipped with modern sensors.

In this paper two relatively new techniques and methods for hydrographic survey: 1. unmanned vehicle systems and 2. satellite derived bathymetry, will be presented as well as comparative advantages and disadvantages in relation to conventional hydrographic survey proposed by International Hydrographic Organization (IHO) standards for hydrographic surveys S-44 (IHO, 2008).

2 UNMANNED VEHICLE SYSTEMS IN HYDROGRAPHIC SURVEY

Nowadays, there is many performance of unmanned vehicle systems (UVS). The movement or navigation of these systems may operate with various degrees of autonomy: either under remote control by a human operator, or fully or intermittently autonomously, by on-board computers. Some of those systems are used in hydrographic survey as following:

1. Unmanned aerial vehicle (UAV), commonly known as a drone is an aircraft without a human pilot aboard;
2. Unmanned surface vehicles (USV) is vehicle that operate on the surface of the water (watercraft) without a crew;
3. Remotely operated underwater vehicle (ROV) is a tethered underwater mobile device.

Each of these types of vehicles on board may have equipment for positioning (usually Global Navigation Satellite System - GNSS), Systems for platform stabilization (Inertial Navigation Systems - INS with Inertial Measurement Unit - IMU) and equipment for hydrographic survey (echo sounder for vessels or underwater vehicles; multispectral camera or LIDAR for drones). Many hydrographic offices increasingly have used such vehicles for hydrographic survey in recent years and there are efficient and inexpensive version of equipment for hydrographic and bathymetry survey.

2.1 Unmanned aerial vehicle (UAV)

Lidar is an instrument that measures distance to a reflecting object by emitting timed pulses of light and measuring the time between emission and reception of reflected pulses. Lidar has been used as a topographic survey method for several decades but recently has been used also for bathymetric measurements (https://oceanservice.noaa.gov/facts/lidar.html). In the last few years Lidar devices for UAV, or so-called drones, developed rapidly. World's first Small-UAV-based surveying system for hydrographic applications is the RIEGL's BathyCopter (http://www.riegl.com/products/unmanned-scanning/bathycopter/). It is a novel topo-bathymetric laser profiler consisting of a laser range finder operating at λ = 532 nm (pulse repetition of 4 kHz), a navigation unit (GNSS, IMU), a flight control system and optional cameras tightly connected to an octocopter UAV platform (an unmanned helicopter having eight rotors; Fig. 1). The system is called RIEGL's BathyCopter and was presented on INTERGEO 2015 in Stuttgart. The main concept of this Riegl UAV is to measure distances to both the water surface and the bottom.

Mandlburger, Pfennigbauer & Wieser (2016) performed a flight experiment with RIEGL' BathyCopter in river conditions, finding sub-decimeter accuracy of shallow water depths in water body profiles with an along-track point spacing < 10 cm.

Source: (http://www.riegl.com/products/unmanned-scanning/bathycopter/)

Figure 1: Unmanned aerial vehicle (BathyCopter) with RIEGL Lidar sensor

2.2 Unmanned surface vehicle (USV)

Modern autonomous and unmanned vessel (Autonomous Surface Vehicle – ASV, Unmanned Surface Vehicle – USV) was first designed in 1993 and was designed for various missions: science, bathymetric mapping, defense and general robotics science (Manley, 2008).
Today USVs have been developed by many corporations and academic labs. Depending of the size and displacement of the USVs, there is a variety of design solutions in the construction of the hull and boat propulsion (Manley, 2008) as well as communications and system operations.
In this paper two USVs will be described with regards to their importance for the use of unmanned boats in hydrography.
„ASV – unmanned marine systems" (https://www.asvglobal.com/product/c-worker-7/) produced C-Worker 7 as a multi-role work class ASV suitable for a variety of offshore and coastal tasks (Fig. 2).
C-Worker 7 can integrate a variety of payloads including multi-beam, USBL, CTD and ADCP via exchangeable payload frames. It can be used under direct control, semi-manned or completely unmanned.

Source: (https://www.asvglobal.com/product/c-worker-7/)

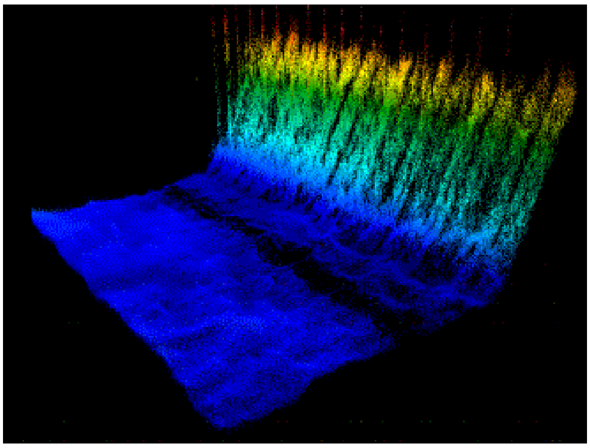
Figure 2: Unmanned surface vessel C-Worker7

The UK Ship Register has signed on 13 November 2017 its first ever unmanned vessel (ASV's C-Worker 7) to the flag, showing how it is adapting to the changes of the maritime industry (https://www.ukshipregister.co.uk/news/uk-ship-register-signs-its-first-unmanned-vessel/).

Unmanned surface Vehicle - GeoSwath 4R USV (Fig. 3), produced by Kongsberg Maritime (https://www.km.kongsberg.com/) offers efficient simultaneous swath bathymetry and side scan mapping using an unmanned remotely operated surface vehicle. The wide swath sonar system - GeoSwath Plus, has been closely integrated with ancillary sensors and communication links into a proven remote controlled platform for quick and easy deployment and operation. This remote hydrographic survey boat allows surveying in locations and situations in which deployment of conventional platforms is not practicable or hazardous.
GeoSwath 4R is a phase measuring bathymetric sonar that delivers high resolution wide swath bathymetry (Fig. 4) data with bottom coverage of up to 12 times the water depth. Accuracies have been shown to exceed IHO standards for hydrographic surveys (https://www.km.kongsberg.com/). In addition co-registered and geo-referenced side scan data is acquired that allows easy object detection and bottom characterization. It is integrated with a GPS position and heading sensor, a motion reference unit and a sound velocity sensor.

Source: (https://www.km.kongsberg.com/)

Figure 3: Unmanned surface vessel GeoSwath 4R



Source: (https://www.km.kongsberg.com/)

Figure 4: Pilings along a river bank as a result of USV GeoSwath 4R bathymetric survey

2.3 Remotely operated underwater vehicle (ROV)

A remotely operated underwater vehicle (ROV) is a tethered underwater mobile device (Fig. 5). This meaning is different from remote control vehicles operating on land or in the air. ROVs are unoccupied, highly maneuverable, and operated by a crew aboard a vessel (https://www.ecagroup.com/en/solutions/h300-ins-rov-remotely-operated-vehicle).

Since their introduction into the commercial world in 1970's, unmanned vehicles have become essential not only in the exploitation and development of deep water oil and gas reserves - far beyond the reach of divers -but also in many other areas. Remotely Operated Vehicles (ROV) are unoccupied underwater robots, connected to an operator via a series of cables. The connecting cables transmit command and control signals to and from the underwater vehicle and the operator, allowing remote navigation of the vehicle.

A typical hydrographic ROV configuration includes a video camera, lights, sonar systems, and an articulating arm. The articulating arm can be used for retrieving small objects, cutting lines, or attaching lifting hooks to larger objects. The ROV system includes the vehicle, deck unit, tether management system, hand box controller, laptop computer, and video display (https://en.wikipedia.org/wiki/Remotely_operated_underwater_vehicle).

Current hydrographic uses for the ROV include object identification (such as submerged navigation hazards), vessel hull inspections, and least depth determination. The system is not intended to be a replacement for hydrographic diver investigations, but could serve as a substitute when diver safety is in question, or when divers are otherwise not available (https://www.controleng.com/single-article/are-rovs-more-like-robots-or-drones/).

Source: (https://www.ecagroup.com/en/solutions/h300-ins-rov-remotely-operated-vehicle)

Figure 5: ECA ROBOTICS Mod. H 300 MKII ROV operated by the Hydrographic Institute of the Republic of Croatia

3 SATELLITE DERIVED BATHYMETRY

Satellite Derived Bathymetry (SDB) is a relatively new survey method which uses satellite or other remote multispectral imagery for depth determination (Marks, 2016). SDB supports various hydrographic and marine applications (bathymetry, coastal management, benthic habitat survey, water quality monitoring…).

Recent advances in satellite technology (spectral, radiometric, temporal and spatial resolution improved) have increased potential of this method as a source of hydrographic data. This method was developed in the late 1970s, but the last few years become widely available and used (Pe'eri, Azuike & Parrish, 2013). SDB is a survey method founded on analytical modeling of light penetration through the water column in visible and infrared bands. It should be pointed out that accuracy of SDB does not meet current International Hydrographic Organization (IHO) S-44 standards (IHO, 2008), but can be useful tool for survey planning of an area that require a new hydrography survey (Pe'eri, Azuike & Parrish, 2013). SDB data has potential to become most important low cost source of a large number of spatial data including hydrographic data also.

The method is subvariant to the Lidar surveying method. The difference is that the satellite navigation path is predefined, each recording is ordered individually and equipment is not included in the cost of the equipment or its maintenance.

The result of satellite derived bathymetry (SDB) method, which used Sentinel 2 image taken on 09th May 2017, for depth determination in the area of the Hramina Bay in Croatia is shown in Fig. 6. It can be seen that generally depth gradients and coastline are very well surveyed by using SDB method, while individual shoals are not detected because of low spatial resolution of the SDB method (Leder & Duplančić Leder, 2017).

It should be pointed out that satellite radar based bathymetry (altimeter bathymetry) has been used in last decade for mapping sea topography by applying SAR (Synthetic Aperture Radar). SAR bathymetry measure wave lengths which detects variations in sea level caused by the gravitational pull of undersea mountains, ridges and other masses (for deep waters) or modification of surface currents and ocean waves (for shallow waters). This satellite method of depth determination has been developing in the last few years and still does not achieve the accuracy required by official hydrographic survey (Marks, 2016).

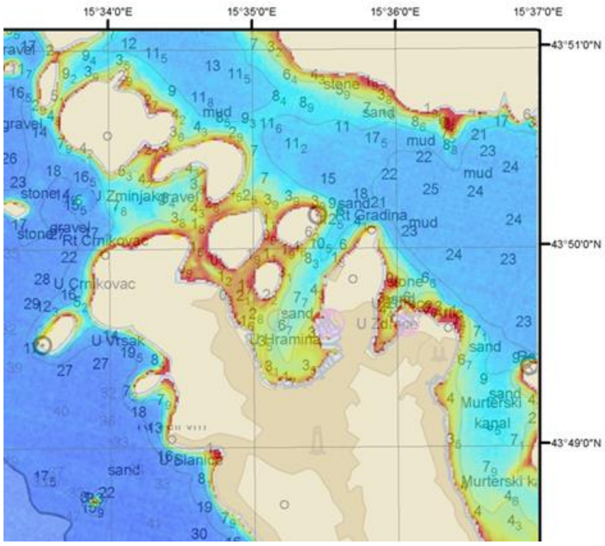


Figure 6: The result of SDB method for Hramina Bay in Croatia

Source: (Leder & Duplančić Leder, 2017)

4 CONCLUSION

The paper presented and summarized new techniques and methods used for hydrographic survey (Tab. 1), comparative advantages and disadvantages as well as an analysis of the accuracy of each system. Results are compared with conventional survey and International Hydrographic Organization (IHO) Standards for Hydrographic Surveys S-44 (IHO, 2008).

Measurement of shallow water depths in water bodies (oceans, seas, rivers, lakes) and coastal zones by applying unmanned aerial vehicles (UAV) platforms and sensors could be used for potential applications like underwater object detection or monitoring of dynamics after flood and storm event, ruther than producing official nautical charts, because it is difficult to obtain full seabed coverage of the surveyed area according to IHO Standards for Hydrographic Surveys.

Modern unmanned surface vessels (USV) are suitable for a variety of offshore and coastal hydrographic surveys. In coastal area it is possible to perform a survey relatively autonomous (communication is between people on the coast and the vessel), while during the offshore survey USV is working simultaneously with a research vessel. USVs can integrate a large number of different research equipment (multibeam echosounder, side scan sonar etc.) and the measurement results may be consistent with IHO Standards for Hydrographic Surveys.

A remotely operated underwater vehicle (ROV) operated by a crew aboard a vessel are currently being used in hydrography for object identification (such as submerged navigation hazards), vessel hull inspections, and least depth determination.

Satellite Derived Bathymetry (SDB) method is suitable for bathymetric survey of shallow areas with clear water (approximately to the depth of 2 secchi disc depth). It should be pointed out that accuracy of SDB does not meet current IHO Standards for Hydrographic Surveys. SDB method could be, therefore, an ideal tool for the determination of bathymetric data in the marine areas without bathymetric data or in the areas with old bathymetric data. The eastern Adriatic Sea coastal area is relatively shallow water, mostly very clear in a large part of the year. Thus SDB method met two basic components which are preconditions for its usage.

Table 1: Depth accuracy, depth range and measurement method for the considered vehicles/survey methods

Vehicle/ Survey method	Depth accuracy	Depth range	Measurement method
UAV	± 10 cm	50 m	Laser beams
USV	± 10 cm	0-11.000 m	Acoustic signal
ROV	± 10 cm	10-2.000 m	Acoustic signal
SDB	± 3 m; depends on depths	≤ 2 secchi disc depth	Electromagnetic waves

Source: own elaboration.

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PEDESTRIAN FLOW AND WALKING BEHAVIOUR ANALYSIS ON THE PASSENGER TERMINAL OF THE PORT OF KOPER BY USING THE SIMULATION MODEL

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ABSTRACT

The paper covers pedestrian flow analysis influenced by large cruise ship arrivals and focuses on the simulation model. The purpose of the paper is to present and analyze passenger terminal occupancy in the Port of Koper. All analyzes and results, as well as the conclusions, based on the microsimulation produced with PTV Vissim software. It focuses on the areas between the exit point, passenger building and the desired destination of passenger. The passenger traffic in Port of Koper has increased due to the increase of cruise traffic in Adriatic. These port is so called "port of call" for cruises. This means that the port is regarded as one of the tourist destinations that cruiser shipping within its itinerary intends to choose. Based on the analysis of traffic flow for last few years and the increasing demand for cruising we can expect that passenger traffic will increase. The main goal of the paper is to examine pedestrian behavior when leaving the cruise ship. The current state of the passenger terminal in the Port of Koper is presented by using the microsimulation software called PTV Vissim.

Keywords: port of Koper, passenger terminal, pedestrian flow, walking behavior, PTV Vissim

1 INTRODUCTION

Cruise ship arriving in the port of Koper carry approximately 1,000 to 3,000 passenger and crew members. The average length of arriving cruise ship is approximately 275 meters, and the average occupancy of cruise ship is approximately 1,900 passengers. The largest cruise ship which has arrived in port of Koper was "Voyager of the Seas" with 3,800 passengers on board and it measured in length 322 meters. Such high concentration of passengers at once can lead to some traffic problems, especially at the point of disembarking and embarking on a cruise ship. These leads to a high density of pedestrians on one place. (Luka_Koper)

Pedestrian flow caracteristics studies mainly focus on the model equations for relationship between speed, flow and density. Pedestrian flow was first studied by the Institute of Architecture of the Russian Academy of Arts in 1937 and then later by the Central Scientific Research Institute of the Russian Fire Protection Service (between 1946 and 1948) which verified the well known equation in traffic flow theory: $q = k * v$ The relationships among flow, speed and density have also been studied by a number of other researchers, namely, Lighthill and Whitham (1955); John J. Fruin (1971); B. Pushkarev and J. M. Zupan (1975). The Lighthill and Whitham (1955) developed a continuum theory in which traffic density is considered. They found out motion of pedestrian crowds by a two-dimensional generalization of the behavior and proposed a microscopic model of pedestrian flow. Based on HCM (LOS 1965) has J. J. Fruin (1971) developed the level of service concept for walkways, showing that reduced capacity leads to congestion and teribly reduced flows. He has also made quantitative observations on pedestrian flows and developed a speed-density model for pedestrian flow on stairways and walkways. The speed–density relationship was found to be linear and then flow-density and flow-space module relationships were obtained from it. B. Pushkarev and J. M. Zupan (1975) demonstrated a strong correlation between independent land use variables and pedestrian movement. They also developed the fundamental diagrams and equasions of relation between speed-densty and flow-space.

In our paper we focused on the empirical data concerning pedestrian behaviour (motion patterns) and pedestrian flow. With a help of a simulation model we presented a pedestrian flow and behavior in comparison to the theoretical characteristics of pedestrian flow. The paper focuses on the exit/entrance points and the desired destination of passengers.

2 PEDESTRIAN FLOW AND WALKING BEHAVIOR

Pedestrian flow can be described with speed, rate of flow and density. The pedestrian unit flow is the number of pedestrians per unit of time per meter, typically expressed as pedestrians per minute per meter (p/min/m). All the main characteristics (relationship between speed, density and volume) of pedestrian flow are analogous to traffic flow of vehicles. The basic characteristics of pedestrian flow are (Hoogendoorn, 2011):

1. Dimensionality (Pedestrians move in two dimensions),
2. Direction (Multiple directional flow -complicated factor),
3. Contact (Physical contact pedestrian dynamics),
4. Interaction (Subconscious of pedestrian's behavior),

5. Anisotropy (Pedestrians are mildly anisotropic, these mean that pedestrians react according to what he sees in front of himself and what he hears behind himself).

Lighthill, Whitham (1955) and Richards (1956) independently proposed a macroscopic model of traffic flow to describe the dynamic characteristics of traffic, which is known as the LWR model. They give equation (1) for continuous flow Q (Fruin, 1971):

$$Q = v \cdot k \tag{1}$$

Where: Q - Flow rate (p/s/m), v - Flow speed (m/s), k - Flow density (p/m2.

The figureical representation of the relations between the macroscopic characteristics of a flow is called “fundamental diagram” developed by Weidmann. Capacity for pedestrian flow is in Weidmann fundamental diagram expressed with P/m/s, because it relates to the width of pedestrian and bottleneck. On the fundamental diagram of pedestrian flow are affecting different factors:

1. Flow composition (age, gender, walking purpose...)
2. Walking infrastructure (surface inclination, stairs…)
3. Environment (temperature, weather conditions…)

Pedestrian flow densities k (p/m2) is difficult to visualize, because of that we have much more practical equation (2) for unit flow rate for pedestrians, recommended by HCM (B. Pushkarev, 1975):

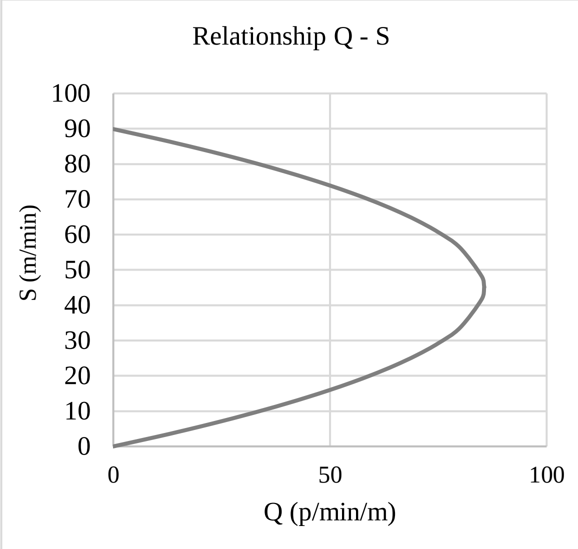
$$Q_{(ped)} = \frac{S_{(ped)}}{M} \tag{2}$$

Where: $Q_{(ped)}$ - Flow rate (p/min/m), $S_{(ped)}$ - Pedestrian speed (m/min), M - pedestrian space (m2/p).

According to HCM the maximum flow rate occurs when the available pedestrian space is between 0. 45 m^2/p and 0. 9 m^2/p. If space is reduced to less than 0. 45 m^2/p, the flow rate declines precipitously, and all movement stops at the minimum space allocation of 0. 2 to 0. 3 m^2/p. These is connected to the pedestrian body ellipse. According to the HCM the width of pedestrian is 0.6 m (in shoulder) and body depth of 0.5 m. These means that the surface of occupies of pedestrian equals 0.3 m2/p (Transport “Highway Capacity Manual 2010, Volume 1: Concepts, 2010).

Each pedestrian requires a certain amount of space; these depends if pedestrian is standing or walking. According to the "Highway capacity manual" is a total area of 0. 30 m^2 a minimum space standard for standing pedestrians (including buffer zone). And total area of 0. 75 m^2 for walking. The amount of space available for each pedestrian is directly connected with average walking speed. HCM determines the average free-flow speed of pedestrians (i.e. an average pedestrian speed on an empty walkways) which is approximately 1.5 m/s and is determined as an average walking speed. Of course different types of pedestrians (i.e. elderly/young people, children, wheelchair users...) move with different walking speed. Walking speed is in relationship with space per walking pedestrian. When space per walking pedestrian drops, comes to reduction in speed (Transport “Highway Capacity Manual 2010, Volume 1: Concepts, 2010).

The relationship between pedestrian flow and space according to B. Pushkarev, J. M. Zupan and HCM is shown in figure 1 (fundamental diagram) (B. Pushkarev, 1975):



Source: adapted from HCM 2010

Figure 1: Relationship between speed (S) and flow of pedestrian (Q)

PTV Vissim is using HCM terminology for defining level of service. The HCM methodology for analyzing pedestrian LOS based on the measurement of pedestrian flow rate and sidewalk space. PTV Vissim is defining LOS ranges as pedestrian per square meter, and not square meter per pedestrian as is it defined according to HCM terminology. LOS ranges are defined in PTV Vissim software (in unit ped/m2) as it is show in figure 2 (Fruin, 1971; Group, 2015).

ExperDens (Unit: ped/m2)

Class bounds and colors:

Count: 6	LowerBound	UpperBound	Color
A	MIN	0,179	(255, 255, 255,
B	0,179	0,270	(255, 0, 0, 255)
C	0,270	0,455	(255, 0, 255, 0)
D	0,455	0,714	(255, 255, 255,
E	0,714	1,333	(255, 255, 128,
F	1,333	MAX	(255, 255, 0, 0)

Source: adapted from HCM 2010 and PTV Group

Figure 2: Level of service by HCM methodology

According to the described HCM methodology of pedestrian flow and walking behavior it will be presented level of service in simulation of pedestrians.

3 MICROSIMULATION MODEL OF PEDESTRIAN FLOW AND WALKING BEHAVIOR ON THE PASSENGER TERMINAL

With micro simulation software PTV Vissim we can show motion patterns of pedestrians. Such a micro simulation models distinguish and trace the time - space behavior of individual pedestrians. Pedestrian behavior is generally described by a set of rules defining pedestrian behavior in specific situation on specific aspect (such as route choice and walking).

The aim of this simulation is to simulate passenger flows and walking behavior on passenger terminal in port of Koper. Pedestrians flows have been simulated with PTV Vissim microsimulation software. In the program the movement of pedestrians based on the Social Force Model (based on dr. Dirk Helbings model), which influences on walking behavior. The basic idea of the model is to model the elementary impetus for motion with forces analogously to Newtonian mechanics. The forces which influence a pedestrian's motion are caused by his intention to reach his destination as well as by other pedestrians and obstacles. The force F, that causes pedestrian to decelerate or accelerate consists of four terms (Ahn, Kowada, Tsukaguchi, & Vandebona, 2017; Peiponen, 2017):

$$F = F_{driving} + F_{social} + F_{wall} + F_{noise} \tag{3}$$

Where: $F_{driving}$ - Driving force into the desired direction, F_{social} - Forces between pedestrians, F_{wall} - Forces from walls, F_{noise} - A random force term that is implemented in order to prevent deadlocks at bottlenecks.

Beside these forces there are also some parameters that influence the pedestrian's path and speed towards reaching the destination. According to these, Vissim offers many parameters to model realistic pedestrian walking behavior. Which parameters to adjust and how to adjust them depend on what is being simulated (Ahn et al., 2017; Peiponen, 2017).

Pre-set parameters in Vissim (Group, 2015):

Table 1: Pre-set parameters of walking behavior in PTV Visim

Parameter:	Tau	ReacToN	ASocIso	BSocIso
Value:	0.4	8	2.272	0.2
Comment:	min0.05	min 0	min 0	min 0

Parameter:	VD	Noise	SidePref
Value:	1.2	1.2	None
Comment:	min 0	min 0	None, Left, right

Parameter:	Lambda	ASocMean	BSocMean
Value:	0.176	0.4	2.8
Comment:	min 0	min 0	min 0

Source: PTV Vissim 8 User manual

Using these parameters, it has been simulated pedestrian behavior and traffic flows on the passenger terminal of the port of Koper.

3.1 Microsimulation model with PTV Vissim software

In year 2016 has Slovenian government adopted a program for the development of a port of Koper for international traffic for the period 2016-2020. According to this program it will be built the main administrative facility for passenger terminal with all activities of a passenger facility. According to the program for the development of a port of Koper for international traffic for the period 2016 - 2020 there will be built passenger facility with 2,000 square meters. The area of passenger terminal will have 7,000 square meters.

The demand of pedestrians can be defined in two different ways in Vissim, either by defining the input of routes manually or by defining the flow between origins and destinations with an OD-matrix. In simulation model we used defining manually routes. PTV Vissim is dividing routes into two types; static routes and partial routes. For our simulation we used static routing decision, where pedestrians are walking the shortest path possible to reach their destination.

Below is presented one scenario models of a pedestrian flow and behavior on a pedestrian platform with administrative facility. The simulation presents the disembark of passengers from cruise ship in port of Koper when arrives in the port a large cruise ship with 2,000 passengers on board (if 60% of passengers leave the ship, these is 1,200 passengers). We analyzed pedestrian flow and walking behavior on a pedestrian platform (with 7,000 square meters) with administrative facility wich has one entrances and one exit. In simulation is shown one directional traffic flow.

In simulation we took different pedestrian types to present realistic situation. Different pedestrian types are representing Commuters at a station (accordins to the PTV Vissim software). Some pedestrians are walking individual and some of them in groups. In order to achieve a more realistic simulation we used different pedestrian types. Individual groups are presenting following pedestrian types: man (three different velocities), women (three different velocities) and wheelchair users. For pedestrians walking in group of two we used women and child. In order to get a realistic movement pattern of the pedestrians we placed some obstacles in simulation model. The obstacles are presenting walls, pass checkpoints, etc.

The aim of the simulation is to analyze pedestrian flow and walking behaviour, and to test if the planed area could handle the projected demand (to service ferries with 2,000 passengers, if is disembarking 1,200 passengers).

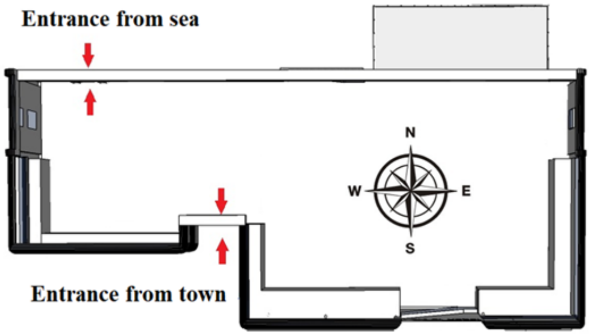


Figure 3: One entrance door for arriving passengers and one for leaving the passenger building

3.2 Microsimulation model and analyzes

Microscopic simulation model of walking has the property to represent random variations in the behavior of the simulated pedestrian flow. Because of random and stochastic processes are required several runs of simulation to generate valid predictions. We have made several runs of simulation to present how the values of the simulation fit to the theoretical fundamental diagrams.

Simulation speed was set to 10 simulation seconds/real seconds. The duration of a whole simulation is 1800 simulation seconds, these equals half of real hour. The simulation resolution has been defined as 1 time steps/simulation second meaning that the state of the simulation (pedestrians speed, etc.) is being recalculated and updated 1 time per simulation second. We have taken into analyzes the time period of 0 – 1800 simulation seconds (30 min). The average time of disembark from cruise ship is approximately 30 minutes.

The following results have been generated and analyzed:

1. Density according to HCM standard helps us assess level of services in different scenarios (Figure 4).

The blue dots are classified in 13 classes according to the density that has appeared in simulation. We analyzed LOS of the whole study via colored heat maps draws for 90 simulation seconds (1 min 30 s) time intervals. For the analyzes we have taken into consider the time period of 0 – 1800 simulation seconds, whole simulation time. The simulation based on HCM (walkways) standards (HCM based on pedestrian's volumes and densities which generates pedestrian flows.). Figure 4 is describing LOS for whole simulation time (1800 s/s). In figure 5 is showing where pedestrians are heading, the density of certain area and the level of service.

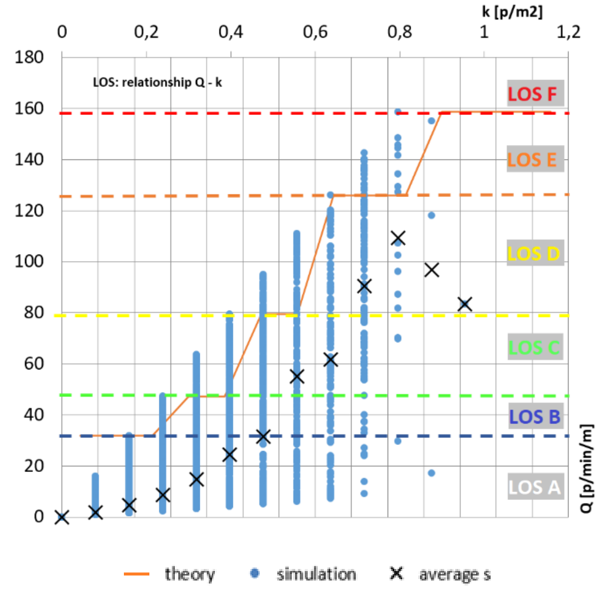


Figure 4: LOS, density and flow comparison between simulation and theory

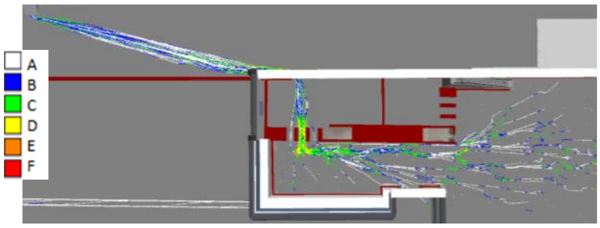


Figure 5: Trajectories of pedestrian's movements and LOS after 1350 s/s

After 1350 s/s or 15 min the simulation reaches the level of service E. These means that the density is between 0.714 p/m2 and 1.333 p/m2. LOS E means that the volumes approach to the limit of walkway capacity, with stoppages and interruption to flow. Typical practice is to design pedestrian facilities for LOS C or D densities.

Figure 5 is showing trajectories of pedestrian movements in time interval 1350-1440 s/s. Trajectories are colored regarding to the LOS.

By analyzing the trajectories of pedestrian movements we find out that line formation occurs mainly at large distance headways (low densities). When density increases the lane formation cannot be formed anymore. Obviously the line formation depends on the length, width of the walkway and on density.

2. Flow in relation to space

From the figure 6 is vissible that the space of walkable areas (and so pedestrian space) has s significant effect on the creating bottleneks. With the correct width and design of walkable areas, pedestrians can go through bottleneks. Also the pedestrian flow depends on the availiability of pedestrian space. It can be seen that deviation between theoretical values and simulated values are small.

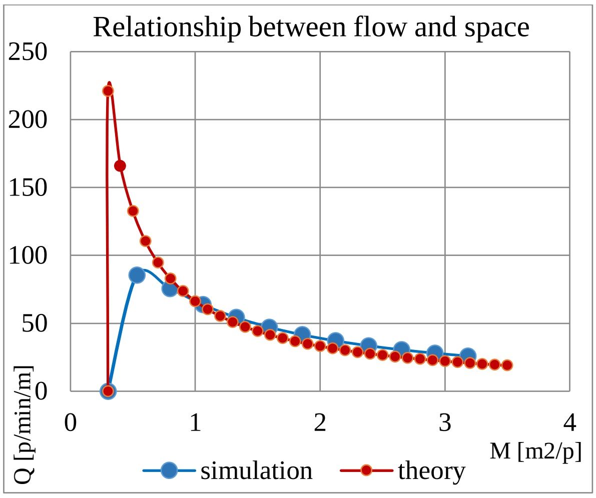


Figure 6: Flow in relation to space

3. Flow in relation to speed

Higher crowd densities leads to interactions between individuals and as such will reduce overall walking velocity. In Figure 7 can be seen that simulated average values are describing the theoretical fundamental diagram.

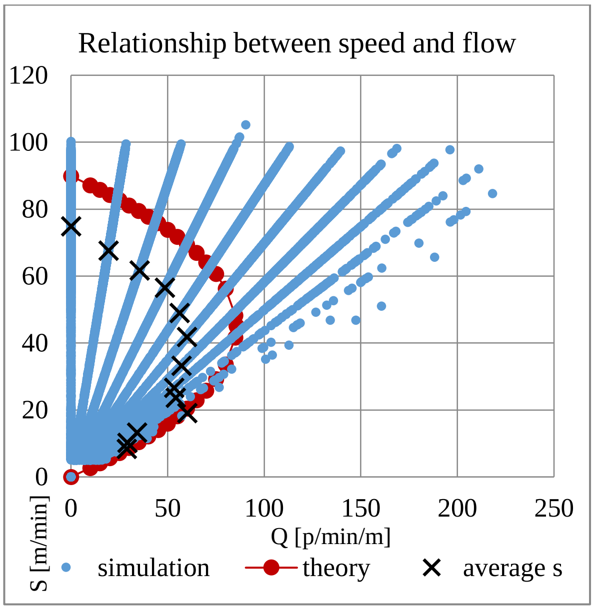


Figure 7: Flow in relation to speed

According to all analizes that have beed done, the simulation model is prepared for future analyzes. Of course we need to calibrate the model according to the real walking behaviour of pedestrians on the passenger terminal. For the calibration we need to capture the behavior of pedestrians, these can be done on many diferent ways. After the calibraton the model is prepared to simulate various scenarious.

3.3 Findings from simulation model

1. From the simulation models we notice that pedestrians are walking too close to each other than they would in real life. They also walked into each other too often. So we need to calibrate parameters of walking behavior to simulate pedestrian behavior as closely as possible to real behavior.
2. With Vissim we cannot simulate stopping pedestrians at unpredictable place, as example: wait for someone to catch up, look at their phone, etc. There is also not possible to simulate pedestrians walking in groups or waiting in groups.
3. We can say that pedestrians in simulation mostly want to take the shortest path.
4. We find out that line formation occurs mainly at large distance headways (low densities). When density increases the lane formation cannot be formed anymore. But, when comes to these phenomena, at which density? Are the width and the length of the walkway influencing on the density and formatting of the line of walking pedestrians?

4 CONCLUSION AND FUTURE RESEARCH

This paper has disussed about pedestrian flow and walking behavior on passenger platform of port of Koper. Regarding to the development program the planed facility has to service cruise ships with 2,000 passengers. In our simulation we took just one entrance and one exit with small width of door. We have found out that these will not be eanough for such a pedestrian flow. For better flow without bottlenecks we recommend to implement a facility with two entrances and two exits. So there will not come to bidirectional and intersecting flows which can lead to higher density.

As a conclusion, we can say that it is always good to have microsimulation examination in spatial and traffic planning to recognize any possible problems according to land usage and traffic flow. The simulation model is helpful as it is able to provide a visual appreciation of the future operation of the terminal. It helps to understand the actual phenomenon that may happen in the field. Researching pedestrian behavior and movement especially in crowded areas will help transportation planners to calibrate time sheadules in public transport, designing walkways and other infrastructure for pedestrians and other transport modes.

For a future researches of walking behaviour with simulation model is necessary calibration regarding to the real behaviour. Calibration ensures that the fundamental parameter values are adjusted to the given simulation implementation scope. Every simulation model reflects different pedestrian’s movements influenced by location, cultural influence, crowd composition..., because of that it is almost impossible to compare results between countries and with other simulation models. Therefore every model is calibrated for different instances. Once the model is calibrated and reflects realistic results for the base scenario (current situation) we can proceed to produce future scenarios.

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IMPACT OF WIND ON STACKED EMPTY CONTAINERS

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ABSTRACT

Stacking empty containers can be strongly affected by winds as ratio between container mass and exposed surface is small. When container tiers are several rows high, wind can pose a great risk to equipment and human lives. Therefore it is important to establish safe operating conditions for port operations. The paper presents a full scale measurements of shipping container tiers in the Port of Koper, Slovenia using ultrasonic anemometers and force transducers. The results are compared with literature data and statistically analyzed to establish a relationship between wind velocity and container tier stability.

Keywords: empty container, stack, tier, wind velocity, force measurement, strain gauge, anemometer, ultrasonic sensor

1 INTRODUCTION

When space is limited and container traffic is steadily increasing, containers are being stacked in higher blocks. When containers are loaded and cross section area to weight ratio is low, winds do not pose much risk. On the other hand, stacking empty containers is subjected to a risk of overturning due to forces that are caused by the wind.

Worldwide there are several recommendations regarding stacking of empty containers, but not much research in the field to analyze in detail, what are the reasons for overturning of the container blocks.

Among the guidelines are the Australian standard AS3711.10-2000 (AS3711, 2000), UNECE/IMO CTU code (Code of Practice for packing of Cargo transport Units) (UNECE, 2000). The AS3711.10-2000 is based on partially defined recommendations. It requires that boundary blocks are introduced in areas that are subject to strong winds. This means that boundary blocks at the borders of stacked containers should be lower than those in the centers. Boundary blocks should be comprised of full containers and should be no more than 3 rows high and 2 deep. In some cases, they may be accompanied by the boundary fences. The standard also requires use of anemometer based early warning systems to detect unsafe operating conditions.

On the other hand, the UNECE CTU code is more prescriptive regarding recommendations for wind speeds up to 20 m/s or 8 Bft, where minimum block widths are prescribed, for example, for 40 feet containers 6 tiers high it should be no less than 4 rows wide and if high cube containers are used, no less than 5 rows wide. In case of higher winds, there is recommendation that containers should be stored in a pyramidal shape and/or lashed to the ground.

Since the recommendations do not refer to the research results which there are not many, it was assumed that the guidelines are based on the experience rather than physical modeling. However, there were some attempts of numerical and wind tunnel simulations of such accidents, such as publication by (Zhen, Xingqian, & Chunhui, 2011). Many different scenarios were simulated in a wind tunnel using rigid models. As a comparison, for 6 tiers high block with a width of 5 rows, critical velocity was assumed to be 25 m/s when the wind is perpendicular to the long axis of the container. The study also includes wind influence at different angles and different tier heights between 5 and 8 tiers. The wind speed was not constant, but it had some randomness of periods about 3 seconds around the average values. It can be deduced that variability of wind velocity is of crucial important for early warning systems and additional analyses should be conducted in this field.

An analysis of container stability on the ocean vessels was done by (Acanfora, Montewka, Hinz, & Matusiak, 2017), but mostly focus was on acceleration induced by the ship movement.

In the paper (van den Bos, 2005), recommendations regarding safe stacking of containers were defined based on the computer simulations. The results were shown separately for different types of displacements, such as: sliding free, sliding last and tilt of entire last row.

Considering that there are many guidelines but very little theoretical basis, it was decided to address issue early warning system by measuring correlation between wind velocities and container load on the supporting structure to determine safe operating conditions.

2 MEASUREMENT SETUP

To measure forces of the wind on the containers, measurements were carried out using a set of 4 strain gauge based force transducers (load cells). The load cells were placed under each corner of the container as it is shown in the Figure 1.

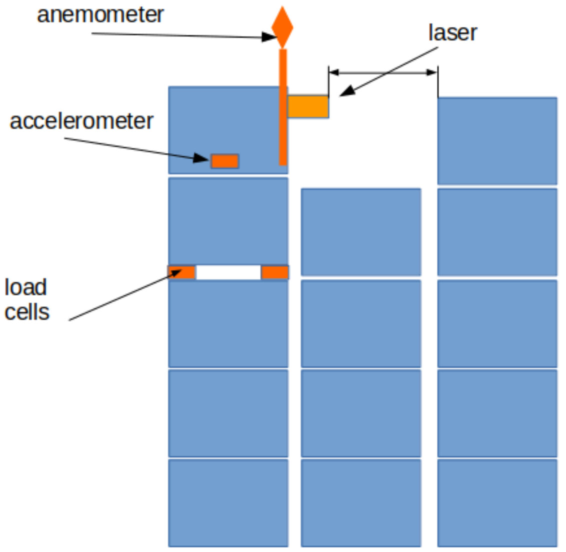

Figure 1: Sensor and container placement

In order to mount the containers on the sensors, special adapters were constructed to fit into holes in the corners. The sensors were mounted while upper container was lifted above the ground and fixed using a thread bar. Afterwards the container was elevated on the top.

Signal amplifiers were fitted in general purpose enclosures magnetically mounted on the container surface to avoid drilling and damage to the sampled container. The sensors were interconnected using the RS485 serial communication and the measurements were sampled at 10 Hz. In the figure 3 connections of the devices are shown. For data recording a low cost Raspberry Pi SBC was used and communication was achieved using the ethernet connection and GSM modem. Whole system was powered with 12V lead acid battery to enable possibility to move point of measurement to different locations in the port to assess impact of wind on different locations.

The connections between the measurement sensors are shown in the Figure 2. Using a single data recorder and synchronization by the NTP protocol all the measurements can be assumed to have same time axis.

3 WIND MEASUREMENTS

Wind was measured using ultrasonic anemometers, 3 installed on fixed positions in the surroundings and 1 on the container itself. To ensure time synchronization NTP (Network Time Protocol) was used. Synchronization was of crucial importance as it was aimed to establish relationship of wind velocities and forces on the container and wind velocities measured on fixed anemometers in the port area that will be used for early warning system. Wind data processing also required to determine, how wind measurements should be averaged to extract the most significant data from the background, as some guidelines recommend several seconds long measurements and some recommend time intervals with several minute length, such as (van den Bos, 2005).

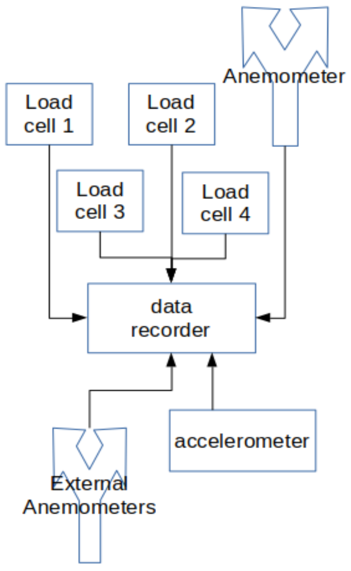

Figure 2: Sensor network connections

4 THEORETICAL MODEL

Container stacks fail in different ways as a result of wind forces:

- slide of top containers
- fall of entire column

Sliding of containers occurs when friction coefficients are low and falling of entire column occurs when friction coefficients are higher. Sliding occurs only on top containers since friction forces are lowest at the top since gravitational forces of objects above friction surface are lower.

Wind force per area can be expressed with equation

$$F/A = 0.5k\rho v^2 \qquad (1)$$

where k is shape factor, ρ is air density and v is air speed.

The simulations were carried out using the Working model 2D simulation tool ("Working Model 2D - 2D Kinematics & Dynamics Software - Engineering Simulation," n.d.).

The wind force dependence per unit area is show in the figure 3. According to the Eq. 1, it is increasing with square of the wind speed.

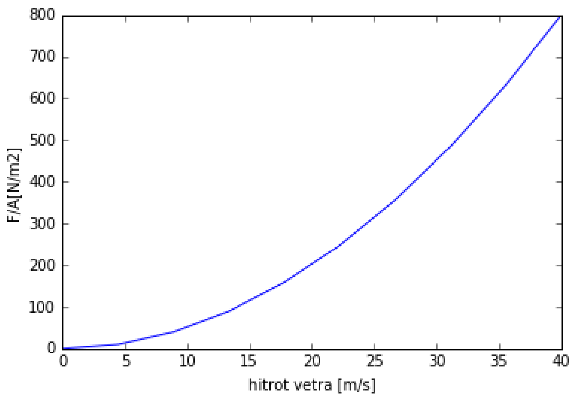

Figure 3: Wind force per container area

In the Figure 4, a force acting on the top container is shown, assuming the friction is low enough for the containers to slide.

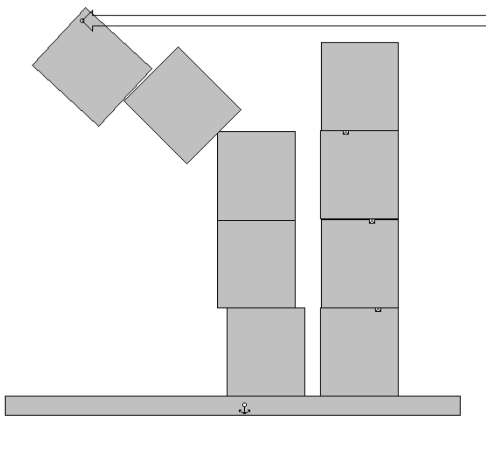

Figure 4: Slide of top rows

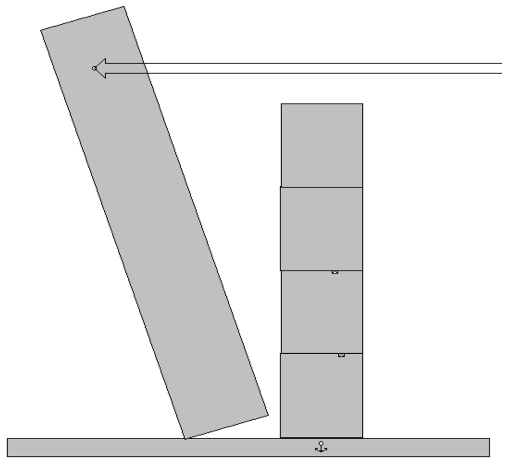

Figure 5: Fall of entire column

In the Figure 5 a model of non-sliding containers is shown, assuming whole block of containers collapsed.

5 RESULTS

Measurements were taken during diverse weather conditions, where wind velocities perpendicular to long axis of the container were assessed.

5.1 Summer thunderstorm

During the measurements whole block of 5 containers stacked next to a block of 2 containers collapsed due to a summer storm. In the Figure 6, a CCTV recording of the event is shown indicating that there was no sliding of containers at all.

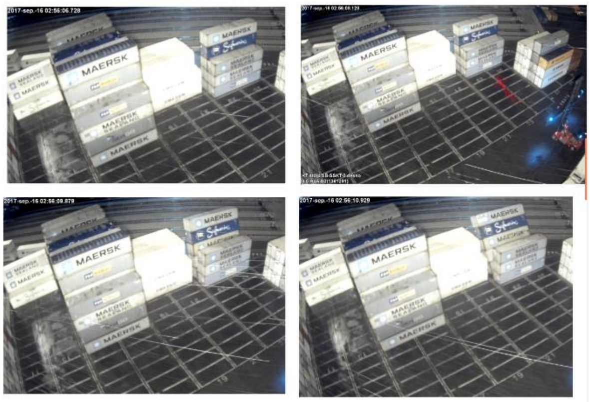

Figure 6: Fall of a container block (source CCTV)

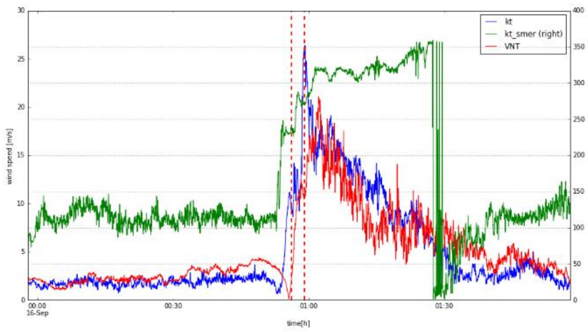

Figure 7: Wind speed during the event

During the collapse of the container block, wind speeds were recorded with a sample rate of 20 Hz during the event. In the Figure 7 wind speeds and direction (green line) were seen. It can be noticed that before sudden increase of wind speed, a change in wind direction for about 180 degrees occurred. In the figure an alarming wind speed was marked using the left red vertical line and time of container collapse is marked by the right vertical line. The wind speed 3-second average during the collapse was about 27 m/s.

5.2 Bora wind case

In the Figures 8 and 9 is a weight in two opposite container corners is shown. During stable conditions and no wind force present, the weight is about 1 metric ton in both corners. Due to the wind load, weight distributes from one corner to another and the fluctuations can clearly be seen. When load is decreased in one corner, it is increased in another. When one side of the container is not supported by the bottom surface, conditions for falling are met. In the Figure 8 a zero weight on one side of the container is was recorded, which means that if such wind force continued for more time, the container would fall.

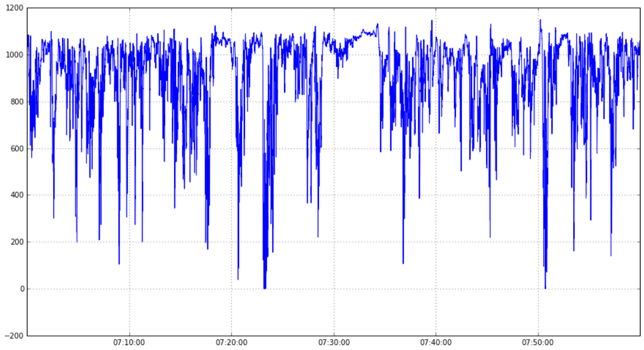

Figure 8: Force in corner 1

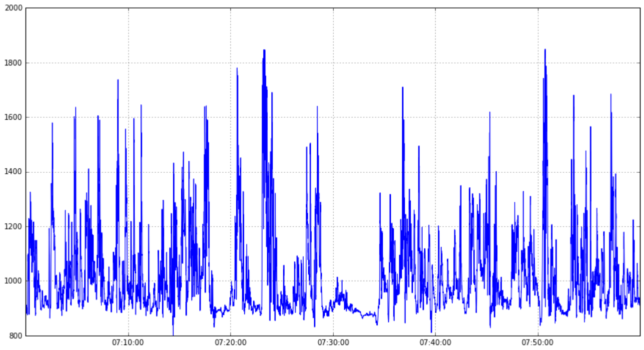

Figure 9: Force in corner 3

In the Figure 10, the wind speed and load in corner 1 and wind speed measured on the container itself is shown in the same time scale. As it can be seen at the time of total relief of supporting container 1s average was 22 m/s and 10s average was 17 m/s.

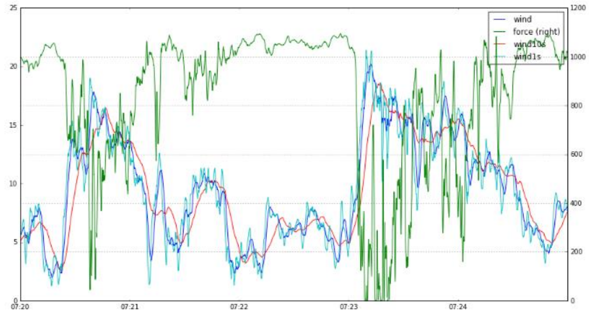

Figure 10: Wind speed during the event

6 CONCLUSION

The study analyses reasons for container block collapses as a consequence of wind forces. It identified mechanisms of container block collapses and shows theoretical models that were simulated and measurements from a unique full scale experiment. The results are useful to determine safe operating limits during the port operations and increase safety of personnel involved. The measurements obtained will be used to find best correlations between the wind measurements and conditions for container collapse in order to develop algorithms for metocean data processing and forecasting for the purpose of early warning system development.

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DEVELOPMENT OF THE EARLY STAGE OF THE FIRE ACCORDING TO THE LIMITED CARGO COMPARTMENT

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ABSTRACT

We want to introduce the problem of transporting dangerous goods (polyoxymethylene) in a limited cargo compartment, in the case of a complex fire scenario. A complex fire scenario means that we handle overpack, inner packaging (high-density polymer) and polyoxymethylene (powder form) as a dangerous substance. In the article, we would like to show how different fire scenarios influence the early stage of fire development. The article will show the difference between the completely sealed and the rest directions they have open boundary conditions of limited cargo compartment. The article we will also show the consequence of uncontrolled development such fire scenario. Specific boundary and initial conditions will be considered. Fire Dynamics Simulator (FDS) and Pyrosim numerical modelling tools will be used.

Keywords: air transport, dangerous goods, polyoxymethylene polymer (POM), numerical modeling (CFD), Fire Dynamics Simulator (FDS), Pyrosim

1 INTRODUCTION

Natural smoke and heat transport is one of the most important theoretical aspects in the field of fire engineering [1]. If a fire occurs in a confined space, smoke and hot flue gases will rise above the surface caught by the fire due to the buoyancy. The speed of formation smoke layer is an important factor in terms of early detection of a fire. [2], [4], [5].

This article presents a complex fire scenario. It consists of the following sets. Polymer polyoxymethylene as a dangerous substance that can be stored or transported between two points. Polyoxymethylene is a fine, granular granulate that is poured into the inner packaging unit [15]. The total amount of polyoxymethylene is 25 kg in the predicted fire scenario.

High viscosity polyethylene polymer is selected for the inner packaging unit. In the modeling of this type of packaging, a high density polyethylene granulates (HDPE) can be used [15]. Multilayer carton packaging (MCP) is available for the outer packaging unit. MCP is technologically processed, in a way that it contains mixtures and chemicals that inhibit the ignition and burning times.

The walls of this limited cargo compartment (LCC) consist of a composite material used in the aviation industry. Two extreme examples will be presented. The first case will be an open boundary condition with bottom and top side with composite material in limited cargo compartment and, on the other hand, a completely sealed limited cargo compartment with composite walls.

Of course, in fire engineering, it is important that there is no situation for breakdown of the construction due to intense fire. In order to avoid such a scenario, the smoke and heat extraction ducts from the room are used. The task of devices for natural smoke and heat exhaust is to enable the most efficient smoke and heat outflow from the room naturally. If we have a flap or hole for the smoke and heat outlet in the ceiling, the smoke and hot gases from the room pass through this horizontal hole. Otherwise, the room is filled with smoke and heat very quickly.

The purpose of the article is determined how the choice of the fire environment affects the rise in temperature, pressure, CO and CO_2 concentrations, and how fast smoke is filled the space. The analysis was carried out using the Fire Dynamic Simulator (FDS) and Pyrosim software tools.

2 COMPUTATIONAL FLUID DYNAMICS (CFD)

We used Fire Dynamic Simulator (FDS) [12-14] and Pyrosim [18] for simulation or modeling. The Pyrosim program is actually an upgrade of the FDS tool and enables the end user to accelerate and, in particular, simplify modeling of geometry in space, layout of initial and boundary conditions in the simulation. FDS is a simulation tool for fluid dynamics modeling developed by NIST (National Institute of Standards and Technology) [17] based on CFD (Computational Fluid Dynamics) dynamics models (turbulent) fluids. FDS software package is a very complex mathematical tool designed to solve various problems in the field of fire engineering.

FDS solve numerically the Navier-Stocks equations, which are based on the assumption of low speed, thermally-driven flow with a special emphasis on smoke, and heat transport from fires. The partial derivatives of the conservations equations of mass, momentum, and energy are approximated by the finite difference method. An implicit predictor-corrector scheme, second order in time and space, is adopted, which embodies the core algorithm of the computer code. Turbulence is treated by means of the Smagorinsky from of large eddy simulation [14]. FDS employs the conserved scalar approach (mixture fraction model) to handle the combustion of fires [3].

2.1. Basic equations of FDS

In general, the movement of liquids can be described by the equations of transfer of mass, momentum and energy [19]. An equation is added in the FDS, which describes the preservation of additional components in the flow of the fluid in question.

Normally, components of combustion products in the smoke mixture are added, for which space diffusion is of interest to us.

The basic equations discussed by FDS are:

Mass conservation:

$$\frac{\partial\rho}{\partial t} + \nabla\cdot(\rho\boldsymbol{u}) = 0 \qquad (1)$$

Preservation of the mass fraction of the α^{th} components:

$$\frac{\partial(\rho Y_\alpha)}{\partial t} + \nabla\cdot(\rho Y_\alpha\boldsymbol{u}) = -\nabla\cdot J_\alpha + w_\alpha \qquad (2)$$

Continuous equation:

$$\frac{\partial(\rho u)}{\partial t} + \nabla\cdot(\rho\boldsymbol{uu}) = -\nabla p^* + \rho g \qquad (3)$$

Energy Conservation:

$$\frac{\partial(\rho h)}{\partial t} + \nabla\cdot(\rho h\boldsymbol{u}) = Dp_0/Dt + Q - \nabla\cdot\boldsymbol{q} \qquad (4)$$

and the equation of the state:

$$p_0 = \rho RT \qquad (5)$$

where is: ρ - the density of the fluid, in equations (1), (2), (3), (4), ∇ - nabla operator, which represents the gradient of the vector field, p^* - pressure change due to the movement of the liquid, p_0 - ambient pressure, R - gas constant, T - ambient temperature, g - gravitational acceleration, Q - is the heat source, w_α – is the α^{th} species production rate in the mixture, and Dp_0/Dt, $\frac{\partial}{\partial t} + u\cdot\nabla$ is a material derivation. The mass flow due to diffusion of a fluid is defined as $J_\alpha = \rho D_\alpha \nabla Y_\alpha$ with mass diffusivity D. The heat flow is defined as $q = -k\cdot\nabla\mathrm{T} - \sum_\alpha h_\alpha J_\alpha + q_r$, k - is thermal conductivity and q_r is the radiant heat flux. In the energy conservation equation, the enthalpy of the system is written $h = \sum_\alpha h_\alpha Y_\alpha$ where is $h_\alpha = \int c_{p\alpha}dt$. Energy conservation is written in terms of sensible enthalpy - h. The above equations (1), (2), (3), (4) are based on inviscid flow formulations [19]. In FDS environment density of fluid is constant value, over all simulation process [12]. The special feature of FDS is that the basic equations (1), (2), (3), (4) are added to the turbulence model. Turbulence description is added by modeling the sub-grid scale dissipative processes either by means of constant or dynamic coefficients of the Smagorinsky model. The default turbulent model uses the Large Eddy Simulation (LES) framework of the solver.

The number of additional equations for preserving the mass fraction of the components does not condition the closure of the equation system, since the system is already closed with a continually, motion, and energy equation. In the area where the mixture of reactants burns, heat release and simultaneous sinking of reactants and source of products occur [12-14].

In the case of complex simulations, it should have in mind that the number of reactants and products, and therefore the equations of conservation of the mass fraction of the substance, can be arbitrary. If we want to simulate complex chemical reactions that take place in several stages, then there are several reactants and products in the system, which increases the complexity of the system.

The problem that we usually encounter in numerical simulations is choosing the appropriate density of a mesh. In FDS, the volume treated is analyzed by the final volume method. Generally speaking, non-density mesh leads to the wrong results, while having a very dense mesh is a numerically very difficult problem, which is often limited by the capacity of the computer. It is expected that by concentrating the network, the results converge to the right solution [12-14].

The equation of state is written in the general form for mixtures, where ρ is the total density of the mixture (5). It is important to mention how we treat the pressure [12-14]. The total pressure is divided into three components:

- ambient pressure (p_0),
- hydrostatic pressure and
- pressure changes due to the motion of a liquid (p^*).

It is important to note that the initial and boundary conditions in the FDS must be selected so as not to reach the so-called. pressure oscillations leading to the numerical instability during the numerical calculations.

FDS basically operates in three key steps:

1. pre-processing,
2. the implementation of numerical problem solving and
3. post-processing.

When pre-processing (1.), this is the process of creating an input file that has a characteristic syntax for FDS. When scanning (3) using the SmokeView software tool [13], we visualize the results that we calculated in step (2).

3 NUMERICAL SIMULATION OF THE INITIAL FIRE SCENARIOS ACCORDING TO THE LIMITED CARGO COMPARTMENT (LCC)

This article has been focused on the initial phase of the fire in a limited cargo compartment (LCC). The dimensions of the LCC are 0.6 m x 0.6 m x 1.2 m. In the first case the LCC is limited by the ceiling and the bottom, in the rest directions they have open boundary conditions. In the second case, the LCC is completely sealed and surrounded by a composite material used in the aviation industry. In the second case, at the beginning of the fire scenario, the space is completely sailed. Volume, measuring sensors, external and internal packaging and polymer were determined using Pyrosim [18]. Pyrosim is an upgrade of the FDS software package and allows the user to easily create an input file for the FDS. The FDS software package is integrated into the Pyrosim environment, but the development of FDS is somewhat faster than the Pyrosim software package. In certain specific cases, Pyrosim does not allow all the functions of the current stable FDS version [12 - 14].

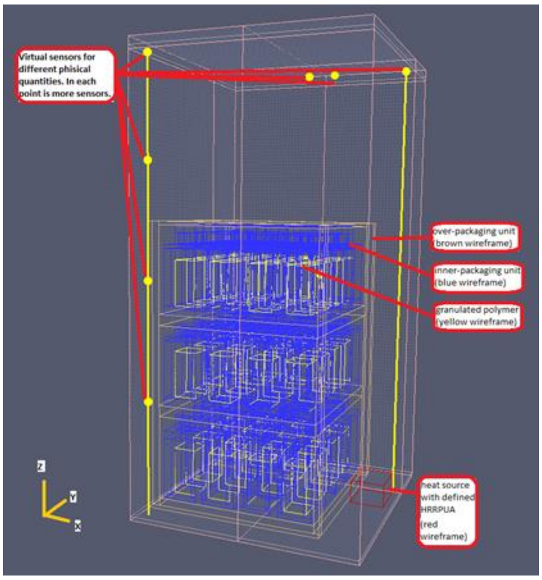

Figure 1: The geometry of the limited cargo compartment (LCC), the location of the burning source and the sets of measurement sensors (TC - Thermocouples, SLH – Smoke Layer Height and SMF – Smoke Mass Fraction).

Initial and boundary conditions set according to expert's suggestions from aviation industry. Ambient temperature is set to 18.0 °C, relative humidity is set to 15.0 % and initial pressure is set to 8.0E4 Pa. Two numerical simulations have made by using close LCC and open LCC. Open LCC scenario had on the bottom and on the top composite material, all other sides have been opened. The term "open boundary" denotes a non-solid exterior boundary of the computational domain. Gases are allowed to flow freely in and out. At these boundaries, the temperature and species mass fractions take on their respective exterior values if the flow is incoming, and take on their respective values in the grid cell adjacent to the boundary if the flow is outgoing. This is a simple upwind boundary condition [19]. Close LCC scenario have been completely sealed with composite walls.

Geometry and grid for open and close LCC set according to our current computer capabilities. The LCC is close rectangular prism (Figure 1) with walls of composite material. It is 0.6 m wide, 0.6 m long and 1.2 m in high. The grid was divided by x, y, and z axis. Division method was uniform. Cell size volume was 0.01 m x 0.01 m x 0.01 m according to x, y, and z axis. In a computer simulation, there was an upper limit on the number of cells in the observed grid or volume. In observed grid is 432.000 finite volumes (cells). The reason for this limitation is the capacity of the current computer on which we performed the simulations. In all simulations, the same configuration of the observed LCC was used for the fire scenario.

The model thus assumes that combustion is mixing – controlled and that the reaction of fuel and oxygen is infinitely fast. Mass fractions of all major relations and products can be derivate from the mixture fractions by means of state relationship, empirical expressions arrived at by a combination of simple-state relationships, empirical expressions arrived at by a combination of simple-field analysis and measurement. Radiative heat transfer is solved via the solution of the radiation transport equation for a non-scattering gray gas. The radiation transfer is effectively handled through the Finite Volume Method [3].

The simplest way of determining the source of the fire in FDS environment is through the heat release rate per unit area (kW/m^2). In the simulation, the time-dependent function of the heat release rate was used in both cases.

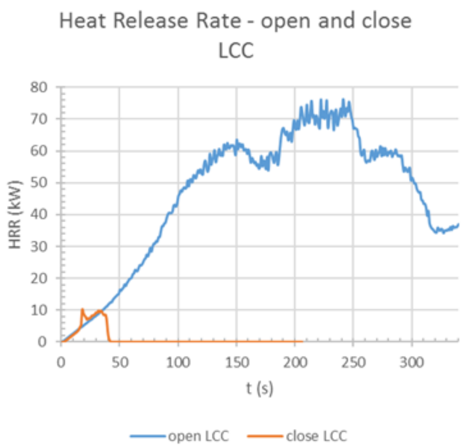

Figure 2: Released heat from the ignition source [kW] as a function of time [s].

The source of fire in FDS was modeled as the formation of combustible gas phase from the fuel surface. Besides the heat of release rate per unit area, it is also necessary to determine reaction for solid material or gas in the source of fire. The methane reaction (CH_4) was chosen in this case. The methane burning process is well researched as a fuel source [16].

In the numerical simulation we selected different measuring sensors for observing changes in temperature, concentration of smoke particles, and smoke layer with unburned particles (carbon black). To observe temperature changes, we have temperature planes or temperature measurements at individual points using the sensors. The advantage of measuring the temperature by means of temperature planes is that in the visualization phase a continuous temperature change in the observed time step is obtained. All the sensors we used in the simulation environment retained the default settings and did not change them.

The FDS software can be used for visualization of the smoke layer formation with respect to the fuel composition [7 - 10]. It is defined by a simple chemical model, such as the proportion of carbon, hydrogen, oxygen and nitrogen atoms. In the specific case, methane is defined as: C = 4.0; H = 1.00. The proportion of carbon monoxide production is 0.1 (volume %) and the percentage of the residue 0.01 (-). In the burning phase, hydrogen is also formed in the proportion of 0.1 [11], [16]. Methane CH_4 is also specified in the SFPE manual (3rd edition) [16].

FDS creates smoke particles using these data, which are then moved around the observation volume. Buoyancy and turbulent flows moved smoke particles from the source to the observation volume. The second source of the formation of the smoke layer is generated with the burning of materials in the fire scenario. [10], [16], [17].

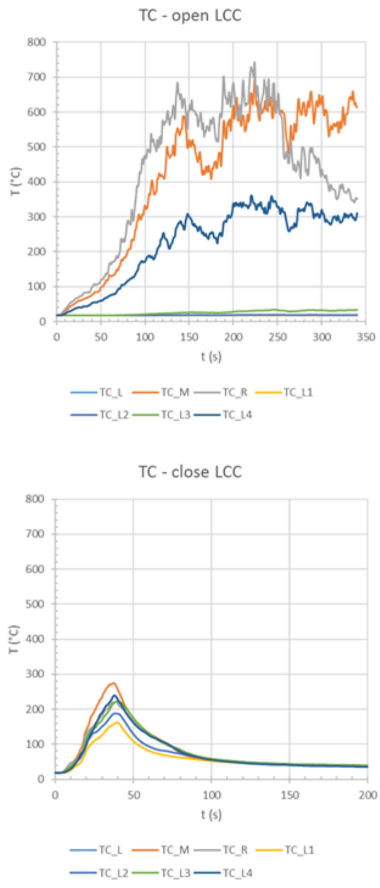

Figure 3: The average temperatures of the temperature sensors for open and close limited cargo compartment

The open case fire scenario has been generated significantly higher temperatures in all three temperature sensors, when comparing the first 100 s according to close case fire scenario (Figure 3.). In the case of an open fire scenario, the temperature ranges from 200 °C to 500 °C, depending on the location of the temperature sensor. In the case of a close scenario, the temperature of the sensors is within 50 °C at 100 s. From 100 s to 200 s in the close scenario, the temperature drops only by about 15 °C. The open fire scenario had a temperature maximum of 720 °C at 220 s is achieved, while in the close fire scenario the temperature maximum is 271 °C at 36 s, as can be seen from Figure 3. From the comparison of the maximum temperature gradients (dT/dt), the open fire scenario yields a value of 3.27 °C/s, while for a close fire scenario it is obtained at 7.52 ° C/s. This means that in the case of a close scenario, the increase in temperature per unit time is approximately two times higher than in the open scenario. This information makes sense, because it is in the case of an open fire scenario had large heat losses in the surrounding area.

Let's take a look at how the smoke particles generates smoke layer in the observed volume. For the smoke layer process is measured using two sensors (SLH) [10], [12-13]. In the FDS software, the Smoke Layer Height (SLH) device is called the smoke layer sensor.

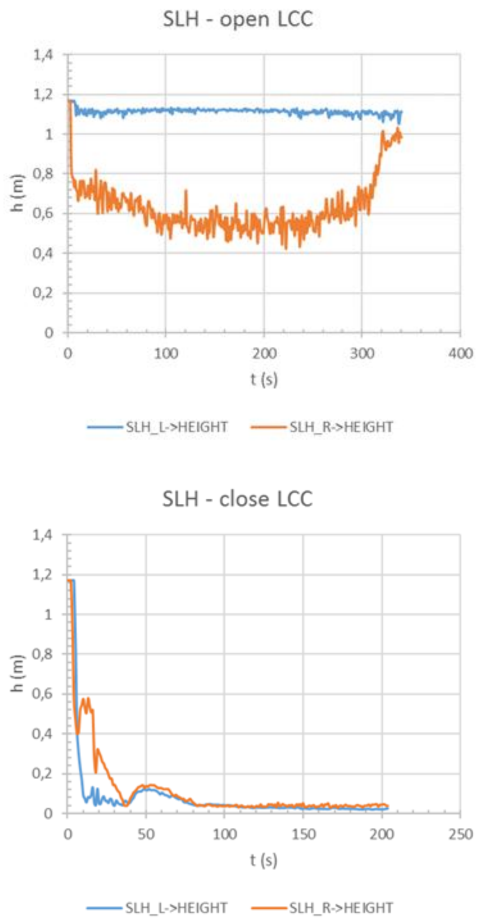

Figure 4: Thickness of the smoke layer (SLH devices) according to open and close fire scenarios for limited cargo compartment

Figure 4 shows a significant difference in the height of the smoke layer when compared first 200 s of simulation time. The height of the smoke layer for the left sensor is 1.1 m and for the right sensor 0.6 m for the open scenario. At the close scenario, the height of the flue layer at the same time for both SLH devices was 0.04 m. This information means that the observed volume is completely filled with smoke.

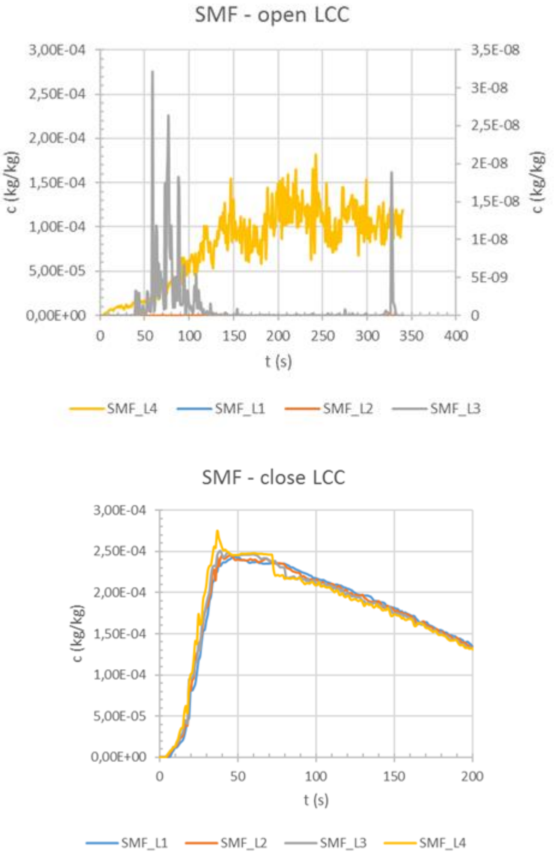

Figure 5: The concentration of smoke particles in open and close fire scenario for limited cargo compartment

Figure 5 shows the trend of increasing concentration of smoke particles. In FDS, this quantity is defined as Smoke Mass Fraction (SMF) [12]. The mass concentration of smoke particles in FDS is determined as the mass fraction of the smoke particles to the total mass of the air (kg/kg or in g/g). Figure 4 shows data on the concentrations of smoke particles, which were obtained using SMF measuring sensors, arranged in height in the corner of the limited cargo compartment

At intense burning, the particulate current is always turbulent. Since every real burning process is incomplete, smoke fragments are also formed. In the simulation, we want to approach this assumption in a way that defines a solid residue when burning solid combustible substances. Due to the buoyancy resulting from the temperature difference between the floor and the ceiling, the smoke particles reach the ceiling area very quickly (the vertical particle motion). The smoke begins to accumulate next to the ceiling. Over time, the smoke-stack layer is lower and lower. It depends on whether the observed volume is open outwards or is completely sealed.

If the limited cargo compartment is open, most of the smoke particles leave the room, therefore the concentration of smoke particles in the case of the open scenario is extremely low and varies from less than 5.0E-9 kg/kg to 1.0 E-4 kg/kg depending on the location of the sensor SMF. In the case of a close fire scenario, the concentration of smoke particles reaches a maximum of 38 s and is 2.66 E-4 kg/kg. At 202 s concentration falls to 1.3E-4 kg/kg for a close fire scenario. The reason why the concentration of smoke particles is reduced in the case of a close scenario is that it occurs at the beginning due to a sudden increase in temperature to the cracks in the wall of composite material. This dilemma will need to be explored in the future.

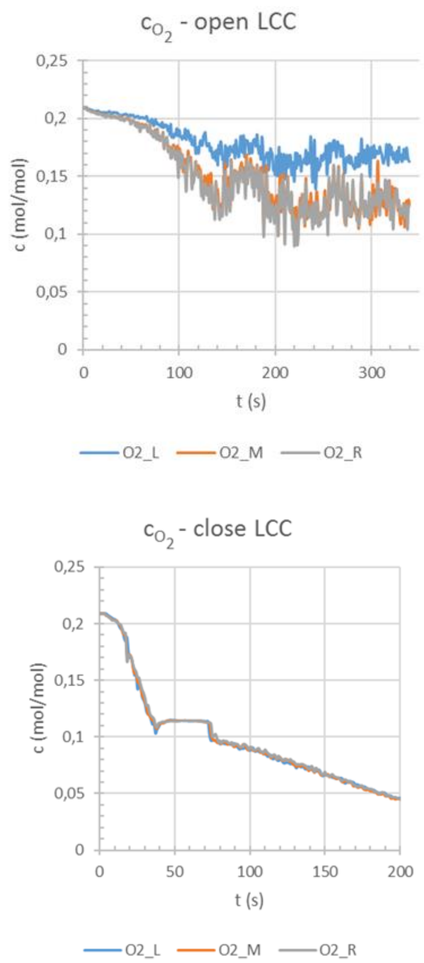

Figure 6: Change in the oxygen concentration for open and close fire scenario for limited cargo compartment

In the open fire scenario oxygen concentration varies between 0.2 mol/mol at the beginning of the simulation and over 0.12 mol/mol after 200 s (Figure 6). In the close fire scenario, the oxygen concentration at the start is 0.2 mol/mol after 200 s and drops to 0.04 mol/mol (Figure 6). Intensive burning process stop after 38 s simulation, while the concentration was still increasing.

In the open and close fire scenario CO_2 and CO concentrations had the same trend as oxygen concentration in figure 6.

4 CONCLUSIONS

Setting up suitable initial, boundary conditions and complex geometry is not an easy task to solve correctly numerical simulations in the field of fire engineering. In this article, we came to the following conclusions:

- boundary conditions (open or close restricted cargo space) have a significant impact on the development of the initial phase of the fire,
- the heat release rate from the source as function of time is reached at the maximum 70 kW between 200 s and 250 s for the open limited cargo compartment and the maximum 10 kW between 20 s and 30 s for the close cargo compartment,
- a significant difference in the height of the smoke layer is observed when comparing the first 200 s simulations. The height of the smoke layer for the left sensor is 1.1 m and for the right sensor 0.6 m for the open scenario. At the close scenario, the height of the smoke layer at the same time for both sensors was 0.04 m. This information means that the observed volume is completely filled with smoke,
- if the cargo compartment is open, most of the smoke particles leave the observed volume, and the concentration of smoke particles is extremely low. In the case of a close cargo compartment, the concentration of smoke particles at the beginning of the simulation rises to 38 s and then the concentration slowly drops to 200 s,
- in the open cargo compartment, the oxygen concentration of the scenario varies between 0.2 mol/mol at the start of the simulation and about 0.12 mol/mol after 200 s. In the close cargo compartment, the oxygen concentration at the start is 0.2 mol/mol after 200 s and drops to 0.04 mol/mol,
- in open and close fire scenario CO_2 and CO concentrations had the same trend as oxygen concentration.

In the future, we are going to do more numerical simulations with a complex fire scenario for an open and close limited cargo compartment. The article presents the contribution of understanding the complex fire scenario depending on the close and open limited cargo compartment.

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EXPOITATION OF DIESEL ENGINES WITH SMALL STROKE VOLUMES IN CITY BUSES

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ABSTRACT

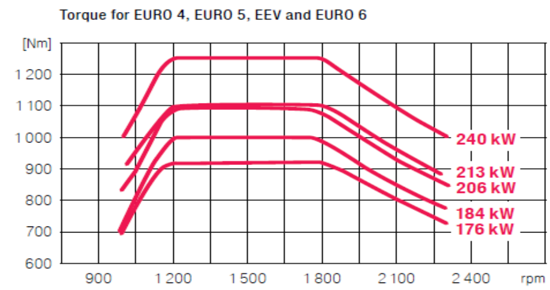
Public transport companies operate a large number of city buses with diesel engines. In the last few years, these companies have seen an increase in operating costs (on the side of the engine's repairs) of buses equipped with engines with smaller stroke volumes. In the case of bus engines, the number (weight) of transported passengers, the number of stops in relation to the route length, the intensity of traffic in the city and the terrain are of significant importance. A very important requirement for internal combustion engines used to drive buses is to ensure proper course of variation of engine torque and its power as a function of rotational speed. The requirements for a high value of power and torque and low emission of toxic compounds from engines with small stroke volume, to some extent contradict each other. This feature favors good vehicle dynamics. The maximum value of the engine power is reached for rotational speeds higher than for the maximum torque values. In turbocharged engines the speed range of maximum torque and maximum power is shifted towards even higher values of engine speed. These translates into an increase in mechanical and thermal loads, increased wear and a higher frequency of engine damage. Engines with a reduced stroke volume to produce a torque comparable to larger capacity motors must operate at a higher rotational speed and with a higher mean effective pressure. The paper presents some examples and real data from city buses exploitation and maintenance related to the problems mentioned before.

Keywords: urban transport, bus engine, torque, displacement, durability

1 INTRODUCTION

Contemporary buses are most often powered by self-ignition engines with direct fuel injection into the combustion chambers. When developing new engines for new vehicles, it aims to get more and more power from the unit of displacement, which helps reduce the total weight of the engine, the mass of emitted exhaust gases and makes it easier to meet the requirements of emission standards. It is possible, among others thanks to the use of one- and two-stage turbocharging systems and modern fuel injection systems. In the case of engines driving buses, the number (weight) of transported passengers, the number of stops in relation to the route length, the intensity of traffic in the city and the terrain are of significant importance.

A very important requirement for internal combustion engines used to drive buses is to ensure proper course of variation of engine torque and its power as a function of rotational speed. The requirements for a high value of power and torque and low emission of toxic compounds from engines to some extent contradict each other. An example of the torque characteristics of the modern bus engine is shown in Figure No 1.



Source: (MAN)

Figure 1: Torque characteristics of the bus engine

A very important feature of the engine is to ensure a flat course of the required torque in a wide range of rotational speeds, so that even at low engine speed the engine has obtained a high value of this parameter. This feature favors good vehicle dynamics. The characteristics of the effective power of the engine run more steeply than the torque characteristics. The maximum power value of the engine is reached for rotational speeds higher than for maximum torque values [3]. In turbocharged engines the speed range of maximum torque and maximum power is shifted towards even higher values of engine speed.

Another very important feature of the engine, from the point of view of operating costs, is the value of specific fuel consumption, in addition the smaller its value, the smaller is the total mass of combustion products. The smaller mass of combustion products, however, is accompanied by a smaller value of the mean effective pressure in the engine cylinders and less torque developed by the engine. In order to determine the actual fuel consumption of city buses, the so-called SORT tests (Standardized On-Road Test) was performed. The SORT-1 test concerns the bus traffic in the most crowded streets, SORT-2 driving in normal city traffic and the SORT-3 test in a suburban area. These tests take into account the bus load, driving at a certain average speed (e.g. SORT-2 - 18 km/h), number of stops per kilometer of the route (3,3), wind force (3-8 m/s) and temperature from 0 to 30 °C. They do not take into account conditions related to terrain configuration.

The construction of engines, including bus engines, is strongly influenced by the requirements resulting from more and more stringent standards regarding the amount of exhaust gases emitted and the content of harmful substances in exhaust gases [1,2,4]. One of the ways to meet the increasingly stringent requirements of successively implemented emission standards is, among others decreasing the engine's capacity (downsizing) which, in order to maintain the appropriate torque and effective power of the engine, translates into an increase in mechanical and thermal loads, increased wear and a higher frequency of engine damage.

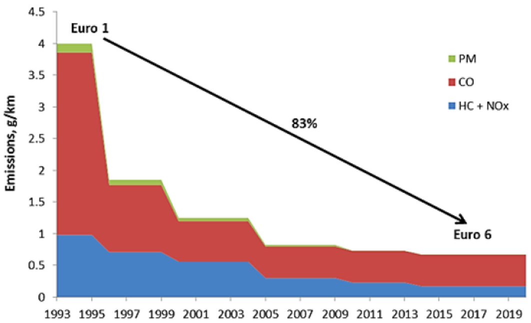


Figure 2: Evolution of the EURO emissions regulations

Engines with a reduced stroke volume to produce a torque comparable to larger capacity motors must operate at a higher rotational speed and with a higher mean effective pressure.

2 REQUIREMENTS AND PERFORMANCES OF ENGINES FOR COMMERCIAL VEHICLES, INCLUDING BUSES

Contemporary commercial vehicles and buses usually use piston combustion engines. These are mostly diesel engines fueled by diesel oil. Environmental protection requirements encourage bus manufacturers to use other propulsion solutions that better meet emission standards, in the form of bio-diesel oil, gas-powered engines (LPG and CNG) as well as hybrid or electric drives.

However, to date, diesel engines powered with diesel oil are the dominating prime movers of city buses. These engines, due to the high ratio of the piston stroke S to the cylinder diameter D of S/D = 1,1 ÷ 1,3, can develop relatively low rotational speeds and achieve relatively high mileages between repairs. In addition, thanks to the large crank radius r (S = 2 • r) these engines reach high torque values.

In order to compare the performances of different types of engines among themselves, their parameters can be divided into three groups of characteristics: structural, energy and operational characteristics. Among the energy indicators when choosing an engine, for example for a bus, the so-called *Volumetric power* and *Weight power* of the *engine* and of the *vehicle* should be taken into account. The values of the corresponding volumetric and weight power values for bus engines are shown in Table 1.

Table 1: Recommended volumetric and weight power values for bus engines

Type of vehicle / engine	Volumetric power	Weight power	
		engine	vehicle
	kW/litre	kg/kW	kg/kW
Commercial vehicles and buses / CI engines not turbocharged	10 ÷ 45	2,5 ÷ 8	60 ÷ 230
Commercial vehicles and buses / CI engines turbocharged	18 ÷ 55	2 ÷ 7	50 ÷ 210

The *Volumetric power* is the maximum effective power obtained from one liter of engine displacement.

The *Weight power of the* internal combustion *engine* informs about how many kilograms of engine mass generate 1 kW of engine maximum effective power.

The *Weight power of the vehicle* informs how many kilograms of vehicle mass is per 1 kW of the maximum effective power of the engine.

Other most frequently used parameters for engines comparison are the effective power *Pe*, the torque *To* and the rated speed of the maximum power n_{Pmax} and the rotational speed of maximum torque n_{Tmax}. These indicators (in particular the value and torque curve) allows to determine the traction characteristics of a vehicle equipped with a given engine. A flat, torque curve, close to the horizontal line, causes that when changing the load (increase in resistance of the vehicle) it will cause a greater change in the engine speed than in relation to the curve of the convex torque with a longer drop.

Having the value of the engine torque T_o and knowing its capacity (stroke volume – V_{ss}), you can calculate the mean effective pressure *pe* with dependence:

$$p_e = \frac{0{,}012566 \cdot T_o}{V_{ss}} \quad (1)$$

where: T_o - torque in Nm, V_{ss} - engine capacity in dm^3, p_e - mean effective pressure in MPa.

From the above equation it follows that for the same value of engine torque T_o, for example a double reduction of its displacement V_{ss}, the value of the mean effective pressure p_e will be doubled. The value of mean effective pressure exerts the greatest influence on thermal and mechanical loads of the main functional systems of the engine: combustion chambers, crank-piston system, charge exchange system, fuel injection system, cooling and lubrication system. Too high p_e value affects the lower durability of the engine and an increase in the number of component failures of the above mentioned functional systems.

Engine with reduced displacement V_{ss} in order to obtain the appropriate value of effective power P_e have to work at higher rotational speed *n*. The increase of the engine speed results in an increase in the mean piston speed c_p in accordance with the dependence:

$$c_p = \frac{2 \cdot S \cdot n}{60} \tag{2}$$

Where: S - stroke of the piston in m, n - engine speed in min^{-1}, c_p - mean piston speed in m/s.

The mean speed of the piston translates into the intensity of wear of the pistons and cylinder liners. From the point of view of engine durability, it is not recommended to build serial engines (not sport or special engines) with mean piston speeds exceeding 20 m/s. For $c_p \leq 6$ m/s, low-speed engines are distinguished, for $c_p = 6 \div 9$ m/s medium-speed engines, and for $c_p \geq 9$ m/s - high-speed engines. Longer engine operating times with higher speed values result in higher mean piston speeds and contribute to its more intensive wear.

For the piston engines as a load index is used the product of the two most recently discussed parameters, the mean effective pressure p_e and the mean piston speed c_p :

$$L_p = p_e \cdot c_p \tag{3}$$

Where: p_e – mean effective pressure in MPa or bars, c_p - mean piston speed in m/s, L_p - engine load indicator in MPa/m/s or bar/m/s.

In the next part of the paper, the values of selected parameters for several types of engines operated in Gdynia transport companies were assessed.

3 PERFORMANCE PARAMETERS OF SELECTED DIESEL ENGINES USED IN GDYNIA BUSES

To evaluate the performance parameters of diesel engines used in city of Gdynia buses, engines with small stroke volumes were selected, and for comparison, two types of engines with larger stroke volumes. The basic data of the engines selected for analysis are presented in Table 2.

Table 2: Chosen bus diesel engines parameters

Bus type/ Number of passengers	Bus own weight / Total weight	Engine manufacturer / Engine type	Engine stroke volume / Engine weight	Engine power /rpm / Engine torque/rpm	Piston stroke/ Piston diameter
	kg / kg		cm^3 / kg	kW / Nm	mm / mm
Engines with low value of stroke volume					
Volvo 7000 „12”/ 105	10600 / 18000	Volvo / D7C250 EC 99	7284 / 750	184 at 2200 rpm/ 1050 at 1400 rpm	135/ 107
Solaris „12”/ 106/104	10800 / 18000	MAN / D0826LOH17	6871 / 532	162 at 2400/ 850 at 1100-1600	125/ 108
Solaris „15” / 159/160	13500 / 25000	MAN / D0836LOH02	6871/ 600	206 at 2400/ 1100 at 1100-1600	125/ 108
Volvo 7700A „18” / 175	15660 / 28000	Volvo / D7C275 EC 99	7284 / 750	205 at 2200/ 1085 at 1400	135/ 107
Solaris „18” / 161	17000/ 28000	Cummins / ISLe4 340	8849 / 706/738	243 at 2100/ 1485 at 1200-1400	144,5/ 114
Engines with bigger value of stroke volume					
Mercedes „12” / 102	6400/ 17200	MB / OM 447 hLAII/2	11967 / -	184 at 2200/ 883 at 1200-1400	156/ 128
Solaris „12” / 104	11800 / 19000	DAF / PR 183 S2	9186 / 860	183 at 2200/ 1050 at 1100-1700	140/ 118

The parameters listed in Table 2 show that the masses of engine with smaller stroke volumes (MAN D0826 and Volvo D7C) range from 532 to 750 kg and are lower than the mass of engines with larger stroke volumes (DAF PR 183) by approx. 100 kg. At the same time, engines with smaller stroke volume have similar or greater values of effective powers.

The torque values of motors with smaller stroke volume range from 850 to 1100 Nm and are analogous to those with larger capacities, ranging from 883 to 1050 Nm. The Cummins engine presented in the list has the theoretical highest torque value of 1485 Nm, but this torque value is reached only from the speed of 1200 rpm.

Values of piston diameters of engines with larger stroke volume range from 118 to 128 mm and are larger by approximately 10 to 20 mm than the diameters of motors with smaller stroke volume. Piston stroke in engines with larger stroke volume is from 140 to 156 mm and in engines with smaller stroke volume from 125 to 135 mm. The value of the piston diameter and piston stroke directly affects the value and course of the torque generated by the engine.

The values of the parameters listed in Table 3 show that the liter capacity of engines with smaller stroke volume is from 23,5 to 29,8 kW/liter and are larger than the liter power of engines with larger capacities, which values range from 15,3 to 20,4 kW/liter.

Table 3: Chosen bus diesel engines basic parameters

Bus type/ Number of passengers	Engine manufacturer /engine type	Engine volumetric power/ weight power	Power per total vehicle weight	Vehicle weight power	Vehicle volumetric power
		kW/liter / kg/kW	kW/ton	kg/kW	kg/liter
Engines with low value of stroke volume					
Volvo 7000 „12” / 105	Volvo D7C250 EC 99	25,2/ 4,07	10,2	57,6/ 97,8	1452,0/ 2465,7
Solaris „12” / 106/104	MAN D0826LOH17	23,5 / 3,28	9,0	67,3/ 111,1	1579,7/ 2608,6
Solaris „15” / 159/160	MAN D0836LOH02	29,8 / 2,91	7,6	-/ 130,8 -/ 121,3	-/ 3623,1
Volvo „18” / 175	Volvo D7C275 EC 99	28,2 / 3,65	7,2	77,5/ 138,6	2145,2/ 3835,6
Solaris „18” / 161	Cummins ISLe4 340	27,3 / 2,91	8,8	65,8/ 115,2	1797,7/ 3146,0
Engines with bigger value of stroke volume					
Mercedes „12” / 102	MB OM 447 hLAII/2	15,3 / -	10,7	-/ 93,4	-/ 1433,3
Solaris „12” / 104	DAF PR 183 S2	20,4 / 4,70	10,4	57,9/ 95,7	1184,7 1956,5

The weight power of engines with smaller stroke volume is from 2,78 to 4,07 kg/kW and is lower than the weight power of larger capacity engines, which value is 4,70 kg/kW.

Table 4: Chosen bus diesel engines parameters

Bus type/ Number of passengers	Engine manufacturer /engine type	Engine maximum rpm	Mean piston speed	Mean effective pressure	Engine load index
		min^{-1}	m/s	bar	bar/m/s
Engines with low value of stroke volume					
Volvo 7000 „12” / 105	Volvo D7C250 EC 99	2200	9,9	18,07	158,07
Solaris „12” / 106/104	MAN D0826LOH17	2400	10,0	20,03	200,30
Solaris „15” / 159/160	MAN D0836LOH02	2400	10,0	15,48	154,80
Volvo „18” / 175	Volvo D7C275 EC 99	2200	9,9	18,68	184,93
Solaris „18” / 161	Cummins ISLe4 340	2100	10,115	20,59	208,22
Engines with bigger value of stroke volume					
Mercedes „12” / 102	MB OM 447 hLAII/2	2200	11,44	9,25	105,82
Solaris „12” / 104	DAF PR 183 S2	2200	10,26	14,34	147,14

The power factor per ton of the total weight of the vehicle for selected engines with smaller stroke volumes ranges from 7,2 to 10,2 kW/t and for engines with larger capacities from 10,4 to 10,7 kW/t.

The weight of vehicles related to their total weight for engines with smaller capacities ranges from 97,8 to 138,6 kg of vehicle per 1 kW. For larger capacity engines, it is lower and ranges from 93,4 to 95,7 kg/kW.

The weight capacity of vehicles with smaller stroke volume engines, related to the total weight is from 2465,7 to 3835,6 kg of vehicle per 1 liter of engine stroke volume. For vehicles with larger engine sizes it is much less, ie. from 1433,3 to 1958,5 kg/liter.

The values of the parameters listed in Table 4 show that the mean piston speed values calculated for nominal power speeds for engines with smaller stroke volume values are from 9,5 to 10,1 m/s. The mean piston speeds for larger capacity engines range from 10,2 to 11,4 m/s. Both groups of engines belong to the group of high-speed engines in terms of a mean piston speed.

The mean effective pressure values of engines with smaller stroke volume values range from 15,4 to 20,5 bar and are much higher than the mean effective pressure values of engines with larger capacities, from 9,2 to 14,3 bar.

Calculated on the basis of the mean piston velocity and mean effective pressure, the engine load indicator for engines with smaller stroke volume values ranges from 154,8 to 208,2 bar/m/s. For engines with larger displacement values, this ratio ranges from 105,8 to 147,1 bar/m/s.

The analysis shows that the parameter determining the occurrence of a higher frequency of damage to engines with smaller values of stroke volume is the mean effective pressure.

4 THE SHAPE OF THE SURFACE OF GDYNIA AND ITS IMPACT ON THE PARAMETERS OF BUS ENGINES

The terrain of the city of Gdynia and neighboring towns is very diverse. The surface was formed by the forces of nature (glacier, melt water, watercourses and sea activities) and human activities. The city of Gdynia lies at the junction of two geographical regions with similar terrain forms: the Kashubian Coast and the Kashubian Lake District.

From the north, Gdynia is surrounded by Kępa Oksywska with an average height ranging from 40 to 60 m above sea level. On the steep hillside of Kępa Oksywska, there are districts of Oksywie, Obłuże, Pogórze and Babie Doły. Streets in these districts are characterized by numerous bends and long steep uphill.

To the south of Kępa Oksywska there is a relatively flat part of the city lying in the so-called Pradolina Kaszubska with districts Cisowa, Chylonia, Leszczynki, Grabówek, Działki Leśne and Downtown. The heights in this relatively flat area of the city are between 5 and 15 m above sea level.

The south-eastern part of the city is Kępa Redłowska located on the Bay of Gdańsk with Kamienna Góra and parts of the districts of Orłowo and Wzgórze Św. Maksymilian (from 40 to 90 m above sea level) surrounded by Redłowski Lower with the districts of Orłowo, Wzgórze Św. Maksymilian, Redłowo and Mały Kack (from 30 to 40 m above sea level).

From the south-west, the city is surrounded by the Tri-City Landscape Park with land elevations of up to 100 m and a decrease from 20 to 50%.

In the Demptowska Valley, there are districts of Pustki Cisowskie-Demptowo, and a part of the districts Cisowa and Chylonia. Elevation differences range from 10 to 60 m above sea level.

To the south of the Demptowska Valley lie the districts of Chwarzno-Wiczlino and Witomino. In this part of the city (between Wiczlino and Dąbrowa) there is the highest hill in Gdynia, Donas Mountain, height 205,7 m above sea level.

The southern part of the city are the districts of Mały Kack, Karwiny, Wielki Kack and Dąbrowa with a strongly hilly terrain with relative heights of up to 100 meters and slopes exceeding 40 degrees.

In addition to the terrain shape, the city's rolling stock is also affected by the climatic conditions in Gdynia. The average air temperature in July and August is 17,4 °C and the lowest in February – 1,3 °C. The average spring temperatures are 6 °C and in the autumn 9,5 °C. The average annual rainfall amounts to 570 mm. The dominant wind direction is the western direction (50%). The Bay of Gdańsk and the Baltic Sea, which are the source of additional winds in the form of a breeze, have a significant influence on the microclimate of the city.

The main communication routes go through the central low-lying part of the city and the high-located districts on the northern, southern and eastern outskirts cause that the engines of public transport buses work more often with increased power. Working times with increased power on long inclines (eg Kielecka Street, Witomińska Street and Wielkopolska Street towards Karwiny district) reach a few and even several minutes, which leads to very high mechanical and thermal loads in the functional systems of the engines. Some streets have such a shape and inclination that vehicles with smaller engine stroke volume with a large number of passengers lack the power to overcome them (eg Stolarska and Benisławskiego streets). Such examples can be found for various Gdynia districts.

The driving torque on the bus wheels must be able to overcome the sum of all resistance to movement in all conditions. This moment is provided by the engine with some excess resulting from the efficiency of the transmission system. For this reason, it is very important to choose the right engine for the bus with the right power and torque. This has an impact not only on the comfort and safety of driving, but also on the durability and economy of operating of city buses. The resistance force of the elevation acting for a long time to the bus's drive system may necessitate pushing the engine at very high speeds at a low transmission ratio in order to obtain a sufficient torque value. The increased speed increases the mean speed of the pistons and accelerates engine wear. The very high value of maximum combustion pressures and mean inducted pressures in the cylinders, which are accompanied by very high temperatures of the combustion process, also contributes to faster engine wear.

5 ANALYSIS OF DAMAGE TO SELECTED TYPES OF ENGINES AND THEIR OPERATING COSTS

Damage analysis of bus engines was made on the basis of data provided by the heads of the bus service departments at two Gdynia public transport company: PKM and PKA.

PKM company has compiled the costs of repairing Volvo 7000 and 7700 bus engines (produced in the years of 2000-2004). These buses are equipped with engines with a cylinder stroke volume of 7284 cm^3. The costs were divided into the costs of spare parts purchase and costs of external services. The costs of additional oil or coolant replacement due to repair, costs of mechanics and other personnel costs and costs due to bus stoppage are not included.

Engine repairs required the purchase of the following parts: pistons, cylinder liners, piston rings, seals for heads and oil sumps, engine cooling water pump repair kits, main and crank bearing sets, intake and exhaust valves and valve seats, cylinder heads, fuel pumps, fuel injection pumps, injectors and high pressure injection lines.

The costs of external services related to engine repairs included: crankshafts grinding, camshafts repairing and grinding, repairing heads and repairing fuel injection pumps. The list of costs is presented in the Table No. 5.

From many years of experience of PKM service employees in Gdynia, it appears that Volvo engines with a small stroke volume of 7,3 liters (compared to engines with a capacity above 10 liters) are weaker, have higher frequency of damage and require frequent repairs. Buses equipped with engines with a stroke volume of more than 10 liters are stronger, more reliable and do not require frequent repairs.

Table 5: List of repair costs for Volvo's diesel engines with small stroke volume in period of 2013 – 2017 years in thousand Zloty

Anual expense for:	2013	2014	2015	2016	2017
Purchase of spare parts	42,3	31,0	6,2	40,4	62,4
Outsourced repairs	7,6	13,2	0,9	14,8	13,6
Sum	49,9	44,2	7,1	55,2	76,0

Repairs to engines with a stroke volume of more than 10 liters of Mercedes Benz and MAN are sporadic, and thanks to the unification of engine parts, their costs are significantly lower.

In addition, from the reports provided by PKM for fuel consumption by various bus types, the so-called short buses ("12" meters long) with lower stroke volume engines had mean fuel consumption from 46,56 to 48,72 liter/100km during the period under consideration (2013-2017). Short buses ("12") with larger stroke volume engines had lower mean fuel consumption in the same period from 45,03 to 48,02 liter/100km. The use of a low stroke volume Volvo engines for articulated long buses ("18" meters long) results in a higher mean fuel consumption of 2 to 5 liter/100km compared to similar buses equipped with larger capacity engines.

Table 6: Repair costs for MAN's diesel engines with small stroke volume in period of 2010 – 2017 years in thousand Zloty.

Engine type / Bus type	D 0826 LOH17 NEOPLAN 12	D 0826 LOH17 NEOPLAN 12	D 0826 LOH17 SOLARIS 12	D 0826 LOH18 SOLARIS 15
Engine power kW	162	162	162	191
Repairs cost	41,7	23,3	37,7	50,1

PKA company has prepared a list of repair costs for 4 selected engines with MAN's 6,9 liter capacity, for a period of seven years (2010 - 2017). The list includes only the costs of purchasing spare parts. It does not include the cost of additional oil or coolant replacement due to repair, costs of mechanics and other personnel, and costs due to bus stoppages. Repair costs are presented in Table No. 6.

As with Volvo's small stroke volume engines, repairs of MAN's small displacement engines required the purchase of the following parts: cylinder liners, piston rings, head seals and oil sumps seals, engine cooling water pump repair kits, thermostats, main and crank bearings, camshafts, intake and exhaust valves and valve seats, cylinder heads, air coolers, turbochargers, fuel pumps, fuel injection pumps, injectors and injection lines, pressure and temperature sensors and even entire engines for parts.

Users of MAN engines with a stroke volume of 6,9 liters (PKA) also noticed their higher fuel consumption by about 2 to 5 liter/100km compared to engines with larger capacities driving buses of the same size.

The experience of PKA company employees shows that the introduction of short buses ("12") with engines meeting the requirements of Euro 6 emission standards has resulted in an increase in fuel consumption, ranging from 43 to 46 liter/100km. The same size buses with engines meeting Euro 5 emission requirements consume less fuel, from 38 to 40 liter/100km respectively.

The listings of damaged parts of both types of engines are characteristic of damage caused by excessive mechanical and thermal loads of the main functional components of engines constituting combustion chambers, crank-piston system, charge air and exhaust system as well as cooling and lubrication systems. These damages are caused by long-term operation of engines with very high loads and at high rotational speeds, without the possibility of properly cooling the engine and its operating fluids.

Figure 3: High pressure fuel pump cam destruction

6 CONCLUSIONS

- Theoretical analysis of piston engine performance shows that for the same value of engine torque T_o, eg double reduction of its displacement V_{ss} causes a double increase in the value of mean effective pressure p_e and that the engine with reduced displacement V_{ss} to obtain the appropriate effective power P_e must work at higher rotational speed n.
- The value of mean effective pressure p_e exerts the greatest influence on thermal and mechanical loads of the main functional systems of the engine - combustion chambers, crank-piston system, charge exchange system, fuel injection system, cooling and lubrication system. Too high p_e value affects the lower durability of the engine and an increase in the number of component failures of the above functional systems.

- The terrain of the city of Gdynia, the route of the main communication arteries through the central low-lying part of the city and the high-lying districts on the northern, southern and eastern outskirts cause that the engines of public transport buses work more frequently with increased power. Working times with increased power on long inclines (eg Kielecka Street, Witomińska Street and Wielkopolska Street towards Karwiny) reach a several minutes, which leads to very high mechanical and thermal loads in the functional systems of engines. Some streets have such a shape and inclination that vehicles with smaller stroke volume with a large number of passengers lack the power to overcome them (eg Stolarska and Benisławskiego streets).
- Damage analysis of both types of engines with smaller stroke volume showed that they are characteristic for damage caused by excessive mechanical and thermal loads of the main functional components of the engines (combustion chambers, crank- piston system, supercharging system and cooling and lubricating system). These damages are caused by long-term operation of engines with very high loads and at high rotational speeds, without the possibility of properly cooling the engine and its operating fluids.
- When designing new engines for vehicles, it aims to get more and more power from the unit of displacement, which helps reduce the total weight of the engine, the mass of emitted exhaust gases and makes it easier to meet the requirements of emission standards. It is possible, among others, thanks to the use of one- and two-stage supercharging systems, more and more modern fuel injection systems. However, this strategy leads to the need to obtain extremely high pressure and combustion temperatures in the engine cylinders. These are the reason for the faster wear of the engines. For a long, reliable, effective and safe operation of the vehicle, it is necessary to choose such an engine, in which the necessary power and torque are generated at the optimum mean effective pressures for which a larger engine stroke volume is required.

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USE OF ECDIS IN ASTRONOMICAL NAVIGATION

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ABSTRACT

This paper deals with the use of ECDIS for plotting position by using celestial bodies. Standard intercept method results in the line of position (LOP) which should be plotted on the navigation (paper) chart or a hand-made auxiliary diagram, where two or more intersecting LOPs indicate the position of the vessel. The navigation (paper) chart is more convenient for direct plotting of LOP than standard blank paper (auxiliary diagram), but the paper charts are being increasingly replaced by electronic chart systems, i.e. the ECDIS (Electronic Chart Display and Information System) that is recognized as an official paper chart equivalent. Accordingly, everything that can be plotted on the paper chart should be also available in the ECDIS. This includes plotting of the astronomical LOPs. Although most of today's ECDIS systems do not support ephemerides nor the possibility of the direct LOP's determination, the available functions of manual drawing of different symbols and objects, combined with ERBL function, enable graphical plotting of LOPs and, eventually, fixing the vessel's position. In addition to the analysis of standard astronomical LOP plotting (for fix and running fix), this work also analyses the ways the ECDIS can assist in approximate position determination when only the azimuths of celestial bodies are known. Certain recommendations for future ECDIS improvements are given as well.

Keywords: **ECDIS, Astronomical navigation, Line of position (LOP), Azimuth**

1 INTRODUCTION

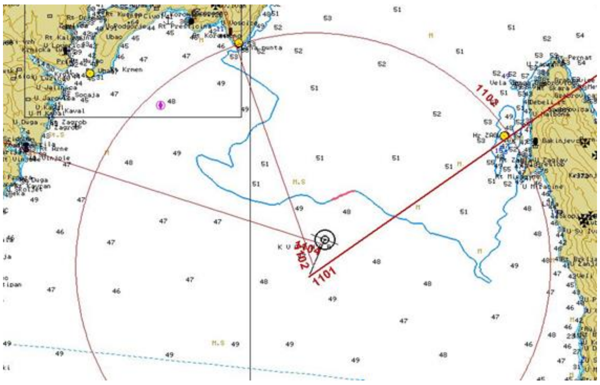
Modern navigation is inconceivable without appropriate electronic devices and systems. One of them is the Electronic Chart Display and Information System (ECDIS), a navigation information system which, with adequate back-up features, complies with the up-to-date charts required by SOLAS Convention. It displays selected information from a System Electronic Navigational Chart (SENC) and positional information from navigation sensors and additional navigation related information if required, thus assisting mariners in route planning and route monitoring (A817). ECDIS is a complex software based system with multiple options for display and integration, primarily designed for sea passage planning and navigation. As required by SOLAS Regulation V/19.2.10, the mandatory introduction of ECDIS onboard vessels is coming into force gradually, in several stages, between 1 July 2012 and 1 July 2018. From 1 July 2018 onward, all cargo vessels over 10,000 GT built before 2013 will have to install ECDIS, whereas for the new build vessels this requirement has applied since July 2013. Likewise, as from 1 July 2012, all passenger vessels over 500 GT and all tankers over 3,000 GT have been obliged to carry ECDIS (SOLAS, Chapter V). The system has been mandatory on high-speed craft since 1 August 2008 (MSC.1/Circ.1503). Mandatory carriage of ECDIS does not automatically mean that paper charts will become superseded. However, it is not likely that the traditional paper charts will stay forever, as SOLAS Convention already allows a vessel to sail without paper charts, provided that the relevant statutory requirements are met

The primary function of the ECDIS is to contribute to safe navigation and to make navigation easier. ECDIS should be able to display all chart information that is necessary for safe and efficient navigation and should reduce the navigational workload as compared to traditional chart work. It should enable the mariner to perform all route planning, route monitoring and continuous plotting of the vessel's position in a convenient and timely manner. Also, ECDIS should have at least the same reliability and availability of presentation as the navigational paper chart. Although the ECDIS system is capable of meeting numerous statutory, technical and functional requirements, there is still room for improvement. Perhaps the best example is the application of astronomical navigation or, generally speaking, when navigating without the aid of any satellite positioning system. Every ECDIS system has the dead reckoning (DR) feature and allows manual record of position, plotting lines, position circles, symbols and text, but all these features are applicable to coastal navigation. The situation is quite different in astronomical navigation as most of the modern ECDIS systems do not enable direct plotting of the astronomical position lines. This paper describes how to draw an astronomical line of position (LOP) given the existing functional capacity of standard ECDIS systems. The analysis primarily focuses on the application of the intercept method and the method of drawing the orthodromic azimuth and isoazimuth. The ECDIS system used in the analysis is Transas Navi-Sailor 4000.

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) still requires that all officers in charge of a navigation watch have knowledge to use celestial bodies in order to determine the ship's position in the open seas, but the Convention also states that the use of appropriate celestial navigation calculation software and electronic almanac is allowed.

2 ECDIS AND MANUALLY FIXED POSITION

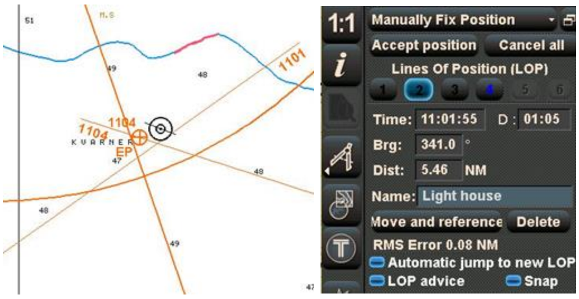
Today's standard ECDIS systems provide the feature of manual plotting of the position. The procedure includes manual insertion of a selected azimuth (or distance) (Figure 1), moving the displayed line of position (LOP) to the reference object, repeating the procedure for another object (plotting another LOP), and fixing the position (Figure 2). As the system has an internal clock, the time of fixing an LOP is automatically set, although it can be also done manually, with certain restrictions). The system keeps record of the time difference between taking bearings of the current and the first LOP, which enables the calculation of the travelled distance. After taking bearings of the relevant reference objects and insertion of parameters, it is necessary to place the LOPs on the bearing objects (or move them, taking into account the ship's speed and course), which is enabled by the tool "Move and reference" for each LOP respectively.



Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 1: Position by two azimuths and one distance

All lines of position can be seen on the ECDIS display, along with the times when their bearings were taken (Figure 1).



Source: (Transas Navi-Sailor 4000 ECDIS)

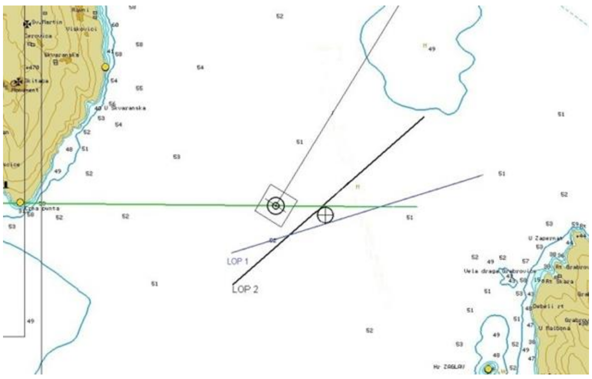
Figure 2: Manually plotted estimated position (EP)

After moving the LOPs, it is necessary to confirm the position by the tool "Accept position". The system then displays the time of fixing the new position and enters the new position into the Ship Logbook. The system accepts and marks the new position as the estimated position EP (Figure 2) (Transas Manual, 2011), regardless of the primary position fixing method (DGPS or DR) that was previously used. These procedures are performed with the help of the tool "Manually Fix Position" (Transas ECDIS).

3 USE OF ECDIS AVAIABLE TOOLS FOR MANUAL PLOTTING

There are "Maps" and "Man Corrs" functions in Transas ECDIS that allow manual insertion of symbols, lines, circles, text, selection of their colour and outline, etc. With this features it is relatively easy to plot the circles and lines of positions. For transferring the lines of position at time intervals, the user can select the option "Shift", within the function "Edit", which allows the user to move the entire LOP to any distance in the desired direction. All that time the ECDIS display shows the values of the LOP's transfer, from its initial position (distance in NM / meters and azimuth). The azimuth of the transferred LOP must correspond to the steered course and the distance must correspond to the distance travelled. The intersection of the LOPs determines the ship's position in required time (Figure 3). Drawing of circles is used for drawing the LOP distance.

When the ECDIS, apart from "Man Corr" option, features an additional tool "Maps" for inserting the symbols, then the function "Maps" has to be used for manual plotting (if the "Manually Fix Position" function is not in use). The "Man Corr" tool is designed for correcting hydrographic data in ECDIS charts. These changes are permanently visible – even when the user erases the changes by using the function "Delete", they can be retrieved and called back on the display subsequently. If the "Man Corr" tool is used for manual position plotting, it is possible to limit the time of appearance of the symbols on the display when inserting them. In this way, the plotted position will be erased from the system after the time limit.

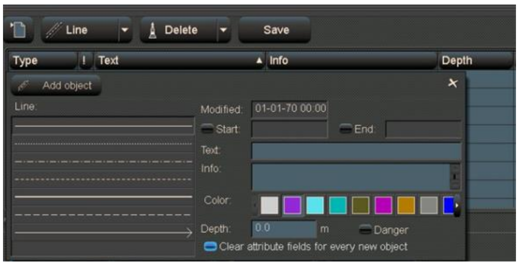


Source: (Transas Navi-Sailor 4000 ECDIS)

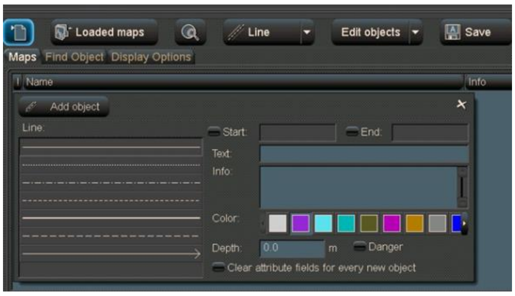
Figure 3: Position fixed by three azimuths, plotted by using "Maps" function tools

On the other hand, the "Maps" tool enables deletion of the drawn symbols without setting their time limit. This function is not used for entering permanent changes of hydrographic data but for entering all other data relevant for the navigation which have to remain visible in the chart. This information has only a short-term importance and must be deleted upon completing the voyage. "Maps" and

"Man Corr" tools offer an identical selection of symbols and equal functionality for manual plotting (Figure 4).



a) Panel "Man Corr"



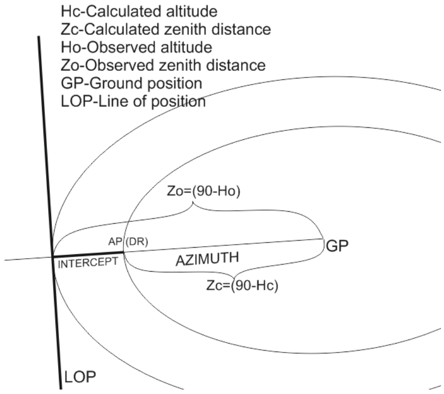
b) Panel "Maps"

Source: (Transas Navi-Sailor 4000 ECDIS)

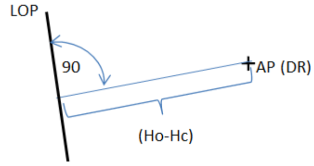
Figure 4: Panels "Man Corr" and "Maps"

4 LINE OF POSITION (LOP) IN ASTRONOMICAL NAVIGATION

To obtain an LOP (line of position) in astronomical navigation, the most common method is the intercept method, also known as Marcq St. Hilaire method. The essence of this method lies in plotting the LOP for calculating the transfer from the dead reckoning (DR), i.e. assumed or approximate (AP) position. It must be noted that the final part of this procedure is performed graphically in the navigational chart or plain sheet of paper (Figure 5). Other (older) methods, such as the Sumner line of position, longitude methods and ex-meridian method, also require graphic work in the final stage of plotting LOPs. Of all astronomical navigation methods that are used today to manually fix the position without graphic drawing is the Dozier method (Čumbelić, 1990) which directly gives the intersection coordinates of two circles of equal altitudes. However, this procedure is rarely applied in manual plotting as it is impractical when fixing the position by three or more celestial bodies (Figure 6).



a) Small scale view

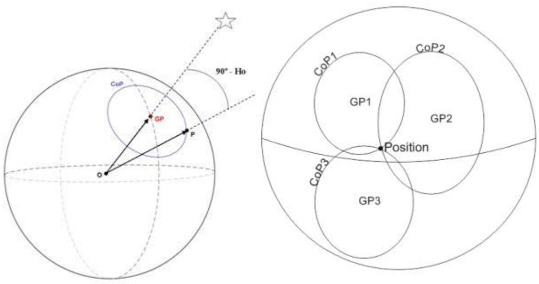


b) Large scale view

Source: (Authors)

Figure 5: LOP by Marcq St. Hilaire (intercept) method[1]

As a rule, ECDIS systems do not feature ephemerides or special software applications for the automatic calculation of the position in astronomical navigation. Therefore, the only remaining solution is to improvise with the options such as Manually Fix Position, Maps and Manual Correction (Man Corr) (Transas ECDIS). Moreover, we can only measure the altitudes and azimuths of celestial bodies, so that only these values can be used for plotting the line of position, i.e. fixing the vessel's position.



a) *CoP* b) *Position by three CoPs*

Sources: Fig a (http://fer3.com/), Fig b (Authors)

Figure 6: Circle of equal altitudes (CoP) and the position by three CoPs

4.1 Use of *Manually Fix Position*

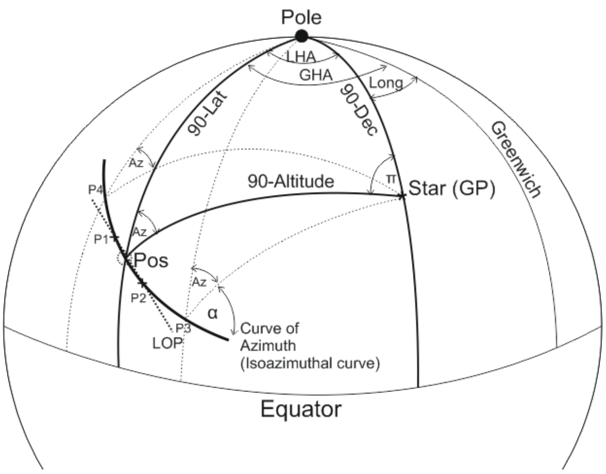
The problem of using the "Manually Fix Position" tool in obtaining the LOP in astronomical navigation lies in the fact that the azimuth of a celestial body is a part of the great circle (orthodrome), while the great circle on the Mercator navigation chart is not a straight line, but a curve. Basically, the azimuth of a celestial body is an orthodrome from the point of the observer to the point of the Geographical Position (GP)[2] that is defined by the declination and Greenwich hour angle (Figure 7). Direct

[1] For additional details see: (Čumbelić, 1990) and (Bowditch, 2002)

[2] Geographical Position (GP), also called Ground or Terrestrial Position, is the place having the body in its zenith (Bowditch, 2002)

plotting of the orthodromic azimuth in the navigation chart, i.e. approximation of the orthodromic azimuth with the loxodromic azimuth (LOP) is feasible only in short distances, which is not the case in astronomical navigation. On the other hand, it is possible to directly draw a circle as a line of position only if the ECDIS system features the display of the circles of equal altitudes (Figure 6) of the observed celestial body (in the shape of ellipsoid, cosine or parabola in the Mercator navigation chart).

Figure 7 shows the basic astronomical triangle whose three main points are the Zenith (Z), the Celestial Pole, and the celestial body (star). The projection of the triangle on the Earth gives s spherical triangle whose points are the Position of observer (Pos), Pole and the projection of the celestial body on Earth (GP). The main angles are Azimuth (Az), Local hour angle (LHA) and parallactic angle (π), while the main arcs are the complement of Latitude (90-Lat), complement of Altitude (90-Alt) and complement of Declination (90-Dec).



Source: (Authors)

Figure 7: Astronomical triangle and isoazimuth curve

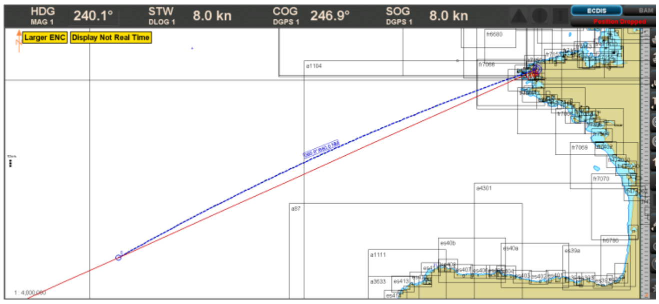
By knowing the Equatorial coordinates (Greenwich hour angle – GHA and Dec) and the observer's position, it is possible to determine the horizon coordinates (altitude and azimuth), which forms the basis of the intercept methods most commonly used in astronomical navigation positioning today. This task can be solved in a numerical or graphical way. Figure 7 also shows the isoazimuth curve whose each individual point closes the same orthodromic azimuth to the reference point, i.e. the celestial body. In the immediate proximity of the real position (Pos in Figure 7) the isoazimuth curve can be replaced by a line, i.e. it can represent a line of position. Its construction requires two points in the close vicinity of the dead reckoning (DR). The points can be obtained by calculating respective geographical longitudes for two estimated latitudes, or vice-versa (points P1 and P2 in Figure 7)[3].

a) Use of the line of position

At short distances from the observed objects (up to around 50 NM), there is no significant difference between the loxodromic azimuth and orthodrome so that the orthodromic azimuth is plotted just as the loxodromic one. At medium distances, ranging from 50 NM to 150 M, it is possible to replace the orthodromic azimuth with the loxodromic one, taking into consideration an appropriate correction[4], while at distances over 150 NM, the approximate position can be determined by constructing an isoazimuth (Benković et al., 1986). Given the fact that in astronomical navigation the objects at high altitudes (small zenith distances) are not sighted, this implies that the distance from the observer to the terrestrial projection point (GP) will be at very large distances so that, accordingly, it is not possible to determine the position by means of azimuths directly. If the deviation from the dead reckoning (or assumed) position was minimal from the actual one, the line of position could be approximately obtained as shown in the following example.

Example 1 (Nautičke tablice, 1984):
From the dead reckoning Lat=44.0°N; Long=19.0°W in the orthodromic azimuth ω_{GC}=066° we observe an object whose coordinates are Lat=48.5°N; Long=004.5°W.

Solution:
Correction c/2=5.1° is used from Nautical table 23 (Nautičke tablice, 1984).
Loxodromic azimuth ω_{RL}= ω_{GC}+c/2=066°+5.1°=71.1°.



Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 8: Orthodromic azimuth and calculated loxodromic azimuth (Example 1)

Figure 8 shows the relationship between the orthodromic azimuth and calculated loxodromic azimuth in the nautical tables: *"Correction to convert (radio) great circle bearing to Mercatorial bearing"*. The ECDIS system displays it as follows (Figure 8): the orthodromic azimuth is drawn by using the tool "Route planning" (as the course); correction (c/2) is calculated manually with the aid of nautical tables, while the loxodromic azimuth (LOP) is plotted by using the "Manually Fix Position" tool. The plotted LOP passes within one nautical mile from the dead reckoning (DR) that actually represents the true position as the correction c/2 has been calculated for it. Therefore, in the context of astronomical navigation this procedure will not be

[3] For more details see (Lušić, 2018)

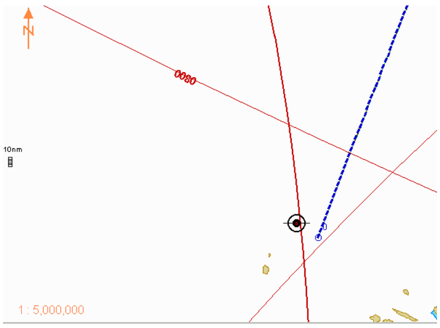
[4] In nautical tables this can be found under the name "Correction to convert (radio) great circle bearing to Mercatorial bearing" (Norie's Nautical Tables, 1991), (Nautičke tablice, 1984).

appropriate as the method itself cannot provide the transfer from the DR to the true position. This problem can be solved by constructing an isoazimuth, as described in Paragraph 5.

b) Use of the circle of position

If the ECDIS tool "Manually Fix Position" features the display of the circle as the line of position of unlimited radius, then the astronomical position can be easily fixed. The truth is that the line of position is defined by the zenith distance (90-Alt), i.e. the radius of circle of equal altitudes, where the circle's centre represents the ground position (GP). The GP coordinates are established as follows: latitude GP=declination of the body (Dec) and Longitude GP=Greenwich hour angle of the body (GHA).

a) *Small scale view*



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b) *Large scale view*

Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 9: Circles of equal altitudes on ECDIS display (Example 2 – Table 1)

Figure 9 shows the position obtained by using the tool "Manually Fix Position" (Transas ECDIS), in such a way that three distances are inserted for the same observation time. The distances are actually true zenith distances (90-Ho) from Example 2 – Table 1. Although the ECDIS in use features the possibility of plotting the line of position of unlimited radius, this LOP is not suitable for practical use due to errors in graphic display. Figure 9b (large scale view) indicates a considerable deviation of the inserted LOPs from the actual distances. For example: the first LOP-Kochab (in Figure 9b LOP perpendicular to the dashed line, deviates several dozen nautical miles from the real position – point "0"; the dashed line represents the true orthodromic azimuth for the same distance as the plotted circle of equal altitudes (Kochab), but calculated and displayed via the option "Route planning". This means that two functions within the ECDIS system (Transas ECDIS) display the distance in graphically different ways.

4.2 Use of *Maps or Manual Correction Function*

Given the fact that the ECDIS system features the possibility of manual drawing of lines, circles, symbols etc. the latter can be used for the display of LOPs, i.e. positions. The obtained positions will not be recognised by the system automatically, but this does not make this function less important in any way. It is exactly owing to this function that the user of ECDIS can also perform operations that have not been systematically defined and embedded as the final ready-to-use options. The basic features of the functions "Maps" and "Man Corr" have been described earlier in Paragraph 3 and now the study will show how to use these functions for obtaining the line of position (LOP), i.e. the position in astronomical navigation. For the purpose of exemplification, the tool that has been most commonly used in recent practice will be used: the intercept method where the final portion of the problem is solved on the navigation chart, i.e. on a sheet of plain paper. It is assumed that the numerical or tabular calculation of the basic elements is performed manually in the form of tables or with the aid of other program solutions. Therefore, only the final stage of the LOP graphic plotting will be carried out using ECDIS. In our example, the elements defining the LOP (GP, ΔH and Azc-from Table 1) need to be drawn in ECDIS system.

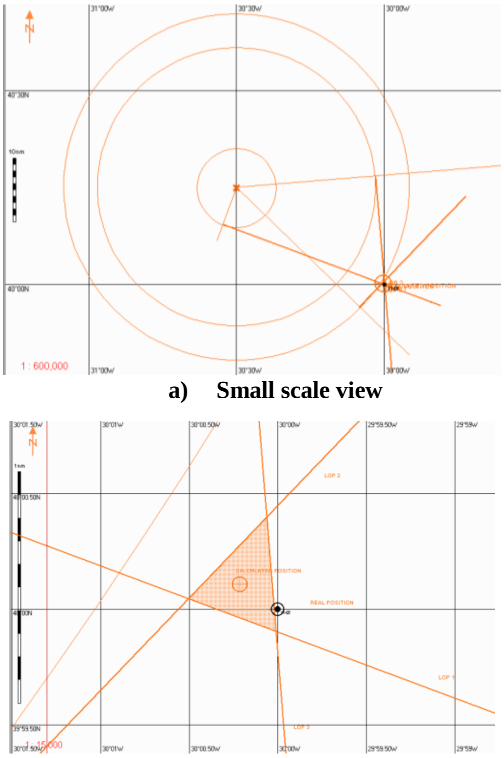
Example 2.
On September 01, 2015 at UT 08 00 00, at DR Position Lat=40°15.0'N and Long=030°30.0'W three bodies (Kochab, Spica and Pollux) are observed.

The measured altitudes (Ho), true azimuths Az, calculated altitudes and azimuths (Hc and Azc), and Ho-Hc are shown in Table 1.

Table 1: Example of the intercept method

Kochab		**Spica**		**Pollux**	
GHA327°43.5' Dec74°04.9N	GP Long032°16.5'E Lat74°04.9N	GHA348°50.5' Dec11°15.0S	GP Long011°09.5'E Lat11°15.0S	GHA073°46.0' Dec27°57.7N	GP Long073°46.0'W Lat27°57.7N
Ho 45°42.9'	Hc 45°49.0	Ho 26°07.2'	Hc 25°40.3'	Ho52°11.8'	Hc52°33.3'
Az 20.3°	Azc 20.5°	Az 134.0°	Azc 133.7°	Az 265.3°	Azc 264.6°
ΔH=Ho-Hc=-6.1'		ΔH=Ho-Hc=+26.8'		ΔH=Ho-Hc=-21.5'	

The results[1] from Table 1 are used to perform the intercept method's last step using the ECDIS system (Figure 10).



a) Small scale view

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b) Large scale view

Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 10: Position obtained by intercept method

Figures 10a and 10b clearly show that the triangle resulting from the LOPs has been sufficiently small for fixing the reliable position. This is the screenshot of ECDIS (Transas ECDIS) where all lines and symbols were inserted via the "Maps" function".

5 USE OF AZIMUTHS AND ISOAZIMUTHS FOR POSITIONING

Azimuth-only direct positioning in astronomical navigation is typically avoided for a number of reasons. Two of them are rather serious. The first reason, described earlier in the paper, refers to the fact that the observed azimuths are orthodromic azimuths and do not represent lines in the Mercator navigation chart. Also, the sighted orthodromic azimuth cannot represent a line of position because the same value of this orthodromic azimuth can be obtained by observers at various positions. Another reason, not less important, is the fact that azimuths cannot be accurately measured. It is very hard, sometimes even impossible, to achieve the accuracy better than +/-1° (Xu et al., 2014), and a minor azimuth error results in major move (error) of the LOP. For instance, an azimuth error of 1° to the object situated 3,000 NM results in the move of the LOP of about 51 NM[2]. For practical use of azimuths in direct plotting of LOPs, it would be necessary to achieve the minimum precision of +/-0.1°, which is presently feasible only in static conditions. Assuming that, nevertheless, it is possible to achieve the azimuth precision of at least +/-0.1°, ECDIS tools can be very useful for quick and simple solving the issue of fixing the vessel's position with the aid of celestial bodies. The following paragraphs will explain how to use the ECDIS system for the construction and display of isoazimuths as lines of position and for direct fixing of the position in astronomical navigation by using only the available azimuths of celestial bodies.

5.1 Isoazimuths

Isoazimuths can be graphically constructed[3] by taking into consideration the function "Correction to convert (radio) great circle bearing to Mercatorial bearing" (Norie's Nautical Tables, 1991). However, when there is a large distance between the position and the observed object (distance from Pos to GP – Figure 7), the method of calculating two points in the immediate proximity of the dead reckoning (assumed) position represents a better solution.

Example 3 (input data from Example 2 – Paragraph 4.2)
Suppose we know the true azimuths (Az) and equatorial coordinates (Dec and GHA). The DR is also known. Altitudes remain unknown. The starting assumption is that the dead reckoning (DR) position is not correct so that, accordingly, two selected latitudes (or longitudes) are shifted by 15' N/S, i.e. 15' E/W from DR. The task can be completed by calculating two longitudes for the two selected latitudes, or vice-versa. In this particular case, the latitude is selected for the first and third body, longitude is calculated, while the procedure is opposite for the second celestial body. This selection is performed in order to make the obtained points as close to DR as possible.

The obtained coordinates of the reference positions are:

First body (Kochab)

- selected long 1: 030° 45.0'W, calculated lat 39° 40.3'N
- selected long 2: 030° 15.0'W, calculated lat 39° 40.3'N

Second body (Spica)

- selected lat 1: 40° 30.0'N, calculated long 030° 13.9'W
- selected lat 2: 40° 00.0'N, calculated long 030° 02.3'W

Third body (Pollux)

- selected long 1: 030° 45.0'W, calculated lat 39° 33.5'N
- selected long 2: 030° 15.0'W, calculated lat 39° 50.1'N

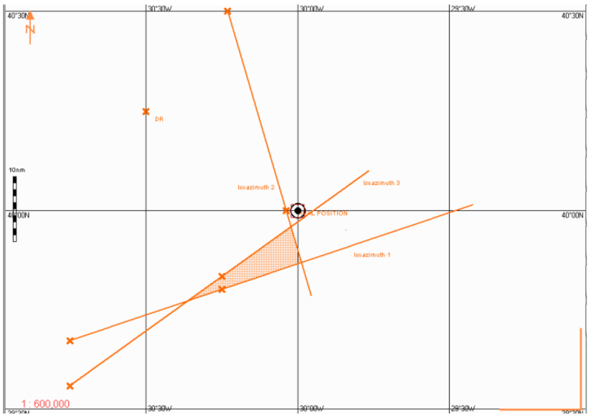
[1] Results (calculated azimuths Azc and calculated altitudes Hc) provided through Skymate software.

[2] Based on the expression d(error)=0.017 D (D-distance to object) (Benković et al., 1986).

[3] More details about the method in (Benković et al., 1986).

Joining of the obtained coordinates results in a straight line that can serve, relatively well, as an isoazimuth so that it can represent a line of position. Its accuracy relies on the accuracy of the azimuth, DR error, but also on the reference (selected) positions in relation to the true position. The LOP is more accurate when the true position takes place between reference positions (closer to the centre), which is not the case in the described example.

Figure 11 shows the intersection of the three obtained isoazimuths (actually, three lines of position). Each of the lines is defined by two reference positions (marks "x" in Figure 11). The position error is relatively large, however yet smaller than the DR error. Figure 11 is a screenshot of the ECDIS (Transas ECDIS) display and all visible lines and symbols have been inserted via the "Maps" function.



Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 11: Position by isoazimuths

5.2 Direct plotting of the azimuth

The estimation of the position based on the direct plotting of the azimuths can be performed by using the tool "Route planning". The procedure is as follows (Figure 12):

- plot the GP as per known Greenwich hour angle and declination;
- draw the GC bearing, i.e. orthodromic azimuth, (or course) between the DR (or assumed) position and GP for the first body. The procedure is repeated for other bodies, after which the obtained azimuths (courses) are compared;
- If the azimuth are not good, the DR is shifted, as estimated, by a certain value (Figure 12: 10' south and 10' east) and the calculation of the azimuths (courses) is repeated;
- The procedure is repeated as long as the obtained results approximately correspond to the sighted values of the azimuths (Figure 12: the third position shifted from the first one by 15'S and 30' E).

Solving the problem in the above described way is a relatively long procedure because the ECDIS system does not feature the direct plotting of the orthodromic azimuths so that the latter are simulated by orthodromic courses with the aid of "Route planning" tool (Transas ECDIS). The procedure would be considerably easier if the ECDIS had the capacity of plotting a number of orthodromic azimuths and if these azimuths could be automatically shifted, following the shift of the DR (assumed) position.

a) *Large scale view*

b) *Small scale view*

Source: (Transas Navi-Sailor 4000 ECDIS)

Figure 12: Direct position by three azimuths

(a – large scale view, b – small scale view)

Figure 12 is a screenshot of the ECDIS (Transas ECDIS) display where all visible lines have been inserted via the "Route planning" function. Textual values of azimuths (Figure 12a) have been subsequently inserted using special graphic design software for the purpose of simple explanation of the problem solution.

6 CONCLUSION

The Electronic Chart Display and Information System (ECDIS) is an electronic device primarily designed for safe passage planning and sea voyage supervision. It has become increasingly mandatory onboard a variety of vessels and has been gradually displacing navigation paper charts from use, thus affecting the traditional ways of performing navigation. ECDIS has become a synonym for modern navigation, the groundwork for building or designing future solutions. On the other hand, astronomical navigation is a synonym for classical navigation, which many modern mariners now consider to be history.

However, astronomical navigation has an essential feature that makes it a valuable navigation asset that is likely to survive, in some form, a number of years to come. Unlike other systems, mainly electronical, astronomical navigation is the only autonomous system that is available as long as the observable celestial bodies exist. If the mariners and watch-keeping officers are allowed to use electronic almanacs and associated software tools for dealing with the elements of astronomical navigation, it seems legitimate to wonder why these elements are not integrated into ECDIS systems. With the exemption of the nautical almanac, which may or may not be fitted into a future ECDIS system, other elements necessary for plotting astronomical lines of position should be definitely incorporated into basic ECDIS functional tools. Even though modern ECDIS systems allow drawing of lines, circles, symbols and other items used for performing any task in paper charts, this feature is not suitable for astronomical navigation, nor does it comply with the basic ECDIS concept of making the navigation at sea simpler and more efficient and reliable. Of all tools for plotting the lines of position (LOP) in astronomical navigation by means of ECDIS, it is important to emphasise the importance of direct drawing of the circles of equal altitudes and GC (orthodromic) azimuths. If ECDIS systems were able to draw the circles of equal altitudes, this would mean that the problem of fixing the position in astronomical navigation could be reduced to measuring altitudes by means of the sextant and direct plotting of the zenith distance in ECDIS whose centre is the Ground Position (GP), just like the circle as an LOP is drawn by using the "Manually fix position" tool. Then the elements of the intercept method would not be needed at all. Moreover, if ECDIS systems could directly plot the GC (orthodromic azimuth) from the selected point towards an object, or if isoazimuths could be calculated, the position fixing would be possible just with the help of azimuths. One of these days, when classic astronomical navigation does become history, i.e. when the sextant disappears from vessels, the suggested improvements could remain as the available back-up option for the mariners. This alternative does not require a comprehensive knowledge of astronomy, or classic astronomical navigation, and would be as simple as the plotting of azimuths and circles (LOPs) within the existing ECDIS function "Manually Fix position".

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STAKEHOLDERS IN ABATING MARINE LITTER IN THE ADRIATIC

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ABSTRACT

Marine litter is identified as one of the major threats to the ecosystem in the Adriatic. The bulk of marine litter originates from land and only a lesser part is generated at the sea itself. The situation with marine litter is also one of the clearest symbols of a resource inefficient economy. The paper analyses sources of marine litter resulting from poor waste management on land as well as discharge of garbage from ships and offshore facilities. Evaluation is made of the sources of law and implementation practice. Analysis is made of the waste management principle to be adhered to with particular reference to pollution of the marine environment by plastics. The authors urge for stakeholder cooperation and networking in abating marine litter in the Adriatic and are proposing the instrument towards circular economy which should be implemented in a vulnerable semi-enclosed sea.

Keywords: marine litter, legal framework, environment, waste management, stakeholders

1 INTRODUCTION

Marine litter is for its most part the result of inappropriate waste management on the land. Marine litter on Adriatic coast is a sign of alarm that measures must finally be implemented in all countries whose shores are washed by the Adriatic Sea to handle the waste in a way which does not make the sea its destination, thus avoiding the damage to marine ecosystems, public health, standard of living and tourism [1].

Marine litter is also one of the clearest symbols of a resource inefficient economy, because of the situation that valuable materials are polluting our beaches and damaging our environment instead of being pumped back into our economy [2].

The paper analyses the concept and sources of marine litter, current policies concerning marine protection and waste, pointing out the deficiencies and elaborating Croatian case. In its second part it presents the solutions to abating marine litter ranging from requisite advancements in after-use plastics economy, particularly the treatment of ‘compostable’ and ‘biodegradable plastics’ to utilizing the role of public procurement, stimulating localization, changing water consumption patterns, developing port reception facilities and achieving stakeholders’ cooperation and networking.

2 THE CONCEPT OF MARINE LITTER

Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Marine litter thus consists of items that have been made or used by people and deliberately discarded or unintentionally lost into the sea or coastline including such materials transported into the marine environment from land by rivers, drainage or sewage systems or wind [3]. Marine litter appears on beaches, on the sea surface, below the surface in water column, on the seafloor and in biota.

The marine litter issue has been identified as one of major threats to marine ecosystems in the Mediterranean due to its environmental, economic, safety, health and cultural impacts. Regional approach to abatement of such pollution is indispensable for any successful solution as the problems of marine litter go beyond national borders.

3 SOURCES OF MARINE LITTER

The bulk of marine litter originates from land (almost 80%), and only a lesser part is generated at the sea itself. Land sources of waste are uncontrolled or poorly managed communal landfills or waste sites along sea coasts [4,5] or river banks, illegal dumping and mishandled waste on land, drainage and sewerage, river discharges, rain washouts and blowout from coasts during storms, as well as tourist activities. Marine litter is waste which falls from ships of all types and designated purposes – floating ropes, nets, floats and other debris, from fisheries, merchant shipping, cruise ships and also from aquaculture, oil and gas rigs and tourist activities. The cause of marine litter is therefore human activity – on the land and in the seas whereby all sectors and individuals contribute to this pollution. Waste delivered from the increasing number of passenger ships and yachts visiting Adriatic coasts additionally aggravates the problem [1].

When it comes to the material composition of litter found in all marine compartments of the Adriatic, most of litter items were artificial polymer materials. The most abundant items for beaches includes: plastic pieces, polystyrene pieces, cotton bud sticks, plastic caps/lids from drinks, cigarette butts and filters, plastic caps/lids unidentified, mussel&oyster nets, crisp packets/sweet wrappers, etc. The most abundant floating litter items were: plastic bags, plastic pieces, sheets, fish polystyrene boxes, cover/packaging, and other plastic items. Results obtained from the bottom trawl surveys showed that sheets, industrial packaging, plastic sheeting are the most abundant types of litter, followed by bags and food containers including fast food containers. In the visual seafloor surveys with scuba/snorkeling the most common items found were glass bottles or pieces thereof, followed by plastic bottles and metal cans. When it comes to the biota, nine marine litter categories were found in the guts of the examined – filaments, films, sheets, industrial packaging and plastic sheeting. The quantity and presence of plastic waste at the bottom of the Adriatic Sea is among the highest in Europe, after North-east part of the Mediterranean and Celtic Seas. The waste from about four million people living along its coasts ends up there, and the number is multiplied almost six-fold during tourist season. The composition and distribution of floating litter suggests that every day public and tourist activities are mostly responsible for this kind of pollution in the Adriatic waters [6].

4 PLASTICS LEAKAGE ISSUE

As stated above, large quantities of plastic waste leak into the environment from sources both on land and at sea, generating significant damage, both economic and environmental. Plastics have become the ubiquitous workhorse material of the modern economy combining unrivalled functional properties with low cost [7].

After a short first-use cycle 95% of plastic packaging material value is lost to the economy. The share of 32% of plastic packaging escapes collection systems, generating significant economic costs by reducing the productivity of vital natural systems such as the ocean and clogging urban infrastructure. Thus, every year at least 8 million tons of plastics leak into the ocean – which is equivalent to dumping the contents of one garbage truck into the ocean every minute. In a business-as-usual scenario, the ocean is expected to contain 1 tone of plastic for every 3 tons of fish by 2025, and by 2050, more plastics than fish (by weight) [7].

Plastic debris is then transported by marine currents, sometimes over very long distances. It can be washed up on land, degrade into microplastics or from dense areas of marine litter trapped in ocean gyres. United Nations Environmental Programme (UNEP) estimates that damage to marine environments is at least USD 8 billion per year globally [8].

Single-use plastics items are a major source of plastic leakage into the environment, as they can be difficult to recycle, are often used away from home and littered. As also evidenced by their presence in the Adriatic (see Section 3), they become the items most commonly found on beaches and represent an estimated 50% of marine litter, see fig. 1.

Figure 1: Items found on EU beaches [9]

5 CURRENT POLICIES CONCERNING MARINE PROTECTION AND WASTE

Since marine litter from one country can end up on the beaches of another, and fragments of plastic from all over the globe accumulate over time in the oceans and seas, carried by marine currents, international cooperation is crucial to tackle this issue. Oceans and seas are a global good and common heritage, and if the current trend is not reversed this could have legacy effect for future generations through degradation of marine ecosystems and threats to human health. Establishing sound waste prevention and management systems, particularly in emerging economies, is essential to keep plastics out of the sea. Many initiatives have been launched at international fora (such as G7 and G20, the United Nations, and in the context of the MARPOL Convention [10] and regional sea conventions; actions against marine litter are also included in the International Ocean Governance Agenda for the future of our oceans [11].

The International Convention for the Prevention of Pollution from Ships (MARPOL Convention), 1973/78 has six annexes, each one dealing with a specific type of potential pollutant from ships, amongst other, Annex V, covering garbage that may become marine litter.

Convention on Prevention of Marine Pollution by Dumping of Wastes and other Mater, 1972 (London Convention) and the 1996 Protocol to the Convention (London Protocol) are legal instruments which regulate activities that might become litter at the sea [12].

Within the framework of the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention), 1976, the Mediterranean states adopted in 1980 a Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources, which in Annex I defines as one of the categories of substances litter [13].

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive - MSFD) sets the framework for Member States to achieve by 2020 Good Environmental Status (GES) for their marine waters, considering 11 descriptors. Descriptor 10 focuses on marine litter, stating that GES is achieved only when properties and quantities of marine litter do not cause harm to the coastal and marine environment [14].

Definitions of the acceptable levels of harm and good environmental status must consider impacts as assessed by the amount of litter in different compartments of the marine environment (seabed, sea surface, water column, coastline), ecological effects of the litter (e.g. plastics ingested by marine organisms, entanglement rates) and problems associated with degradation of litter (microplastics) as well as social and economic aspects.

The European Strategy for Plastics in a Circular Economy [8] states that the Commission will continue to make use of policy dialogues on environment and industry and dialogues under free trade agreements, and to actively cooperate in Regional Sea Conventions and work on international responses for combating plastic marine litter and microplastics. It will also examine possible ways to take action to reduce plastic pollution in the Mediterranean, in support of the Barcelona Convention, and in major world river basins, as a vast proportion of waste plastic is carried by rivers before it reaches the seas. Finally, the Commission will facilitate the cooperation of the outermost regions of the EU66 with their neighbours along the Caribbean Sea, the Indian, Pacific and Atlantic Oceans across different fields, including in waste management and recycling.

5.1 Deficiencies in implementing existing regulations

The main reason that the problem of marine litter has not been successfully addressed is the lack of integrated legal framework (MARPOL Convention Annex V deals only with garbage from ships) or Global Programmes – making it difficult to tackle the problem [15].

Nationally, several countries have taken comprehensive action to address the marine litter issues through legislation, enforcement of international agreements, providing reception facilities for ship-generated wastes, improving their waste management practices and supporting extensive beach clean-up activities, as well as information, education and public awareness programmes.

At national level in the European countries there are general ordinances, regulations, implementation regulations and acts governing mainly waste handling and port reception facilities, while some countries have municipalities acting on collection of litter from beaches.

Shortages in the implementation and enforcement of existing international, regional, national regulations and standards that could improve the situation, combined with a lack of awareness among main stakeholders and the public, are other major reasons why marine litter problem not only remains, but continues to increase worldwide. Also, marine litter is a part of broader problem of waste management, which is becoming a major public health and environmental concern in many countries.

5.2 Croatian case

Valid 2017-2022 Waste Management Plan (WMP) [16] for instance, states that the system of marine litter management has not been established and that currently there are neither official data nor appropriate assessment regarding the quantity of marine waste in the Republic of Croatia. Also, MFSD lays down obligation on the Member State to adopt a marine strategy, but the Republic of Croatia has never adopted the Strategy on Marine Environment and Coastal Area Management, although one has been drafted in 2015.

The quantity of mixed municipal waste landfilled annually in the Republic of Croatia is about 1.300.000t. The recycling target for municipal waste is at least one half of said quantity, with the potential for recycling of materials contained in that quantity being estimated to be even higher than 50%. To achieve recycling targets, it is necessary to collect separately a significant part of plastics, paper, metal, glass and textile and biodegradable waste, which presently constitute municipal waste. In other words, dry fraction such as paper and cardboard, metal, plastics, glass and textile or all waste packaging and similar materials should be collected separately from biodegradable waste and mixed municipal waste. It is also necessary to increase the capacities for separating waste – sorting plants (for dry fraction and where appropriate mixed waste) and the capacities for treating biodegradable waste (composting plants, biogas plants).

Draft Waste Management Plan 2016-2022 [17] which was later not adopted in its original from envisaged embarking upon true circular economy and consequently the reduction or elimination of marine litter from domestic sources. It embraced marine litter issue as well in an integrated manner. Given that about 80% percent of marine litter originates from land base-sources, it stated that in regulating the system of special categories of waste particular attention should be paid to preventing that waste ends up in the sea. An overview of anticipated waste management system is shown in figure 2.

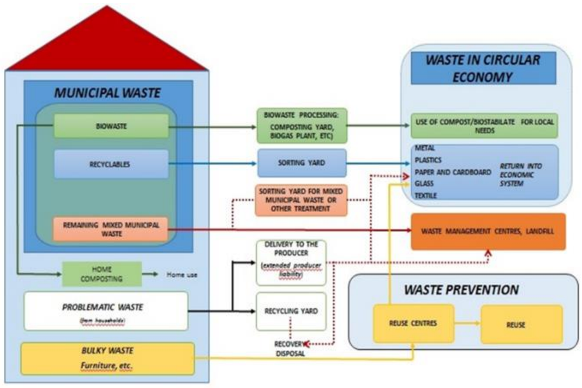

Figure 2: Flow diagram of planned municipal waste management system [17]

In support of proposed concept and with regard to greenhouse effect, a study for the EU Commission comparing different waste management options from a greenhouse gas perspective concluded that overall, source segregation of mixed solid waste (MSW) followed by recycling (for paper, metals, textiles, and plastics) and composting/AD (for putrescible wastes) gives the lowest net flux of greenhouse gases, compared with other options for the treatment of bulk MSW [18].

6 AFTER-USE PLASTICS ECONOMY

In order to reduce the severity of marine litter problem globally, it is necessary to create an effective after-use plastics economy by radically increasing the economics, quality and uptake of recycling, scaling up the adoption of reusable packaging, and scaling up the adoption of industrially compostable plastic packaging for targeted applications such as garbage bags for organic waste and food packaging for events, fast food enterprises, canteens and other closed systems, where there is low risk of mixing with the recycling stream and where the pairing of a compostable package with organic contents helps return nutrients in the contents to the soil. Compostable packaging can help return organic nutrients to the soil in applications that are prone to be mixed with organic contents after use. According to FAO roughly one third of the food produced globally is lost or wasted. A large share of this food is not returned to the soil. Furthermore, the leakage of plastics into natural systems and other negative externalities should be drastically reduced by improving after-use collection, storage and reprocessing infrastructure in high-leakage countries, increasing the economic attractiveness of keeping materials in the system, and steering innovation investment towards creating materials and formats that reduce the negative environmental impact of plastic packaging leakage [7].

Most currently available plastics labelled as biodegradable generally degrade under specific conditions which may not always be easy to find in the natural environment and can thus still cause harm to ecosystems whereby biodegradation in the marine environment is particularly challenging. In addition, plastics that are labelled 'compostable' are not necessarily suitable for home composting. If compostable and conventional plastics are mixed in the recycling process, it may affect the quality of the resulting recyclates [7]. For consumer applications, the existence of a well-functioning separate collection system for organic waste proves to be essential. It is important to ensure that consumers are provided with clear and correct information, and to make sure that biodegradable plastics are not put forward as a solution to littering. This can be achieved by clarifying which plastics can be labelled 'compostable' or 'biodegradable' and how they should be handled after use. As for the interface between chemicals, waste and product policy, the plastics value chain should be far more integrated, with the chemical industry working closely with plastics recyclers to help them find wider and higher value applications for their output. Substances hampering recycling processes should be replaced or phased out [8].

7 THE ROLE OF PUBLIC PROCUREMENT, LOCALIZATION AND WATER CONSUMPTION

An instrument of public procurement should significantly contribute to sustainability [19]. Public procurement rules should be used to generate more demand for recycled materials. Recycled content should be integrated in public procurement criteria.

With groceries returning to the high street, they would occupy smaller spaces closer to residential areas with localized stores that stock a range of products tailored to the local demographic. The evolution of high-frequency, small-based transactions means the idea of one large weekend grocery shopping trips fading, and the megastore distribution model with a large-scale, long-haul, hub-and-spoke network may no longer be fit for purpose everywhere [7].

The Plastics Strategy [8] also states that through its upcoming legislative proposal for a revision of the Drinking Water Directive, the Commission will promote access to tap water for EU citizens, therefore reducing packaging needs for bottled water. The criteria for the Ecolabel and Green Public Procurement also promote reusable items and packaging.

8 PORT RECEPTION FACILITIES

To reduce discharges of waste by ships, the Commission is presenting together with the Strategy a legislative proposal on port reception facilities [20]. This presents measures to ensure that waste generated on ships or gathered at sea is delivered on land and adequately managed. The Commission also plans to develop targeted measures for reducing the loss or abandonment of fishing gear at sea. Possible options to be examined include deposit schemes, Extended Producers Responsibility schemes and recycling targets. The Commission also intends to further study the contribution of aquaculture to marine litter and examine a range of measures to minimize plastic loss from aquaculture.

9 STAKEHOLDERS COOPERATION AND NETWORKING

Innovations required for the transition to the circular economy and New plastics economy are driven collaboratively across industry, cities, governments and non-governmental organizations (NGOs). In this initiative, consumer goods companies, plastic packaging producers and plastics manufacturers would play a critical role, because they determine what products and materials are put on the market. Cities control the after-use infrastructure in many places and are often hubs for innovation. Businesses involved in collection, sorting and reprocessing are an equally critical part of the puzzle. Policy makers can play an important role in enabling the transition by realigning incentives, facilitating secondary markets, defining standards and stimulating innovation. NGOs can help ensure that broader social and environmental considerations are taken into account. Collaboration would be required to overcome fragmentation, the chronic lack of alignment between innovation in design and after-use, and lack of standards, all challenges that must be resolved. After-use systems, currently shaped by fragmented decisions at municipal and regional level, should be rethought and redesigned to achieve optimal scale and economics [7].

Consequently, there are numerous stakeholders that should approach marine litter problem jointly and in a holistic manner.

10 CONCLUSIONS

Marine litter in the Adriatic Sea presents a significant problem for the Republic of Croatia and marine litter mirrors waste management problem on the land. Key contribution to the solution of marine litter problem is waste management involving source separation, numerous local sorting facilities, home composting, municipal composting and biogas production, with minimum resources left for disposal

Prevention is generally more effective and efficient than remedial action. In many cases, preventive mechanisms and the authority to enforce them are already implicit in existing global or regional conventions and action plans, even when marine litter is not specifically mentioned. Waste management principles to be adhered conceived to embark upon true circular economy and consequently the reduction or elimination of marine litter from domestic sources, embraced marine litter issue as well in an integrated manner.

The authors are advocating for reducing landfilling and to increase preparation for reuse and recycling. Designing products to ensure they are compatible with recycling, followed by appropriate collection and recycling will simultaneously reduce the quantity of waste in managed systems and in the environment. Moving toward a circular economy will also lead to increasing resource efficacy.

There is a pronounced role of public procurement, of localization as well as of the access to and consumption of tap water in reducing the leakage of plastics in marine environment.

The authors urge in particular for stakeholder cooperation and networking in abating marine litter in the Adriatic and are proposing the instrument which should be implemented in a vulnerable semi-enclosed sea. In that sense of utmost importance is the synergy of the governance capacity and management competence of the industry with the knowledge and enthusiasm of the non-governmental organisation and civil society public awareness. The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution in abating marine litter in the Adriatic.

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THE IMPACT OF URBAN PLANNING ON THE TRANSPORT SYSTEM AND CITIZENS' MOBILITY

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ABSTRACT

Rapid urbanization process causes the increase of mobility demand by its citizens. Integration of transport, health and environmental objectives for integrated urban and spatial planning in order to reduce the impact of transport on health and environment is a priority direction of urban lands' sustainable development. It would reduce the dependence on personal vehicles and increase the use of public and non-motorized transport for short distances and daily commutes. However, to improve an attractiveness of the public transport is possible only through the use of complex solutions, which are based on the analysis of cities and their specifics. The article gives examples of the impact of urban planning on citizens' mobility. To implement complex strategic decisions, it is necessary to use micro and macro models which allow comparing situations "as is" and "as to be" to predict consequences. The case study of the article's authors show that with the help of models it is possible to check the effectiveness of the changes of public transport's route network and the configuration of dangerous sections of the street-road network. The authors give concrete examples of developed own solutions and efficiency calculations.

Keywords: sustainable transport, transport system's efficiency, route network, public transport

1 INTRODUCTION

The world economy in the new millennium is characterized by two main trends. On the one hand, it is the rapid development of engineering and technology that requires significant amounts of resources and that causes the emergence of an increasing number of sources of negative impact on the environment. On the other hand, it is the growing number of supporters of transition to a green economy that initiate the development of strategies and policy documents on sustainable development in all spheres of human activity. The processes of globalization and urbanization are accompanied by the growth of transportation demand and, consequently, require to increase stability and safety of transport system. Negative consequences of urbanization, development of the real sector of the economy and unwarranted harmful environmental impact of the humanity is the reason of the priority of the 5 sectors underpinning the UNEP (United Nations Environment Programme) report "Global Green New Deal". One of these sectors is the "Sustainable Cities, including planning, transportation and green building" [1]. The three-pronged strategy of UNEP in the area of transport, a sector, which accounts for approximately one quarter of all energy-related greenhouse gas emissions, is "Avoid – Shift – Clean". This UNEP's program is promoting a paradigm shift for a less motorized, but no less mobile, world. A lot of methods are proposed to solve this problem. One of the most perspective method is intellectualization of transportation process. Mobility is a key dynamic of urbanization. By 2005, approximately 7.5 billion trips were made in cities worldwide each day. In 2050, there may be 3-4 times as many passenger- and freight-kilometers travelled as in the year 2000. Transition to inclusive green economy should be based on viable ecosystems, cleaner production, healthy consumer preferences.

2 NEW TRENDS IN URBAN MOBILITY

2.1 Impact of sustainable urban development on the transport system

Examples of sustainable cities, as a rule, belong to the most developed countries (biopositive countries). Currently, examples of countries that have embarked on a path of sustainability are Germany and the Netherlands. For example, Germany, which had by the beginning of the 20th century. only about 4% of the areas under forests, currently has about 25% of the forested areas [2]. Germany is a country of small cities, surrounded by a large number of forests, fields, farms. Thus, the length of Frankfurt am Main from east to west is 10 km, from north to south is 6 km, the area of the city is only about 60 km^2. Nevertheless, Frankfurt am Main is the largest logistics and transport hub in Europe, the city has the largest airport in Germany, and is also positioned as a European financial center. These "incompatible" characteristics were achieved due to the principles of sustainability, a competent urban lands use, a policy in the field of public transport, which, for example, resulted in the total reconstruction of the city's tramway system by its expansion and modernization. Today, the problem of sustainability is relevant in the Russian context. In the last 20 years, the humanization of the urban environment has been growing in Russia by improving the aesthetic and functional characteristics of buildings and structures, but there is a discrepancy between architecture and man in big Russian cities. This is because the existing master plans can not always be realized in practice because of the rapid change in the political and momentary utilitarian and practical conjuncture. It is stated in [3] that sustainable city's environment may be improved with the help of eco-friendliness: 1. Integration of social, economic and ecological factors into the creation of sustainable city's environment. 2. Maintenance of a high-quality eco-friendly infrastructure in sustainable city and nearby to support the quality of environment. 3. Eco-friendliness of the architectural-building environment to provide satisfaction of citizens' needs and, at the same time, to achieve an ecological equilibrium. 4. Eco-friendliness of all activity in city-industry, power engineering, transport, water consumption, waste processing, etc. 5. Eco-friendliness of citizens' needs and inculcation of ecological ethics.

Eco-city encourages public transport that either does not pollute environment at all, or has only small pollution. The advantage is given to electric transport (ideal is electric transport in an underground tunnel, e.g. metro), personal electric cars or vehicles on gas. Pedestrian traffic and cycling are encouraged: for this purpose, a special network of pedestrian and bicycle paths, that do not intersect with transport routes, parking lots and parking for bicycles is arranged. All private parking facilities are located on the borders of the eco-quarters, so that there is no passage inside the quarters, and it is recommended to equip highly loaded sections by moving sidewalks [4]

One of the interesting solutions in the biopositive country is the arrangement of "green" corridors that connect all the green areas and natural landscapes with each other. These corridors should be created in the scale of the country, city, microdistrict. The main idea of the "green" corridors is the creation of the possibility of migration of animals without crossing their paths with roads and buildings, as well as ensuring the possibility of walking people. For free migration, these corridors should nowhere intersect at the same level with the transport highways, crossing the corridors should be arranged interchanges in the form of overpasses, pipes and tunnels under the roads.

Much attention should be paid to supporting bicycle transport. For bicycle routes, individual paths are arranged alongside the usual motorways, or individual bicycle paths are made in the level of the 2 floors (on supports) or in the level of the day surface. There are Bicimetro - Eco Bahn projects for different cities. To improve the quality of life in cities, it is necessary to place bicycle paths on the most convenient territory. This will provide residents with the possibility of a safe movement for man and nature. If you transfer vehicles to the ground, you can clean the polluted air from transport tunnels by filtration.

2.2 Smart transport as one of the drivers of smart city development

There is a need for substantial changes in Europe's transport systems, as well as in the mobility behaviour of people and businesses in urban areas. Solutions concern the creation of an efficient and integrated mobility system that allows organizing and monitoring seamless transport across different modes; increasing the use of environmentally-friendly alternative fuels; creating new opportunities for collective mobility. The proposed solutions lead to a decreased environmental impact. Ensuring the mobility of population means ensuring access to all functions, services, places of work, etc. At the same time, city residents should be able to address their needs using as little travel as possible. It can be completed in two ways: (1) reducing the needs to travel by implementing modern information and communications technologies (Internet of Things, Industry 4.0 and other concepts) and (2) reducing distances between places of residence and functional endpoints (the reasons for travel), so that the population could use more sustainable modes of transport, such as walking, cycling, etc.

To make people use more sustainable mobility concepts, it is necessary to ensure possibility to reach any point of passengers' attraction by public transport. However, sometimes it is rather difficult to allow residents easy access to the public transport system: it is the so-called Last Mile Problem [5, 6, 7]. To solve this problem, cities need to provide multi-modal transport systems. For example, bicycle sharing systems can serve as a good way to connect users to public transit networks. Transport system is one of the major intellectual systems in the Smart City. To ensure its sustainability and safety, the work is being done in three ways: smart infrastructure, smart vehicles and smart users. Solutions concern the creation of an efficient and integrated mobility system that allows for organizing and monitoring seamless transport across different modes, increasing the use of environmentally friendly alternative fuels and creating new opportunities for collective mobility. One of the main areas of ITS, which is actively promoted over the past 15 years, is the implementation of intelligent vehicle. International program "Increased safety vehicle" is implemented. The first experiments of usage of onboard intelligent systems have shown that they are able to reduce the number of traffic accidents by 40% and to reduce the number of fatal accidents by 50%. The transition from the creation of driver assistance systems to the development of semi-autonomous unmanned vehicles is a global trend, and it is explained by the desire of developers to ensure the sustainability and the transport system safety [8].

However, it should be understood that the emergence of new types of vehicles with fundamentally new control systems could cause problems of security and interaction with other road users. It is especially true in connection with the development of the "livable cities" concept that is aimed at encouraging the non-motorized mobility, such as walking or cycling On the one hand, streets need to be adapted, with safe walkways, crossings and cycling lanes, as well as transport junctions need to be established to create safe connection points between different transport modes. On the other hand, it is necessary to identify potential risks of the use of autonomous vehicles, to predict the likelihood of the traffic conflicts (between autonomous vehicles and pedestrians and cyclists, first of all) and to determine the possible consequences. In addition, ways should be devised to prevent risk situations and to reduce the severity of the consequences should such situations arise.

Road transport is the main transport in urban areas, so if vehicles traffic management is inefficiently then it can create significant problems for other road users. In addition, the quality traffic management of reduces the negative impact of vehicles on the environment. The main idea of Smart City is that the city can be "smart" only if the management of all its subsystems is built according to the same rules. If we talk about road transport, then it actually means the management of the vehicle's life cycle as a separate component of the vehicle fleet, and at a higher level — the management of the vehicle fleet as a whole. Along with it, all processes at all stages of the life cycle should be intellectualized. At the same time, the orientation to customer needs should be one of the main factors that should be taken into account when planning and implementing these processes. The main directions are creation of the elemental base of intelligent systems and software development.

2.3 Cities structures and their influence on citizens mobility

Sustainable cities cannot exist without sustainable mobility. Apart from the shift to renewable energy sources, we should not forget about the shift towards more sustainable transport modes like public transport. It plays an indispensable role to make the cities livable and less polluted. Sustainable urban mobility plans and transport strategies therefore aim to reduce mobility demand, shifting to environmentally friendly modes of transport such as walking, cycling and car sharing, increasing the share of public transport and clean vehicles, and the use of state of the art technology for the remaining individual motorized transport. Reducing travel distances and travel demand is therefore an important cornerstone for sustainable urban transport. This imply that the city's inhabitants should not be forced to travel far to fulfil basic needs. Distances should ideally be kept so short that walking or cycling is the attractive/likely mode of transport.

Short distances also improve the possibilities for an enhanced modal shift. This is important to achieve a fair transport system that gives all groups in society equal or high accessibility to important services, independent of car ownership. Transport demand reduction is achieved through the application of sustainable spatial planning policies that support and encourage cross-functional development. This planning ensures the location of housing, shops and jobs within walking and Cycling distance or close to convenient public transport. For urban planning assessment of the transport system, the indicators specified in the regulatory documents are used.

The regional patterns of settlement that have developed in Russia, as a rule, do not correspond to the idealized ecological scheme. Thus, the studies by Central research and design Institute of Ministry of construction of Russia in Central, Volga-Vyatka and North-West regions of Russia made it possible to establish that the zoning and structure of the large agglomerations such as the Moscow, Nizhny Novgorod, Tula and many other territories - do not correspond to the tasks of ecologically balanced development of natural and urbanized landscapes.

Currently, the sustainable development of the largest cities (megacities) of the Volga region, Kazan and Ufa, has just begun. For example, last two years, the city authorities of Ufa have adopted a program to expand streets by eliminating lawns and cutting down part of the trees. This city is third in Russia in length, but in the narrowest place its areas are connected only by means three streets, which causes to traffic jams. The city's master plan for the city's development suggests further expansion around, without taking into account the construction reserves on the Ufa Peninsula. In the city, which has more than two hundred public transport routes and more than 1800 transport units, a significant part of which passes through one Avenue, currently no one has implemented any specific proposals for optimizing the network. Although over the past year, the city authorities have presented many promising projects in this direction.

Kazan also has a lot of problems that hinder sustainable development. First, it is a large residential blocks of the same type of serial apartment buildings of the seventies years last century construction with underdeveloped yard spaces and adjacent social sphere. This creates a low-quality environment in areas within residential areas due to physical, moral and aesthetic wear and tear. The municipal programmes provide only minimal care for the existing landscaping and playgrounds. The significant degeneration of the tram network and the stagnation of the trolleybus network do not correspond to the development of a sustainable eco-friendly transport frame of the city. To improve the environmental transport of Kazan "Architectural Studio Arthur Atbegin" created cycleways project, which is published on the website "Architecture of Russia". Cycleways (Bicimetro) is raised above street level bike lanes in the tunnels. The project of covered Bicimetro is relevant, first of all, for Russia because of climatic conditions. Bicimetro makes it possible to ride bikes and velomobiles year-round, in any weather. Bicimetro in combination with conventional bike lanes create a full bikes' transportation network. It ensures the safety of travel, independence from traffic jams and other transport problems, while unloading the urban transport system.

In 2010, a strategy was proposed to register the cities that are being created [9]. On this basis, the urban project was patented - the concept of the city "Solntsegrad", which reflected the practical aspects of sustainable development of the city , including its appearance.. "Solntsegrad" is designed as a kind of template city, which can be implemented in different regions. At the same time, adaptation taking into account features of the geographic area is provided. This project or parts of it can be used as a basis for the development of the adapted city in almost any region of Russia or in Europe. His main idea: an attempt to combine modern development trends and accumulated Russian and Soviet urban development potential. During the development of the project, a city comparable to the regional centers was formed.

The city as a whole and its center have a classical planning structure, it is very similar to European and old Russian cities. From the Moscow layouting scheme borrowed experience in the creation of ring roads, but in the project they are turned into semi-rings, closing the city from the West. In the project of the city implemented radial-ring structure, as well as chords. This concept is the development of the idea of architects J. Stubben and O. Wagner, who believed that the radial-ring system is optimal. The basic principles of the plan "Solntsegrad" can be combined in the "Concept of four". These are four main directions of highways and four main directions of development, polycentric structure of the city environment, four green zones and four main industrial clusters in the urban fabric of the city. All the principles are closely interrelated and aimed at creating a city that is comfortable for modern living.

The main part of the city's transport system is urban passenger transport. The main indicator of passenger transport is the time spent on traveling, including pedestrian approaches. Today, for large and major cities, the normative figure is 40 minutes for 80-90% of passengers; in other cities – 30 minutes. The city's transport network must meet the following requirements:

- Provide comfortable passenger communications along the shortest routes;
- Provide comfortable passenger connections for the external transport hub facilities with residential areas and the city center
    - transport lines must pass in the direction of the main passenger traffic;
    - the length of transport lines should be in accordance with the total area of the city and the number of vehicles traveling on the network;
    - the length of the transport network should be minimal provided that the maximum service of the city territory;
    - ensure that the expected number of vehicles is missed;
- Provide the necessary message rates, guaranteeing the standard time spent on movement;
- The transport network should ensure the reliability of the transport system, in the event of traffic blocking, in some parts of the network, there should be bypass directions;
- The system of urban mass passenger transport should ensure the functional integrity and interconnectedness of all the main structural elements of the urban area, taking into account the prospects for the development of the city and the region;
- When developing the project of organization of public transport services, the population should ensure the speed, comfort and safety of the transport movements of the city's permanent and temporary population, as well as of daily migrants in settlement systems.
- Lines of ground public passenger transport should be provided on the main streets and roads with the organization of the movement of vehicles in the general flow, along a designated strip of the carriageway or on a separate canvas.

3 OPTIMIZATION OF URBAN TRANSPORT SYSTEM: CASE STADY OF NABEREZHNYE CHELNY CITY

3.1 Optimization of the bus route network

Naberezhnye Chelny, one of the youngest Russian cities, is a major railway, motor transport, and aviation hub, known on the Kama river port. Linear structure open type with the "classic" functional zoning was laid in the basis of planning organization of the city with a parallel location of industrial and residential areas, suburban recreation zones. Longitudinal highways which connect the residential areas of the city compose a transport-planning frame of the city that gives rise to attribute the planning scheme of its road network to rectangular. The main "diameter" of the city is a longitudinal thoroughfare, which includes M. Jalil avenue, Naberezhnochelninsky avenue, and Mira avenue [10]. One more feature of the cities of similar planning is the proportional distribution of the population throughout the residential area, and there are kindergartens, schools and shops in each residential district (complex). It was made in order to minimize the number of trips to education and shops. Due to the fact that a significant part of all trips during peak hours is the trips to (from) work, the separation of industrial and residential areas causes the problems on the longitudinal and cross streets' intersections.

Public transport represents 14 tram routes, more than 25 bus routes and taxi, the taxi (including the so-called Social taxi carrying several passengers fares in taxis). Naberezhnochelninsky tram is one of the latest new tram systems in the USSR and Russia, which is close to the light rail. One of the very few in post-Soviet Russia, a tram system of the city has increased in the 1990s and 2000s, and has plans for further development, including both new lines in the city, and creating inter-city light rail line to the Yelabuga city. Expansion of the tram route network and its combination with the existing bus route network can help to reduce the traffic load of road network. In 2009, the city launched the reform of the city bus system. Its aim was to displace small capacity buses and to update the bus fleet and the route network. In 2013 city carriers have bought 100 new buses of large capacity run on gas fuel: 84 buses for urban transportation and 16 for suburban. In 2015 optimization of urban bus transport was made: 136 new buses of large capacity run on gas fuel NEFAZ-5299 were bought. All shuttle buses are equipped with GLONASS devices.

The Strategy of social and economic development of Naberezhnye Chelny city till 2030 [11] is directed to increasing of the city transportation system's sustainability. But, from our point of view, the existing Strategy pays insufficient attention to non-motorised modes of transport as well as to multimodal transportation development. For example, construction of the walking and cycling facilities is planned only along the river walk, i.e. as a recreational area, not as an element of the city transport infrastructure. At the same time, in the case when the destination point is situated on the longitudinal avenue that is parallel to the point of departure (in connection with the above described peculiarities of urban planning) and there is the lack of the lateral routes of public transport in the city, the "last mile" problem exists.

To assess the functioning of transport systems in the case of changing certain parameters, it is customary to use methods of simulation [12]. Analysis of the possibilities and designation of existing software developments for modeling traffic movement showed that the best option for solving the problem of forecasting traffic loads in urban areas is a specialized modeling package at the macro level – PTV VISUM.

One of the main factors affecting on the characteristics of transport systems is the transport demand of the population, which is the basis of correspondence matrices. The study consisted of several stages. In the first phase, a survey was organized involving more than 300 respondents. The results of the survey made it possible to create a correspondence matrix. After that, the macroscopic transport model of the city was create. Validation and verification of the model was carried out based on the results of field observations of traffic flows.

The problem of overloaded roads is actual for Naberezhnye Chelny, despite the fact that it was designed with the possible growth of the number of both individual and passenger transport on the roads. In view of the fact that a significant part of trips during peak hours are labor trips, the separation of industrial and residential areas in the city creates problems at the intersections of longitudinal and transverse highways. This is due to the fact that for the delivery of workers to industrial zones there was a network of factory routes. Currently, there are no such routes, but the route network of urban public transport has not changed significantly. Therefore, employees are forced to travel to work on individual transport. Besides, a hypothesis was put forward on the possibility of reducing the transport load on the city's roads by the transition from the traditional form of education to the mixed education. Figure 1 shows a map of the city with the locations of educational institutions of higher and secondary special education put on it. The process of building a transport model of Naberezhnye Chelny is described in [13, 14]. We chose to study one of the most problematic site of the city's road network, which merges routes connecting the old and new parts of the city. It is central avenue - Naberezhnochelninsky where there are 5 educational institutions.

Figure 1: Location of educational institutions of Naberezhnye Chelny city

By developing a new route network of bus transport, it is necessary to take into account the following aspects:

- All transport districts in the city must be connected between each other by direct routes . Special attention must be given to new districts with underdeveloped transport infrastructure.
- Improvement of route network should reduce situations, when routes overlap each other.
- The time interval between arriving buses must correspond to standard values and satisfy fully transport demand of population.
- Choice of vehicles for each route and bus timetable must be done according to predicted values of transport mobility and must be corrected according to changes of traffic parameters.

Although the existing configuration of road and street network do not allow to avoid fully the overlapping of public transport routes, it is possible to reduce significantly an amount of routes, which pass through the same segment of road network, thus having saved an opportunity to satisfy mobility of urban population. The Figure 2a presents a part of existing route network together with showing route numbering, which pass through problematic segment of road network. The upgraded bus route network is shown on the Figure 2b.

Figure 2: Scheme of the existing (a) and of the proposed (b) route network

Figure 3: Distribution of transport load according to: a) existing passenger flow and route network; b) predicted passenger flow and upgraded route network

The comparison of transport load values on the most problematic segments of road and street network according to existing and proposed route networks are presented on the Figure 3: numbers marked with red color specify an amount of private cars passing through this segment, numbers marked with blue color – volume of public transport passengers.

3.2 Optimization of road infrastructure

The quality of the transport system's operation and its safety are often affected by the configuration of the road network and the quality of management. To analyze, we have chosen one of the bottleneck of Naberezhnye Chelny city. At peak hours, this road section does not cope with the traffic flow: there are the overload, serious traffic jams and high statistics of road accidents. Drivers spend a lot of time maneuvering around corners because of the huge flow of vehicles. These dangerous problems arise in connection with the non-optimal organization of traffic flows. The situation was aggravated by the introduction of a new line in tram routes network.

The optimal method for analyzing the situation on local areas of the city are micromodels [15]. We created a simulation model in AnyLogic 7 on the basis of a discrete-event approach using the library of traffic. The results of experiments on the model showed that the geometry of the studied road segment adversely affects the characteristics of the traffic, since it does not correspond to the parameters of the flow of motion. To improve the situation, we proposed to organize a circular movement, which reduces the number of conflict points on this stretch of the road. The experiment was carried out by comparing two variants of the model with the similar input parameters of the transport flows (Figure 4).

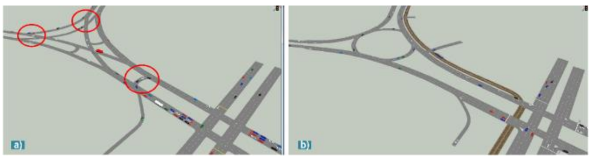

Figure 4: Simulation model a) before optimization; b) after optimization

Besides, we have suggested to apply at the adjacent intersection (Avenues Druzhba Narodov and Mira) traffic light regulation with alternative number of phases, i.e. set of the main and intermediate traffic light stages.

Table 1: Traffic light phase change on the crossroad depending on the traffic density

Traffic density of the road section	Total stage duration, sec.	basic tact, sec.		Red and yellow signal,	Yellow signal, sec.
		Red signal	Green signal		
95%	85	41	38	3	3
82%	83	37	40	3	3
74%	82	35	41	3	3
61%	81	32	43	3	3

We conducted an simulation experiment for selecting the optimal duration of the traffic light-signal phase. Analysis of the results of the study of this road section showed that the most acceptable option is the organization on this road section of circular traffic and changes in traffic light control. Table 1 shows the changes in the traffic light phase with adaptive control, depending on traffic density. The research results demonstrate that parameters of traffic of studied stretch of road could be greatly improved (traffic density will decrease by 34%).

3.3 Efficiency assessment of our proposed solution

The efficiency of the proposed solution consists of 4 components: positive social effect (SE), economic efficiency (EE), increasing environmental friendliness and sustainability of the urban transport system. For example, the EE could be considered as savings on costs per one transported passenger associated with fuel products. Such effect could be reached by reducing the amount of vehicles and the total amount of kilometers on routes as well due to operation of buses, which run on gas engine fuels. To calculate the EE, the following formula is used:

$$E = \sum_{k=0}^{2} \frac{L_k \cdot FC_k \cdot P_k}{100 \cdot N_k \cdot q_k} \qquad (1)$$

where: k – type of buses, which operate on route: k=1, if buses have a small capacity (18 persons) and run on a diesel fuel; k=2, if buses have a large capacity (115 persons) and run on diesel or gas engine fuels; L_k – total amount of kilometers done by all buses related to type k, km; FC_k – fuel consumption of buses related to type k, l/100 km; P_k – price of fuel used by buses related to type k, rubles; N_k – amount of buses related to type k; q_k – passenger capacity of bus related to type k, persons.

The positive SE could be assessed by using an amount of transported passengers as well as by using the different types of time delays and, especially, their reduction. Time delays concern not only time spent by passenger waiting for a bus and idle time spent by bus on bus stops, but also idle time spent in traffic jams. To combine particular values of passenger travel time between two transport districts into a single criteria of SE, it is necessary to adjust them to a common basis (per one transported passenger):

$$SE = \frac{\sum t_{l-m}}{\sum_{k=1}^{2} N_k \cdot q_k} \quad (2)$$

where: l – index number of origin district, m – index number of destination district, t_{l-m} – passengers' travel time from district l to district m, min.

Environmental performance is provided by 2 ways. The first tool assumes to reduce the total amount of buses, which go through problematic sections of the road network. The second approach is based on the idea to substitute diesel-powered buses by more ecological ones, which runs on methane. The volume of pollutants (VP) is calculated according to (3):

$$VP = \sum_{k=0}^{2} \frac{N_k \cdot H_k}{1000} \quad (3)$$

where: H_k – content of pollutants in the engine exhaust gases, gr.

Positive influence of the proposed solution on the transport system sustainability could be assessed with regard to the approximation of its parameters to target values of the system, which are recommended in the different regulatory documents. For this purpose, an integrated efficiency indicator was developed and "radar map" was built. The key efficiency parameters were pointed out and calculated for existing and proposed route networks.

4 CONCLUSION

Today there is much talk about what does the concept of sustainable city mean. Technology and infrastructure are the key points in ensuring sustainability, but they can't be really effective without coordinated planning, vision and managerial decisions. Transportation system is the basis of any city: it contributes to economic system development through transportation of passengers to their places of work and cargos' delivery to all enterprises of the city. At the same time transport system is the main source of environmental pollution. Thus, the advantages of increased mobility need to be weighed against the environmental, social and economic costs that transportation systems pose. The possibility to increase sustainability of the transport system was considered in the case study of Naberezhnye Chelny city. The following tools were chosen: optimization of bus route network, the improvement of the road infrastructure, as well as optimization of vehicle fleet on routes in accordance with the real transport demand of population. It was shown that decrease of route overlapping, public hearing of local inhabitants by design of new routes, usage of buses with large capacity as well as use of more environmental friendly types of buses allow to increase the quality of transport service and the population mobility together with decrease of negative environmental impact as well as load on the urban road network. Also complex parameters to assess the efficiency of proposed solution and the sustainability of transport system were described. The use of the measures listed in the article can be realized independently of each other and receive certain insignificant results. However, their integrated implementation will provide the maximum effect and significantly reduce the negative impact of road transport on the environment.

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INCREASING CHILDREN'S SAFETY ON ROADS BY CHOOSING RATIONAL SCHOOL ROUTE

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ABSTRACT

Education is the most common purpose of students' everyday trips, therefore it is important to ensure safety of school routes. In many countries, documents regulating the organization of children transportation are adopted at the national legislative level. However, world statistics of road accidents shows that despite the efforts made, the mortality rate on the roads is still high. One of the most efficient methods to ensure safety of school transportation is the best route selection. Ranking of the route can be carried out taking into account factors complicating traffic conditions, so we propose a methodology for multicriteria assessment of the route's safety. The paper proposes an algorithm for the rational route selection and an algorithm for its safety evaluating. A conceptual scheme of the DSS for school transportation that takes into account the indicator of the chosen route's safety is presented in the paper. The proposed system is based on the developed Haddon Matrix aimed at reducing the risk of accidents.

Keywords: School Route, Safety, School bus, Multicriteria Assessment, Haddon Matrix

1 INTRODUCTION

Transport system's safety is an essential component of sustainable urban mobility and should be firmly integrated into the mobility planning processes by cities. To stem the road death epidemic, the United Nations have set the target of halving traffic fatalities by 2020. Approximately 1.25 million people die every year on the world's roads as a result of road traffic crashes. They are the number one cause of death among young people aged 15–29 years. As well as the public health impact of road traffic injuries, the disproportionate impact of road traffic crashes on the younger age groups makes them an important development problem: road traffic crashes are estimated to cost countries approximately 3% of their GDP, with the economic losses in low- and middle-income countries equivalent to 5% of GDP [1].

Although road traffic injuries have been a leading cause of death and injury globally for many years, most road traffic crashes are both predictable and preventable. There is considerable evidence on interventions that are effective at making roads safer: countries that have implemented these interventions have seen corresponding reductions in road traffic deaths [2, 3]. The most successful examples of reductions in the numbers and rates of road traffic deaths have been achieved are where a "safe systems approach" has been implemented. This approach to road safety set of complementary interventions are put into place to create safer roads, safer vehicles, safer speeds, and safer behavior by road users. Adopting a safe systems approach necessitates the involvement and the close collaboration of many sectors including transport, health, police, industry and civil society.

Children and teenagers are the most vulnerable road users among all types of city dwellers [4, 5]: 186 300 children become victims of the road accidents each year [6]. Because of their age, many do not have the ability to make an accurate judgment about safe road use, while lack of experience of particular situations also means they are at greater risk. Children are often impulsive, easily distracted and unpredictable and for these reasons need special consideration by other road users. Since the main type of regular trips of children and teenagers are the trips to school, ensuring school transportations' safety is the main direction of the children's safety improving. While solving this problem there are two main issues: the selection of the safest walking and cycling routes and the school buses transportations safety ensuring.

The task of ensuring the safety of school routes is complicated by the fact that the needs of pedestrians and cyclists, among which, in general, 49% of all deaths as a result of road accidents in the world [1] are given insufficient attention. At the same time, the mixed movement in many countries means that children on the way to school use the same roads as high-speed moving vehicles where they have to adapt to dangerous situations and fast traffic. Ensuring the safety of children and adolescents on the roads will be possible only on the condition that the planning and development of traffic routes will be carried out, first of all, in terms of minimizing the number of conflict points where road accident can occur.

2 WAYS OF IMPROVING ROAD SAFETY IN SCHOOL

2.1 National Safe Routes Programs: the Worldwide Experience

The safe routes to school (SRTS) concept began in the 1970s in Odense, Denmark, rooted in concern for the safety of children walking and bicycling to school [7].

The SRTS concept spread internationally, with programs developing in other parts of Europe, Australia, New Zealand, Canada and the United States. The Bronx, a borough of New York City, started the first SRTS program in the United States in 1997. In the same year, the State of Florida implemented a pilot program. In August of 2000, the U.S. Congress funded two SRTS pilot projects through the National Highway Traffic Safety Administration [8]. Within a year of the launch of the pilot projects, many other grassroots SRTS efforts began throughout the United States. Success with the pilot projects generated interest in a federally funded national program. In 2003, advocates convened meetings with experts in pedestrian and bicycle issues to talk about SRTS issues and ideas for developing a national program. Momentum for a national SRTS program in the United States continued to build as several states developed their own programs.

Congress created the Federal-Aid Safe Routes to School Program in 2005 through comprehensive transportation legislation, ultimately resulting in nearly $1 billion in funding. Subsequent transportation legislation, Moving Ahead for Progress in the 21st Century (MAP-21) passed in 2012 making SRTS activities eligible to compete for funding alongside other programs, including the Transportation Enhancements program and Recreational Trails program, as part of a new program called Transportation Alternatives [9].

Starting SRTS program is an opportunity to make walking and bicycling to school safer and more accessible for children, including those with disabilitie, and to increase the number of children who choose to walk and bicycle. On a broader level, SRTS programs can enhance children's health and well-being, ease traffic congestion near the school and improve air quality and improve community members' overall quality of life. The steps outlined in this section are meant to provide guidance by providing a framework for establishing a SRTS program based on what has worked in other communities. Some communities may find that a different approach or a reordering of these steps works better for them. The SRTS program is built around the "Five Es of Safe Routes to School" — education, encouragement, enforcement, evaluation and engineering. This comprehensive approach enables communities to establish, maintain and continue to increase safe walking and bicycling opportunities to school by addressing students, parents, teachers, police and motorists [10].

Education — This aspect of SRTS involves teaching students that walking and bicycling are healthy, fun and sustainable transportation choices. As part of the education component, schools usually focus on stressing the many benefits of walking and bicycling: increasing physical activity, improving health, reducing fuel consumption, and improving air quality. Students are also taught how to safely travel by foot or bicycle to and from school. In addition, motorists might be educated about the rules of the road as they relate to bicyclists and pedestrians.

Encouragement — Events, activities and lessons are used to promote walking and bicycling. This component is especially helpful in areas where safe walking and bicycling opportunities exist but students need motivation and leadership to take advantage of them. In communities where walking conditions are considered unsafe, encouragement should not begin until the engineering component has been addressed, and safer routes can be established. Encouragement efforts often dovetail with education to get students moving and to build support for SRTS from the community.

Enforcement — In this component, activities seek to encourage safety and to ensure that pedestrians, cyclists and motorists abide by the rules of the road. Enforcement is essential for ensuring the safety of students especially as walking and bicycling to school gain popularity. When planning enforcement efforts, schools should partner with local police departments.

Evaluation — Successful SRTS programs evaluate the progression of habits and attitudes of students and parents toward walking and bicycling. Schools are encouraged to use student / parent evaluation materials to track the number of children walking or bicycling to school and to reveal why parents do not allow their children to walk to school and what could prompt a shift in behavior. By conducting evaluations at both the start and the conclusion of a school year during which an SRTS push was made, a school may be able to determine if SRTS activities held throughout the school year had any effect on students' walking and bicycling habits and parents' attitudes toward having their children walk or bicycle to school. Another important component of evaluation is reviewing "crash data" available from PennDOT to map where collisions are occurring and to use this information to try to ensure safer routes to school. Evaluation provides useful data as to the scope and the success of a Safe Routes to School program; this data may also help to ensure that federal SRTS funding is available in future transportation bills.

Engineering — Engineering improvements to infrastructure is a critical component of the SRTS approach. Successful SRTS programs often begin with a walkability audit, which provides a thorough assessment of the barriers that keep children from walking and bicycling to school. This assessment will help to establish a list of recommended improvements, from short-term suggestions such as painting crosswalks, clearing overhanging tree limbs and brush, or altering traffic light timing to long-term recommendations such as installing sidewalks or reconstructing intersections. Engineering also includes the planning and implementation of actual improvements to the local infrastructure to make it safer for school children to walk and bicycle. Now, the program "Safe school route" is developed in many countries. For example, the Ljubljana city introduced web-site, the so-called portal of safe routes, with particular focus on the elementary schools. On a yearly basis each school examines and, if necessary, updates its safe routes plans. Teachers are trained by City Council for Prevention and Education in Road Traffic [11]. The city Nova Gorica (Slovenia) is involved in a cross-border Sustainable Urban Mobility Plan (SUMP) with five other municipalities in Slovenia and the nearby Italian city of Gorizia. One of the aims of the SUMP is to increase the safety of children travelling to school on foot or by bicycle. Experts from the University of Maribor will develop guidelines for high-quality safe school routes based on best practice from Slovenia and across Europe, as well as on fieldwork conducted in Nova Gorica [12]. The project "Support to sustainable transport in Belgrade" is a joint effort by UNDP Serbia (United Nations Development Programme), the Ministry of Energy, Development and Environmental Protection and the City of Belgrade (the traffic department and the Directorate of Land Development) in the field of providing a better framework for urban traffic [13]. The public information campaign called "Safe routes to schools" have started in December 2011 as a part of the project Pedibus. The aim of the campaign is to improve road safety for school children during daily travel between home and school, as well as the education of children and parents in terms of selection and use of "green" transport with the aim to reduce emissions of gases that contribute to the greenhouse effect arising in traffic between home – school [14].

In the United States, efforts to promote walking to school emerged in the late 1990s. Initial and ongoing successes led to strong national enthusiasm, inspiring Congress to establish a federal Safe Routes to School program in 2005. Safe Routes to School is present in all 50 states and around the world included Canada, Puerto Rico, Great Britain, and Europe. In the United States, Safe Routes programs serve approximately 25% of eligible public elementary and middle schools. In Massachusetts, the number of elementary and middle schools participating in National Center for SRTS is significantly great at over 45% [15]. Thus, the program developed in San Diego indicates that "Implementation of best practices for pedestrian safety and encouragement toward active modes of transportation will lead to a number of positive benefits for both children and the community at large. The two largest benefits will be increased safety and a reduction in injuries resulting from walking or biking to school, and a reduction in obesity as a result of increasing the duration of exercise to a level that is shown to maintain a healthy weight" [16]. San Diego Regional Safe Routes to School Strategic Plan is developed [17]. The Healthy Works SRTS project encourages and supports comprehensive SRTS planning, programs and coordination that actively engage local schools, cities, residents, families, etc. in improving routes to school and increasing the number of kids that walk or bike to school.

In Russia, a program for improving the safety of routes to school, are implemented within the framework of the program "Passport to road safety" by educational institutions. Passport displays information about the educational organization from the point of view of ensuring the safety of children on the stages of the route "home-school-home", as well as to conduct training sessions and additional events, and contains various plan safe traffic routes [18]. There is also a created portal which contains information for children, teachers and parents about safe behavior on the road [19].

2.2 Specificity of transportation of pupils by school bus

All over the world a greater focus is being placed on School Buses. The greatest success in this area was achieved by the USA, where about a hundred years ago for the first time school buses were introduced for the mass transportation of children to study. In the United States, state, national and local governments work closely together to organize and ensure the safety of children transportation by school buses. The federal government develops laws, standards, regulations, rules covering the entire school transportation system from the production of school buses to the organization and safety of pupils' transportation. According to statistics, school buses are the safest mode of transport: students are about 70 times more likely to get to school safely when taking a school bus instead of traveling by car. That's because school buses in the USA are the most regulated vehicles on the road; they're designed to be safer than passenger vehicles in preventing crashes and injuries [20]; and in every State, stop-arm laws protect children from other motorists [21].

Outside North America, purpose-built vehicles for student transport are not as common. However, major accidents with a large number of children who died on the way to school made central government of China to announce strict rules for school buses. For example, all buses must have seatbelts and GPS transponders [22]. Transportation of pupils to schools in Europe is a lot like that in the United States, but with key operations and safety differences. According to Department of Defense Education Activity [23], safe student transportation in Europe consists of three parts: high standards for mechanically sound vehicles, qualified, trained drivers and safe student behavior on the bus. In the USA, school bus transportation safety has lately been considered from the point of view of the choice of specific locations for school bus stops and the planning of school bus routes [24].

The main field of the use school buses in Russia is the transportation of the schoolchildren from the rural areas where there are no schools, and pupils have to travel to neighboring communities for long distances. According to [25], pupils have to be transported by school buses if they live more than one kilometer from the place of study. Due to the fact that regional roads in rural areas are unsafe, the situation with the school transportation system leaves much to be desired. The federal program "School Bus" is realized to ensure safety while children transportation. This program implies to supply the schools by buses specially designed for the children transportation and that are corresponding to GOST 33552-2015. However, to ensure children's safety while transportation is still a serious problem. Taking this into account, the "Rules for the organized transportation of a group of children by buses" have been approved by the Decree of the Government of the Russian Federation [26]. In particular, as one of the concepts in the "Rules…", a new term "school bus" is introduced. This term will imply a specialized vehicle (bus) that meets the requirements for transport vehicles for children's transportation, established by the legislation on technical regulation, and which belongs to the right of ownership or other legal basis of a pre-school educational or school organization. At the same time, the adopted amendments provide the opportunity school buses to move along the allocated lanes for route vehicles. The decisions made will increase the comfort of transportation of children when students follow their places of residence to places of study and sightseeing facilities, reduce the temporary loss of students in the process of traveling on the roads and the cost of operating school buses, and increase the attractiveness and, most importantly, the safety of children's transportation.

In addition, the Government of the Russian Federation decided to resume the state program "School bus" to provide educational organizations with school buses since 2016-2017 academic year from the federal budget. New school buses will replace vehicles that have already served their service life, or do not meet the safety requirements for schoolchildren. Regions of Russia will receive 1,835 buses for a total of 3 billion rubles. School modification of a small class bus for transportation of children, PAZ-32053-70, is produced by Pavlovsky Bus Plant LLC, which is part of the largest Russian manufacturer of commercial vehicles, GAZ Group. This bus completely meets the technical requirements of GOST R 51160-98 "Buses for the transportation of children". The bus has 22 seats: 20 for children and 2 adults accompanying. In the bus interior near each row of seats there are emergency communication buttons with the driver, and the driver's workplace is equipped with external and internal loud-speaking devices. All seats are equipped with special seat belts, in addition, the bus has baggage shelves for the backpacks. An additional step at the front door will help even to the smallest passengers to get up in the bus. Special devices prevent movement with open doors and limit the speed of movement no more than 60 km / h. All buses are equipped with a digital tachograph and a GLONASS satellite system.

3 PROCEDURE OF CHOOSING A SAFE WAY TO SCHOOL

3.1 Factors affecting the safety of the route to school

Since the school route can have several sections with a different mode of transportation, first of all, it is necessary to establish qualitative characteristics of the route. Security will be determined by different sets of factors that must be considered when choosing the safest possible route.

If the route is bicycle or pedestrian, the factors determining the category of route complexity for each particular child are first identified. Factors determining the route safety can be both objective (for example, relief, the presence of unregulated intersections, etc.), and subjective because of the characteristics and physical condition of the student. Adequacy of the assessment will depend on the correctness of the selected factors and their combined inclusion. The same route can be safer in daylight than in the dark, in summer, than in winter, etc.

Factors that influence on the safety of the walking and combined routes can include, first of all, the number and the type of crossings of the road. Despite the fact that pedestrian crossings are safe places for pedestrians where they are given priority, most often the deaths of pedestrians occur precisely during the crossing the road. The evaluation of the route can be done with the help of a complex indicator, which is calculated according to the formula of the factors' weighted average values:

$$K = \sum_{i=1}^{n} K_i \cdot \alpha_i \tag{1}$$

where K_i – the value of the i-th parameter, α_i – weight of the index.

To summarize different indices in (1), their reduced values are calculated. To evaluate possible routes on the base of this information, the specified route parameters matrix is constructed, and then the total route safety indicator is calculated taking into account the correction factors that depend on the physical state and characteristics of the user. The general scheme of the route safety algorithm is shown in Figure 1.

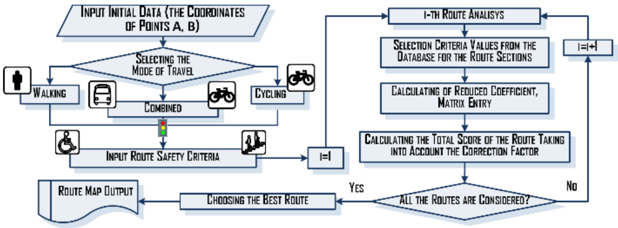

Figure 1: Algorithm of the route safety assessment

The bus traffic safety of depends not only on the safety of the route, but also on the technical condition of the bus, as well as on the characteristics of the driver (experience, driving style, compliance with rules, etc.). Therefore, for assessing the safety of transportation, these three groups of indicators are taken into account and the total rating is output. When assessing the safety of the route, the condition of the roadway, the relief terrain, crossroads and road junction, as well as the potentially dangerous of the route sections, should be taken into account. When assessing the technical condition of the bus its age, mileage, reliability, etc. are taken into account. When assessing the driver, it is necessary to take into account his age, the experience of transporting children, the total driving experience, style, personal qualities, health status.

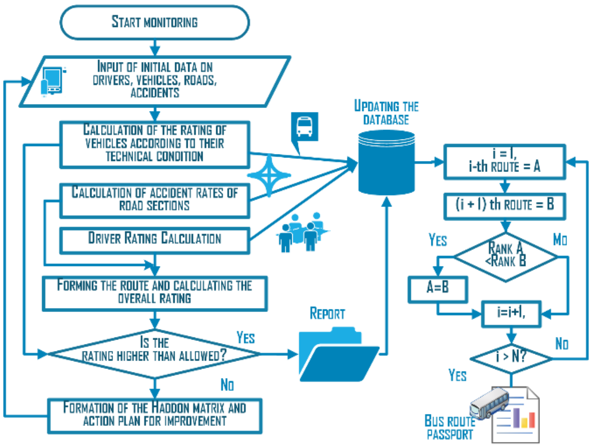

Figure 2: Algorithm of the school bus route safety monitoring system

3.2 The Haddon Matrix for Planning Activities to Improve the Safety of School Routes

Improving road safety involves identifying risk factors that contribute to crashes and injuries, then identifying the interventions that reduce the risks associated with those factors [1]. One of the methods to identify factors related to road accidents is a model, called "Haddon's Matrix", which divides factors into human, vehicular and environmental causes across three temporal phases – pre-crash, crash and post-crash [27, 28]. Once the multiple factors associated with a crash are identified and analyzed, countermeasures can be developed and prioritized for implementation.

Haddon has described road transport as an ill-designed "man-machine" system in need of comprehensive systemic treatment. Each phase – pre-crash, crash and post-crash – can be analyzed systematically for human, vehicle, road and environmental factors. The Haddon matrix is an analytical tool to help in identifying all factors associated with a crash. Once the multiple factors associated with a crash are identified and analyzed, countermeasures can be developed and prioritized for implementation over short-term and long-term periods. For the pre-crash phase, it is necessary to select all countermeasures that prevent the crash from occurring. The crash phase is associated with countermeasures that prevent injury or reduce its severity if it does occur. Finally, the post-crash phase involves all activities that reduce the adverse outcome of the crash after it has occurred.

Algorithm of development of the set of measures to improve the safety of the transportation system includes the following steps: (1) analysis of violations and accidents statistics, (2) identification of violations that increase the probability of accident, (3) formation of the list of actions to prevent violations, causing the growth of the accidents' probability (filling the "before crash" column), (4) identification of violations that may aggravate the severity of accidents, (5) formation of the list of actions to prevent violations, aggravating the severity of accidents (filling the column "in crash"), (6) identification of violations that prevent rapid post-accident clean-up, (7) formation of the list of actions to prevent violations hindering rapid post-accident clean-up (filling in the column "after crash").

After the implementation of the measures described in Haddon matrix, the next step can be to evaluate their effectiveness. For example, the use of photo and video cameras to detect overspeeding allowed reducing speed. The use of more advanced cameras to capture other offenses, for example, leaving the oncoming traffic, can be an effective method to reduce the possibility of accidents on difficult areas. Accident, associated with the leaving the oncoming traffic can be also prevented by road barriers separating traffic lanes that is widely used in European countries.

To prevent violations by pedestrians infrastructure solutions can be used. For example, obstacles to cross the road in the wrong place, and safe forms of crosswalks (overhead pedestrian crossings, underground crosswalks, adjustable crosswalks). It is possible to apply such measures as penalties. To fix the violations in dangerous places traffic enforcement cameras can be established. To reduce the number of accidents caused by reckless actions of pedestrians it is necessary to carry out awareness-raising activities aimed at teaching the correct behavior on the roads at an early age.

If an accident happened, the measures to reduce accidents severity should be provided. The use of seat-belts and child restraints are understood as a human factor. The vehicle is already designed with all the security requirements using modern technology. Infrastructure, in turn, should provide the safest consequence in the case of an accident. This can be achieved by means of safety barriers, road markings, warning scoreboard, etc.

The actions which are performed after the accident include the timely provision of assistance to victims of road accidents, traffic recovery, elimination of consequences of the accident and determining the causes. In Russia, since the January 1, 2017 it is necessary to equip all new vehicles by the emergency response system ERA-GLONASS". The uniform distributed infrastructure of "ERA-GLONASS" consists of three elements: navigation and information platform, data network and a communication network. After the accident the system automatically determines by signals of GLONASS/GPS vehicle position, data about the vehicle (brand, model, the VIN, fuel type) and the magnitude of the overload in the moment of the crash. This system allows you to respond instantly to the accident that reduces the time of medical aid provision and timely informs road users about the accident. All measures are documented in the form of Haddon matrix. Then the plans of implementation for each action are made (Figure 3).

Phases →	Before Crash	In Crash	After Crash
Human Behaviour (drivers, cyclists, pedestrians etc)	• Training, experience • Behaviour & attitudes, eg drink driving, speeding • Tougher penalties both for drivers and pedestrians	• Use of in-vehicle restraints eg seat belts	• Emergency response • Control of the behavior of the accident's culprit • Emergency response
Vehicle & Equipment	• Braking, road worthiness, visibility • Active safety vehicle systems • Control of vehicle's technical condition	• Impact protectioneg airbags, safety belts, vehicle's design	• Victim extraction • Means of the first aid • Emergency response system "ERA-GLONASS"
Road Environment	• Delineation, road geometry, surface condition • Visibility, weather • Walking and cycling facilities	• Roadside safety, eg clear zones, safety barriers	• Restoration • Risk reduction • Road users alert system
↑ Factors	Primary safety	Secondary safety	Tertiary safety

Figure 3: Haddon matrix

3.3 Development of DSS for choosing a rational route

The planning of school bus routes usually consists of evaluating possible variants of displacements and choosing the optimal one based on several criteria. At the same time, their safety should be taken into account as one of the essential indicators, that is, we consider the SBRP as a problem of multicriterial optimization taking into account the safety of schoolchildren. We have identified the following:

1. Route safety complex indicator. While developing routes of the school buses, the factors that determine the level of the route's safety can include the number of the areas of the route where accidents are likely to happen, statistical data on accidents, etc. This indicator should also take into account the safety indicator of the walking routes of the approach to the bus stop.
2. Costs associated with transportation are largely depend on the number of used vehicles, the number of routes and their length. Therefore, the number of buses, routes and their total length should be minimized.
3. The load balance. It is the search for the minimum deviation of the scope of work of each bus. This criterion is defined as the number of transported passengers to the number of kilometers that these passengers have traveled.
4. Balance of distances. This criterion is defined as the minimum difference of the route distances.
5. Walking distance from the place of living to the bus stop represents the total distance from the residence of all schoolchildren to the points for their collection along the safest walking routes.

In addition, the school bus network should meet the following restrictions: (1) each bus stop should be visited only once, (2) the beginning of all routes is established from the garage (g), and the end conditionally is in the school (s), (3) the number of school-children transported by bus in one run should not exceed the capacity of buses, and (4) the maximum travel time spent by a schoolchild for one trip to school should not exceed (D), where D is the matrix of distances between selected bus stops.

To solve the problems of planning the processes of school transportation organization, it is necessary to provide the possibility of operative simultaneous access to information databases (geographic, economic, technical and operational, etc.). The data in these databases are constantly updated, relevant, complete and diverse. This information should be presented in a convenient for analysis form and should ensure the adoption of the most rational decisions. In our opinion, operational control requires a software solution that integrates modules that provide the ability to quickly collect information, store large amounts of data, and also analyze them intellectually. A conceptual scheme of the interaction of the modules of the proposed DSS is shown in Figure 4.

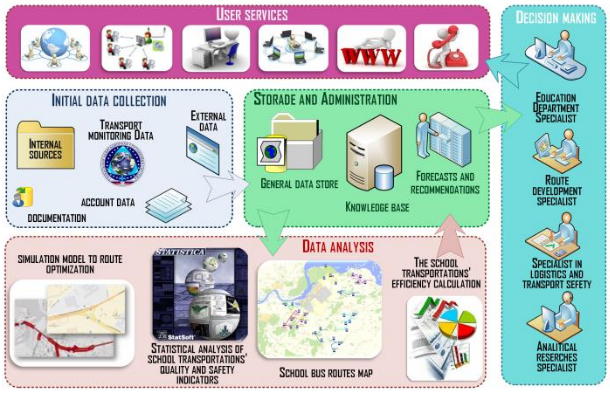

Figure 4: Conceptual scheme of the Schoolchildren's Transportation Management System

The proposed software solution consists of several modules that implement various functions. The initial conditions (characteristics of the transportation area, the number of schoolchildren in each locality indicating year of education, location of schools, the structure of the bus fleet and its technical characteristics, location of the garages and other elements of the processing and technical base, etc.) and parameters for the calculation are entered into the database. The functions of building and editing the map and the road network are realized using GIS-technologies. This module contains a set of geometric primitives for representing the elements of the road network with their attributes (number of lanes, speed limits, traffic on the road network sections is in both or only one side, etc.). After the graph construction, the elements of the real system are presented in the mathematical model, and all the necessary structures are ready for triggering the algorithms. All possible functions of the proposed system are based on routing algorithms and presented in the main menu. They return information on the constructed routes, represented as a sequence of vertex numbers. Then the user can evaluate the quality of the solutions obtained, recalculate them, if necessary, with other parameter values, or save the results in the form of reports if they suit him. The "Route" tab displays possible routes in the order of their priority (from the best to the worst), as well as the bus schedule. The peculiarity of the school bus routing is that the determining parameter is not to minimize the cost of transportation, but to ensure safety, reliability, regularity and compliance with restrictions that are regulated by official documents. Only after determining the set of such alternative routes options, the determining parameter is the cost price.

4 CONCLUSION

The issue of child safety while on the road to school is an urgent problem in all countries.Its relevance increases due to the growth of motorization and its negative effects. The School Bus Routing Problem should be solved in a complex way. This solution should take into account all possible modes of movement as well as risks that may occur on any part of the route. Safety of pedestrians and cyclists is an actual problem. To improve the effectiveness of measures aimed at reducing the risks of road accidents the special tool is needed. It should allow responding quickly to changes in the transport system and to assess the effectiveness of the measures taken. Proposed system for the route's safety assess-ment and evaluation of the effectiveness of measures aimed at reducing the risks of dangerous situations will allow making justified managerial decisions.As a method to develop proposals to improve road safety the Haddon matrix was used. To do this, the existing ways to improve road safety in the directions "before crash" (active vehicle safety and road infrastructure), "in crash" (passive safety), "after crash" (road safety after the accident) were structured. While routing, optimal variant should be chosen not only from the point of view of transportation costs but also taking into account the social effect: first and foremost is the safety of children. Evaluating the effectiveness of made decisions should also be carried out based on the feedback: it is necessary to analyze how the adoption of certain laws and other measures affects on accident statistics.

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ROADSIDE DESIGN AND TRAFFIC SAFETY

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ABSTRACT

In accordance with the contents of various projects, professional documents and relevant literature, road traffic accidents are a leading cause of death, injury and disability around the world. As a result of accidents involving vehicles, nearly 1,3 million people die each year, and between 20 and 50 million more are injured. Additionally, single-vehicle crashes cause a large proportion of fatalities and serious injuries to the vehicle occupants. (about 45% of fatal accidents in Europe). Bearing in mind the results of the numerous investigations, the roadside design is one of the key issues of this fatality rate. Therefore, despite the different opinion among professionals about the elements of which roadside consists of, it is obvious that the well-identified set of roadside features is one of the ways for reducing the number of accident severity.
The main goal of this paper is identification and analyses of the roadside factors associated with the crashes, as a base for developing the guidelines in roadside design safety projects. Using the mentioned guidelines, provides the professional approach for the hazard identification and designing of roads for safe and efficient traffic operations, with maximum benefits for the community as a whole.

Keywords: transport infrastructure, traffic safety, roadside design, guidelines for roadside safety elements

1 INTRODUCTION

As seen in the global documents, one of the main issues for the transport sector of many countries is the level to which roads support efficient, reliable and safe transport services for various road users.This is emphasized by the fact that roads account for 90 percent of all transport in the world, andthus, for most people they are the vital links connecting communities with goods, services and leisure activities.

As an integral part of the overall system, among other things, road transport should havea significant influence on improving safety, through the ongoing reductions in the number and severity of crashes, and the resultant costs of repairs, medical and insurance costs. Namely, road traffic injuries and deaths have a terrible impact on individuals, communities and countries. Therefore, safety can be enhanced into various stages of road projects, (planning, design, construction, maintenance and operation).

An important component of total road design regarding safety, is the design of the roadside, (used for supporting safety, mobility, environment, economic sustainability). This is based on the fact that run-off-road accidents comprise almost one third of all motor vehicle accidents along the roads. (ROR - traffic accidents in which the vehicle leaves the roadway, enters the roadside and contacts some objects).

The subject of consideration is roadside elements and features and their impact on road traffic safety.

The applied methodology follows the comparative approach and is based on the analysis of the results of studies made in different countries.

Therefore, the main goal is to present the current international knowledge in order to examine the relationship between safety and roadside design elements. In addition, the obtained results clearly show that the roadside is a significant factor of influence onroad safety.

2 ROADSIDE SAFETY – SIGNIFICANT PROBLEMS TO BE ADDRESSED

Bearing in mind the relevant literature, it is widely accepted that road safety experts are faced withthe challenge of addressing safety issues within the transport system,more precisely, on its elements, such as: human, vehicle, road and environment.Therefore, it is important to consider all the elements as a system, because, in most cases, road traffic accidents are the result of a combination of the mentioned components, and the way they interact.Namely, some of them are part of crash causation, other contribute to trauma severity, while some elements are not directly related to accidents.However, it is obvious that identifying the risk factors is very important in order to take the proper interventions that can reduce the risks associated with those elements.

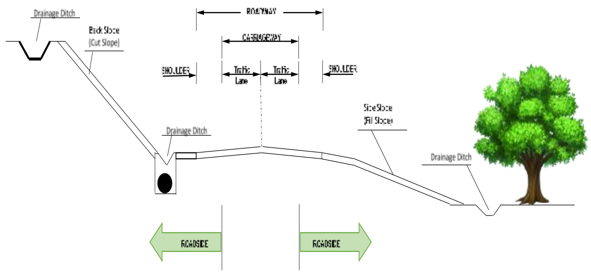
When it comes to road related features, (type of road, design and geometry, pavement materials, engineering structures, maintenance, roadside, traffic management control devices), the latest global documents show that factors which derived from roads, have a significant impact on road users safety. [3]

Why worry about roadside safety? The answer to this question is based on the results of numerous surveys of the impact of roadside characteristics on accident frequency and severity. Theyshow that theROR crashes area very important field in dealing with road safety problems. Therefore, according to national statistics, almost one third of all motor vehicle accidents in USArefer to ROR [4], with about 15.000 deaths per year[5].Data analysis of road accidents in Australia and New Zealand, suggests that 21% and 26% respectively, [6] of all casualty crashes, are the result of roadside as a malfunctioning transport system element. The mentioned statistics show that (4 – 5) % of these type of crashes have fatal consequences.

2.1 Literature review

The analysis of relevant literature leads to the conclusion that there are different views as to which elements are part of the roadside. In an oft-side definition, roadside appliesto the area outside of the roadway, i.e. the area between the outside shoulder edge and the right-of-way limits – the area between roadways of a divided highwayis also considered as roadside.[7]

Therefore, according to [8], it consists of clear zones, slopes and cuts, ditch sections, barrier systems, and all of them significantly affect road safety. Bearing in mind [9], not only roadside characteristics, but also its condition can contribute to the occurrence of theROR crashes.The term clear zone includes shoulders, bicycle lanes and additional space, if any, while the components of roadside, [10], arebeyond the traffic lanes.(Figure 1).



Source: (Forgiving roadsides design guide. (2012). Conference on European Directors of Roads – adapted by authors of the paper)

Figure 1: Roadway cross-section with examples of roadside elements

Generally speaking, road design elements associated with the roadside safety refer to the functional and structural design of roads, such as: geometric design, pavement materials and design, road drainage, traffic management and control, lighting. It implies that roadside characteristics which impact safety include its geometries, (terrain slopes), lateral offsets to potential hazards, (distance from a specified point on the roadway to a roadside hazard), as well as use of shielding. [11].

Additionally, according to [12]roadside is a part of green infrastructure which has two categories of functions: operational, regarding access control, guidance and navigation, glare and distraction screening, recovery areas and sight distances with accommodations for signs and utilities, snow storage, and environmental which relates to the protection of road surroundings, as a whole. (water and air quality, noise and erosion control, habitat development and connectivity).

The results of the investigationinto the relationship between roadside features and safety, show that presence of bridges, cut-type slopes, ditches and culverts, fences, tree groups, sign supports, utility poles, isolated trees and guardrails, effect the accident frequency and severity.[13]

ROR crashes are more common along the two-lane roads. (these collisions with fixed objects refer to 18,9% of all crashes and 41,6% of fatal crashes in Kentucky. [14] The analysis of data about traffic accidents in Minnesota indicate that over 4 000 people are injuredand over 70 people are killed when vehicles depart two-lane highways (accounting for nearly 20% of all road fatalities each year). [15]

Collisions with roadside trees are serious problem. Namely, approximately 1,9% of all crashes are with fixed objects in roadside space, and 46% of them are with fatal consequences. [16]. Additionally, in Germany in 2015, around 17% of people were killed in such road accidents, while this percent is 15 in France, and 9 in Italy.

Main roadside hazard in Poland are trees, (up to 3 metres away from the edge of the carriageway, especially near the curves of horizontal alignment, junctions, exits), particularly in the north-west area of the country. Therefore, hitting a tree amounts to 54% of all roadside related accidents for two years, (from 2013 to 2015). [17].

The frequency and severity of tree crashes are related to the tree's location and proximity to the roads. In accordance with [5], crashes into trees are the greatest single road hazard and result in over 3000 deaths each year in USA. In addition, the distribution of fatal tree crashes depending on the typeof road in Massachusetts, shows that the situation is worse on local rural roads, followed by major rural collectors.

The collisions with trees account about 17% of all 3459 road users killed in 2015 in Germany. Additionally, 26% of all traffic fatalities along two-lane roads in the same year in Germany relates to tree crashes. [18].

This type of accident happens along the city streets, too. However, bearing in mind the current knowledge about circumstances of city tree crashes, it can be concluded that landscape and community improvement can reduce the number of thesetype of accidents.

Additionally, impact of roadside advertisingdevices on traffic safety is studied. [19].The obtained results depend on road characteristics, type and location of adverts, however, the general conclusion that can be drown is that they can lead to poorer vehicle control. It implies that there is no evidencethat they have a direct and significant impact on the occurrence of these type of crashes.

3 ROAD ELEMENTS AND THEIR IMPACT ON TRAFFIC SAFETY

Knowledge of elements affecting safety is important for the planning, designing, construction and maintenance of roads.

As conclusion to the contents of the previous chapter, and according to the latest results regarding the ROR events, it can be said that the following elements contribute to the risk of their occurrence:

- horizontal and vertical alignment;
- cross – sectional elements;
- intersections;
- width of road clear zone;
- roadside slope;
- type of roadside hazards;
- type of roadside protections;
- type and characteristics of roadside drainage;
- roadside surface and type of vegetation;

Therefore, the fact that safety does not depend only on the characteristics of the road, but also on the condition of the roadside, involves sharing of information and operating practices related to policy, criteria and technology within the roadside design procedures.
Additionally, bearing in mind the above presented, these are the most widely used actions for a safe roadside:

- removing of hazards;
- redesigning of features;
- implementation of roadside hardware.

Benefit/cost analysis is a commonly used method for economic evaluation of roadside safety. It implies estimation of benefits and costs of a specific safer design, according to the period of time needed for providing the benefit. Thus, the design which best meets the public's requirements for economy and safety, should be applied.

Using of roadside safety design is possible on low-volume roads, as well. (This is important for the road network in Macedonia). However, it may not be practical to provide the same measures applicable to higher volume roads. In these cases, smaller interventions or concentration on areas with higher number of crashes, are recommended.

4 POSSIBLE ACTIONS FOR IMPROVING ROADSIDE SAFETY

In order to improve roadside safety, i.e. eliminatefactors that contribute to accidents, numerous actions as a result of applied system-wide approachcan be undertaken. This implies joint and coordinated efforts of state and local authorities, professional bodies, industry, and civic associations, in order to increase awareness of roadside safety. Additionally, the effective way for continuous solving of safety issues is based on data - base management system which provides the required information for theabove mentioned stakeholders.

The main goal is tohighlight measures that have proven successful in various phases of the highway development process,(planning, design, construction, operations, maintenance), bearing in mind the latest research results. This should improvethe roadside design principles, applied safety hardware and ITS technologies, road environment, maintenance programs.

Therefore, respecting the most important rule, "keep the vehicle on the road", and considering the principle of priority, these are usually recommended measures: removing roadside hazards, (obstacles), redesigning the feature, relocating the obstacle, reducing impact severity, shielding the obstacle with a traffic barrier, and its delineation.

Theseare part of so called "forgiving roadside concept", i.e. "forgiving roadside design", based on the requirements forapplyingstandards which will contribute to minimize the reasons for ROR crashes.It is the activity realized by Technical Group Road Safety within the Conference of European Directors of Roads, (CEDR). The main goal is oriented towards establishing standards and producing guidelines for designing of so called forgiving roadsides. The focus is placed on certain features, such as: barrier terminals, shoulder rumble strips, support structures for road equipment, shoulder width.[10].

It is worth mentioning that these guidelines are derived from the best practice approach regarding the various international experiences in roadside safety.

Bearing in mind the fulfillment of two categories of roadside functions, (chapter 2.1), Washington State Department of Transportation, (WSDT), has developed comprehensive policy focusing on achieving the required roadside characteristics, i.e. its sustainability through:guiding the roadside design, using of various construction and maintenance activities, developing the roadside to fulfill the environmentaland economic requirements. [12].

Proposing of roadside safety management framework is the key goal of the project titled as "Improving Road Safety". [6].It is investigation -directed towards providing more forgiving roadside structures and minimizing the effect of ROR crashes, including: different type of shoulders, roadside surfaces and vegetation types, increase of clear zone widths, traversable batter slopes, frangible poles, safety barriers.

5 TOWARDS SAFE ROADSIDE IN MACEDONIA

The entities responsible for road safety, developed the roadside safety management framework, (as a part of national documents), and focused on minimizing the ROR crashes. Therefore, since 2009, two national strategies for traffic safety improvements along the roads have been approved. The main goal is directed towards the effort of reducing the number and the consequences of traffic accidents, as a whole.

In addition, to date, the authors of this paper have participated in more than one hundred road accident investigations. On the base of the gained experiences, it can be concluded that roadside characteristics on rural roads are the contributing factor in the occurrence of many traffic accidents.

5.1 National Road Safety Strategies – documents for delivering considerable savings for society

National strategies for the promotion of road traffic safety, (the first from 2009 and another from 2015), recognize the need for developing safety transport systems which will contribute to environment, economic and social sustainability as a whole. In recognition of the fact that roadside have a significant effect on safety, led to measures for roadway and roadside safety design.

Therefore, the sixth chapter of the First National Road Safety Strategy, (2009 – 2014), [22], contains recommendations for ensuring safety road environment. This involves taking measures for reducing the causes and consequences of ROR crashes, along the network of rural roads, as well as the urban network.

In order to make sure that the goals in the above mentioned strategy can be implemented, the action plan which is presented in chapter 2.6 of the Second National Road Safety Strategy, (2015 – 2020), [23],is created.

This action plan includes the following measures:

- road safety audit;
- section – by – section road safety evaluation;
- removal of billboards which limit visibility;
- lighting of junctions and sections in urban and rural environment;
- application of EuroRAP and similar methodologies in the process of analyzing the causes and consequences of traffic accidents;
- roadside interventions based on the application of iRAP and other methods.

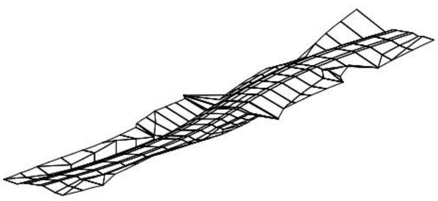
In fact, this action plan is the result of the national implementation of European contemporary, system approaches in road safety management.

5.2 Upgrading national standards on roadside design

The national legal acts contain articles related to criteria and standards which should provide sufficient sight distance, clear zone width and adequate roadside slope, treatments of drainage features, location and selection of fixed objects and various vegetation types, treatments for watercourses and canals, selection and placement of safety barriers, signing and lighting roadside features, traffic signals, intelligent transportation systems, and advertising devices.

Therefore, respecting the mentioned standards harmonizes thebasic roadside elements in the stage of its design. This enable the creation of a road with safe, efficient and economic traffic operations, while maintaining esthetic and environmental quality.

The inclusion of sight distance analysis for combined, three-dimensional alignments in the national rule-book, is the additional measure which will contribute to roadside safety. (Figure 2).



Source: (Easa, M.S., (2003). Geometric design, Ryerson Polytechnic University)

Figure 2: Sight distance analysis for three – dimensional alignments

However, it should be emphasized that, in order to provide safer environment along the entire national road network, there is a need for proactive approach in all stages of roadside safety development. This impliesconsideration of this type of safety at network level, as well as at individual locations, (for existing and new roads), based on accident data with high accuracy of recording of impact elements, persons and consequences involved in crashes. Therefore, bearing in mind the latest results of scientific research activities, professional knowledge and best practices worldwide, there is a need, in the first phase, to make recommendations that eliminate factors which contribute to accidents and their consequences.

Further improvement of the above mentioned approach should be oriented towards the production of roadside guidelines. The basic goal is to improve the roadside design and construction regarding safety, (according to "forgiving roadside concept"), as well as to evaluate the benefit of applying the mentioned standards. (through continuous analysis of the number of the crashes and their consequences). Additionally, this implies improving the scope and depth of the available evidence of roadside safety.

6 CONCLUSIONS

Based on research and professional findings, it can be concluded that roadside safety is an important issue in many countries worldwide. Namely, according to the available relevant references, it is obvious that roadside elements, as a part of roadway factors, impact on crash frequency and severity.

Knowledge of the relationshipbetween roadside and safety can help in different stages of road development. (planning, design, construction, operations, maintenance). Therefore, one of the proposed measures, (among others), is applying of the so called "forgiving roadside concept", i.e. applying standards which will minimize the cause of/or severity of roadside crashes.

Legal acts concerning highway engineering in Macedonia, are based on the scientific research results, professional knowledge and best practices presented in relevant literature resources. These include applying of number of fundamentals, concepts, standards, criteria that guide and control the manner in which highway is designed. The final goal is producing a road with design consistency, coordination between horizontal and vertical alignment, cross section elements, and landscape developments.

The results of reviews and analysis of national Rule-book of Technical Elements for Construction and Reconstruction of Rural Roads, lead to the conclusion that there is a need for inclusion of sight distance analysis for combined, three-dimensional alignments.

Further efforts and a coordinated approach should be oriented towards producing "forgiving" roadside guidelines.It should also be based on accurate, comprehensive, readily available data on outcomes, underlying factors and outputs of roadside crashes. This implies the development of a comprehensive road safety observation, integrated and focused on safety treatments that minimize the likelihood of serious injuries of run-off-road crashes.

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SIMULATION OF FUEL AND EMISSION BENEFIT ON A RANDOM SHIP VOYAGE BY POWERING THE AUXILIARY CONSUMERS WITH PEM FUEL CELL

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ABSTRACT

The conventional marine propulsion systems are mainly equipped with diesel engines. The diesel engine does not only provide the thrust but also powers all other consumers on the ship. This results in high fuel consumption and pollutant production. Due to high fuel costs and stricter legislations, ship owners are forced to consider alternative, more efficient ways of powering their vessels. The technology that has a great potential in reducing the environmental impact of the transport sector is the hydrogen fueled polymer electrolyte membrane (PEM) fuel cell technology. The life cycle analysis of fuel cell propulsion systems as well as optimum integration strategy of the PEM fuel cell in hybrid systems is in the focus of today's researchers. Numerous commercial propulsion systems are normally equipped with auxiliary power consumers that run on electricity. These auxiliaries usually have constant power demand which is delivered by the internal combustion engine, which results in increased diesel fuel consumption. In this research the commercial propulsion system powered by the diesel engine will be simulated on the random ship voyage, firstly with auxiliary loads powered by diesel engine and secondly with PEM fuel cell. The intention is to reduce cumulative fuel consumption and gaseous emissions by shifting the power production for auxiliary loads from the internal combustion engine to PEM fuel cell unit.

Keywords: marine propulsion simulation, marine engine model, system simulation, PEMFC, auxiliary load

1 INTRODUCTION

Efficient zero emission ships are important for the future sustainable development. Fuel cell systems are considered for powering future ships in an efficient and low emitting manner, as they are environmentally friendly source of energy due to their superefficient use of fuel for electricity and heat. Fuel cell devices, particularly Proton Exchange Membrane (PEM) type, are strong candidates for replacing internal combustion engines in the transport industry (Alaswad, 2016). The electrical energy conversion efficiency of most fuel cells ranges between 40% and 60% based on the lower heating value (LHV) of the fuel (El-Gohary, 2007, 2008; Hordeski, 2008). Fuel cell emission levels will be accepted by the required international marine regulations addressed by the International Maritime Organization (IMO) and the International Convention for the Prevention of Pollution from Ships (MARPOL). The parameters, which affect fuel cell performance, include the number of cells, cell voltage, open cell voltage, fuel cell efficiency, and fuel utilization coefficient. The actual polymer electrolyte membrane (PEM) cell voltage is 0.868 volt and the open cell voltage is 1.031 volt. These two values affect the efficiency and performance of the fuel cell. Also, fuel utilization coefficient determines the amount of hydrogen consumption in the fuel cell and also affects the cell's efficiency. The percentage of the power lost in heating for a fuel cell power plant is much less than that of the diesel generator and micro gas turbine. The use of a diesel generator or micro gas turbine will increase the fuel energy consumption rate by 23.59%, i.e. 43.95% more than that of the fuel cell fuel energy consumption at full load for the same output power (Yousri M. A., 2013). There are various possible marine applications. Standard distributed electricity or emergency electrical requirements can be generated by fuel cells systems (Jose J., 2016). While fuel cell use in the civilian and military surface ships is still at the investigation and demonstration stages, PEM fuel cells using hydrogen and oxygen have achieved serious maturity in submarines (Sattler et al., 2000). The results of the comparison of a high-speed hydrogen PEM fuel cell ferry and a ferry powered by the traditional diesel engine Tier 4 compline technology, show that operating a hydrogen fuel cell ferry on nearly 100% renewable hydrogen provides the reduction in GHG and pollutant emissions (Klebanoff L. E., 2017). The problems of global climate change and marine air pollution worldwide can be reduced with the help of this technology. The development and demonstration of a PEM fuel-cell-battery hybrid system for the propulsion of a 20-m-long tourist boat revealed a reliable operation of the fuel-cell battery hybrid system and boat speeds of 6.6-7.8 knots at a power output of ~85 kW (Choeng, 2016.). On sailing yachts, the consumption of electrical power is very restricted during long cruises because of low battery capacities. In this case, an additional power supply based on the noiseless fuel cell technology promises an essential comfort increase without disturbing emissions (Beckhaus, 2005). The so-called auxiliary power units (APU), suitable for a large scale of applications, ranging from power-driven automobiles and leisure applications to stationary uninterruptible power supply devices (UPS), are in the focus of fuel cell engineering. Auxiliary power units (APUs), i.e. devices designed to provide additional power in vehicles, are believed to be an important entry point for fuel cell (FC) technology into commercial markets. Three technologies are under consideration for this market: solid oxide fuel cells (SOFCs), proton exchange membrane fuel cells (PEMFCs) and direct methanol fuel cells (DMFCs). (Agnolucci, 2007). A data-validated power-efficiency model of a diesel-powered fuel-cell-based auxiliary power unit (APU) system has been investigated for the various sizes of the power unit and evaluated for the optimal choices for specified load profiles (Pregelj 2016). The challenge came from the FCGEN (Fuel Cell-based power GENeration) EU FP7 project, where such an APU was developed. The relation for optimal combinations, in terms of efficiency and degradation, is proposed and the confronted tradeoffs are discussed.

This paper aims at introducing a good solution for replacing the conventional marine power plants or for co-working with them. This implies the use of a fuel cell power plant operated on hydrogen produced through water electrolysis. This research provides a simulation of a commercial vessel fitted with a diesel engine operating under realistic conditions of a realistic voyage, with and without the auxiliary loads necessary for the analysis of fuel consumption increase. The increase in the fuel consumption and emissions will be reduced by shifting the power production for auxiliary loads from internal combustion engine to PEM fuel cell unit.

2 MARINE DIESEL ENGINE LOCAL FERRY RUN SIMULATION

A simulation model was built for demonstrating the benefit of using PEM fuel cell over the consumed fuel of the internal combustion engine. The simulation model was built using Cruise m simulation tool. For this purpose, Caterpillar C32 engine was chosen for the analysis. The engine is V12, 32.1 liter 500kW at 1800 rpm, with the bank separate turbocharging (2 turbochargers), electronically controlled injection. For this application, the load is following the propeller curve as shown in Figure 1.

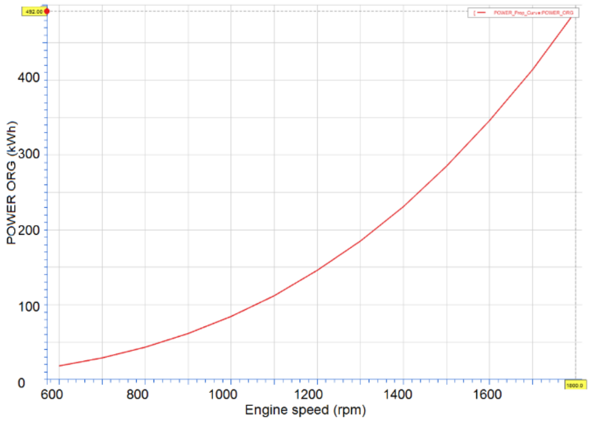

Figure 1: Propeller curve

The simulation model was built using main geometrical data such as the bore of 145 mm, stroke of 162 mm and compression ratio of 15. The rest of the geometrical data such as port dimensions, intake, exhaust, charge air cooler and air filter dimensions were assumed based on experience. The model was calibrated with experimental data obtained from the testbed: measurements of pressures and temperatures measured in intake and exhaust ports, fresh air mass flow, fuel flow, torque and emissions over the engine load range from 3% to 100%. For modelling the working fluid, the quasi-zero-dimensional model of components is used. Static parameters are determined using filling and emptying method coupled with the energy balance. Dynamic parameters are determined by flow equations that need to be followed with an adequate flow coefficient representing the pressure drop over the specific component. The turbocharger model is defined by the compressor and turbine mass flow and efficiency maps measured on the turbocharger hot-bench. The cylinder model consists of the intake and exhaust port model, injector model, heat transfer model that includes the piston, cylinder head and liner, and combustion chamber model (Figure 2).

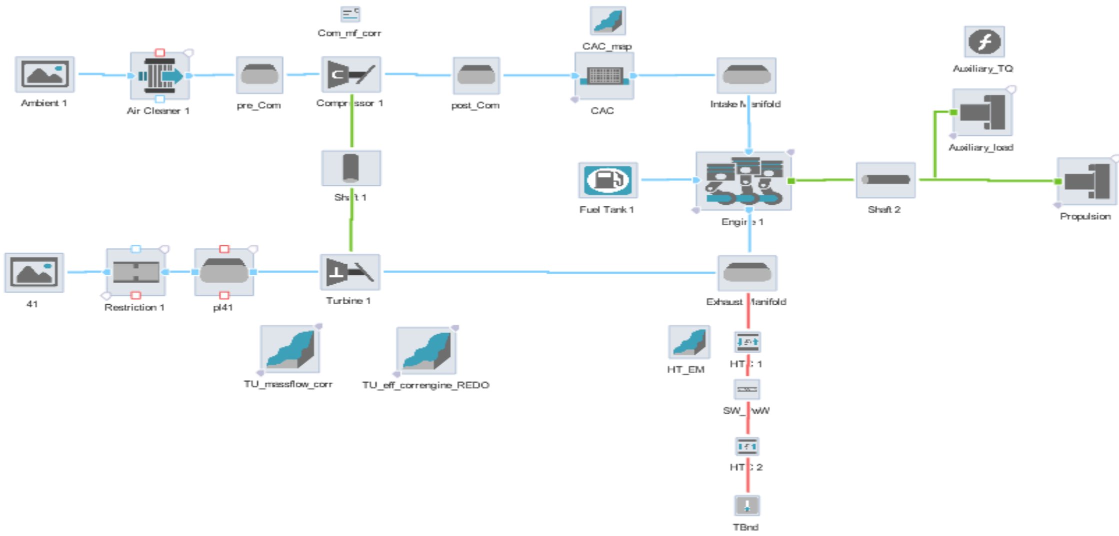

Figure 2: Cylinder model component overview

Part models are dynamic parameters determined by the valve lift profiles and timings as well as the flow coefficients. The injection model is made of rail and injector models. They are defined by geometry, injection signals and profiles. The injection process is defined with reference to the crank angle. The rail model is a 0D volume based model that considers the compressibility of the fluid. The approach used for injector rate determination is based on the injection velocity and nozzle area. The flow coefficients include the friction and are introduced into the model over the hole and needle seat area.

The combustion chamber model is in the function of the crank angle and consists of combustion and emission models. The combustion model used for this application was AVL Mixture-Controlled 2014 divided into the sub-models including the ignition delay, premixed combustion, diffusion combustion and wall impingement. It is a two zone combustion model. There are 3 pollutant formation models available, NOx, CO and Soot production models.

2.1 Model calibration

For the calibration purposes, the model was divided into two standalone models. This approach achieves the better results correspondence to the measurement of each component individually, without affecting the deviations caused by neighboring components in the system simulation. The first standalone model is the cylinder model where the states around the cylinder such as pressures, temperatures and mudflows, are stimulated from the measurements. The cylinder standalone calibration was divided into the three groups. The first group is the motoring phase where the fresh air mass flow is stimulated and the intake flow port parametrization is performed to match the intake manifold pressure to the measured one. After matching the port size, the friction mean effective pressure multiplier is also adjusted to achieve the desired engine model friction. In the second phase or group, the amount of the injected fuel needs to be matched to the testbed measurements by adjusting the fuel multiplier in the injector element model. When the air and fuel massed are matched, the next step involves the combustion parameters adjustment, for reaching the torque measured on the engine test bed. The adjusted parameters for the ignition delay model are of Arrhenius and Magnussen multiplier type. Higher values lead to reduction in the ignition delay. For premixed combustion, two parameters are available: the premixed fuel fraction that defines burned fuel fraction during ignition delay, and the combustion parameter that is a multiplier on the heat release rate in the premixed phase. For the diffusion combustion phase, three parameters are available. The combustion parameter is a multiplier on a heat release rate in the diffusion combustion phase, the spray lambda limit defines fuel fraction in the lambda distribution in spray model that is available for the combustion, and the turbulence parameter is the scaling factor for the kinetic energy in the spray. Finally, the wall impingement has two adjustments. The penetration length defines the free spray length into the combustion chamber and the reduction multiplier is the scaling factor of the wall impingement on the combustion rate.

After adjusting the combustion to fit the measured engine torque, the exhaust temperature at the exhaust port and in the exhaust manifold will be higher than the one on the testbed because of the influence of the heat transfer from the heat rejected between exhaust port and temperature sensor location. This effect was also modeled to fit the exhaust manifold temperature to the measured one.

For the turbocharger standalone model the goal is to achieve the desired boost pressure and temperature as well as the realistic backpressure, under test conditions stimulated from the measurements.

In the following figures, the simulation results are shown in blue color and measurements from the engine testbed in red color.

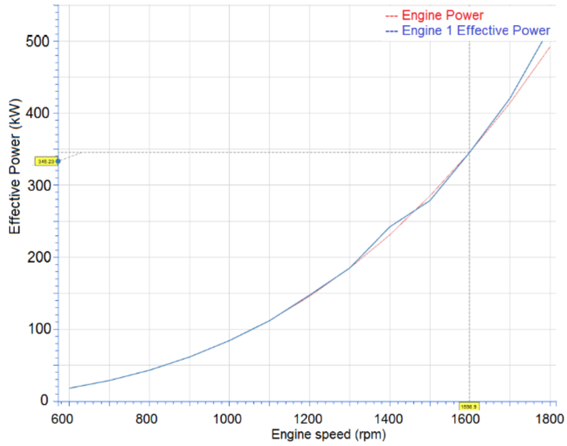

Figure 3: Power simulation result quality

Figure 3 shows the simulation results of the power output of the engine model compared to measurements results. Maximum deviation in the simulated power output is 5.5 % at full load point.

Maximum deviation in simulated intake manifold pressure output is 2 kPa at low load.

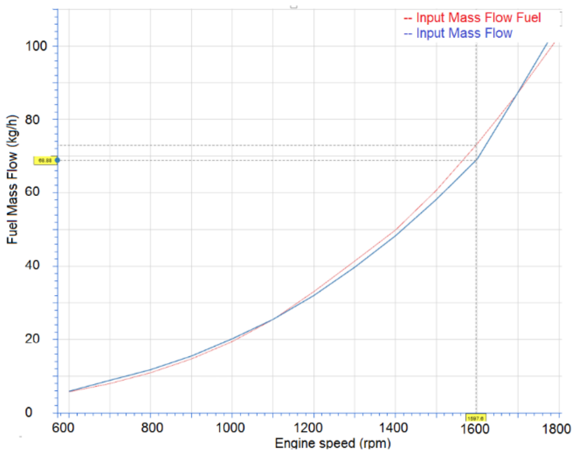

Figure 4: Fuel consumption simulation result quality

Figure 4 shows the simulation results of the fuel mass flow from the injection model, compared to measurement results. Maximum deviation in the simulated fuel flow output is 5.5 %. The fuel amount deviation is also causing deviation in the power output and in exhaust temperature. It can be further improved but here it represents a high model quality.

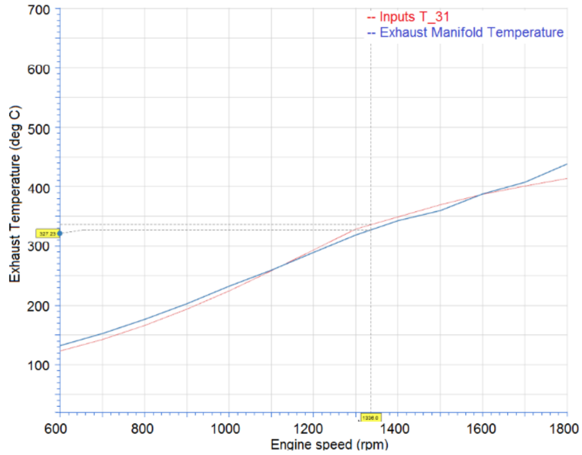

Figure 5: Exhaust temperature simulation result quality

Figure 5 shows the simulation results of the exhaust temperature compared to measurement results. Maximum deviation in simulated exhaust temperature is 10°C or 3.1%.

The simulation results have showed a high model quality and good model interpolation capability that also points to a robust model calibration parameters.

2.2 Fuel and emission benefit simulation

After calibration of the engine model according to the testbed data, the realistic voyage profile was simulated to estimate the amount of consumed fuel and CO_2 emissions during the local ferry one-hour run. It is assumed that the sea is calm. The engine load profile is: 5% load for 5 minutes during maneuvering in the port, raising the load from 5% to 80% in 2.5 minutes, sailing under 80% of load for 45 minutes and then derating to 5% for entering the next port of call in 2.5 minures and at 5% load for port maneuvering during 5 minutes (Figure 6.).

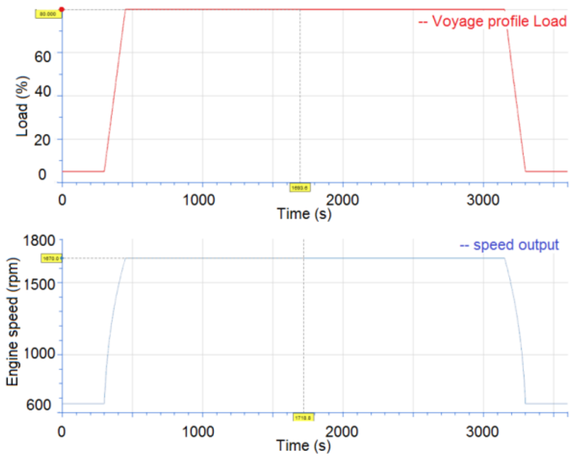

Figure 6: Engine speed and load profile during 1 hour voyage

During the 1-hour voyage, the generator on the shaft was mounted for supplying power to the auxiliary consumers on the ship. The power demand on the generator for auxiliary consumers power supply is based on using the fraction of engine produced power and it is showed in Figure 7.

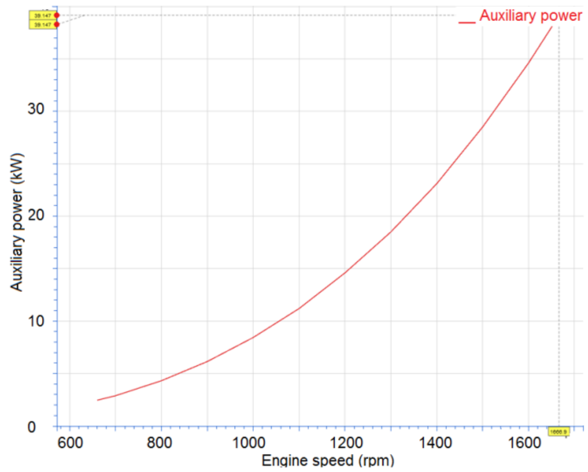

Figure 7: Auxiliary power demand for external consumers on the ship during the defined voyage

Figure 7 indicates that at 80% of the engine load the power demand for auxiliary consumers reaches 40 kW and at 100% load the auxiliary power demand rises up to 50 kW.

The voyage simulation was performed two times. Once simulation setup included the shaft generator at the engine front, for supplying auxiliary power demand to additional consumers on the ship, and the second simulation was performed under assumption that auxiliary power demand is supplied by an external power source such as fuel cell. By removing auxiliary power demand from the internal combustion engine, the load is decreased and fuel consumption and emissions are reduced.

In the following figures the blue color represents the voyage simulation with auxiliary power demand supplied by the internal combustion engine, while the red color represents the voyage simulation with auxiliary power demand supplied by an external power source such as fuel cell.

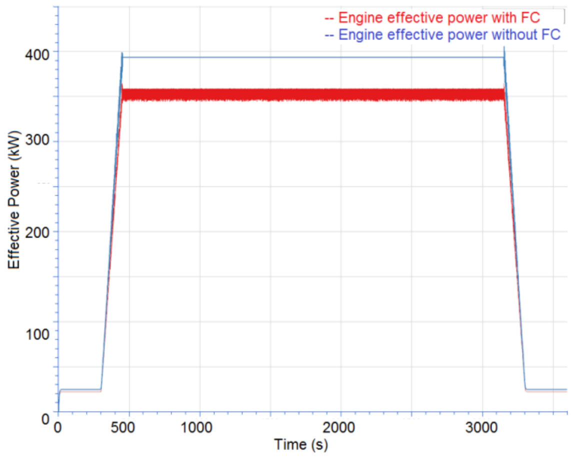

Figure 8: Engine power reduction due to the external power supply for auxiliary demand during the voyage

Figure 8 shows that during the voyage when power for auxiliary consumers is supplied from fuel cell, the decrease in internal combustion load is about 10%. This leads to reduction in fuel consumption and has a significant impact on emissions reduction, without influencing the voyage duration. Additionally, the intake manifold pressure was reduced by 20 kPa and the exhaust manifold temperature by 25°C, which implies a positive reduction in thermal load.

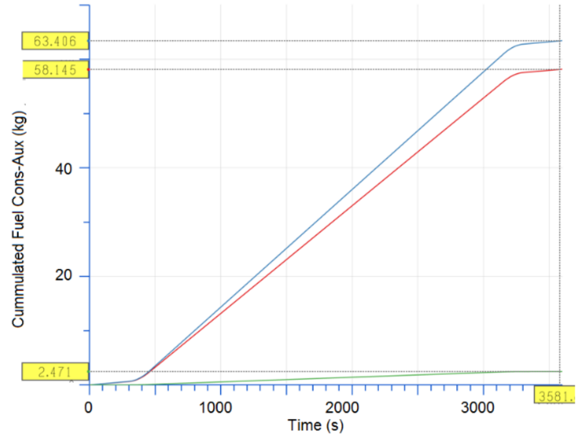

Figure 9: Cumulated fuel reduction due to the external power supply for auxiliary demand during the voyage

By excluding the load for powering auxiliary consumers from the internal combustion engine, at the end of 1 hour voyage, a fuel consumption decrease of almost 5.26 kg, or nearly 9% less diesel fuel consumption, is achieved by using 2.47 kg of hydrogen (Figure 9.). Since the ferry uses 4 identical main engines and sails 16 hours per day, this results in a fuel saving up to 336 kg of diesel fuel per day.

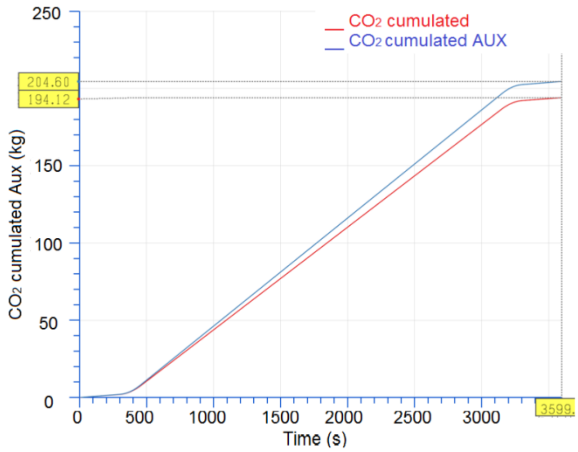

Figure 10: Cumulated CO_2 reduction due to external power supply for auxiliary demand during the voyage

Figure 10 shows the reduction in cumulated CO_2 emissions by 5.5%. Per 4 engines and 16 hours of sail per day, the reduction of CO_2 amounts to 670 kg per day.

3 FUEL CELL CALCULATION FOR POWERING AUXILIARY LOADS

Polymer electrolyte membrane (PEM) fuel cells are chosen as optimal solution for this application due to delivery of high power density with low weight compared to other fuel cell technologies.

PEM fuel cells are mostly used in transportation due to fast readiness for operation and low weight compared to other fuel cell technologies. The PEM fuel cell system calculation was performed and the stack was defined for this case with the maximum power supply of 50 kW.

The power of the fuel cell is calculated by:

$$P = I \cdot V_{stack} \quad (1)$$

Where P is the power, I is the current and V_{stack} is the voltage of the fuel cell stack. Current is given by:

$$I = iA \quad (2)$$

Where i is current density and A is the stack surface. The voltage of the stack is defined by:

$$V_{stack} = NV_{cell} \quad (3)$$

Where N is number of cells in the stack and V_{cell} is the voltage of the cell. The voltage of the cell can be described as:

$$V_{cell} = V_{th} - \frac{RT}{\alpha F}\left(\frac{i}{i_0}\right) - iR_i \quad (4)$$

Where V_{th} is the theoretical cell voltage, R is gas constant, T is the operating temperature, α is charge transfer coefficient, F is Faraday´s constant, i_0 is the exchange current density and R_i is the resistance. Theoretical voltage can be expressed as:

$$V_{th} = -\left(\frac{\Delta H}{nF} - \frac{T\Delta S}{nF}\right) + \frac{RT}{nF}\ln\left(\frac{P_{H_2}P_{O_2}^{0,5}}{P_{H_2O}}\right) \quad (5)$$

Where ΔH is the heat of formation, ΔS is entropy, n is number of electrons per molecule and P_x are partial pressures.

The cell characteristic is defined by the cell polarization curve. The standard polarization curve available from manufacturer was chosen (Figure 11) and the number of cells was adjusted to fit the needs of the power for auxiliary consumers on the ship (Figure 12).

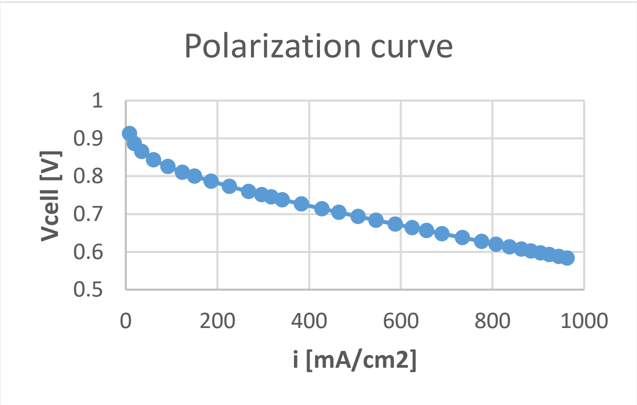

Figure 11: PEM fuel cell polarization curve

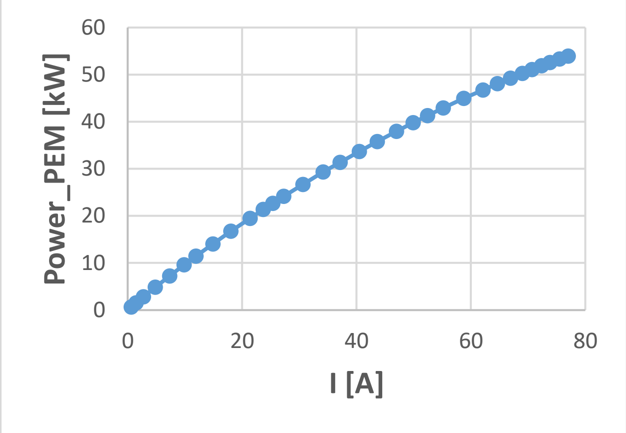

Figure 12: PEM fuel cell power curve

4 CONCLUSION

Since the auxiliary onboard loads such as cooling systems, ventilation, hydraulic pumps and others are powered by diesel-generator sets and sometimes by using the shaft generator attached to the propulsion engine, they consume fuel and produce pollutants. In this paper, the propulsion engine fitted with the shaft generator was analyzed. The auxiliary power demand implies extra load on the propulsion engine and increases fuel consumption, especially in port where the propulsion engine runs at low loads, which is the most inefficient mode of diesel engine operation. The fuel cell stack was designed to meet maximum 50 kW of the auxiliary power demand. When the auxiliary power demand for the ship consumers was taken off the internal combustion engine, the simulation showed benefits in fuel consumption and pollutant production on a realistic voyage. During the 16 hours of the simulated ferry's sailing in calm sea condition, the fuel saving was up to 336 kg which resulted in the reduction of 670 kg CO_2 per day. The diesel fuel consumption was decreased by 9% and CO_2 emissions reduced by 5.5 %.

Further steps would be to calculate the hydrogen tank capacity for certain voyage or to do the economic analysis of the electrolyzer installation, and to perform a feasibility study of the whole system.

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COMPLEX APPROACH TO MARITIME SECTOR ATTRACTIVENESS AND STATE COMPETITIVENESS

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ABSTRACT

Maritime transport sector, seaport and shipping, create preconditions for maritime states to implement strategically significant national market regulatory measures in order to create added value to the national economy. The state seaport as an element of the maritime transport sector is analyzed as an area of activities of the whole state and region in the transport sector which create preconditions for improving the international, political and economic positions of maritime states in the region. Therefore the efficiency of the state seaport from the management and economic perspective is one of the features of the attractiveness of the maritime transport sector in the region, which directly influences the competitiveness of the entire economy of the country. The peculiarities of the efficiency of the maritime transport sector have to be analyzed in a complex manner and its complexity can be revealed in various ways: optimal and effective distribution and exploitation of state-owned resources, effective private capital involvement by strengthening the supra-structure of the seaport, attractiveness for the cargo consignor and the consignee, performance, socio-economic progress and other. In order to maximize the positive impact of the activities of the maritime transport sector on the country's economy and its competitiveness, a shift in the seaport’s mission is observed: the aim to increase the productivity by the growing volume of cargo has shifted to the goal of creating added value to the stakeholders. Taking into consideration the nature of seaport and shipping activities in order to increase the attractiveness of the maritime transport sector and the competitiveness of the country in the region, it is relevant to substantiate the value-oriented management as a means of increasing efficiency on theoretical and managerial assumptions. The theoretical assumptions are illustrated by the results of the analysis of the activities of the Estonian, Latvian and Lithuanian maritime transport sector.

Keywords: maritime transport sector attractiveness, state competitiveness, seaport governance, seaport economics, ADDED VALUE

1 INTRODUCTION

The globalization process of the international logistics chain has significantly affected not only the private capital sector, but the public sector as well. Such an impact manifested itself through the transformations of management forms and scientific paradigms, which were preconditioned by the imbalance between intensive and dynamic changes in the environment and the rigid, complex and ever-expanding state management apparatus, defined by the vast variety of procedures and functions. The public sector has become a highly complex system of allocating economically significant national resources, which operates in an ever-changing environment characterized by high uncertainty. The problems of the effective allocation of said resources is evident from the lack of flexibility of the operational decision-making process. Even the application of new principles of public management and the seaport reform that began at the end of 1980s did not yield the expected result in increasing the efficiency of seaport management. Ports did not become objects of strategic importance to the state, whereas the decision-making on regional development and other strategically important decisions in many cases remained implemented centrally as in the progress of the reforms seaport authorities were only granted financial autonomy and prompt decision-making discretion.

The results of the seaport reform under the principles of the new public management are criticized arguing that the reform did not address crucial issues of ensuring the public interest, identifying the eco-social added value, the issues of connectivity with other land transport systems, and the implementation of the principles of green logistics (Notteboom, de Langen, Jackobs, 2013; de Langen, 2015; Ibrahimi, 2017, etc.).

According to scientific discussions and despite its acknowledged importance, the concept of competitiveness is still misunderstood, and a discussion of its underpinnings remains a central task (Porter, Ketels, Delgado, 2007; Navickas, Malakauskaite, 2010; Cann, 2017, etc.). This research described the competitiveness as relative or comparative position of an economical subject with regard to others similar subjects and titled it a central preoccupation of advanced and developing countries in an increasingly open and integrated world economy. On the supply side maritime transport sector are seeing the introduction of new technologies that create entirely new ways of serving existing needs, significantly disrupt existing industry value chains and leads to creation of sustainable added value based on productivity.

The latter supports the relevance of the problems of seaport management, attractiveness of the maritime transport sector and regional competitiveness arguing that legal simplicity, functionality and "government-without-government" are modern value-added-oriented methods of the management of maritime transport sector by enhancing its attractiveness in the region.

Object of the research: relation between maritime sector attractiveness and state competitiveness. **Aim of the research:** to evaluate relation between maritime sector attractiveness and state competitiveness.

Objectives of research:

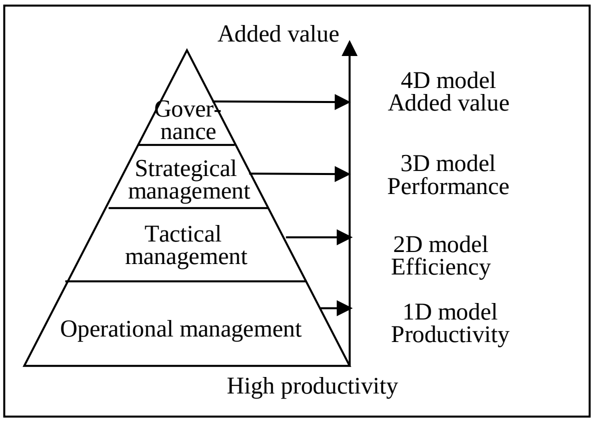
1. To explain complexity of relation between state seaport governance, maritime sector attractiveness and state competitiveness;
2. To describe the complex maritime transport sector attractiveness and state competitiveness research methodology;
3. To explain the consequences of the relationship of seaports attractiveness and countries competitiveness.

Research methods: analysis of scientific literature, statistical and financial analysis, multi-criteria analysis based on the principles of modeling.

2 THEORETICAL APPROACH TO LINK BETWEEN STATE SEAPORT GOVERNANCE, ATRACTIVENESS AND STATE COMPETITIVENESS

2.1 The Role of State Seaport Governance in the Context of Maritime Sector Attractiveness

The application of the notions of the new public management in the research on effective management of state enterprises expanded the field of issues of effective management of state-owned seaports. Said application also formed the preconditions for the application of the complexity approach, and the establishment of the interpretative approach to investigated phenomena and their interrelationships.



Source: de Langen, 2015; Rainey, Steinbauer, 1999

Figure 1: Complexity of effective management concept

The concentration of the principles of the theory of effective governance of state-owned enterprises (Ayub, Hegstad, 1987; Rayney, Steinbauer, 1999) presupposes the interconnectivity of high productivity with the efficiency of management through a variety of measurable and mutually comparable criteria (Fig. 1):

- Criteria of the efficiency of technological operations: absolute performance indicators, productivity indicators, performance indicators.
- Criteria of the efficient financial management: profitability, return on capital, real added value, return on investment.
- Criteria for the effectiveness of strategic management: cooperation and partnership, competitiveness and attractiveness, meeting the needs of stakeholders, leadership and mission clarity.
- Legal-political criteria for management efficiency: financial and institutional autonomy and accountability.

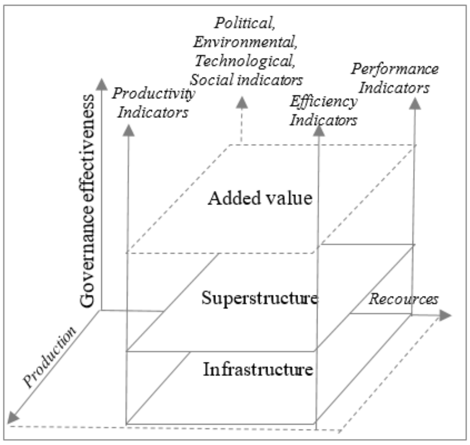
Analysis of the elements of effective seaport management in theory of effective management point of view supposed to form a multi layered complex structure (de Langen, 2015; Ibrahimi, 2017). This structure combine the qualitative characteristics of management attributes with the quantifiable indicators in a multidimensional model (Fig. 1). This possibility follows from the preconditions under the theory of public management stating that state-owned enterprises are not only complex hierarchical structures but also complex social structures with a sufficiently large number of social entities forming a complex and highly predictable multiplicative communication network operating in a highly uncertain environment complex systems that are based on adaptability and self-reflectivity (Naguyen, 2015).

G. Teisman and E. Klijn (2008) distinguished the phenomenon of the public sector and determined the key principles for analyzing it and developing its development scenario. The first principle - dynamism of systems, which is used to analyze the changes and development of the phenomenon. This principle defines the decision-making process not in the linear equilibrium state, but as non-linear processes, during which the phenomenon endures various effects from the external environment. Another principle encompasses the features of self-organization and self-regulation of systems that trigger changes in control mechanisms and forms in systems. Based the latter principle, the aforementioned authors state that while the public sector managers are focused on realizing their personal ambitions and changing their capabilities, actors in the complex system of public sector entities are dependent on circumstances and the state of the system is changing as the external conditions change. Such a division of management and management subjects into different systems results in the ineffectiveness of the decision-making process. The application of the complex approach introduced by G. Teisman and E. Klijn (2008) creates preconditions to model the potential decisions of effective public sector management.

By analyzing the model of efficient state-owned seaport governance (Fig. 1) it may be noted that the application of the rules of new public administration theory to the theoretical provisions for effective seaport management include not only the principles of complexity, but also the multiplicative effect of the network economy effect. The multiplicative effect is interpreted differently by the contingency (Cho, 2014;) and through the theory of complex systems (Noteboom et al., 2013).

H. Cho (2014) distinguishes various dimensions of uncertainty, such as eg. behavioral uncertainty. T. Notteboom, P. de Langen, W. Jacobs (2013) based their research methodology on the systematic complex approach. They defined importance of the interconnection between the system actors and the status of each of them, brought the methodology of modeling of seaport management reform closer to systemic self-regulation, based on the theory of economic evolution. The research methodology is based on the theory of complexity according to which seaports are complex structures that depend on geographic location, various actors, operating in different levels and sectors, and the multiplicity of their interests and interactions in different territorial dimensions. Based on the key elements of effective management, an efficient seaport management model is constructed starting with the lowest level of management that is dominated by high productivity indicators: indicators of cargo flow characterizing infrastructure productivity. Relying on the theory of configuration and the theory of uncertainties, R. Baltazar and M. Brooks (2007) modeled economic performance efficiency indicators related to the indicators of resource allocation. Their model of efficient seaport governance is based on economic returns as a result of high productivity and economic returns as a result of high efficiency. The first is related with the economic return that forms the system of requirements for the organization, which is based by high productivity in providing services and produce. The other states that the pursuit of maximal economic return between similar organizations requires the highest efficiency and effectiveness and, at least, the average competence and strategic planning of that field.

In analyzing the development of the new public governance theory in the context of the uncertainties theory, the link between the environmental change oriented strategic planning and the effectiveness of the organization's management becomes evident. The latter proves the influence of the configurations doctrine. Under the configurations theory, alternative strategies mean the selection of the operating environment and related characteristics. The latter justifies the link between tactical and strategic governance levels in modeling the possibilities of improving the efficiency of seaport governance in a 3D model perspective. This model encompasses the indicators of productivity, efficiency and performance indicators (Fig. 2).



Source: authors own elaboration

Figure 2: Concept of efficient seaport governance

In order to link the concept of efficient governance with the principles of high productivity management, based on the importance of financial and institutional autonomy under the theory of efficient governance of state-owned enterprises, the principles of increasing the efficiency of seaport governance, developed and analyzed X. Naguyen (2015) and other researchers, may be employed. The latter authors prove that efficiency of seaport governance can be measured by port performance indicators. However by relying on the principles of the theory of complex systems, the authors also emphasize the formation of quasi-market in the maritime transport sector, where demand and supply decisions are coordinated by market-based mechanisms. The quasi-markets encompass only a part of the main market elements, which are directly linked to the legal regulation. Actors of such quasi-markets aim to promote the public and private actors to operate under the principles of the market, whereas the elements of competition, rules on charging and tolls, individual accountability and autonomy are introduced via financial and institutional autonomy and accountability models. In this way the internal market in the maritime transport sector is formed. In this case state regulation and financing become an important mechanism for representing the efficiency of management of state-owned seaports, the impact of which can be measured by the dimensions of attractiveness of the maritime transport sector. T. Notteboom, P. de Langen, W. Jacobs (2013) rely on the results of their research in justifying the link between the effective seaport governance with the attractiveness of the maritime transport sector by distinguishing the created added value as a separate measurement unit. In this way it becomes possible to link the highest level of management with the lower levels of management, combining all the indicators into one model (Fig. 2).

Considering the concept of the attractiveness the maritime transport sector provided by R. Sanchez et. al. (2011) and in analyzing the peculiarities of efficient seaport governance, the application of the particularistic internationally comparable management approach provides preconditions for analyzing not only individual productivity, efficiency and effectiveness indicators, but also the interactions between institutions and the ambiguity in the environment. This approach may also be applied in analyzing the seaport governance model in the dynamic logistics chain, where the efficiency of seaport governance may be measured in a complex manner by combining the basic productivity, efficiency, effectiveness indicators and the indicator of external environment into one multi-criteria model. Moreover the approach may be employed to identify the significance of the seaport for increasing the logistic connectivity of the transport sector, which creates preconditions for assessing the attractiveness of the maritime transport sector through the integrated logistic performance indicator.

2.2 The Phenomenon of Competitiveness

Competitiveness can be described as a complex economic phenomenon which has macro- (national economy), mezo- (regional economy, industry), and micro- (company economy) levels (Navickas, Malakauskaite, 2010). Each level has its own specifics and unique indicators that are to be applied in the process of competitiveness evaluation. The evaluation of competitiveness is economically relevant for few reasons: it is a process which enables to identify all the strengths and weaknesses of a national economy, striving for balanced and sustainable economic growth; provides the basis for the creation of efficient economic stimulation instruments, as it identifies the competitive advantages of goods and services, and enables to forecast their ability to compete with analogical goods and services in local and foreign markets. Evaluation of competitiveness enables to define the relative position of an object with regard to other analogical objects by the use of various competitiveness indicators.

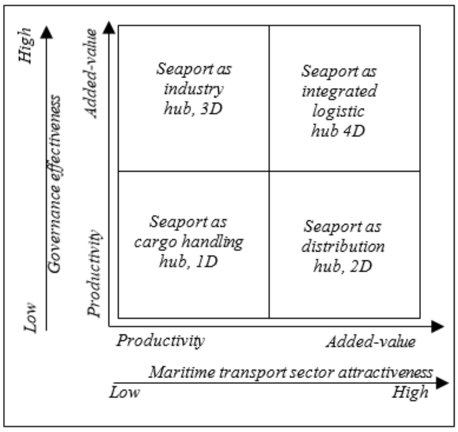
The World Economic Forum defines the competitiveness as the set of institutions, policies and factors that determine the level of productivity of a country (Cann, 2017). This definition related to the M. Porter, C. Ketels, M. Delgado (2007) conclusion, that country's competitiveness can be define with a focus on the microeconomic level, because competitiveness focused on the macroeconomic, political, legal, and social circumstances, that underpin a successful economy, progress in these areas is necessary but not sufficient. Productivity ultimately depends on the microeconomic capability of the economy, rooted in the sophistication of companies, the quality of the national business environment, and the externalities arising from the presence of clusters of related and supporting industries. Productivity depends both on the value of a nation's products and services, measured by the prices they can command in open markets, and the efficiency with which they can be produced

Another way to think about what makes a country competitive is to consider how it actually promotes our well-being. New approach of the socio-economic progress the actual economic state is characterized by applying an integrated analysis of various aspects of life welfare indicators - material living standards, health, employment, environment, i. e. competitive economy is a productive one, and productivity leads to growth, which leads to income levels and improved well-being (Porter, Ketels, Delgado, 2007; Stiglitz et al., 2010; Cann, 2017).

The similar dimensions formed the concept of sustainable development, which assumes relations between economic, environmental and social aspects on the societal as well as on the entrepreneurial level (Figgea, Hahn, 2004; Faber, 2008). The dilemma of sustainability in the age of globalization in the XXI century reflects the various political, social, economic and cultural circumstances that created the conditions for the start of sustainable development and are inspired by the context of neoliberal capitalism and globalization (Bakari, 2017). Growth that distorts ecosystem services is sometimes called "non-economic growth" as it leads to a deterioration in quality of life. This trend can be proven by population, economic growth and environmental performance indicators. Sustainable value added allows assessing the sustainable performance of enterprises similar to financial performance in monetary terms and supports better knowledge and understanding of other competition – sustainable practices are considered to be one of the competitive advantages, enterprise could determine its strengths and weaknesses, enhances creative leadership and better formulation of an efficient business strategy (Strakova, 2015).

Added value in maritime transport sector, presented mainly by shipping and ports industry, in global supply chain related on differences of operated assets: enabling a charterer to provide a value added service to the sender or the carrier are different from those of the ship operator, which allows the ship operator to add value to the service to the sender. What captures value added is another question that depends on the individual transactions of the chain participants. A port agent can add value to the carrier, ensuring smooth operation of the port, thereby reducing waiting times. However, the added value can be captured by the forwarder, which forces the carrier to reduce the price or is likely to be distributed to several actors (Olesen, 2015). On the supply side, many industries are seeing the introduction of new technologies that create entirely new ways of serving existing needs and significantly disrupt existing industry value chains, and leeds to creation of sustainable added value based on productivity. In the future, technological innovation will also lead to a supply-side miracle, with long-term gains in efficiency and productivity. The 4th Industrial Revolution has the potential to raise global income levels and improve the quality of life for populations around the world. Transportation and communication costs will drop, logistics and global supply chains will become more effective, and the cost of trade will diminish, all of which will open new markets and drive economic growth (Schwab, 2016).

The physical footprint of supply chains is being reshaped partly in response to infrastructure improvements (Mapping Global Transformations, 2018). Infrastructure projects including ports, pipelines and highways provide the bedrock of national prosperity and well-being. Logistics real estate is being restructured in response to the upgrading of transport infrastructure. Ports have strengthened their position within supply chains by diversifying their storage and handling services. Companies are generally becoming more interested in logistics facilities that combine good road access with rail or waterway transport connections. Physical products and services can be enhanced with digital capabilities that increase their value. Thus, in certain level developed maritime transport sector will be attractive for the maritime business actors and will be able to create added value. To summarize the maritime transport sector attractiveness level, there is a possibility to establish the link between maritime sector governance efficiency and sector attractiveness. It can be defined by the matrix model (Fig. 3), which generated the scope of attractiveness indicators: 1D – productivity indicators; 2D – efficiency indicators; 3D – performance indicators; 4D – effectiveness or added value indicators.



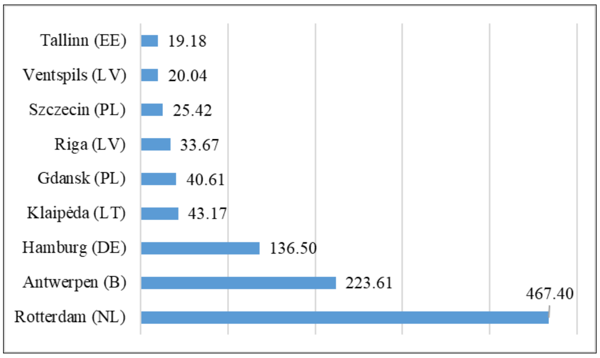
Source: authors own elaboration

Figure 3: Maritime transport sector attractiveness levels matrix model

The arguments show that, the country's competitiveness can be described by the sustainable added value indicator, which measures whether a maritime transport sector creates extra value while ensuring that every environmental and social impact is in total constant, and increasing of added value in maritime sector creates and raises attractiveness of the maritime transport sector.

3 MEASUREMENTS OF BALTIC SEA PORTS ATTRACTIVENESS AND COUNTRIES COMPETITIVENESS

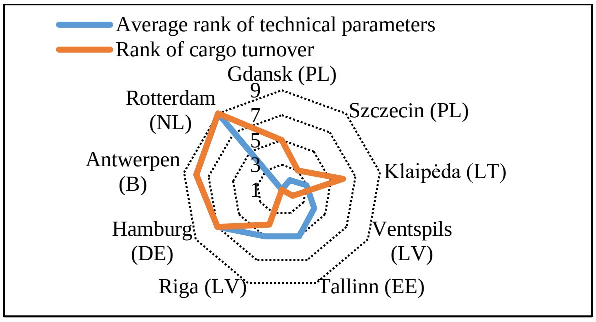
Expected to illustrate the present situation in Baltic sea ports, the number of seaports was selected for the benchmarking according to following criteria: region of activity; port model (mainly landlord); port technical parameters; types of handled cargo; cargo turnover. According to cargo turnover in seaports (Fig. 4), it can be highlighted, that the competitors for the Eastern coast of Baltic Sea ports in the region are the polish seaports from the Southern coast of the Baltic Sea.



Source:Seaport Authorities Statistics, 2018

Figure 4: The cargo turnover of seaports in 2017, mio t

The set of the technical parameters of the port - depth of port channel (m), territory area (ha), length of the quays (m) - not always leads to the biggest turnover of cargo (Fig. 5). The rank is from 1(lowest) to 9 (highest).



Source: Seaport Authorities web pages, 2018

Figure 5: The rank of cargo turnover and average of rank of ports technical parameters in 2017

The correlation between rank of turnover and technical parameters is week (0.6). An exceptional situation is evident in the case of Klaipeda (LT) port – with the smallest port territory (rank 1 of 9) port reach the turnover, rated by 6 of 9. Different situation in Tallinn (EE) port – average rank of port technical data 5, rank of the turnover 1 (Fig. 5). The analysis of ports productivity ranking (Fig. 6) shows, that highest rank of port area, territory, productivity is reached in Klaipeda (LT) port, despite, that, productivity of quays length and port workers are very low (rank 2).

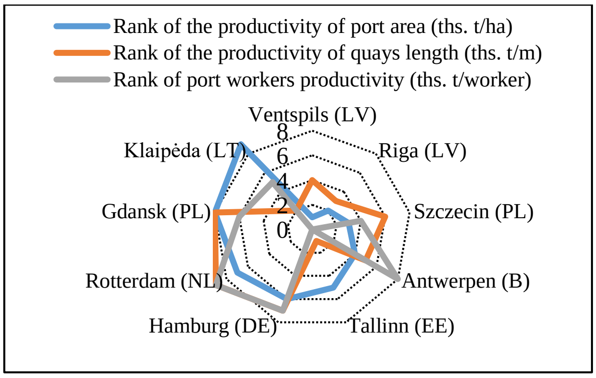
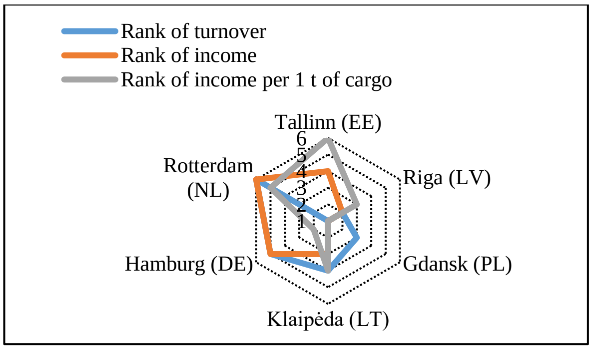


Figure 6: The rank of productivity of ports in 2017

For all ports of eastern and southern region of Baltic sea are characteristic low level of productivity of port workers.

According to the ranking (Fig. 5-6), ports can be divided into three groups: worldwide leaders Hamburg (DE), Antwerpen (B) and Rotterdam (NL) (rank 7-9), region leaders Riga (LV), Klaipėda (LT) and Gdansk (PL) (rank 4-6) and ports "in transition" - Ventspils (LV), Tallinn (EE), Szczecin (PL) (rank 1-3). These ports are undergoing changes in cargo flow: Ventspils changing from row oil cargo to the dry bulk (coal), Tallinn – switched to the passengers and ro-ro cargo. The analysis of financial indicators describe different picture (rank from 1 – lowest, to 6 – highest, Fig. 7). The port of Tallinn shows best financial results of income per 1 tone of handled cargo in 2017 (rank 6), port of Hamburg – rank 2. Lowest financial results rank (1) of port of Gdansk.

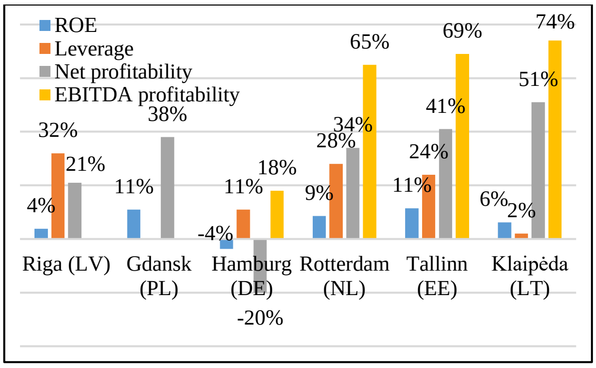


Source: Seaport Authorities Annual reports, 2017

Figure 7: The rank of cargo turnover and financial indicators of ports in 2017

There may be various reasons for it, e.g. port dues and land rent price of ports are inadequate with the low level of income; not certain level of utilization of port infrastructure; high level of port authorities expenditures; not certain level of productivity of technologies of stevedoring companies in the port etc.

Measurement of financial efficiency of ports (Fig. 8) describes possibilities to create added value and proves the motto of leading seaports in Europe: „From tones - to added value".

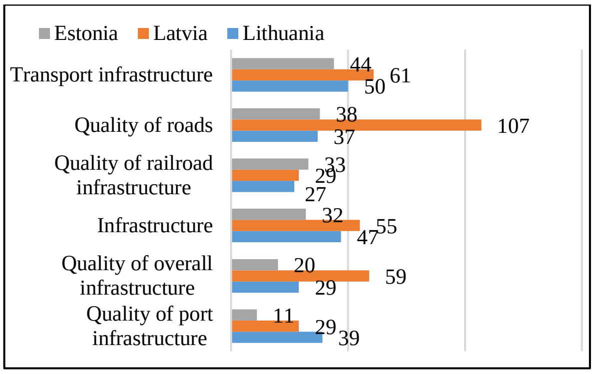


Source: Seaport authorities Annual reports, 2017

Figure 8: Financial efficiency of ports in 2017

The best financial performace of profitability fixed in Klaipeda (LT) seaport authority (Fig. 8). The difference between EBITDA and net profitability depends on country's tax policy. The lowest level of financial leverage is stated for the Klaipeda (LT)– 2%, and Gdansk (PL) – 0%. This level rate is discussed by economists, because small number of leverage can be provided by low level of investment of port, and to high level of leverage shows the appropriate level of financial risk. For port authorities indicator of return on equity (ROE) is useful for comparing the profitability with others. Best return on equity fixed in port of Tallinn (EE) and Gdansk (PL) - 11%.

According to the World economic forum, Latvia and Lithuania are in transition from stage 2 to 3, Estonia – in stage 3, innovation-driven economies group. The indicators of infrastructure clarify the difference between maritime transport sector indicators (Fig. 9).



Source: The Global Competitiveness Report 2017-2018

Figure 9: Infrastructure competitiveness index in 2017

The competitiveness of quality of roads and railways infrastructure of Lithuania is in higher position then other Baltic states, but the competitiveness of port infrastructure is at the lowest position (Fig. 9). Exceptionally high level of competitiveness, 11 position, is of the Estonian port infrastructure. To increase the competitiveness of port infrastructure, Lithuanian government decided to build an external deep-water port. The potential of the external port is 34-38 mio. tons of additional cargo to Klaipėda port (capacity of Klaipeda port is 60-80 mio. tons). The priority would be containerized cargo and oil products. Two variants of the use of an external port are considered: the formed territory and a tender for the operator or a concession variant.

Analysis the Eurostat (2018) data of 2014-2016 shows, that indicators of Lithuania in social exclusion, poverty and income inequality are distinguished by negative trends with a rising trend: the share of persons in the area of social exclusion and poverty in increased by 3%, while in Estonia it decreased by 3%, in Latvia it increased by 0.2%; the inequality income distribution indicator in Lithuania remains of the second largest in the EU – 7.5 (income quintile share ratio), indicator of Estonia 5.6, in Latvia 6.2 and it's characterized by a consistent downward trend. The part of the population by the low intensity of work, in Lithuania is more than 10%, in Latvia by 7%, in Estonia less than 6%, the proportion of people who suffer from external noise in 2012-2016 Lithuania and Latvia are more than 13% (Estonia 10%). The change in the indicator is due to the consistent development of national, EU and international environmental maritime transport. The positive impact of seaport activities can be illustrated by the Lithuanian municipal index – Klaipėda city and district are in the best position: business is active, it creates more and better paid workplaces, higher quality of life, less emigration.

4 CONCLUSIONS

1. The application of the principles of complexity theory makes it possible to analyze the seaport management in a 4D perspective, by assessing the efficiency of seaport governance in terms of productivity, efficiency, effectiveness, and taking into account the external political, economic social and technological conditions. On the basis of the principles of the new public administration and the theory of complexity, using the particularistic approach to the study of systems, it is evident, that results of the 4D model create preconditions to link the indicators of effective state-enterprise management with the indicators of logistic connectivity of the maritime transport sector in the multi-criterion integrated assessment model of logistic productivity, which can be used to assess the attractiveness of the maritime transport sector. The attractiveness of maritime sectors can be explained as the maritime transport competitiveness and its sustainability have impact to the formation of the country's competitiveness advantages.
2. Countries competitiveness indicators links on maritime sector economic indicators. Effective operation of the Baltic ports is likely to have a positive impact on the indicators of the social and ecological environment, but examples of social indicators form the opposite of the theoretical view. The social indicators of Baltic States are different and it is difficult to establish a direct link between state's strategic sector, seaport, development, and socio-economic development and quality of life. The infrastructure competitiveness of Baltic States is influenced by the infrastructure of the port. It is likely that the development of a deep-water port in Lithuania will increase the competitiveness of the country's infrastructure, seaport performance indicators, employment of the population, reduce social exclusion, but there is a danger of increasing pollution of the environment and separation of the seaside and the territory of the other country.

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CHANGING STABILITY PARAMETERS OF THE SHIP WHILE FLOODING COMPARTMENTS IN THE ASPECT OF MARITIME SAFETY

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ABSTRACT

The paper contains the computational stability issues after flooded ship's compartment. Watercrafts, especially warships, due to the tasks they perform, are exposed to fires. The main extinguishing agent used on ships is usually seawater, which in large quantities poses a threat to the ship's stability and subdivision. During the putting out of marine fires the ship's compartments are flooded with this extinguishing agent. A free surface effect appears after a partial submersion of the compartment. It has influence on the deterioration of the stability of the entire ship and in particular cases may lead to its sinking. The threat to the ship's stability is influenced by the flooding of high located compartments. Therefore, the main focus of the work was to determine the impact of the high-located ship compartment on the boat deck for the stability of the ship. The method of assumed mass and the algorithm of calculating the righting levers with respect to the free surface effect were used for the determination of stability parameters. The results of the calculations presented in the paper contain information about the amount of water in the range causing deterioration of the stability of the ship. Based on the results of the graphical calculations, appropriate conclusions were done.

Keywords: ship stability, angle of heel, safety of warship

1 INTRODUCTION

Increase in migration of people and in trade by sea have contributed to substantial increase in traffic on sea lanes and progress in technology has made it possible to build ships having big displacement. More than 80% of the world trade makes use of maritime transport, which has become one of the pillars of international trade. Apart from many advantages, this has created several hazards to safety in maritime transport and to natural environment.

Special role, having impact on maritime safety, is played by naval ships. Due to the nature of missions they carry out they are exposed to damage, fires and even sinking. A naval ship is a complex technical system whose combat capability depends on her reliability. The analysis of literature and maritime practice shows that even the best organized naval fleets suffer from accidents and ship malfunctions. They can be hazardous to lives and health of a ship crew or result in the ship's total loss.

Fire presents serious hazard to a ship when at sea. It results in her sinking rarely, however the left devastation is usually very serious and, as ever, depending on the level of the crew training in respect to the damage control plan. During peaceful operation of the combat vessel, short-circuits in electrical installations, failures of devices and mechanisms, self ignition of pure oxygen when contacted with petroleum materials and so on make most sources of fires. Seawater is usually the main extinguishing agent used on ships and high volumes of the water are hazardous to the vessel stability and subdivision. Therefore, in the paper, the main emphasis has been made on defining the impact of high located and flooded compartments on the ship stability safety. Results of calculations presented in the elaboration contain information regarding volumes of water in the compartments causing deterioration of the ship stability.

2 DEFINING STABILITY PARAMETERS OF THE SHIP

For Water broken into the vessel's hull and the flooded compartment or tank result in deeper draught of the ship, possible heel and trim as well as a change in her stability. The change may improve or aggravate operational conditions of the boat. In some case, lower stability may be serious enough to endanger safety of the ship and her crew as well as it may cause overturning of the vessel. To avoid accidents of such a kind, it is necessary to check stability of the damaged ship and apply appropriate remedial measures that would stop its lessening.

Flooding of high situated compartment or several compartments always results in aggravation of the vessel's stability. As a consequence, a heel or trim of the ship, change in the metacentric height and the righting levers may occur.

A vessel of standard displacement D for which a mass m is loaded in the point A (X, Y, Z) as in the Figure 1 [1,2,3] has been taken into consideration in the stability calculations.

At the beginning, acceptance of the mass was assumed so that to have its centre vertically above the centre of water-plane section's surface WO in the point A_1 (X_S, 0, Z). For this cause the draught increase and the new transverse metacentric height were calculated [1,2,3].

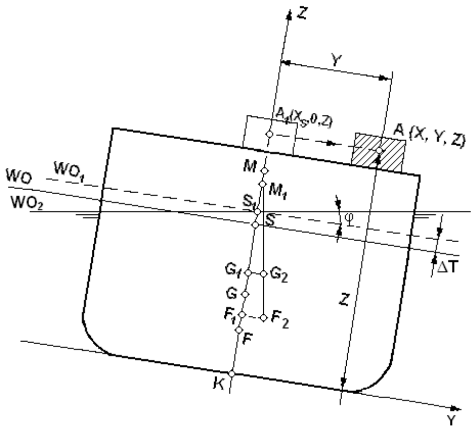

Figure 1: Scheme of the ship situation after acceptance of the mass m in the point A [1,2,3]

In the next step, the mass was moved from the imaginary position onto the place occupied in reality:

- towards the transverse direction by a distance of

$$e = Y - Y_1 = Y - 0 = Y,$$

- towards the longitudinal direction by a distance of

$$l = x - x_S.$$

Than, the angle of heel, the angle of trim and the new bow and stern draughts of the ship has been calculated.

For large angles of heel (above 7°), the ship stability is defined based on the righting lever curves (Reed's curve). This curve allows determining dimensions of the righting lever for any angle of heel of the given ship, at invariable displacement and position of the gravity centre.

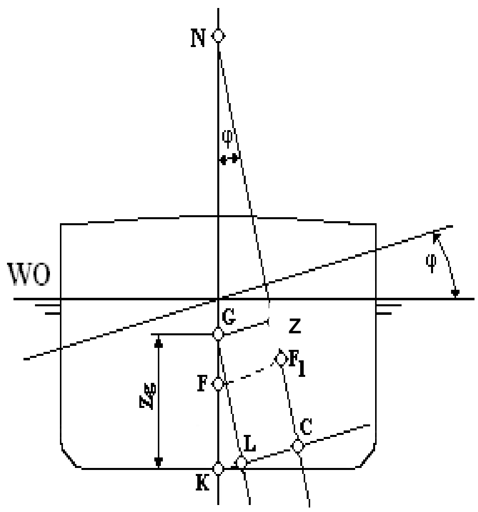

Figure 2: Righting lever of the form and weight *[3,12,13]*

Value of the righting lever $\overline{GZ}$ is determined with the following formula applied [3, 12, 13]:

$$\overline{GZ} = \overline{KC} - \overline{KL} \tag{1}$$

where:

$$\overline{KL} = Z_g \sin\varphi \tag{2}$$

Z_g the gravity centre height [m], $\overline{KL}$ – the weight stability lever [m], $\overline{KC}$ – the form stability lever [m].

The formula (1) may be presented in the following way:

$$\overline{GZ} = \overline{KC} - Z_g \sin\varphi \tag{3}$$

For the determination of the righting lever for any angle of heel it is necessary to know the form stability lever that changes depending on the angle of heel. This value is read from the so-called Pantecaren graph, which is developed during the design phase of the ship.

Reed's curve which is a graph of righting levers provides information about the basic parameters of the stability of the ship, such as:

φ GZmax – heeling angle at the maximum value of the righting lever occurs [deg],
GZmax – the maximum righting lever [m],
φr – the angle of vanishing stability [deg],
GM – the metacentric height [m].

3 IMPACT OF FREE SURFACE ON THE SHIP STABILITY

Presence of fluid free surface after partial flooding of compartment always results in reduction of the vessel's metacentric height. This decrease depends, among the others, on the shape and magnitude of this surface.
Receipt of liquid cargo on board of a ship, accompanied by occurrence of the free surface, has influence on change of position of the vessel gravity centre and thus on the metacentric height $\overline{GM}$. Hence usage of, for instance, larger quantities of water for fire-fighting purposes on upper decks results in shifting the boat's gravity centre up, and – if connected with occurrence of free surfaces – it may cause the loss of stability and overturning of the ship.

Impact of inertia moment derived from the free surface of the flooded compartment has been taken into account in the calculations of the metacentric height. It has been assumed that surface of the compartment under flooding is rectangular. The moments of inertia of the permanent constructional elements present in the compartment have been taken into consideration in calculations regarding the inertia moment of the entire body.

Influence of the free surface effect on the righting levers' curve (the Reed's curve) has been taken into account by implementing an allowance marked with an X symbol [1,2,3].

$$X = \left[y_{G1}(\varphi)\cos\varphi + z_{G1}(\varphi)\sin\varphi \right] \tag{4}$$

where:
$y_{G1}(\varphi)$ and $z_{G1}(\varphi)$ – constituents of shift of the vessel's mass centre, at the heel to the angle φ[m],

$$y_{G1}(\varphi)=\frac{\sum_{i=1}^{n} m_i\left[y_g(\varphi)\right]_i}{D} \tag{5}$$

$$z_{G1}(\varphi)=\frac{\sum_{i=1}^{n} m_i\left[z_g(\varphi)\right]_i}{D} \tag{6}$$

D – ship displacement together with liquid cargo [t],
m_i –mass of the liquid cargos in particular tanks [t],
$[y_g(\varphi)]_i$ and $[z_g(\varphi)]_i$ – constituents of shifts of the fluid gravity centres in the flooded compartments at the heel to the angle φ [m] [10]. These parameters have been calculated with a used of an elaborated computer programme. This software is adapted to calculate stability parameters for a floating structure of rectangular shape.
After defining the allowance from the free surface effect, the new GM is:

$$GM = G_1M_1 - X \tag{7}$$

Where:
GM – the metacentric height [m].
Based on the formula 7, the calculations and analyses of the vessel's metacentric height after flooding the ship compartment have been made.

4 CHARACTERISTICS OF THE RESEARCH OBJECT

The training vessel selected for the tests is a flagship of the training and research ships' wing of our fleet. This ship operates on different seas in hazard, changeable weather conditions where is the high propability it's damage. The analysis of damage stability after flooding high located compartments is necessary for the maritime transport safety. The boat is divided, with ten transverse watertight bulkheads, into 11 watertight compartments located on the frames: 3, 16, 25, 35, 50, 60, 71, 80, 91 and 101. Such division ensures maintenance of unsinkability when two neighbouring compartments have been flooded, excluding main engine room and adjoining compartment.

General characteristics of the vessel:

- main dimensions:
  - overall length: L_c = 72,20 m,
  - length between perpendiculars:L_{pp} = L = 64,20 m,
  - maximal breath:B_{max} = 12,00 m,
  - breath: B = 11,60 m,
  - height: H = 5,55 m.

The calculations have been made for load displacement and no icing. These conditions are characterized by the following quantities:

- displacement: D = 1745,34 t,
- ordinate of the mass centre from the main plane: z_G = 4,31 m,
- stern draft: T_R = 3,97 m,
- bow draft: T_D = 4,05 m,
- average draft: $T_{śr}$ = 4,01 m,
- trim: t = 0,08 m,
- metacentr height from the base plane:
- z_M = 5,44 m,
- metacentric height: GM = 1,13 m,
- speed: V =16,8 w
- coordinates of the mass centre:
  - x_G = 29,649 m from the after perpendicular,
  - y_G = -0,007 m from the plane of symmetry,
  - z_G = 4,314 m from the base plane [1].

Figure 3: Picture of the training vessel ***[9]***

5 RESULTS OF CALCULATION THE VESSEL STABILITY WITH FLOODED COMPARTMENT

The ship's stability calculations have been performed for two high altitude, flooded ship compartments. The first one was located at a height of 8,1m from the base plane. This range of dimensions: beam 8.67 m and a length of 36,78 m have the surface area, taking into account its equipment, equal to 188.5 m^2. The second compartment dimensions: beam 8.64 m and a length of 19,49 m was at a height of 10.2 m from the base plane. This compartment had a surface area, taking into account its equipment, even 147,6m^2. Both compartments during tests poured into previously established water height H = 0.1 m, H = 0.4 m, and H = 0.8 m. Stability calculation were conducted for both parameters: metacentric height and righting levers assuming flooding of compartments to the same water level H.

The results of the calculations of matacentric height and maximum values of righting levers taking into account the free surface effect of the considered amount of water in the range shown in the table 1 and Figure 4 and 5 *[7,8,9]*.

Table 1: Result of matacentric height calculation

H [m]	0,1	0,4	0,8
GM [m]	1,01115	0,7274	0,6587
G_1M_1 [m]	-0,2251	-0,4577	-0,4632

Table 1 presents the results of the metacentric height calculations before (GM) and after taking into account the free surface effect (G_1M_1) for the considered water level in the compartments.

A negative value of the metacentric height is already present when the compartments are flooded to a height of H = 0.1 m.
The dependence of the metacentric height GM and G_1M_1 on the water level inside a flooded compartments shows Figure 5.6.

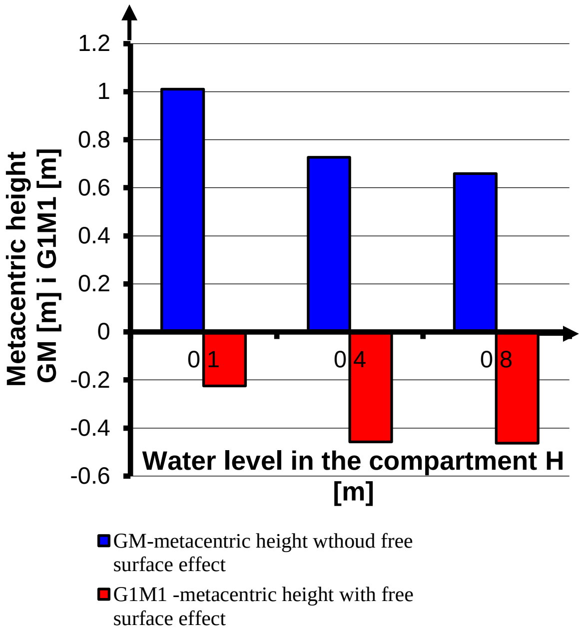

Figure 4: Result of metacentric height calculation depending on the water level inside a compartment *[9]*

The figure above shows that with the increase of the water level H in the compartments, the value of the metacentric height G_1M_1 decreases.

Figure 5 presents changes of righting levers (Reed's curve) as a function of the angle of heel of the ship for selected water levels in the flooded ship compartments.
The analysis of the results of righting lever calculations presented in the Figure 5 shows a clear decline in the value of the maximum righting lever depending on the water level in the flooded ship compartments. For the amount of water in the compartment H = 0.1 m the maximum righting lever had value GZ = 0.91 m. However, after increasing the level of water in the compartment to H = 0.8 m the maximum righting lever significantly reduced until the value to 0.04 m.

The angles of steady heel of the ship, resulting from flooding of the vessel compartment under discussion, amount respectively: φ_{S1} = 12° for the water level in the compartment equal H = 0,4 m and φ_{S2} = 40° for H = 0,8 m. The metacentric heights for these cases display negative values. But for the amount of water in the compartments H = 0.8 m the angle of vanishing stability reduced from approx. φr = 100º to approx. φr = 60 °.

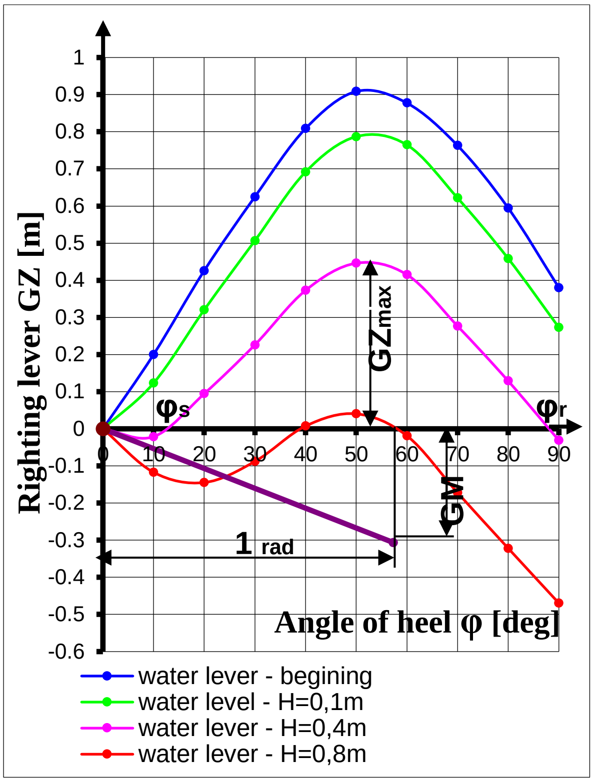

Figure 5: Influence of the amount of water in the compartment on the Reed's curve

6 SUMMARY

As a result of analysis of the ship's stability after flooding a high situated compartment provides the following conclusions:
Flooding of high located compartments results in:

- a reduction in a value of metacentric height,
- a reduction in a value of righting levers,
- a reduction in the angle of vanishing
- stability φr,
- an increase in a value of steady heel angle φ_S.

The analysis of changes in the stability of the ship shows, that the worst option is the simultaneous flooding of two compartments have to height

H = 0.4 m. It causes a loss of initial stability of the ship. The recovery of stability followed by an inclination of the ship equal φs = 12 °.

At the lower level of the water in the ship's compartments retains a positive initial stability.

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AIRPORT LANDSIDE SECURITY: FROM RECOMMENDED PRACTICE TO STANDARD

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ABSTRACT

The landside represents the area of the airport to which the wider public has unrestricted access to. Landside security is poorly regulated. Until recently, preventive security measures regarding airport landside were stated as a recommended practice in Annex 17 to the Convention on International Civil Aviation. However, following the terrorist attacks first of all in Brussels and then in Istanbul which happened on the airport landside, the necessity of substitution of security measures from recommended practice to standards was recognized. Approach to landside security differs from airport to airport. Regardless the lack of regulations dealing with mentioned subject, some airports are conducting certain security measures such as patrols and video surveillance.

In the context of landside security, the paper will analyze events that have led to changes in the regulatory aspect of airport landside security. The purpose of the paper is to investigate the current security measures with the aim of determining the scope and implementation possibilities of potential preventive security measures based on security risk assessment.

Keywords: Airport landside, regulation, terrorist attacks, preventive security measures

1 INTRODUCTION

Development of air traffic, technical and technological achievements and the level of service provided to all of the users, classify it as one of the largest contributors to the progression of modern society. Usage of aircraft as the primary mean of transport, i.e. air traffic as a primary transport branch, due to its characteristics is in constant growth. It is often a target of acts of unlawful interference, especially terrorist attacks, because of its influence on state's economic growth.

Terrorism is the intended use of unlawful violence or threat of illicit violence to embed fear with the intention of forcing or intimidation government or society to attain goals which are generally political, religious or ideological. There are multiple potential targets ranging from individual facilities (such as commercial buildings) to certain social, religious and political groups. Transportation facilities like airports, subways, train and bus stations are potential terrorist targets, not only because of their vital importance to stable economy and business activities of countless companies, but because they represent visible, easy accessible and prominent places where many people gather.

Primary target for carrying out acts of unlawful interference in aviation are airports. In 2016th, around 7.6 billion people were transported at world airports according to International Civil Aviation statistics [1] which implies the fact that airports generate a large number of passengers. High level of passenger traffic within the airports entails a certain level of vulnerability reflected in factors characterized by the state's status symbol, increased flow of passengers of different nationalities and, inter alia, security checks and screenings carried out on the boundary of surveilled and protected area.

Landside due to its characteristics (public accessibility and, accordingly, limitations in conduction of particular security measures) is considered as surveilled airport area. Preventive security measures related to landside were until recent expressed only as a recommendation.

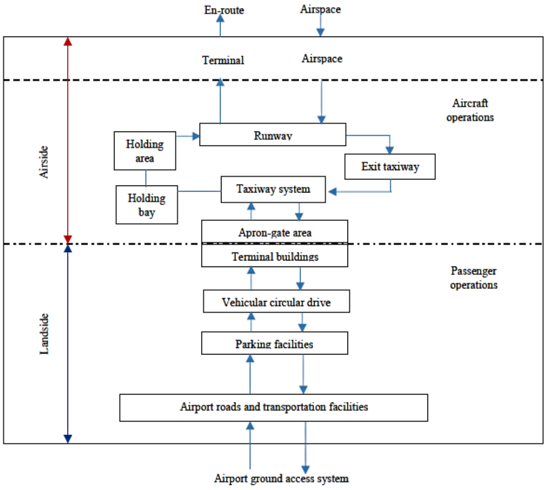
Terrorist attacks in Brussels and Istanbul in 2016th were committed at the landside. These events brought the airport security, especially the landside protection, to the focus of air traffic stakeholders, the governing bodies and media, and led to a turning point in protecting the areas with public access.

2 SPECIFICTY OF AIRPORT LANDSIDE SECURITY

Airports are usually divided into three areas: airside, landside and the terminal itself. Due to its position (both on airside as well as landside) and special requirements which are referring to it, the best way is to treat the terminal as a separate area.

Depending on the security level in each part of the airport, security areas are divided into the protected and the surveilled area.

The boundary between the protected and the surveilled area must be a physical obstacle clearly visible to the general public which prevents unauthorized access [2]. In terms of security and processes conducted within the passenger terminal, the boundary represents the first security checkpoint – passenger screening (figure 1).



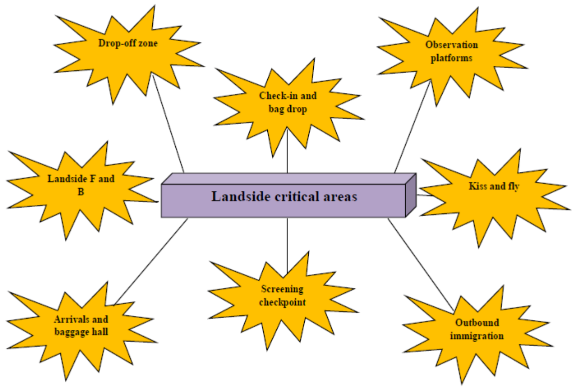
Source: http://web.engr.oregonstate.edu/~hunterzk/other/primer/ch2.html

Figure 1: Airside/Landside

Airport landside is an area to which a wider public has access to and a first contact point with the airport system for passengers. Landside encompasses common features of every airport: access roads, transport infrastructure, parking lots, buildings and other facilities not located on the airport airside. Landside facilities provide access to the terminal as well as to the airside to passengers and other people. Landside position is conditioned by the airside position and the boundaries of airport perimeter [3]. As the aforementioned facilities do not directly affect the aircraft operations, less stringent measures are applied within the landside then within the airside. Landside protection and overall security is hard to monitor due to public accessibility and limitations in implementation of specific security measures. Measures to be implemented must comply with local safety and security standards of the general public which can result in special requirements connected to the overall security system.

Passenger terminal is an integral part of the landside and it is considered to be an area of the airport with the highest security, safety and operational requirements arising from the close connection to security areas inside the terminal and in its immediate vicinity. Representing the boundary between the airside and the landside by the first security checkpoint, certain segments of the terminal must meet security criteria of both areas.

Passengers are subjected to two types of activities at airports – processing activities (passenger handling - registration and handing over the baggage) and leisure activities. According to [4], passengers spend around 40 minutes in average on the landside, of which 55% of mentioned time (22 minutes) spend in processing activities and the remaining 45% (18 minutes) in leisure activities. During peak loads and increased number of passengers, there is a distinct level of vulnerability present or weaknesses in applied measures and procedures which could be used for committing an act of unlawful interference. Vulnerability is particularly expressed in landside critical areas (figure 2).



Source: Hentschel, T., Neuser, M. (2017). Maintaining the Passenger Experience at Airports Under Increased Landside Security Requirements. Summary of a Research Study. TH Airport Consulting.

Figure 2: Landside critical areas

Serious threats such as improvised explosive devices may appear in those areas (whether it is considered to be a person or a vehicle as a carrier of a mentioned devices), vehicle as a weapon, firearms and any forms of chemical, biological and radioactive materials [5].

Although it is a surveilled area, the airports are carrying out some physical and technical security measures. Physical security measures include the installation of barriers and obstacles in the form of concrete pots, pillars, bollards and separation of parking lots from the terminal entrance. As a technical mean of security video surveillance is used and electronic detection and monitoring systems in case of landside border monitoring by electronic sensors. In addition, patrols and surveillance by airport officers are conducted.

The latest terrorist attacks in a difficult way gave insight into the delinquencies of the landside security, which resulted in not only the regulatory changes but also in the implementation of preventive security measures.

3 LANDSIDE SECURITY REGULATION

For a better understanding of terrorist attacks perpetrated on the landside, it is necessary to recognize the gap between the airside and the landside security. Fundamental document that provides standards and recommended practices regarding the aviation security at a global level is ICAO Annex 17 to the Convention on International Civil Aviation. At the European level, standards to be complied with by EU Member States are provided by Commission Implementing Regulation (EU) 2015/1998 laying down detailed measures for the implementation of the common basic standards on aviation security, together with the last update in 2017th - Regulation 2017/815. Standards incorporated in Regulation 2015/1998 are more detailed elaboration of standards and recommended practices of the Annex 17.

Annex 17 defines security restricted areas as „those areas of the airside of an airport which are identified as priority risk areas where in addition to access control, other security controls are applied. Such areas will normally include, inter alia, all commercial aviation passenger departure areas between the screening checkpoint and the aircraft, the ramp, baggage make-up areas, including those where aircraft are being brought into service and screened baggage and cargo are present, cargo sheds, mail centers, airside catering and aircraft cleaning premises"[6]. Basically, this definition does not cover the landside. In Regulation 2015/1998, the landside is mentioned only in the context of borders with the airside and conduction of patrols and surveillance.

Until recently, preventive security measures relating to landside were stated only as a recommended practice indicating the establishment of preventive security measures in accordance with risk assessment carried out by relevant national authority. Following the tragic events in Brussels and Istanbul, recommended practices have been translated into standards since 2017th. Standards of the revised version of the Annex 17 imply that every Member State shall [6]:

- identify the landside areas,
- ensure that security measures are established for risk mitigation and prevention of possible acts of unlawful interference in accordance with risk assessment carried out by relevant national authorities,
- ensure coordination of landside security measures in accordance with standards between relevant departments, agencies, organizations of the State and other entities,
- identify appropriate responsibilities for landside security in its national civil aviation security programme.

The applicable standards and recommended practices from the scope of the ICAO are summarized in the Doc 8973 – Aviation Security Manual, which is restricted due to sensitivity of contained data. New and updated guidelines related to unpredictability, behavioral detection techniques, landside security and screening of people other than passengers are covered by this manual. Standards and recommended practices are the baseline for all preventive security measures but they cannot be applied equally to each Member State. Each state has to develop its own regulations, practices and procedures through the National civil aviation security programme by adjusting the important elements of the programme on the basis of incessant assessment of the level and nature of threats and overall risk to the civil aviation on its territory and the associated airspace [6].

Besides the programme on a national level, each airport must have its own security programme within which the definition of a landside and the comprehensiveness of measures applied are construed by National civil aviation security programme.

4 OVERVIEW OF THE ACTS OF UNLAWFUL INTERFERENCE COMMITTED ON THE AIRPORT LANDSIDE

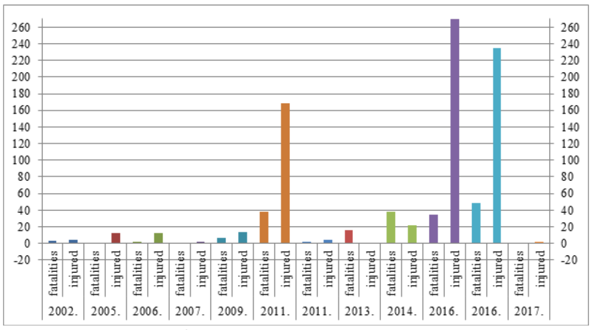
Acts of unlawful interference are defined by the International Civil Aviation Organization and three Conventions – Tokyo, Hague and Montreal which form an aviation criminal justice system identified as the beginning of the anti-terrorist legislation [7]. Acts of unlawful interference are acts or attempts of jeopardizing civil aviation safety and include but are not limited to [6]:

- „unlawful seizure of aircraft,
- destruction of an aircraft in service,
- hostage-taking on board aircraft or on aerodromes,
- forcible intrusion on board an aircraft, at an airport or on the premises of an aeronautical facility,
- introduction on board an aircraft or at an airport of a weapon or hazardous device or material intended for criminal purposes,
- use of an aircraft in service for the purpose of causing death, serious bodily injury, or serious damage to property or the environment,
- communication of false information such as to jeopardize the safety of an aircraft in flight or on the ground, of passengers, crew, ground personnel or the general public, at an airport or on the premises of a civil aviation facility".

Acts on unlawful interference are the instrument deliberately used by terrorists in order to achieve their goals, imbedding fear with the intention of forcing or intimidating government or society. Aviation terrorism has been present since its very beginnings where airports have emerged as easy targets because of their public accessibility (at least partial) and status symbol, making them the preferred targets. Over the years, perpetrators have used various methods of airport attacks, from mass killings using bombs, improvised explosive devices and automatic firearms to homemade improvised explosive devices without hurting anyone. Airport attacks can be characterized as the replacement of aircraft attacks (such as hijacking) which is a simpler way of expressing political stance without exposing to risk. According to [7], attacks within the passenger terminal, especially near the check-in and certain offices, may be considered as symbolic attacks indicating which specific aircraft and states would terrorist attack if security measures were less stringent.

Until recent, quite attention has been given to terrorist attacks committed on the airside which is the reason why security measures have been greatly altered and became stricter trying to reduce the potential risks and maintain a desirable level of safety. Attacks did not just occur on the airside but on the landside as well. Figure 3 shows the landside attacks committed in the period from 2002 until 2017, with the number of fatalities and severely injured.

The attacks were committed by terrorist individuals, terrorist and extremist groups.



Source: University of Maryland, Global Terrorism Database 2002 – 2017

Figure 3: Attacks on the airport landside committed in the period 2002 – 2017

Targets of the attacks by years with the number of fatalities and severely injured are shown in table 1.

Table 1: Landside attacks targets with the number of fatalities and injured people

Year	Target	Type of attack	Fatalities / injured
2002	LA International airport	armed assault	3/4
2005	Thai Hat Yai airport	bombing / explosion	1/12
2006	Madrid Barajas airport	bombing / explosion	2/12
2007	Glasgow airport	armed assault	1/2
2009	Kandahar airport	bombing / explosion	7/14
2011	Domodedovo airport	bombing / explosion	38/168
2011	Frankfurt airport	spree shooting	2/4
2013	N'Djili airport	armed assault	16/1
2014	Jinnah International airport	armed assault; bombing / explosion	38/22
2016	Zaventem airport	bombing / explosion	35/270
2016	Istanbul Atatürk airport	bombing / explosion	48/235
2017	Paris Orly airport	armed assault	1/2

Source: University of Maryland, Global Terrorism Database 2002 - 2017

The 2011 attack on the Domodedovo airport left many victims and fatalities behind. Executed by the extremist Islamic army, the Caucasian Emirate, it is the first attack on the airport landside that left a mark in the number of casualties and fatalities [8]. After that event, security checks of people present in the landside area were implemented. The majority of Russian airports imposed additional security measures. Despite the aforementioned, the turning point in adopting standards and defining landside preventive security measures were are the attacks that took place in 2016 – in Brussels and Istanbul. These events led the airport security, especially landside security, to the focus of all stakeholders in air traffic, governing bodies and media.

Bombings that took place in Brussels in March 2016 are the deadliest act of terrorism in the history of Belgium. Three coordinated bomb attack actions happened – two at the airport and one at the metro station in the city center. In the airport attack, 35 people (including perpetrators) were killed and 270 were injured. Two suicide bombers, carrying bombs in their hold baggage activated them in terminal lobby in front of check-in. The third suicide bomber was prevented by the force of previous explosions from the intention of activating the bomb. The remaining bomb was found during the airport search and destroyed in controlled conditions [8]. The airport was closed for traffic for 12 days.

The Istanbul attack, which was at the same time a suicide and firearms attack, happened the same year just three months after the Brussels bombing. Improvised explosive devices and firearms assault was committed by three people and after the explosion four more people were seen running from the parking lot in front of the airport [8]. Duration of the attack and gunfire between armed perpetrators and police was around 90 seconds. In Istanbul attack, 48 people were killed while 235 were injured [8]. Both attacks (in Brussels and Istanbul) are attributed to the Islamic State.

These attacks influenced not only the states concerned, but also the other European states. They have resulted in auditing of the former preventive measures at airports by national authorities across the Europe and the implementation of more stringent and additional security measures. Consequently, Zaventem and Istanbul Atatürk airport implemented additional measures. Additional security checkpoints are implemented at Zaventem airport in the form of travel documents check as it is considered, who does not have a proper travel document, does not have a reason to be inside the passenger terminal. Istanbul Atatürk airport made access control stricter, intensified video surveillance and worked on coordination of the airport communication channels. Security checkpoints are guarded by specially trained personnel and so – called security culture is initiated (reporting of suspicious circumstances to competent bodies) [9].

5 PROPOSAL OF GUIDELINES FOR LANDSIDE SECURITY IMPROVEMENT

All regulations, practices and procedures as well as preventive security measures that states adopt in their National civil aviation security programme are based on security risk assessment. Security risk is an objective probability of an event with unwanted or harmful outcome caused by an action or its absence. It is necessary to distinguish defined and undefined risk during its assessment. Defined risk is a risk type for which perpetrators and their targets are known and accordingly, specific intensified measures are applied in a given time period. Undefined risk is more complex risk type because, as the name itself insinuates – perpetrators, their targets and the time of the attack are unknown which requires the need for permanent and intense security measures. Speaking of acts of unlawful interference, they represent undefined risk requiring continuous application of security measures.

In the risk assessment methodology, it is necessary to evaluate the level of threat. The term threat does not have the same meaning as the term risk. Threat is quantification of probability/possibility of an attack on a specific target, or perpetration of acts of unlawful interference [10]. Since the threat is a possibility of attacking specific target, to evaluate the danger on a national level, referent factors must be examined such as the presence of terrorist groups on the state's territory, organized crime, radical ethnic groups, religious sects and any sort of current conflicts [10]. For a complete risk assessment, vulnerabilities have to be analyzed (weak points in applied measures and procedures which could be used for committing the acts of unlawful interference).

Following means are stated as the most significant threats to airports and aircraft [11]:

- improvised explosive devices on vehicles (in public areas),
- small improvised explosive devices (in public areas),
- suicide bombers in surveilled terminal area,
- shootings inside the protected and surveilled area,
- small improvised explosive devices in hold baggage,
- suicide bombers on board the aircraft,
- hijackers,
- MANPADS[1].

Landside security measures applied at individual airports largely depend on the level of risk present in the state territory where airport is located. Regardless the fact that in some airports acts of unlawful interference did not happen, it does not mean that certain dose of risk is not present. The risk is omnipresent, although its level may be low which has to be taken into account when conducting preventive security measures.

For the landside protection, it is necessary to clearly define the boundaries of the protected and surveilled area in order to determine the extent of implementation of security measures. Measures to be applied must be flexible in terms of adaptation to potential threats and emerging situations. Strengthening of already existing capacities – enhancing video surveillance and security measures inside the terminal, police patrols and random security checks of passengers and their baggage can contribute to security reinforcement. Behavioral detection techniques and passenger profiling are methods which have been used for a long time but with a quality staff training only for that purpose and the implementation of such measure, attacker's intentions can be detected in a timely manner. Biometric passenger identification and biometric system of self-handing the baggage not only accelerate the process, but a visual trace of passengers also remains thus considerably increasing safety.

In the terms of physical protection of the landside, protection can be carried out through security-by-design concept. An approach which can reduce risk in all aspects and parts of the airport processes through risk-based security infrastructure design. Landside can physically be protected by:

- using blast proof infrastructure (explosion venting walls, anti-terrorist shelter, anti-terrorist screens, blast proof portals),
- bollards and structures to prevent drive-in attacks (hydraulic and static),
- terminal fitting put and furniture (based on risk assessment),
- enhanced lighting in vulnerable areas,
- automatic license plate recognition,
- stand-off explosive detection and mass transit metal detection equipment.

Enhanced access control through additional security checkpoints for examining vehicles and checkpoint for passenger screening at the terminal entrance could be used as supplemental security measures.

6 CONCLUSION

Air traffic safety has always been a priority of governing bodies, leading aviation organizations and all traffic stakeholders. Although safety can be reduced on a desirable level, a certain amount of threats and risks from terrorist attacks is always present which can disrupt the aforementioned safety. With security, whose primary purpose is to preserve safety of civil aviation by combination of measures as well as human and material resources, the stated threats and risks are striving to be minimized. Nevertheless, this may be a challenge regarding the innovativeness of the methods used by terrorists to commit acts of unlawful interference.

The acts of unlawful interference are present in aviation since its very beginnings. As the attack methods were changing over time, the preventive security measures have been developed accordingly. Greater attention was devoted to terrorist attack committed on the airside because of the consequences they have left behind. The attacks occurred in the landside also, but with a lesser number of fatalities and casualties. However, the 2011th attack and particularly the 2016th attacks left many victims and fatalities behind which influenced the contemplation of landside security.

Airport landside is specific and because of its features (public accessibility) and security measures currently being carried out is considered as surveilled area. It is necessary to clearly define boundaries between security areas and to identify the landside area. Landside security can be increased by application of physical and technical measures but the scope of the security measures to be

[1] MANPADS – Man-portable air-defense system

applied differs from the airport to the airport. There are no universal measures equally applicable to all. The situation within each state is different and the implementation of measures depends on the risk level present on the state's territory.

Continuous threats of the acts of unlawful interference can be efficiently managed by identification, understanding and solving the potential risk to the overall air traffic or its segments (passengers, baggage, cargo…). Assessments of national or local sources together with the overall risk factors provide important and useful information on potential attacks, targets, types and methods of their execution. Responsibility of each state is to make own risk assessment which is present on its territory and establish appropriate measures for its mitigation (which is eventually assigned by Annex 17). All security measures, including those related to the landside, are therefore implemented on the basis of threat and risk assessment and contained within the National civil aviation security programme.

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A DECADE A DECADE OF THE MONTENEGRIN MARITIME LEGISLATION

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ABSTRACT

In this paper, author presents the Montenegrin maritime legislation in the period from 2007 to 2017. Firstly, she points out the institutional organization of maritime administrations in Montenegro (MNE) and then gives a short overview of MNE position in relevant international maritime organizations. The author also pays special attention to the relationship of national legislation with the international maritime conventions and acquis communautaire of the EU. The central part of the paper is an overview of the activities of the Montenegrin legislator in the adoption of maritime regulation in the context of the integration of MNE into the European maritime framework and its better integration into contemporary international trends.

Keywords: Maritime legislation, Montenegro, adoption of international regulations

1 INTRODUCTION

Montenegro is a state with surface area of 13.812 km^2, sea area of 4.800 km^2 (internal waters and territorial sea), and a very attractive coast stretching toward the South of the Adriatic Sea, with 293.5 km in length. Although at this moment its fleet is not big, Montenegro is a maritime country with a long maritime tradition. Looking back to the previous period, namely last twenty five years, a completely different impression is gained. In 1988, Montenegro had 44 ships owned by two reputable companies: "Prekookeanska plovidba" from Bar and "Jugooceanija" from Kotor. Both companies continuously performed very well, and produced a considerable profit to Montenegro and the former Yugoslavia as well.[1] However, a general political situation caused Montenegro to remain without its maritime fleet and any merchant ship.

Twenty years later, a once respected maritime country Montenegro intends to renew its maritime fleet and starts from the beginning. The country is aware that numerous activities should be undertaken and that a long and difficult path is before it in order to make its maritime industry reanimated at least to some extent. Surely, the prerequisite for the creation of a favourable environment for the development of maritime industry is the setting up of clear legislative framework which is to comply with applicable international standards and conventions, on one hand, and EU *acquis communautaire*, on the other. Following 2006, when Montenegro became the member of IMO, it increasingly became committed to the implementation the maritime legislative project in as better way as possible. The purpose of this project is the ratification of numerous international conventions and its application in the Montenegrin legislation and practice.

2 MARITIME ADMINISTRATION OF MONTENEGRO

A special significance in legislative reforms is attributed to well-organized institutional framework in the field of maritime affairs. The maritime administration of Montenegro has been set up using as a model the structure which existed in the former state. The Ministry of Transport and Maritime Affairs is an overarching institution in Montenegro in charge of maritime transport. Within the Ministry, there is the Directorate for Maritime Transport under which Harbour Master's Offices[2] and Maritime Safety Department[3] fall.

The Ministry of Transport and Maritime Affairs performs activities related to maritime transport, safety and security of sea-going navigation, security protection of merchant ships and ports for international transport; prevention and taking of emergency measures in case of sea pollution from vessels etc.

Harbour Master's Offices are in charge of (responsible for): keeping register books, acquisition of competences by the crew members, inspection over ships and other waterborne crafts (in terms of their seaworthiness, the condition of their plants, devices, instruments, apparatuses and equipment, as specified in the documents issued by competent authorities), inspection over crew members of ships and other waterborne crafts (in terms of their number, capacity and authorisation to perform certain duties and operations in compliance with loading documents),

[1] At the time, the merchant fleet of the former Yugoslavia took the 27th place in the world in terms of ship tonnage, according to the ranking list of the Lloyd's of London. It has been estimated that 27 ships of „Jugooceanija" of around 900.000 tons of carrying capacity produced profit for Montenegro in the amount up to 100.000 million dollars.

[2] In Montenegro, there are two Harbour Master's Offices: Harbour Master's Office Bar and Harbour Master's Office Kotor with Harbour Branch Offices in Ulcinj, Budva, Virpazar, Tivat, Zelenika and Herceg Novi.

[3] The maritime-management bodies have been set up in compliance with national legilslation of Montenegro. Article 18 of the Decree on the Organization and Manner of Work of the State Administration ("Official Gazette of MNE", No. 5/2012) defines the scope of their operation.

maintenance of order in ports and other parts of coastal sea, carriage of persons and goods by sea etc.

The Maritime Safety Department[4] is in charge of activities related to navigation safety in the coastal sea of Montenegro, issuance of certain documents and certificates to Montenegrin ships, organization and performance of maritime search and rescue action, protection of sea against pollution from waterborne and floating crafts etc.

Of particular importance is normative-legal activity of these institutions, which includes: preparation of laws and by-laws falling within their field of competences, incorporation of international conventions into national legislation, harmonisation of laws and by-laws with international standards and EU regulations, ensurance of implementation and monitoring of laws and by-laws in the field of maritime transport etc.

All these institutions participate in the work and cooperate with international bodies and organizations in the field of maritime transport.

3 MONTENEGRO AND INTERNATIONAL ORGANIZATION

Under the Constitution of Montenegro, Montenegro shall cooperate and enter into regional and international organizations, based on the principles and rules of international law.[5] In this sense, Montenegro is a member of numerous international organizations. From the aspect of maritime traffic, of particular importance is its membership of International Maritime Organization (IMO), a specialised agency of the United Nations in charge of adoption of international maritime legislation. We are not wrong if we say that this organization, in terms of its normative activity, is one of the most active ones among similar organizations and agencies acting within UN, being in charge, among the other things, of safe navigation. Montenegro became its member on 10 October 2006.

Following the accession to IMO, Montenegro (or, more precisely, its Government) submitted an official communication (successor declaration) to the General Secretary of IMO, informing him that Montenegro accepts certain international conventions and protocols of IMO, as well as the rights and obligations arising from them. As a member of IMO, Montenegro is a party to the most important international conventions such as: The International Convention on Load Line (LL), 1966; The International Tonnage Convention, 1969; The International Regulations for Preventing Collisions at Sea (COLREG), 1972; The International Convention for Safety of Life at Sea (SOLAS), 1974/1978; The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978; The International Convention on Maritime Search and Rescue – SAR 1979. In relation to sea pollution MNE is a member of the following Conventions:UN Convention on the Law of the Sea (UNCLOS 1982); International Convention relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969 (INTERVENTION l969); Protocol to the International Convention relating to Intervention on the High Seas in Cases of Pollution by Substances other than Oil, 1973, as amended (INTERVENTION PROT 1973); Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, as amended (LC 1972); International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL, 1973) as modified by the Protocol of 1978 relating thereto, and its Annexes from I to VI (MARPOL 73/78); Convention concerning Minimum Standards in Merchant Ships, 1976., In 2011, MNE ratified following treaties: International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004. (Official Gazette of MNE — International Treaties, No. 7/2011); International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001. (Official Gazette of MNE — International Treaties, No. 7/2011); International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001. (Official Gazette of MNE — International Treaties, No. 7/2011); International Convention on Civil Liability for Oil Pollution Damage,1992. (Official Gazette of MNE — International Treaties, No. 7/2011); International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1992. (Official Gazette of MNE — International Treaties, No. 7/2011); Protocol of 2003 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Official Gazette of MNE — International Treaties, No. 7/2011); International Convention on Liability and Compensation for Damage in connection with the Carriage of Hazardous and Noxious Substances by Sea,1996. (Official Gazette of MNE — International Treaties, No. 7/20 11).

Montenegro became the member on 14 July 2006. of the International Labour Organization – ILO, and, by means of successor declaration, adopted numerous ILO Conventions.[6] Of particular importance is Maritime

[4] Maritime Safety Department comprises the following organizational units: Technical Inspectorate for Vessels Division, Division for the Prevention of Sea Pollution from Vessels, Marine Telecommunications Division, Maritime Search and Rescue Division, Aids to Navigation Division, Register of Yachts Division, and Administration, Finance and Technical Maintenance Division.

[5] Article 15 para.1 and 2 of the Constitution of Montenegro *"Official Gazette of Montenegro"*, No. 1/2007.

[6] The Conventions are as follows: C No.8 Unemployment Indemnity (Shipwreck) Convention, 1920; C No. 9 Placing of Seamen Convention, 1920; C No. 13 White Lead (Painting) Convention; C No.16 Medical Examination of Young Persons (Sea) Convention, 1921; C No. 17 Workmen's Compensation (Accidents) Convention, 1925; C No. 22 Seamen's Articles of Agreement Convention, 1926; C No. 23 Repatriation of Seamen Convention, 1926; C No. 27 Marking of Weight (Packages Transported by Vessels) Convention, 1929.; C No. 53 Officers' Competency Certificates Convention, 1936; C No. 56 Sickness Insurance (Sea) Convention, 1936; C No.69 Certification of Ships' Cooks Convention, 1946; C No. 73 Medical Examination Seafarers Convention, 1946.; C No. 74 Certification of Able Seamen Convention, 1946.; C No. 91 Paid Vacations (Seafarers) Convention (Revised), 1949; C No.92 Accommodation of Crews Convention (Revised), 1949; C No. 113 Medical Examination (Fishermen) Convention, 1959; C No.114 Fishermen's Articles of Agreement Convention, 1959.; C No. 119 Guarding of Machinery Convention, 1963; C No. 126 Accommodation of Crews (Fishermen) Convention, 1966; C No. 136 Benzene Convention,

Labour Convention (MLC), which was ratified by Montenegro in December 2014.[7]

4 RELATION BETWEEN INTERNATIONAL AND NATIONAL LAW

The 2007[8] Constitution of Montenegro stipulates that "The ratified and published international agreements … shall make an integral part of the internal legal order of Montenegro, shall have the supremacy over the national legislation and shall apply directly when they regulate relations differently than the national legislation".[9] Based on the above, it can be concluded that international and national law make an integral part of the legal order of Montenegro, with supremacy of international conventions over national legislation. Accordingly, all maritime conventions which have been accepted and ratified became a part of the legal order of Montenegro and have supremacy over the national legislation.[10] The Parliament of Montenegro adopts a law on ratification of an international convention. By entering into force of such law, the convention becomes an integral part of the legal order of Montenegro.[11]

The Constitution of Montenegro, and that is a general principle as well, clearly specifies that all national regulations, including maritime regulations, have to be compliant with accepted international conventions.[12] The Constitutional Court of Montenegro is the institution authorised to examine the compliance of laws with ratified and published international treaties, this falling with its scope of action. In case the Constitutional Court ascertains that a law is not compliant with international conventions, it shall pass a decision thereon. The law becomes repealed on the day of the publication of the decision.[13]

5 MARITIME LEGISLATION OF MONTENEGRO

Following the recovery of its statehood in 2006, Montenegro set up a legislative framework in the field of maritime affairs. Firstly, Montenegro incorporated the non-amended Law on *Maritime and Inland Navigation (LMIN)*[14] *into its own legislation but, concurrently, started a very difficult and serious legislative reform in the field of maritime law. The question which arose at the very beginning was how to regulate the subject of maritime law conceptually: to adopt a separate law on maritime navigation and a separate one on inland navigation or to make the existing LMIN compliant with conventions and law of EU in those aspects where it has not been harmonised*, or to adopt new laws that conceptually differ from the existing LMIN.

Unlike the former member states of Yugoslavia, Croatia and Slovenia, which started the development of maritime-legal framework by separating maritime and inland navigation and adopted separate laws in these fields, Montenegro opted for a different approach oriented to adoption of several laws which separately regulate specific fields of maritime law. The provisions of LMIN which related to the subject in question repealed with effect from the date of entry into force of separate laws.

While creating the legislative framework, and given the strategic commitment of Montenegro to EU integration, the *acquis communautaire* of EU was taken into consideration, on one hand, and relevant international instruments, on the other. Given the subject matter of regulation, the majority of laws required the transposition of numerous EU directives and contemporary international solutions. Since 2006, Montenegro adopted the following laws: the Law of the Sea[15] and Law on Yachts in 2007[16], Law on Ports[17], Law on Marine Fisheries and Mariculture in 2009[18], Law on the Prevention of Sea Pollution from Vessels in 2011[19], Law on Maritime Navigation Safety[20] and Law on Security Protection of Ships and Ports from 2016.[21] Although the above laws regulate different maritime fields, hardly can one of them be considered separately, without taking into consideration legal solutions from other laws

In terms of regulating the coastal region of Montenegro, the Law on Coastal Zone from 1992[22] still prevails. Despite the attempts to adopt a new legislation in this field, the new Law on Coastal Zone has not been adopted up to date (10

1971; C No.148 Working Environment (Air Pollution, Noise and Vibration) Convention, 1977; C No.162 Asbestos Convention, 1986.

[7] The Convention has been ratified and now is entirely a part of the Montenegrin legislation. This was published in the Official Gazette of international treaties No. 13/2014, which entered into force on 3 February 2016 – according to the official ILO web page.

[8] Article 9 of the Constitution of Montenegro.

[9] Under the Law on Conclusion and Enforcement of International Treaties („Official Gazette of MNE," No.77/2008.), ratification implies the adoption of the law declaring the acceptance of Montenegro to be bound by an international treaty.

[10] What could arise a dilemma (in some fields, but certainly not in the field of maritime safety) is the wording of Article 9 of the Constitution of Montenegro, which relates to direct application of international conventions. The literal interpretation of the above provision makes one conclude that international conventions will directly apply only if it is previously proved that "they regulate relations differently than the national legislation" thus leaving the space for different interpretation in terms of their direct application if a national law does not regulate a relation or an issue at all. However, despite this conclusion, the existing provision of Article 9 of the Constitution of Montenegro must not arise any doubt when it comes to application of accepted international conventions in the field of maritime safety if one bears in mind the necessity of their strict application, without any limitation, by any state.

[11] Article 82 item 17 of the Constitution of Montenegro.

[12] Article 145 of the Constitution of Montenegro.

[13] Article149 para.1.item 1 and 152 para.1 of the Constitution of Montenegro.

[14] "Official Gazette of the FRY", Nos.12 / 98, 44/99, 74/99 and 73/2000.

[15] "Official Gazette of the RMNE ", Nos.17/07 and 6/08.

[16] "Official Gazette of the RMNE ", Nos.46/07, 73/10, 40/11 and 42/15.

[17] "Official Gazette of the RMNE ", Nos.51/08, 40/11 and 27/13.

[18] "Official Gazette of the RMNE ", Nos. 56/09 and 40/11.

[19] "Official Gazette of the RMNE ", Nos. 20/11 and 27/14.

[20] "Official Gazette of the RMNE ", Nos. 62/13, 06/14 and 47/15.

[21] "Official Gazette of the RMNE ", No.53/16.

[22] In addition to the Law, the present legislation on the coastal zone of Montenegro is comprised of the following by-laws: Decree on the Establishment of the Public Enterprise for Coastal Zone Management, Decision on the Conditions, Duration and Charge for the Utilisation of the Coastal Zone, and Rulebook on the Development and Maintenance of the Costal Zone Cadastre.

February 2018). Montenegro has not yet experienced the acute need for adoption of maritime-property law. As a result, the LMIN still applies in this respect. The adoption of the new law which is to regulate contract and tort relations and legal relations in maritime traffic, contracts on utilisation of sea-going ships, actual rights on the ship, ship mortgage and privileges, ship registration etc. is expected in the foreseeable future.

The sea and submarine areas of Montenegro have been regulated by the Law of the Sea. This Law defines the sea and submarine area of Montenegro, the inner boundaries in the sea, as well as the procedure of ship detention and hot pursuit. The Law incorporates the rules of international law with a special emphasis on the United Nations Convention on the *Law of the Sea from 1982*[23] *and* Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean – the so called *Barcelona Convention – adopted in 1976*.[24]

The Law on Yachts creates a user-oriented legal framework for the development of nautical tourism in Montenegro. This Law at one place regulates registration, navigation, stay and rental of yachts in the waters of Montenegro. Although international conventions do not apply to yachts (the so called *non-SOLAS ships*) but, instead, national regulations apply, the Law expressly species that a yacht entered into the Montenegrin register, as well as a foreign yacht staying in the waters of Montenegro, has to meet the requirements stipulated in the provisions of SOLAS and STCW Convention in the manner defined by the Montenegrin regulations.[25] The application of solutions contained in other regulations such as the Law on Safety of Maritime Navigation, Law on the Prevention of Sea Pollution from Vessel etc. is particularly emphasised during the implementation of the Law on Yachts. The Law on Yachts has been harmonised in particular with the Directive 94/25/EC of the European Parliament and of the Council of 16 June 1994 on the approximation of the laws, regulations and administrative provisions of the Member States relating to recreational craft and Directive 2003/44/EC amending the previous Directive.[26]

The port sector of Montenegro has been primarily regulated by the Law on Ports, which regulates the legal status and classification of ports, management, charges, concessions, order and inspection, as well as other questions of importance for the ports in Montenegro. This Law incorporates the solutions of numerous international conventions and codes (SOLAS, MARPOL, Bunkers Convention, Barcelona Convention, ISPS Code, IMDG Code). A special attention was paid to the transposition of Directive 2005/65/EC on enhancing port security and Directive 2001/96/EC establishing harmonised requirements and procedures for the safe loading and unloading of bulk carriers. Despite amendments to the Law made in 2011 and 2013, there is a need to further amend this Law in terms of resolving property-legal issues, regulation of facilities of coastal infrastructure, regulation of cession of rights to construction and use of ports and other facilities of coastal infrastructure.

The Law on the Prevention of Sea Pollution from Vessels regulates the manner of prevention of sea pollution from vessels which sail or are located in internal waters and territorial sea of Montenegro, responsibility and compensation of damage in case of pollution, waste reception and management in ports, seaworthiness, materials prohibited from discharging into the sea, introduction of obligation to apply anti-fouling substances. The Law prohibits and sanctions deliberate dumping and incineration of waste and other materials, and stipulates the communication procedures to be observed while ships enter and leave the ports of Montenegro. The Law particularly emphasises the importance of ballast water management through the manners and procedures for replacement of ballast waters on ships which enter the internal waters and territorial sea of Montenegro. The work on the adoption of the Law lasted seven years. Until its adoption, the field of protection of sea against pollution form vessels had not been regulated by separate legislation. This Law has been made compliant with numerous legal instruments in the field of protection of marine environment: AFS 2001, Ballast Water Management 2004, BUNKERS 2001, CLC 1969. - Protocol 1992, FUND 1971. - Protocol 1992, HNS 1996, LDC 1972. - Protocol 1996, MARPOL 73/78, OPRC 1990, OPRC/HNS Protocol 2000, Directive 2002/59/EC of the European Parliament and of the Council establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC, Directive 2000/59/EC of the European Parliament and of the Council on port reception facilities for ship-generated waste and cargo residues, Resolution MEPC 2(VI), Resolution MEPC 159(55), Resolution MEPC 83(44).

A special attention has been paid to the adoption of the Law on Safety of Maritime Navigation, which regulates the conditions to be observed by maritime crafts, crew and waterborne crafts which sail in internal waters and territorial se of Montenegro, with respect to safety of maritime navigation and other questions ensuring the safety of navigation. The Law comprises sixteen parts and its provisions regulate different aspects of safety. Given the

[23] Montenegro ratified UNCLOS Convention on 23 October 2006.

[24] Montenegro ratified the Barcelona Convention in 2007. The Law on Promulgating the Law on Ratification of the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its four Protocols (»Official Gazette of the RMNE« No. 64/07). The Protocols are as follows: Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea, Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities, Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean, as well as the Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal.

[25] Article 34 of the Law on Yachts.

26 The Directive 2013/53/EU on recreational craft and personal watercraft was adopted on 20 November 2013, repealing the Directive 94/25/EC. Consequently, the new Directive has to be taken into consideration while amending the Law on Yachts in future.

subject of the Law, numerous Conventions, Codes and Directives had to be incorporated into the Law. Despite attempts to transpose certain Directives into the Law as much as possible, the majority of Directives have been partly incorporated whereas their full incorporation will be achieved by adoption of by-laws. Up to date, Montenegro adopted around thirty by-laws thus ensuring full incorporation, whereas the adoption of other acts is expected in the foreseeable future.

The last law adopted by Montenegro was the Law on Security Protection of Sea-Going Ships and Ports in 2016. This Law regulates the manner of security protection of ships and ports for arrival and anchoring, procedures in the event of threat or the possibility to threat the security of a ship and port, as well as other questions of importance for the security protection of ships and ports. The Law incorporated the provisions of Chapter XI-1 SOLAS as well as ISPS Code resulting from Chapter XI-2 SOLAS. Additionally, in terms of pirate attacks on the ships under the Montenegrin flag, the following has been incorporated: MSC 1- Circular 1334, Guidance to ship-owners and ship operators, shipmasters and crews on preventing and suppressing acts of piracy and armed robbery against ships. The following has been transposed into the Law: Regulation (EC) No 725/2004 on enhancing ship and port facility security, Directive 2005/65EC on enhancing port security, Commission Regulation (EC) No 324/2008 inspections in the field of maritime security, as well as Commission Recommendation of 11 March 2010 on measures for self-protection and the prevention of piracy and armed robbery against ships.

6 CONCLUSIONS

In the recent years, Montenegro made a significant progress in terms of creation of maritime-law legislation. The conceptual commitment of the Montenegrin legislator is the adoption of several separate laws in specific fields of maritime law. Given the basic orientation of Montenegro towards tourism and tourism industry, the adoption of laws which regulate this field when it comes to coastal and maritime aspect of this field is indispensable. The principal law which has been governing the coastal region of Montenegro for quite a while is the Law on the Coastal Zone from 1992. At the moment, the subject of coastal zone has not been adequately regulated. Certain questions related to the coastal zone should be regulated precisely since they have not been regulated or have been insufficiently regulated by the positive law of Montenegro. What should primarily be regulated is the ownership-legal regime of the coastal zone, boundaries of the coastal zone on mainland and seashore, utilisation of the coastal zone i.e. special rights of use (concession and lease), coastal zone management (definition, institutions, competences). Nautical and yachting tourism have to come to the fore in terms of commercial use of the sea. Hence, Montenegro adopted the Law on Yachts. For the purpose of creation of as better possible user-oriented legal framework for the development of nautical tourism, the Law on Yachts was amended several times (in 2010, 2011 and 2015) since its adoption in 2007. The ports of Montenegro are different. The port of Kotor is the most important passenger port and a well-known cruising destination in the Mediterranean. The port of Bar is the main and the biggest cargo port with one passenger terminal and significantly smaller number of passenger transfers in comparison with the port of Kotor. The port of nautical tourism – Marina Porto Montenegro – with 450 berths for big, so-called "mega yachts", located in Tivat, is one of the most luxurious marinas in the Adriatic. Montenegro has the needs, resources and ambitions to develop sea-water fishery. Accordingly, the construction of a bigger fishing port in Njivice, in the vicinity of Herceg Novi, is planned. Given the above, the Law on Ports adopted in 2008 has a special significance. The Law attempts to regulate all these questions, and its greatest novelty is the introduction of the Port Authority as a state-management body. By doing this, the port management has been spun off and this body was entrusted with the authority over port acquatoria and mainland parts of ports.

Related to the above, Montenegro adopted another four laws: the Law of the Sea, the Law on the Prevention of Sea Pollution from Vessels, the Law on Safety of Maritime Navigation and the Law on Security Protection of Ships and Ports. Most probably because the Montenegrin maritime shipping industry is facing a big crisis due to the loss of ships while our country was under sanctions and due to the underdevelopment of the shipping industry and export-import maritime industry, Montenegro has not yet felt the acute need to adopt a maritime-property or maritime-commercial law, but its adoption is expected in the near future.

In addition to the aforementioned, the process of creation of maritime-legal framework in Montenegro has not yet been completed. The adoption of the missing laws and by-laws as well as the continuous update of the Montenegrin maritime-law regulations is to ensue in the forthcoming period.

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AIRPLANE BOARDING STRATEGIES FOR REDUCING TURNAROUND TIME

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ABSTRACT

The need to simultaneously increase efficiency, profitability and customer satisfaction puts airline industry under pressure. The turnaround time of an airplane is crucial for utilization of an airplane since airlines obtain revenue when the airplane is in the air. Airlines make every effort to minimize the time their flight is grounded. While the boarding process is only one component of the turnaround time event set, it is on its critical path. The substantial reduction of the boarding time can reduce turnaround time in most cases. Adopting fast and easy boarding strategy can benefit the airlines, but also airport operators and passengers. It increases utilization of the ground equipment and the level of service at the airports departure hall. Inefficient boarding processes effect the passenger`s perception of quality of service. The purpose of the paper is to identify the various strategies in boarding of passengers onto an airplane which can reduce the turnaround time.

Keywords: Airplane boarding, boarding strategies, airplane turnaround time

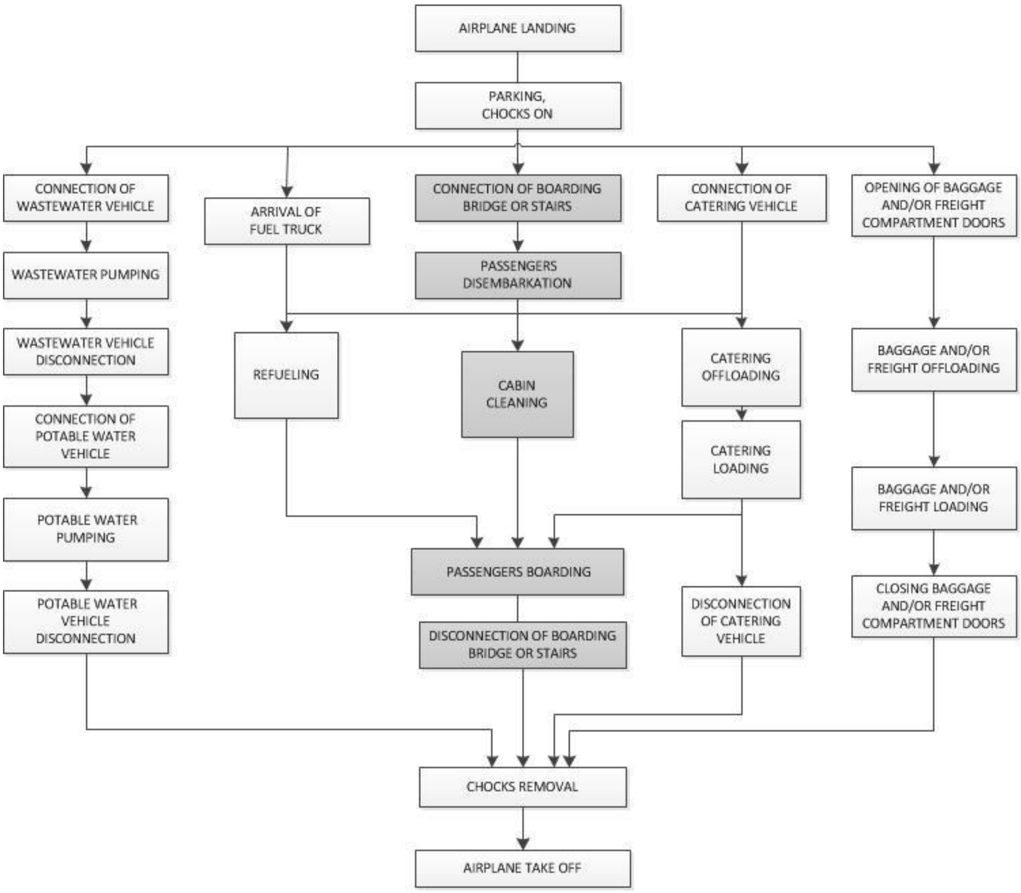
1 INTRODUCTION

The airline industry is highly capital intensive, and its profitability is highly influenced by fuel efficiency and airplane utilization. Considering the fact that airlines obtain revenue only when the airplane is in the air, the common goal of all airlines is to minimize the time that the airplane spends on the ground. However, the minimization of airplanes' time on the ground must not compromise or in any way diminish safety in airline industry. Airplanes' time on the ground is usually referred to as turnaround time. By definition it is a time required to unload an airplane after its arrival at gate and to prepare it for departure again [1].

Optimizing airplane utilization, amongst others, includes efficient, i.e. shorter, airplanes' turnaround time. There are two basic turnaround models: full turnaround model and short turnaround model [2]. In a full turnaround model several different operations are performed during turnaround time, and most of them are performed at once. However, there are operations, such as passengers boarding, which cannot be performed simultaneously with other operations, such as refueling, cabin cleaning and catering (off) loading, either for safety reasons, or for passengers' satisfaction. In a short turnaround model some operations are not performed, such as cabin cleaning and catering loading, which provides the boarding process to start sooner than performing the full turnaround model. Additionally, special procedures can be applied for the refueling process, so it can be performed along with passenger boarding. These procedures involve assistance from a fire brigade and presence of a fire truck while refueling, for safety reasons[1]. The full turnaround model consists of several different operations (in accordance with the requirements of the flight), shown in Figure 1, and can (broadly) be divided into groups:

- disembarkation and boarding of the passengers,
- refueling the airplane,
- cabin servicing,
- catering servicing,
- toilet and potable water servicing.

[1] Low cost carriers usually use these procedures at their en route stations to shorten their turnaround time.



Source: Adapted from [6]

Figure 1: Airplane full turnaround model scheme

All operations which influence the duration of turnaround time are determined as critical [3]. Therefore, passenger boarding, as seen in Figure 1, is on a, so called, critical path [4] of a turnaround since it significantly influences the course of other operations. Even though the boarding is only one of the operations in a turnaround event set, it is much easily adaptive and modifiable than some other operations. In the last 20 years numerous boarding strategies were proposed to optimize airplane utilization and shorten turnaround time. This paper identifies proposed boarding strategies and evaluates their advantages and disadvantages.

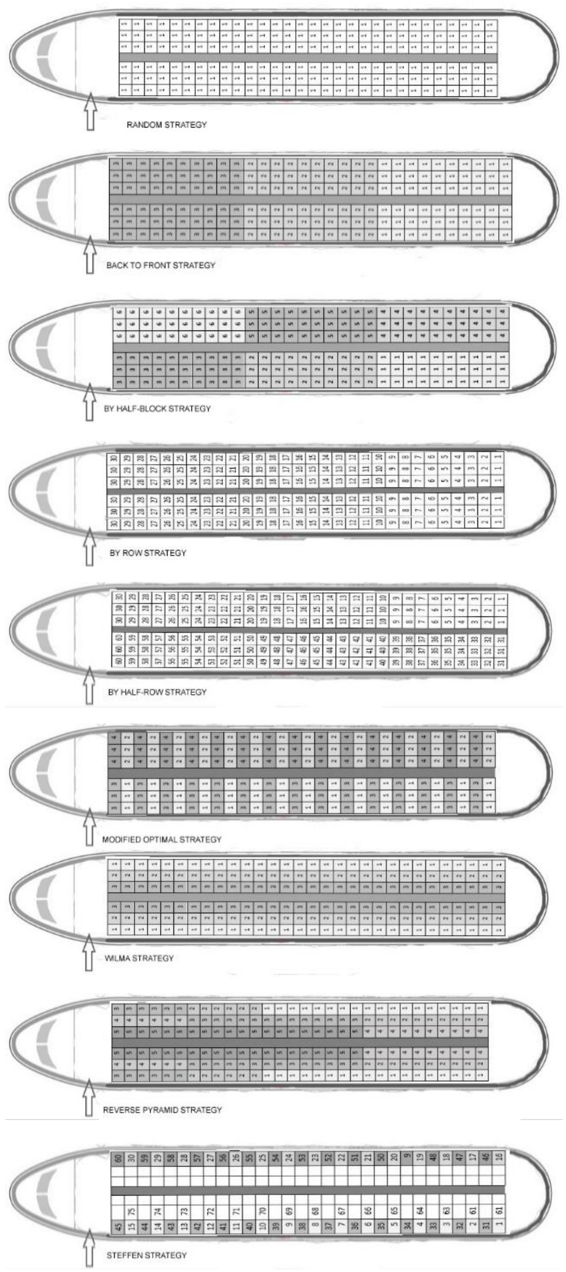
2 BOARDING STRATEGIES

The boarding process consists of a simple set of rules for the passenger movement [5]:

- entrance in the airplane at the assigned door,
- move forward along the aisle until reaching the assigned seat row,
- store the carry on in the overhead compartment (while the aisle is blocked for other passengers) and take the seat.

This, at first a simple process, can be complicated if added more variables, such as more points of entrance (front, back, and in some cases, if an airplane configuration permits, a middle entrance), more aisles in a cabin, restrictions (or a lack of it) on number of carry-ons, etc. There is also a possibility of open seating, without prior seat assignment, which will not be considered in the following strategies.

To illustrate various boarding strategies, all of them were reviewed on a model of a narrow body airplane with a single aisle layout (Figure 2). The aisle divides 30 rows into 3 seats on the left and 3 seats on the right side. There are no first class and business seats, since most of the airlines that provide such a service, board these passenger classes first, nevertheless the strategy they are applying. The same goes for passengers with reduced mobility.



Source: Adapted from [2]

Figure 2: Various boarding strategies schematic illustrations

The first, and most broadly applied boarding strategy is a *random* strategy. There are no conditions given to the passengers before boarding. They are not divided into groups, or assigned with any particular order of entering in an airplane. There is only one zone in an airplane, and passengers are boarded in a First-Come First-Serve principle.

In other strategies passengers' movements from gate to their seat are somewhat pre-managed. The theoretical assumption of those strategies is to develop a sequence in which passengers are boarding without interfering one another [2]. The objective of proposed strategies is to reduce the boarding time by reducing the number of times passengers wait for or come across each other inside a cabin, weather in the aisle (an aisle interference) or within a given row (a seat interference).

One of the widely used strategies is a *back to front* strategy (also referred to *by block*). It requires a division of passengers into groups. Boarding begins at the back of the airplane and works its way forward. Quite similar strategy is *by half-block*. This strategy proposes that opposite sides (right vs. left) of cabin has different boarding sequence. The *by row* strategy, as well as *by half-row*, groups passengers according to the row their assigned seat is in. This strategies also apply back to front principle, i. e. back rows board first, front rows board last. A combination of *by half-row* and of *by half-block* is a strategy called *modified optimal.* Passengers are divided into (usually) four groups and boarded sequentially at predetermined order.

Mentioned strategies are based on a premise that passengers are grouped by row or by block. Some authors [6, 7] refer to these as traditional strategies. According to that non-traditional approaches group passengers by seat or seatgroup. There are two basic strategies that group passengers by their seat group. *WilMA* strategy, or *outside in* strategy, propose boarding of window seat passengers first, following with middle seats, and finally aisle seats (acronym *WilMA* comes from: window, middle, aisle order). The *reverse pyramid* strategy is somewhat of a hybrid between traditional and non-traditional boarding strategies. Designed by [8] the *reverse pyramid* strategy is an attempt to board diagonally so that a boarding group consists of passengers who are actually boarding a few seats in the front of the airplane, while other passengers within the same group are boarding in the middle of the airplane [6].

Finally there is an approach solely by seat, in which there are as many divisions as there are blocked seats. Each passenger is given a number of airplane entrance sequence by which he/she enters the airplane. This is commonly known as *Steffen* method, and has its modification *Steffen-lug* method. The *Steffen* boarding strategy was proposed by Jason H. Steffen [9] using a Markov Chain Monte Carlo optimization algorithm. Sequence numbers are assigned in such a manner that two adjoining numbers are divided with exactly one row (for example: 30A, 28A, 26A…). The *Steffen-lug* barding strategy considers basic principle of the *Steffen* method, but it assigns passengers to seats so that their carry-on luggage is spread roughly evenly throughout the airplane [7, 10]. This strategy requires a prior knowledge on number of carry-ons'.

Proposed boarding strategies only address the management of the passengers' behavior by generating boarding sequences or reducing the amount of carry-ons, but with implementation of the innovative technology such as Side-Slip Seat [5], the cabins layout can be dynamically changed providing a wider aisle. This concept provides passengers to pass each other without aisle interference. This concept, applied with a specifically proposed *left right random* strategy could provide a low level of complexity and a more stable boarding process.

3 STUDIES ON THE IMPLEMENTATION OF BOARDING STRATEGIES

As priory stated, the proposed boarding strategies are only simplified principles and can be modified in numerous ways by adding more variables (classes, more entrance points, multiple aisles, etc.) but provide a basic overview on boarding strategies which are a subject matter of numerous studies carried out in the last two decades.

The very first study of boarding strategies was a study carried out by Marelli, Mattocks and Merry for Boeing [1], and is referred to as Boeing study. Self-developed computer simulation call PEDS was used along with the empirical test to validate the simulation. A comparison was made between a traditional boarding strategy (not specified which one) and an *outside in* strategy with following results: the use of *outside in* strategy can reduce boarding time for 46% while the use of both doors as an entrance point can reduce it for 20% (compared to traditional boarding strategy using only one door as an entrance point).

Van Landeghem and Beuselinck [11] from Ghent University, carried out a computer simulation study of different boarding strategies (*random, back to front, by half-block, by row, by half row, WilMA and by seat).* Simulation has shown that the choice of boarding strategies highly influences the boarding time, both in total and individually per passenger. The *by seat* approach reduce total boarding time with 100% or more versus *random* strategy.

At the request of America West Airlines, Van den Briel et al. [8] conducted a study in pursuit of finding an optimal boarding strategy. A computer simulation tested boarding times for two commonly known strategies: *back to front* and *WilMA*, and a new strategy was proposed: *reverse pyramid*. The results of the study were that when a *reverse pyramid* strategy is applied boarding time can be reduced for 26% compared to *back to front* strategy. They also simulated the situation of implementing a second agent to the gate. The simulation resulted with reduction of 39%.

In 2008, Nyquist and McFadden [6] calculated potential cost savings on account of boarding time reduction. According to Nyquist and McFadden an airline accrues a cost of approximately US$30 per minute on ground. They've concluded that applying non-traditional strategies like *outside in* or *reverse pyramid* over traditional strategies could save 35% annually. If airlines would consider implementing non-traditional strategy combined with two doors concept and reduce the number of carry-ons on one per passenger, the cost savings would be 66% annually over the traditional strategy. They did not consider any *by seat* strategies while conducting their study.

In his paper, Steffen [9] ran a simulation on *random, back to front, front to back, WilMA, modified optimal* and *by seat, i.e. Steffen method* strategies. His simulations showed that the worst case scenario is when *front to back* strategy is used, followed with the *back to front* strategy. He compared every other simulation to the worst case scenario, *front to back*¸ which is a strategy that is purely hypothetical and not even intuitively applied in practice. The results were therefore harder to compare with other studies, but provide an illustration of every simulated strategy. *WilMA* strategy reduced the boarding time for 57% compared to the worst case, and *Steffen method* strategy reduced it for up to 80% compared to worst case (i.e. half of the time needed for non-traditional strategies).

Steiner and Philipp [4] developed Airplane Boarding Simulator (ABS) which was used to simulate different scenarios by varying different factors: number of carry-ons, pre-boarding area, used boarding strategy and procedures at the gate. They've studied *random* and *back to front* strategy, and concluded that the *random* strategy outperforms the *back to front* strategy, and if there is a 15% to 5% reduction in number of carry-ons boarding time can be reduced by two to four minutes. Having that in mind they also concluded that both of proposed actions influence customer satisfaction, as they either restrict their freedom of choice (reduced number of carry-ons) or increase the number of aisle or seat interferences in an airplane (for *random* strategy).

Steffen and Hotchkiss [12] conducted an empirical experiment of different boarding strategies in a mock Boeing 757 airplane layout. They have compared *back to front, WilMA, Steffen* and *random* strategy. Their test supported the premise that the boarding time for strategies that parallelize the boarding process by utilizing the aisle more effectively (more passengers stow their carry-ons' simultaneously) is shorter from those that do not. They have concluded that the best strategy is the *Steffen method*, but also stated that even in the controlled environment of their experiment there were some practical hindrances during the implementation (such as boarding of passengers with small children).

A simulation study by Mas et al. [13] focused on *back to front, WilMA, block and random* strategy. Their computer based simulation only confirmed that the most common boarding method, *back to front*, is not the most efficient one. Their results helped to quantify how the time difference among boarding strategies increases as the occupancy level raises.

Kierzkowski [2, 14] presented advantages and disadvantages of currently proposed boarding strategies. Their study covered the duration of activities during passenger boarding and the occurrence of seat and aisle interferences. They recommend passenger boarding strategies which divide them according to rows, not columns. They justify this proposal with the fact that passenger groups book their seats in the same row (parents with children, passengers with reduced mobility with their accompanied person, etc.) and is practically impossible to separate them at the terminal. This claim is in consistence with the conclusions of the empirical experiment conducted by Steffen and Hotchkiss [12].

In [2] authors provided a ranking of methods according to the average time of boarding shown in the Table 1.

Table 1: Boarding strategy ranking according to the average time of boarding

Rank	Strategy
1	Steffen method
2	WilMA
3	Reverse pyramid
4	By half block
5	Back to front
6	By half row
7	By row
8	Random
9	Modified optimal

Source: [2]

4 CONCLUSION

Considering all the proposed methods there are considerable amount of pros and cons for each strategy. It is quite obvious that if only considering a financial impact the proposed *Steffen method* strategy and its modifications, can reduce boarding time significantly and consequently save the loss of an airlines' revenue. However, even the author admits that there are some obstacles in the use of *by seat* strategies. They are commonly considered complicated and passenger-unfriendly. Even though the purpose of boarding strategy implementation is to reduce the boarding time, and consequentially the turnaround time, it is not at the expense of passengers' satisfaction. It is inevitable to evaluate boarding strategies in terms of passengers' satisfaction, since none of the mentioned studies have fully dedicated their research to that aspect. With detailed empirical data considering passengers' preferences more detailed analysis is possible on which strategy is more applicable for the concrete airline. Considering the vast implementation of modern technologies in the check-in process, possible implementation of the same technologies should be reviewed in the boarding process, which is a proposition for further research.

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APPLICATION OF THE MARPOL CONVENTION ON WARSHIPS

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ABSTRACT

The International Convention for the Prevention of Pollution from Ships (MARPOL) is a fundamental document with world-wide application in the area of marine environment protection. The Convention regulates the issues of marine environment protection and the prevention of sea pollution from ships. The Convention has been drafted for the application on SOLAS (Safety of Life at Sea) ships. It is also possible to apply the Convention to non-SOLAS ships. One of the important categories of non-SOLAS ships are also warships. Due to specific legal status of these ships, states have developed the application of the MARPOL Convention within the framework of their national legislation. This paper deals with the application of provisions of the MARPOL Convention on certain types of warships of contracting parties of the MARPOL Convention. The application of MARPOL Convention on warships during the operational status is analyzed. NATO has undertaken a full range of standardization activities in the area of application of the MARPOL Convention's procedures and measures on warships. The specificity of these standards is that their application does not affect the combat capabilities of warships. The paper analyzes in particular the applicable solutions of the MARPOL Convention measures to warships.

Keywords: Warships, NATO, MARPOL Convention, marine environment protection

1 INTRODUCTION

MARPOL Convention is developed due to need for create a legal framework to regulate the protection of the marine environment and to prevent pollution of the sea from ships. The Convention applies directly only to SOLAS ships. It does not, inter alia, apply directly to warships. This approach has been developed because of technical and legal reasons. Technical reasons are related to the purpose and characteristics of warships. By carrying out their tasks, warships generate different types and amounts of waste. As a result, it is necessary to provide a space for the disposal of waste on warships and equipment for the recycling of waste. It is commonly known that most of the space on warships has been used primarily for the armaments and weapons, and only a minor part for crew accommodation and other needs. The Navies also has a relatively large number of older warships, and cannot apply on board of this ships all international rules and regulations for the protection of the marine environment. The legal reasons why warships are excluded from the application of the MARPOL Convention are linked to the legal status, exemptions and immunities enjoyed by these ships in different sea areas. The Navies should align the operations of their own ships with the numerous and complex international and national regulations, rules and environmental laws.

Due to the numerous specifics, the main regulations and their basic provisions relating to warships are indicated in this paper. Nevertheless, states generally adhere to the principles under which the MARPOL Convention may apply to their warships to a degree that does not endanger the combat capabilities of these ships. The paper analyzes in particular the application of the MARPOL Convention to the United States, United Kingdom and Kingdom of Spain warships. These countries have developed their own approaches and standards for applying the MARPOL Convention to their warships. The application of its standards is analyzed on warships such as aircraft carriers, destroyers, and submarines. NATO has also devoted considerable attention to the issues of the marine environment protection and the pollution prevention from ships of its member states. To achieve this goal, NATO has organized a special department that develops the policy of protecting the marine environment and preventing pollution of the sea from warships. This department has developed a series of publications called Allied Maritime Environmental Protection (AMEP), which seeks to harmonize numerous environmental issues in NATO-led activities. These issues are in line with international and member states regulations on the protection of the marine environment. The paper also analyzes NATO's approach to marine environmental issues. In order to fulfill all aspects of the MARPOL convention, a NATO member states seeks to coordinate the rules and recommendations in the construction of new warships. For this reason, the application of the MARPOL Convention to the new warships is much easier to apply than on the old warships.

2 A SHORT OVERWIEW OF LEGAL FRAMEWORK APPLICABLE TO WARSHIPS

The warship is part of the armed forces of sovereign state and its legal status is especially determinate in international law [15]. The legal status, the sovereign immunity and the exclusions of warships are governed by the United Nations Convention on the Law of the Sea (UNCLOS). In relation to the protection and conservation of the marine environment, the Sovereign immunity principle is valid, according to which "the provisions of the UNCLOS concerning the protection and preservation of the marine environment do not apply to any warship, naval auxiliary, other vessels or aircraft owned or operated by a State and used, for the time being, only on government non-commercial service. However, each State shall ensure, by the adoption of appropriate measures not impairing operations or operational capabilities of such vessels or aircraft owned or operated by it, that such vessels or aircraft act in a manner consistent, so far as is reasonable and practicable, with this Convention [19]." Accordingly, warships are exempt from the direct application of the international legal regime for the protection of the marine environment and the prevention of pollution of the sea from ships, but are expected to comply with the substantive standards to the greatest extent possible. This rule is also contained in Article 3(3) of the MARPOL Convention [9]. MARPOL 73/78 built upon the experience of Convention on the Prevention of Pollution of the Sea by Oil (OILPOL 1954) with regard to operational discharges of oil and expanded its regulatory scope to encompass other common vessel-source pollutants, including noxious liquid substances carried in bulk, harmful substances carried in packaged form, sewage and garbage [14]. Although the MARPOL Convention does not apply to warships, it represents the international umbrella document on the basis of which the flag States develop their national regulations and rules applicable to their own warships in matters of protection of the marine environment and the prevention of marine pollution from ships. Connected to responsibility of flag state in territorial waters UNCLOS assumes that ''the flag State shall bear international responsibility for any loss or damage to the coastal State resulting from the non-compliance by a warship or other government ship operated for non-commercial purposes with the laws and regulations of the coastal State concerning passage through the territorial sea or with the provisions of this Convention or other rules of international law [19]." It is important to mention other international regulations such as the Barcelona Convention (1975 Convention for the Protection of the Mediterranean Sea against Pollution), and Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft. The Protocol to Barcelona Convention in Article 11(2) provides the same exemption for warships from its application as the MARPOL Convention [21]. The same or similar provision is incorporated in other regional conventions that regulate the issues of marine environmental protection. It is concluded from these provisions that flag states have an obligation to develop their own regulations and rules to be applied to their warships in order to minimize the impact of this ships to the pollution of marine environment respecting principles from UNCLOS and MARPOL Convention.

3 TECHNICAL AND OPERATING LIMITATIONS OF WARSHIPS RELATED TO APPLICATION OF MARPOL CONVENTION

Warships have a wide range of specificities in relation to other types of ships. Their primary purpose is to carry out various types of combat activities at sea. This means that their construction should enable these tasks to be carried out, depending on the purpose of the ship. There are relatively large quantities of flammable and explosive substances (in relation to their dimensions) such as propellant fuel, ammunition, and explosives used by their weapons systems and armaments. One of the fundamental requirements for the construction of warships is to achieve as much functionality as possible within a minimum of space. Furthermore, the fact is that complements of warships are much more numerous than on the other types of merchant ships. The higher the number of crew members, the larger the amount of waste generated. Also one of the specifics of warships is the increased risk of fire. Accordingly, fire hazards on board navy ships is additionally increased by storage of accumulated wastes. Due to all the above mentioned, approaches related to the issues of marine environmental protection and the prevention of marine pollution from warships, are significantly different in relation to other types of ships. It should also be stressed that within one Navy it is not possible to achieve a unified approach to solve these problems. There are many reasons for this. It should also be mentioned that warships have different missions, weapons and auxiliary systems, configurations, arrangements and crew size and they generate different types and amounts of wastes. In addition, warships have different time spent in missions and operations in different parts of the sea with different legal regimes. The time spent in missions and operations may last relatively short, so there is no need for special waste disposal facilities for such ships, apart from its separation and safe storage on board. That time can be very long, especially with the largest types of ships that can stay on the sea for several months. This is a common case for long-term national or international combat or non-combat operations. In these cases, the primary task is not to interrupt or delay operations and stations keeping because of the need to discharge accumulated wastes. Based on the above mentioned, it is not possible to develop an approach "one size fits to all", simply because it is neither technically nor operationally possible. Instead of that, flag states develops shipboard pollution control systems standardized across hull types or classes of their warships. Generally, it can be concluded that there are "three different approaches emerged to address warship treatment under international marine pollution-control regimes. The earliest approach was to simply exempt warships from the operation of the convention's norms; for the most part, this approach has been abandoned. A second method is to specifically provide a sovereign immunity reservation; under this approach, the convention's norms are made fully applicable to warships but enforcement is reserved exclusively for the Flag State. The third approach is to provide exemption for warships, coupled with obligations that States ensure their warships act consistent with the convention's norms so far as reasonable and practicable [14]."

4 THE IMPACT OF WARSHIPS ON ENVIROMENT

The marine environment (seawater, sea bottom, airspace, and coastal line) is exposed to various damaging effects from warships. They generate similar harmful substances like other types of ships. The type and amount of harmful substances generated by warships depend on a number of factors such as the type and purpose of the warship, the size of the crew, and the type and duration of the operation or mission in which the vessel is participating. Specifically, the most generated is waste water, which is collected, treated and discharge on warships by the same principles as on merchant ships. The amount of waste water varies, depending on a numerous factors. However, in general, the proportion of gray water is higher than that of bilge water. The specificity of warships in that segment is associated with a much larger number of crew members compared to other types of ships of the same size. More recently, due to the increasing automation, there is a trend to reduce the number of crew members, which directly contributes to reducing the amount of wastewater generated and other types of waste (especially food waste) on these vessels. Relatively large number of warships still use biocide coatings against fouling the hull under the water line. As a rule, they are self-healing biocides, which, in contact with sea water, continuously release poisonous and harmful substances into the marine environment. Preventing fouling on the underwater part of the ship's hull is extremely important for warships, as it results in a reduction in speed and increased fuel consumption. The Navies dedicates considerable attention to this problem, participating in the development and application of new anti-fouling systems based on fluoropolymer foul release coating. Eg. Royal Navy and the Spanish Navy apply the above-mentioned systems on their ships, with the aim of increasing the speed of ships (2-3 kts) with a marked reduction of the impact on environmental pollution through reduced fuel consumption, reduced emissions of pollutants (9%) and reduced pollution of the marine environment due to the chemical system of biocidal coatings [20]. U.S. Navy has developed through the Office of Naval Research non-toxic advanced technology for anti-bio-fouling solutions, being developed as a patterned coating, trademarked as "Sharklet", which "mimics the inherent texture and antimicrobial properties of shark skin". Another is based on zwitterionics (mixed – charge) compounds, which "manipulate surface environments at the molecular level to prevent proteins from binding of the ships surface [20]." For oil pollution, it is important to mention replenishment of oil at sea (RAS), which is another specific feature of warships. The RAS is carried out in such a way that one or two vessels are simultaneously filled from oiler while in navigation. During this operation oil can reach directly into the sea. In order to prevent such a possibility, the Navies develops its own procedures and restrictions for RAS. NATO has also developed its own RAS procedures. Warships can pollute the environment by releasing pollutants into the air. We are talking about discharging technical gases and gases created by the combustion of fuel. Technical gases that are still encountered on warships are certain Freon and halon groups, which are environmental pollutants. These gases reaches the environment due to improper handling, installation failures, or fires (halon). "Navies are faced with the dual challenge of putting out fires caused by both accidental ignition and enemy action. Over the years the Navy has sought ways to improve firefighting capabilities as ships have been required to handle increasing quantities of munitions, and have been equipped with propulsion systems requiring high-pressure, easily atomized fuels. Continuing this tradition of evolutionary improvement to meet changing needs, halon was introduced into the Navy as a principal fire extinguishing agent in recognition of its extraordinary fire extinguishing capabilities [3]." In terms of food waste generation from warships, research has been carried out to determine the amount of generated waste and the trend related to this type of waste to several different types of warships including the submarine. The research has established a trend of reducing the amount of generated waste in kilograms per person per day. In order to promote the active environmental policies the Navies and NATO developing their own programs and regulations to reduce or prevent environment pollution from warships.

5 ENVIRONMENTAL PROTECTION POLICY APPLICABLE TO CERTAIN NAVIES WARSHIPS

Navies develop their own regulations, technical rules and ways of applying the MARPOL Convention to their warships. For example "the U.S. Navy, by action of the Congress is directed to comply with regulations set forth in the international agreement MARPOL Annex V (MARPOL 73/78). The Committee on Shipboard Pollution Control was convened by arrangement between the Navy and the National Research Council to evaluate technology options that are relevant to Navy compliance with Annex V for surface ships by 2000 and submarines by 2008 [4]." The U.S. Navy basic document for the implementation of Congress direction regarding environmental policy is Environmental readiness program manual. "This manual contains the Navy's policy guidance for environmental readiness. It discusses requirements, delineates responsibilities, and issues policy guidance for the management of the environmental, natural, and cultural resources for all Navy ships and shore activities.

Environmental readiness encompasses all aspects of environmental compliance, planning, conservation, cultural resources, and restoration [5].” Other manuals of lower hierarchical levels have been derived from this manual. The manuals define the procedures for implementation of the environmental protection policy on the U.S. Navy ships. Royal Navy also applies environmental protection policy. This policy is implemented in accordance with UK standards for the protection of the environment and applies to the planning and implementation of the action of the Royal Navy in UK home waters and abroad [6]. Environmental protection policy for Royal Navy was defined, in addition to other documents in Environmental Protection Guidelines (Maritime), Standard Operational Procedures and Fleet Operating Orders, which are in compliance with environmental regulations in the United Kingdom [6]. In addition, other navies develop their own programs related to this area. In the course of the paper, examples of the application of the MARPOL Convention to surface warships and submarines of the U.S. Navy, Royal Navy and Spanish Navy are analyzed.

5.1 Waste management on surface naval ships

The largest warships in the world are aircraft carriers. They are part of several world navies. Aircraft carriers have a large number of complement (more than 6000) and generate very large amounts of waste. That is why Navies with aircraft carriers, has developed a series of measures aimed to implement certain chapters of the MARPOL Convention. E.g. “Royal Navy has installed Integrated Waste Management System (IWMS), onto both the UK Royal Navy’s Queen Elizabeth-class aircraft carrier. The IWMS operates the oily water system, black sewage and greywater system from showers, sinks, galleys and laundries, as well as Solid Waste and Final Treatment System. Following completion of the black and grey water process, the wastewater treatment plant discharges permeate that is compliant with the international standard for marine pollution control MARPOL 73/78 Annex IV [8].” “The Solid Waste and Final Treatment system is based on Pyrolysis process which breaks down the molecular structure of the matter by exposing it to temperatures in excess of 800 degrees. This will usually incorporate a mixture of food waste, bio-sludge, dry solids and waste oil and medical waste. On completion the leftover product known as Char is stored within drums on pallets ready to be disposed of ashore. Additionally, glass processing equipment crushes and compacts leftover glass products for subsequent recycling [24].” U.S. Navy has conducted studies to determine the total amount of waste generated on two different aircraft carrier classes. A study on board of USS Truman (Carrier Vessel Nuclear – CVN 75) was conducted in 2004 and on board of USS Nimitz (CVN 68) in 2008 [12]. The study was conducted in different operational conditions. During the 2004 Truman study, the ship was operating in the Persian Gulf (combat Operation Iraqi Freedom) while the 2008 Nimitz study was conducted during a transit period in Pacific Ocean [12]. The study has shown that these ships produce different quantities and types of waste in different operational conditions [12]. Due to the problem of storage of large amounts of threated wastes on aircraft carriers, U.S. Navy has applied new waste treatment systems – Plasma Arc Waste Destruction System to the new class of these ships CVN 78 Gerald R. Ford [13]. This will significantly reduce the quantities of treated waste storage for disposal. “All U.S. Navy warships have suites of solid waste equipment (Plastic Waste Processors, Large and Small Pulpers, Metal/Glass Shredders) onboard to compress and store all plastics for shore disposal or recycling and to, process biodegradable materials for safe discharge while at sea. Large deck ships (aircraft carriers and amphibious assault ships) are also equipped with incinerators which burn some of the paper, cardboard and plastics the ship generates while at sea. Ships are also equipped with Oil Pollution Abatement equipment which separate oily waste from the water in bilge water. For the treatment of sewage ships are also equipped with Marine Sanitation Devices, which prevent discharge of untreated sewage in port and near land [23].” A special problem on warships is waste that contains food remains. Such waste, due to long-term storage, can cause unpleasant smells and be harmful to health and lead to crew infection. Therefore, such waste must be treated in a special way. Newer processing plants such debris deodorize and pack it in order to be completely detached from the atmospheric air influences. As a member of NATO, the Spanish Navy also complies with the Allied recommendations in relevant document when in NATO operations, and in any case they always take into account the environmental considerations stated in other related NATO standardization agreements [18].” The Spanish Navy began establishing environmental management systems in 1992, with the creation of a committee for the preservation of the environment within the department [16]. Later in 1997, it was established an environmental management system which complies with ISO 14000, which covers not only the Navy but the whole Armed Forces of the country [17]. The Spanish Navy is pioneer in building zero-emission vessels, as they are not using asbestos in their installations, using coatings which are more modern and give better thermic insulation, like mineral or refractory wool of silica, aluminum silicates, boron, chromium or alumina, among others. Lubricating oil containing PCB (Polychlorinated Biphenyl) or PCT (Polychlorinated Terphenyl) have been substituted by silicone oils or dielectric minerals. Transformers are manufactured dry or air-cooled. CFC (Chlorofluorocarbon) from old installations have been substituted by gases like R-134 for the air-conditioning, and R-404 for freezing. These gases are chlorine and bromine free. Halons have been replaced by fire systems based on high and low pressure water mist. New buildings like frigates and the LHD (Landing Helicopter Dock) Juan Carlos I have been provided with electrical motors or POD (Azimuthal Thrusters) which minimize the generation of CO_2 [1].

5.2 Waste management on submarines

In terms of waste disposal, submarines represent an enclosed system that generates considerable quantities of waste [2]. A general goal of waste management on submarines is to reduce generation of waste, after that reduce waste volume, sanitary packaging and storage in a suitable spaces. Given the extremely small available space and the very long duration of operation, the problem of disposal of solid waste on submarines is accessed in a specific way. Before departure, all unnecessary packaging material is removed so that the minimum amount of waste is generated during the mission. Prior to the beginning of the mission, the packaging is also very carefully selected. On U.S. Navy submarines has been developed the principle according to which it is "feasible to store waste materials in sealed containers in areas occupied by the supplies at the outset [4]." So, the space used at the beginning of the mission to store supplies during the mission is used to store the residues of the treated waste. The specificity of the submarines is that during missions (that can last for several months) almost never resupplied at sea. This means that all necessary supplies must be loaded before the mission begins. Also, there is no possibility of incineration on the submarines because they are in underwater navigation in missions. Waste material is collected in a submarine and periodically discharged into the sea. Only permitted types of waste are emptied into the sea. Since 2008 it is prohibited to discharge of plastic waste from the U.S. Navy submarines. Usually, management of food waste in a submarine is centered on ejecting of the offending material from the submarine [2]. This operation is carried out using the compressed air system, periodically, depending on the mission requirements, that the submarine would not be detected in underwater navigation, because, during the process, large quantities of air bubbles are emitted, which will compromise the concealment of the submarine [2]. Another method is to consolidate dry waste using a trash compactor and then place in special cans, fabricated on board. Metal weights are added to ensure that the cans will go to the bottom. The cans are ejected from the submarine using a Trash Disposal Unit (TDU) through a combination of gravity and air pressure [4]. This method is time-consuming and is forbidden when the submarine is running silently in the hunter mode [2]. The TDU method have been used effectively in the submarine fleet since World War II [10]. In order to meet contemporary requirements for the pollution prevention from submarines one of solutions proposed is to use supercritical water oxidation technology for rapid oxidative destruction of organic compounds for dealing with the treatment of garbage on submarines [2]. Another important issue is related to bilge water treatment on submarines. There are different bilge water sources on submarines. Bilge water includes seawater accumulation, normal water leakage from machinery, and fresh water wash-downs [22]. These waters are collected in the tank systems and processed before their release. The submarine's drain system has a series of non-oily bilge collecting tanks, oily bilge collecting tanks, and a waste oil collecting tank or tank complex [22]. As a rule, gravity separation is used, after which the non-oily waste is discharged overboard outside of 50 nautical miles from the shore, while oily waste must be held for future transfer to appropriate shore/disposal facilities [22].

6 NATO ENVIRONMENTAL POLICY AND STANDARDS

NATO pays great importance to the segment of environmental protection at the general and particular levels. NATO defines environment as "the surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelations [6]." From this term NATO defines environmental protection as ''protection of the physical and natural environment from the harmful and detrimental impact of military activities [6].'' On strategic level NATO has established several NATO groups to address environmental challenges from various angles. The group responsible for development of NATO policies, standardization documents, guidelines and best practices in the planning and implementation of operations and exercises is the Environmental Protection Working Group (EPWG) [6]. In the hierarchy of NATO documents related to environmental protection we can talk about three levels. First level are Military Committee (MC) Policies. Second level includes doctrines while the third level includes standards. Of particular interest at strategic level is MC 469 "NATO Military Principles and Policies for Environmental Protection [6]." MC 469 objective is to facilitate the integration of environmental protection into all NATO-led military activities, consistent with operational imperatives with respect to host nation environmental laws. This document defines that national standards should be implemented if more stringent than respective NATO standards. Within this document, the principle under which it is applied shall apply each nation ultimately responsible for the actions of its own forces [11]. At the doctrinal level, a set of documents is being applied to joint NATO-led operations. These documents define planning, responsibilities, training and education [11] focused on protection of the environment during NATO-led military activities [6]. Within these doctrines, NATO's and national responsibilities are defined. For every NATO-led military activities NATO provide guidance, while NATO commander is responsible to develop direction and guidance's regarding environmental protection. Training, education and application is national responsibility. On third level, NATO has developed series of documents which are applied in NATO-led maritime activities. These publications are named as Allied Maritime Environment Protection Publications (AMEPP). To date, nine publications have been developed. AMEPP publications on Maritime Environmental Protection includes a Glossary of Terms, National Environmental Regulations, an Equipment Catalogue, Ship Design Guidance, Ozone Depleting Substitute Solvent and Cleaning Agent Alternatives, and a Hazardous Material Offload Guide. These publications also apply the same principles of marine environmental protection as above mentioned NATO doctrines with the primary aim to achieve necessary level of standardization and interoperability between NATO navies.

7 CONCLUSION

Although MARPOL does not apply directly to warships, Navies apply certain provisions in accordance with national regulations. The provisions apply to a degree that does not reduce the operational capabilities of warships. Navies have developed their own specter of regulations that apply to warships in order to meet the provisions of the MARPOL Convention. Nevertheless, warships continue to retain the rights associated with their specific status in international law. Today, it is a general trend that the Navies wants to apply environmental regulations while at the same time respects technical and operational constraints. New technology solutions are therefore being implemented in order to comply with MARPOL and mission requirements on board of new warships. On old warships the provisions apply to the extent that does not affect the operational capabilities. The type and quantity of equipment depends on the class of the ship, year of construction, ships complement and the estimated duration of the operation as well. Apart from the national level, the issue of marine environment protection is also given considerable attention within NATO. NATO has developed a full range of tactical and joint publications, operational and strategic directions and guidance addressing these issues. Given the increasingly stringent international environmental regulations, the application of new technological solutions to warships represents a challenge for every navy, so it can be said that there will also be doubts in the future as to how much space on warships can be sacrificed to comply with MARPOL Convention provisions.

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DISTRIBUTION OF WASTEWATER POLLUTION FROM CRUISE SHIPS ON FREQUENT ROUTES IN THE ADRIATIC SEA

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ABSTRACT

Adriatic Sea is closed type of sea and therefor is vulnerable to all kinds of pollution. Cruising is a growing industry and it brings to the recipient country lots of benefits but also a negative impact through pollution. In this paper quality and quantity of discharged sanitary wastewater from cruise ships on most frequently used routes in the Adriatic Sea is calculated through developed models of cruise traffic in the Adriatic Sea and model of wastewater pollution. Distribution of discharged wastewater in geographic areas is defined regarding wastewater treatment system and most common wastewater management practices on board ships.

Keywords: wastewater pollution, cruise ship traffic, Adriatic Sea

1 INTRODUCTION

The Adriatic Sea is considered as closed type of the sea. With average depth of 252 meters Adriatic Sea is classified as a shallow sea. Depth decreases gradually from southern towards the northern Adriatic while north of the Jabuka basin maximal depth is less than 100 m, figure 1.

Source: Petrinec, D. (2010). Radiološka karakterizacija srednjeg i južnog Jadrana, doctoral disertation. Zagreb: Univesity of Zageb, Faculty of Science.

Figure 1: Batimetric map of the Adriatic Sea

On the coast of the Adriatic Sea lives 3.5 million people out of which 1.1 million on the Croatian coast (URBOS, 2014). At the same time since 2009 more than one million persons per year visited Adriatic Sea with cruise ships. Therefore, growing concern about pollution of the sea which purity is the foundation of Croatian tourism is justified.

Researched literature shows that sanitary wastewater have negative impact on the marine environment (US Environmental Protection Agency, 2008; Herz & Davis, 2002; Chen, 2014; Eley & Morehouse, 2003; Professional Yachting Association, 2011). This problem is particularly pronounced on large cruise ships that can carry over 8,000 people. Given the steady growth trend of cruise ship traffic globally, as well as the increase in ship capacity, arises a need for an effective assessment of the pollution of the Adriatic Sea by sanitary wastewater from the cruise ships.

The legal regulations of sanitary wastewater discharges as well as wastewater treatment systems and management practices on board ships will be analyzed below. Its application on cruise ship traffic in the Adriatic Sea derives quality and quantity of discharged sanitary wastewater from cruise ships on most frequently used routes in the Adriatic Sea.

2 WASTEWATER ON CRUISE SHIPS

Wastewater on cruise ships are generated in large quantities. Therefore, method of wastewater management on board and the quality of wastewater discharged into the sea is very important. Wastewater on ships can be divided into sanitary and bilge waste water. Discharge of sanitary wastewater from ships is regulated with Annex IV of MARPOL Convention while bilge wastewater is regulated with Annex I as oily water. Sanitary wastewater, for more efficient treatment and disposal, are divided into black water and gray water. Black water or fecal wastewater comes from toilets and medical facility sinks. Gray water comes from cabin sinks and showers, laundering, galley sinks, air conditioning condensate, and salon sinks.

2.1 Legal regulations of wastewater discharge and treatment

International Maritime Organization, IMO, is the global standard-setting authority for the safety, security and environmental performance of international shipping. Through its MARPOL Convention IMO sets international regulations for prevention of pollution from ships. Black water is regulated by Annex IV of MARPOL Convention. Gray water is not recognized as a pollutant from the IMO.

Regarding the criteria for discharge of black water, Annex IV of MARPOL Convention divides the sea into four zones:

- Port/anchorage – zone 1,
- Sea area at distance less than 3 M from the nearest land – zone 2,
- Sea area at distance 3-12 M from the nearest land – zone 3 and
- Sea area beyond 12 M from the nearest land – zone 4.

For each of these zones Annex IV proscribes standards of quality for discharged wastewater. Generally, untreated black water can only be discharged in zone 4 at regulated rate of discharge. The quality of discharged wastewater in other zones depends on wastewater treatment system installed onboard cruise ship.

2.2 Wastewater treatment equipment

There are two types of sanitary wastewater treatment systems available: marine sanitation device, MSD and advanced wastewater treatment system, AWT. The main difference between them is in quality of effluent. MSD is smaller in size and it is designed for treatment of black water only, so ships with MSD always discharge untreated gray water (UGW) while black water can be discharged treated (TBW) or untreated (UBW). In addition quality of discharged TBW is significantly worse than quality of treated wastewater from AWT which will be shown later on. On the other hand, AWT systems are large and expensive engineering plants. In most AWT systems black and gray water are collected and processed together through several treatment stages. Some final treatment stages like UV disinfection are optional so ships with AWT system can discharge: untreated sanitary wastewater (UWW), partially treated wastewater (PWW) or treated wastewater (TWW).

2.3 Quality and quantity of generated wastewater

The quality of sanitary wastewater is determined by the amount of certain substances and energy that wastewater contains. It should be noted that depending on their source from the ship all wastewater are containing various amounts and concentrations of waste products that are characterized with respect to their physical, chemical and microbiological properties. There are a number of indicators, but their impact on the marine environment and human health distinguishes following most important factors of wastewater quality: thermotolerant or fecal coliform (FK), total suspended solids (TSS), 5-day biochemical oxygen demand (BOD_5), pH value and chlorine residual (Cl). Concentrations of these factors in the wastewater effluent are directly dependent on the wastewater treatment system installed on the cruise ship.

Quantity of generated wastewater onboard ships depends on capacity of the ship which allows us to calculate total number of people on board. Taking into account the results of previous studies (US Environmental Protection Agency, 2008) that one person on board produces 31.8 l/day of black water and 253 l/day of gray water, it is possible to calculate how many black and gray wastewater is generated at a given point in time in a particular area.

Generated black water (GBW) and generated gray water, (GGW) is calculated according to the following formula (Perić, 2016):

$$GBW = \frac{K \cdot F_{CV} \cdot t}{1000} \quad (1)$$

$$GGW = \frac{K \cdot F_{SV} \cdot t}{1000} \quad (2)$$

where GBW is volume of generated black water in cubic meters, GGW is volume of generated gray water in cubic meters, K is average number of persons on the ship, F_{CV} is black water constant and it is 1,325 l/person/h, F_{SV} is gray water constant and it is 10,54 l/person/h, t is retention time in sea area in hours.

3 DISTRIBUTION OF CRUISE SHIP WASTEWATER POLLUTION

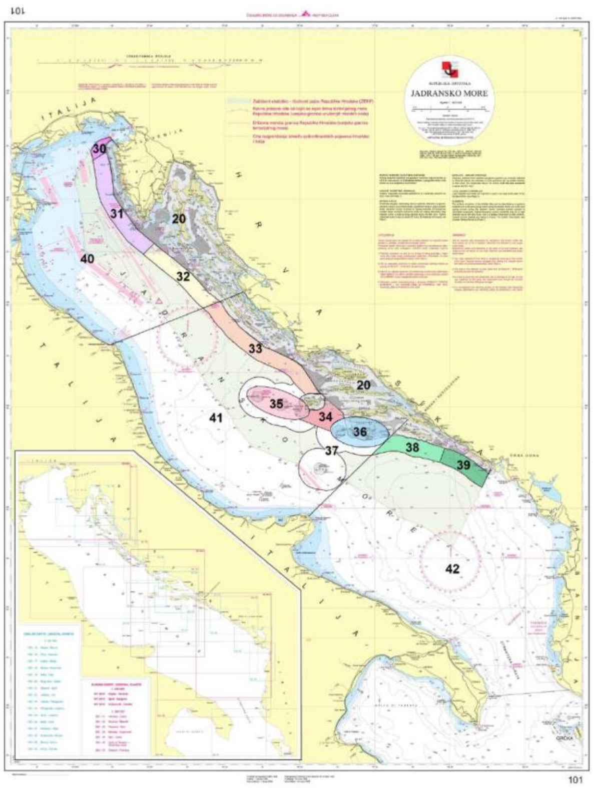
For the purpose of evaluation of wastewater pollution in the Adriatic Sea from cruise ships, Adriatic Sea was divided in 14 geographical areas shown in table 1 and figure 2 and a case study was made (Perić, Komadina & Račić, 2016). Case study included monitoring of cruise ship traffic in the Adriatic Sea during the period of one year (1.8.2014 – 31.7.2015). Traffic was monitored using an internet monitoring system "Marine Traffic". For this case study limit was set for the capacity of cruise ships and were observed only those ships carrying more than 500 passengers as relevant to the impact on the quantity of discharged wastewater.

Table 1: Geographical areas of navigation with corresponding marks.

Annex IV zones	Geographical areas of navigation	Mark gz
Zone 2	zone 2	20
Zone 3	North Istria	30
	West Istria	31
	Zadar - Unije area	32
	Šolta - Kornati area	33
	Vis - Lastovo area	34
	Jabuka- Biševo area	35
	Lastovo area	36
	marginal sea area	37
	Mljet area	38
	Dubrovnik - Kotor area	39
Zone 4	northern Adriatic	40
	central Adriatic	41
	southern Adriatic	42

Source: Perić, T. (2016). Evaluation model of sanitary wastewater pollution from cruise ships in the Adriatic Sea, doctoral dissertation. Rijeka: University of Rijeka, Faculty of Maritime Studies.

In the year of a case study cruise ships traveled on 122 different routes (Perić & Račić, 2017) out of which 100 was between two ports, both in the Adriatic Sea and remaining 22 between one port in the Adriatic Sea and one outside of the Adriatic Sea. For the purposes of this case study ports outside the Adriatic were not relevant so they were defined as entrance/exit from the Adriatic Sea. For each route geographical zone share parts UB_{gz} were developed (Perić & Račić, 2017). Their purpose is calculation of retention time distribution in specified areas if navigation time between ports is known.



Source: Perić, T. & Račić, N. (2017). Analysis of cruise ship traffic in the Adriatic Sea considering MARPOL Annex IV areas of limited wastewater discharges. IMSC 2017 (pp. 243-255). Solin, Croatia: Faculty of Maritime Studies.

Figure 2: Division of Adriatic Sea in geographical areas of navigation

During their stay in the Adriatic, cruisers had 21 different ports of call, out of which eleven Croatian. Ports can be divided into 3 categories according to the frequency of calling:

1. Frequent ports: Venice (387), Dubrovnik (338), Kotor (169), Bari (136), Split (110) and Zadar (52);
2. Regular ports: Koper (34), Brindisi (34), Trieste (33), Ravenna (26), Korčula (20), Hvar (17) and Ancona (16);
3. Rare ports: Durres (5), Rijeka (4), Rovinj (4), Šibenik (4), Bol (1), Pula (1), Trogir (1) and Chioggia (1).

From 122 routes used in the monitored year, only a tenth of all routes were used more than 40 times. A half of all routes were used four times or less. This leads to a conclusion that cruise ships use established itineraries in the Adriatic Sea. Most frequent routes are shown in table 2. On these nine routes there was 506 travels which is 51 % of total number of travels between two ports in the Adriatic Sea.

Table 2: Geographical areas of navigation with corresponding marks.

Route	Number of travels
Dubrovnik – Venice	161
Venice – Bari	100
Venice – Dubrovnik	50
Venice – Split	48
Dubrovnik – Kotor	44
Venice – Kotor	30
Split – Venice	30
Kotor – Dubrovnik	29
Kotor – Venice	25

Source: Perić, T. (2016). Evaluation model of sanitary wastewater pollution from cruise ships in the Adriatic Sea, doctoral dissertation. Rijeka: University of Rijeka, Faculty of Maritime Studies.

3.1 Quality and quantity of discharged wastewater from cruise ships

Quality of discharged wastewater is directly depended on wastewater treatment system installed on ship and wastewater management practices. Comparison of quality of discharged sanitary wastewater is shown in Table 3.

Table 3: Comparison of quality of discharged sanitary wastewater due to type of wastewater treatment system

Sanitary Waste-water Pollutants	MSD		AWT	
	TBW	UGW	TWW	PWW
Faecal Coliforms [in 100 ml]	2.04 mil.	36 mil.	14.5	25.500
BOD_5 [mg/l]	133	1140	7.99	7,99
TSS [mg/l]	627	704	4.49	4,49
Chlorine residual [µg/l]	1070	372	338	338

Source: data obtained from United States Environmental Protection Agency: Cruise Ship Discharge Assessment Report

It can be concluded that ships with AWT systems can continuously discharge treated wastewater but they can also discharge partially treated wastewater in zone 3 and untreated wastewater in zone 4. Ships with MSD can legally discharge black water in zones 3 and 4 while the gray water is discharged untreated.

Most common wastewater management practices on board ships vary between different cruise companies. All of them claim that they follow legal regulations and in addition they have their own internal rules. For example, they do not start to discharge their treated wastewater before 4 nautical miles although Annex IV defines the 3 M distance as the boundary. Also, cruise companies avoid all discharges while in port or anchorage.

While quantity of generated wastewater onboard ships depended only on capacity of the ship, quantity of discharged wastewater also depend on mode of the ship.

The ship at sea has 4 modes of operation due to the discharge of wastewater:

- MODE 1: Ship's wastewater is not discharged – it is kept in ship's wastewater tanks.
- MODE 2: Ship is discharging wastewater purified by advanced wastewater treatment plant installed on board;
- MODE 2*: Ship is discharging wastewater purified by advanced wastewater treatment plant without last stage of purification – UV disinfection;
- MODE 3: Ship is discharging partially treated wastewater (comminuted and disinfected) and
- MODE 4: Ship is discharging untreated wastewater directly into the sea.

Ship's operation mode is directly dependent on the type of wastewater treatment system installed on board because the system performance must meet legal regulations for each MARPOL Annex IV area of navigation so modes 1 and 4 can be used by ships with either one of the wastewater treatment systems and mode 2 is specific for ships with AWT system while mode 3 is specific for ships with MSD.

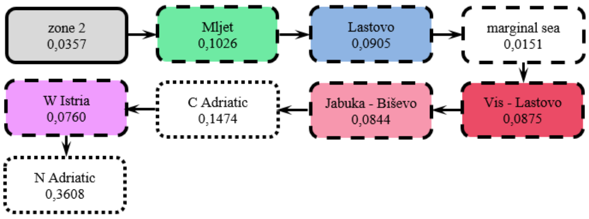
3.2 Traffic on most frequent routes in the Adriatic Sea

Nine most frequent routes have already been mentioned. It should be noted that these nine routes can be combined and presented as only 5 different routes if we watch navigation between two ports in both direction as one route. In this way most frequent routes are following:

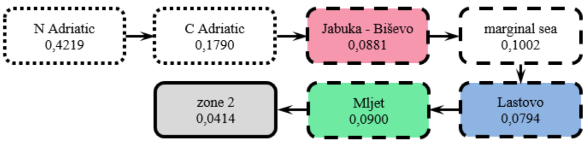
3.2.1 Dubrovnik – Venice– Dubrovnik

Movement of cruise ships between Dubrovnik and Venice is shown in Figure 3. In the year of the case study route Dubrovnik – Venice (light blue line) was used 161 times and route Venice – Dubrovnik (dark blue line) 50 times.

Geographical zone share parts for route Dubrovnik – Venice:



Geographical zone share parts for route Venice – Dubrovnik:



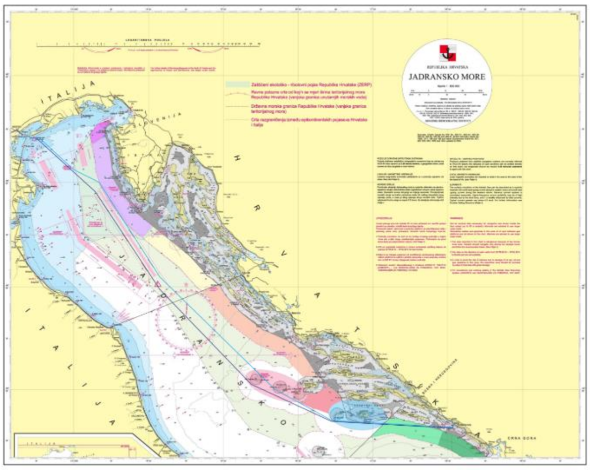
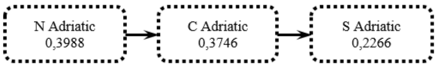


Figure 3: Dubrovnik – Venice – Dubrovnik

3.2.2 Venice – Bari

In the year of the case study route Venice – Bari was used 100 times. Geographical zone share parts for route Venice – Bari:



3.2.3 Venice – Split – Venice

Movement of cruise ships between Venice and Split is shown in Figure 4. In the year of the case study route Venice – Split (light blue line) was used 48 times and route Split – Venice (dark blue line) 50 times.

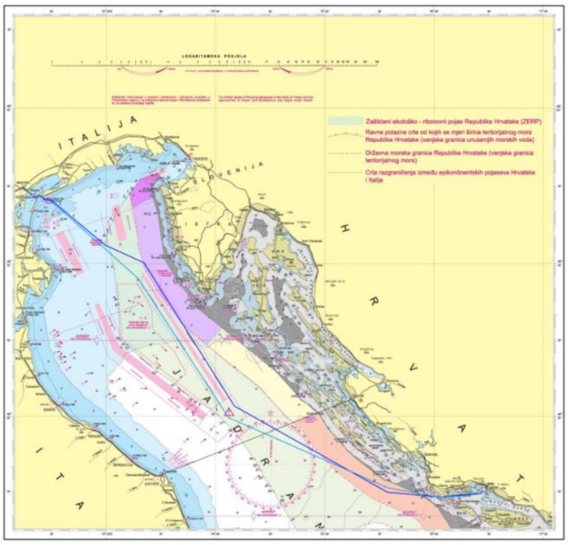
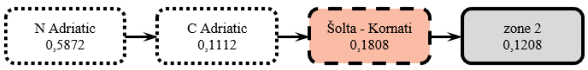
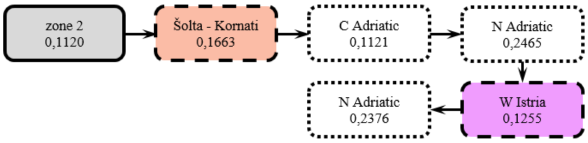


Figure 4: Venice – Split – Venice

Geographical zone share parts for route Venice – Split:



Geographical zone share parts for route Split – Venice:



3.2.4 Dubrovnik – Kotor – Dubrovnik

Movement of cruise ships between Dubrovnik and Kotor is shown in Figure 5. In the year of the case study route Dubrovnik – Kotor was used 44 times and route Kotor – Dubrovnik 29 times.

Because of the nature of their work, cruise ships generally visit one port a day, usually arriving early in the morning and departing in the afternoon so that cruise guests can visit port of call and all of its attractions. However, distance between Dubrovnik and Kotor is rather small and to keep the described schedule part of the cruise ships sailed out further into the zone 4 (dark blue line) while the other part decided to prolong their stay till the late night in the port and shorten the traveling time between ports (light blue line) in that manner.

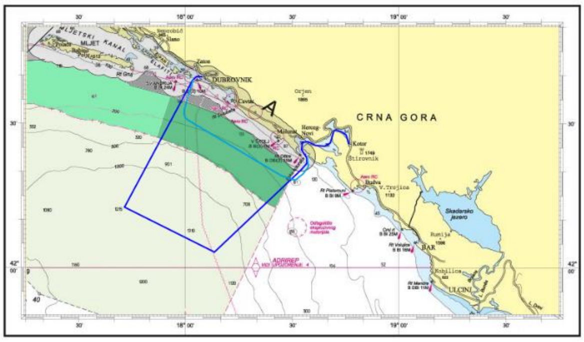
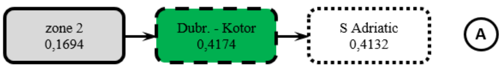
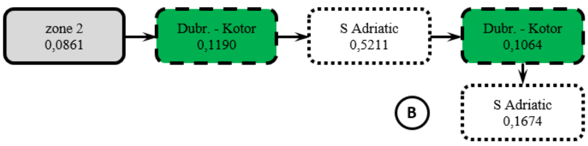


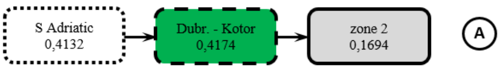
Figure 5: Dubrovnik – Kotor – Dubrovnik

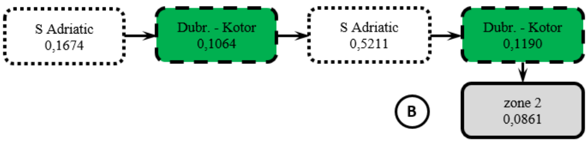
For traveling time less than 8 hours ships use shorter light blue route marked as ″A″, and for traveling time more than 8 hours ships use longer dark blue route marked as ″B″. Geographical zone share parts for route Dubrovnik – Kotor:





Geographical zone share parts for route Kotor – Dubrovnik:





3.2.5 Venice – Kotor – Venice

Cruise ships traveling from Venice to Kotor used equally two different routes: shorter east Adriatic dark blue route with arrival in the port of Kotor tomorrow (mark ″A″) and longer west Adriatic dark blue route with arrival in the Kotor day after tomorrow (mark ″B″). In the same manner on the return voyage from Kotor to Venice cruise ships used two routes: shorter east Adriatic light blue route (mark ″A″) and longer west Adriatic light blue route (mark ″B″), figure 6.

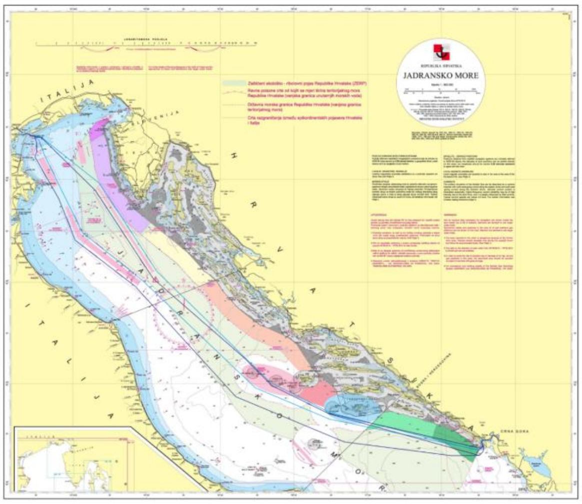
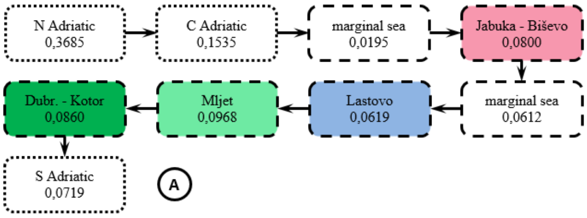
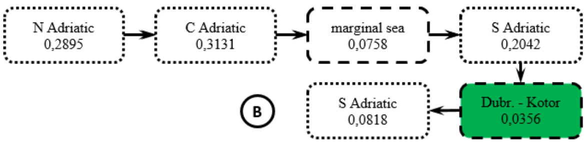


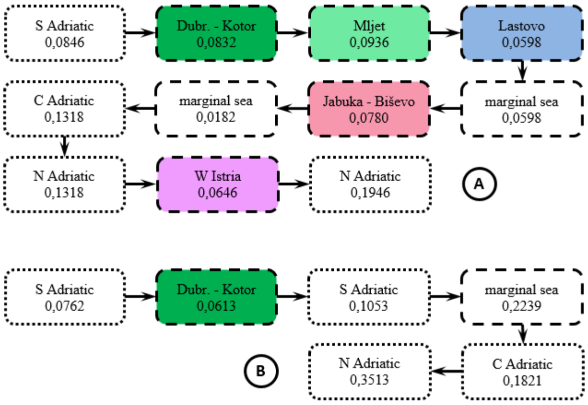
Figure 6: Venice – Kotor – Venice

Routes marked as ″A″ are for travelling time less than 24 hours and routes marked as ″B″ are for travelling time more than 24 hours. Geographical zone share parts for route Venice – Kotor:





Geographical zone share parts for route Kotor – Venice:



3.3 Distribution of wastewater pollution

Wastewater pollution on most frequent routes in the Adriatic Sea can be calculated if all factors defined and explained in this paper are taken into consideration.

Cruise ships can use different scenarios regarding combination of working modes in different navigation zones. However, in this paper, the main scenario is the one following minimum legal regulations of Annex IV of MARPOL Convention. Also, the ratio of time spend in the Adriatic Sea between cruise ships with AWT to cruise ships with MSD is 52,7 % for AWT systems and 47,3 % for MSD (Perić, Komadina & Račić, 2016).

Average capacity of cruise ships in the monitored year calculated regarding retention time in the Adriatic Sea and its capacity is 2909 persons. Using equations (1) and (2) total GBW and GGW on each route can be calculated. Using geographical area share parts UB_{gz} for each route together with total time spend in each geographical area of the route total generated wastewater can be broken down to generated wastewater for each area.

Cruise ships have limited capacity of holding tanks for wastewater. Their capacity is proportional to the number of persons on board ship, therefor, time of retention of wastewater is given as a factor and not the volume of the tanks. Average retention time of wastewater in holding tanks is 62 hours for black water (US Environmental Protection Agency, 2008) and 56 hours for grey water (US Environmental Protection Agency, 2000). It is logical to assume that cruise ships tend to empty their holding tanks between ports of call if possible. So on every route, generated wastewater from port of departure and generated wastewater from that route are discharged (if legally possible) to the sea (Perić, Komadina & Račić, 2016).

Under the assumption that the rate of discharge is continuous and equally divided throughout the route and that cruise ships are following minimal requirements of Annex IV, quantity and quality of wastewater was calculated and results are presented in Tables 4 and 5.

Table 4: Quantity of discharged sanitary wastewater due to type of wastewater treatment system

Geographical area of navigation	MSD		AWT
	DBW [m^3]	DGW [m^3]	DWW [m^3]
zone 2	0	0	14146
North Istria	0	0	0
West Istria	951	7566	7285
Zadar - Unije area	0	0	0
Šolta - Kornati area	1025	8153	7365
Vis - Lastovo area	814	6472	6313
Jabuka- Biševo area	2330	11389	10132
Lastovo area	2080	11014	9985
marginal sea area	1912	8002	6967
Mljet area	2760	13308	11801
Dubrovnik - Kotor area	2361	11096	9136
northern Adriatic	16412	97635	89995
central Adriatic	7395	45114	42843
southern Adriatic	4331	28033	26316

Table 5: Quality of discharged sanitary wastewater on frequent routes in the Adriatic Sea

Geographical area of navigation	Quality of DWW			
	FK (*10^9)	BOD_5 [kg]	TSS [kg]	Cl [g]
zone 2	2.05	113.03	63.517	4781.4
North Istria	0	0	0	0
West Istria	3E+06	28087	24763	24680
Zadar - Unije area	0	0	0	0
Šolta - Kornati area	3E+06	30263	26682	26431
Vis - Lastovo area	2E+06	24024	21181	21138
Jabuka- Biševo area	4E+06	60597	55596	55194
Lastovo area	4E+06	55061	50224	49897
marginal sea area	3E+06	48184	44671	44338
Mljet area	5E+06	71567	65724	65241
Dubrovnik - Kotor area	4E+06	60879	56009	55372
northern Adriatic	4E+07	493441	403939	401538
central Adriatic	2E+07	224824	182811	182122
southern Adriatic	1E+07	134162	108215	107685

Results presented in tables 4 and 5 show that greatest quantities of pollutant are generally discharged in zone 4 which was expected because no treatment is required for this zone. However, in zone 3 few areas have greater values than other surrounding areas. There are two areas that are considered particularly vulnerable as they are part of protected nature in Republic of Croatia: Mljet area (national park Mljet) and Lastovo area (Nature Park).

4 CONCLUSION

Cruising tourism is a growing industry with increasing number of ships and their capacities. Annex IV of MARPOL Convention divides sea in three navigation areas with different requirements for quality of discharged wastewater. To evaluate marine pollution from cruise ships in the Adriatic Sea a case study was made which provided geographical area share parts UB_{gz} for each route in the Adriatic. These share parts allows us to calculate retention time of cruise ships in fourteen defined geographical areas which is necessary for calculation of generated wastewater.

Generated wastewater are basis for calculation of wastewater pollution in the Adriatic Sea from cruise ships in different working scenarios of ships. Different scenarios include different wastewater management practices. In this paper movement of cruise ships on 9 frequent routes in the Adriatic was shown, share parts on these routes are shown and all parameters for calculation of discharged wastewater were provided. Quantity and quality of discharged wastewater was calculated in working scenario that follows minimal requirements of MARPOL Annex IV. Results show that Mljet area, Dubrovnik – Kotor area and Lastovo area are effected worst with wastewater pollution. However, special effort should be made to save purity of two of these areas which are part of protected nature in Republic of Croatia.

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RESPONSES TO CHANGES IN URBAN TRAFFIC SYSTEM

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ABSTRACT

As the sociological and psychological outcome of generating travels, their distribution and choosing the means of transport and finding the optimal path, traffic engineers learn about the travelling habits of individuals or groups of people with similar travelling habits. Generally speaking, travelling habits are regular human habits which shows a pattern in everyday traffic behaviour. Any interference in human habits, especially travelling habits, can cause stress which shows as positive or negative emotions and leads to different reactions and passengers responses. The City Municipality of Maribor held two experiments to try and figure out the reactions of local residents to changes in traffic system in Maribor. Based on domestic and international scientific studies on changes and reactions in travelling habits, there's a report that with the method of stated intentions and revealed preferences, shows different approaches of observation and describes peoples responses to changes in urban traffic that could happen in the area of the City Municipality of Maribor.

Keywords: travelling habits, urban traffic, passengers, responses to changes

1 INTRODUCTION

Insight in road traffic through the eyes of a traffic engineer connects three major systems that form the so-called group of definitions of a traffic system. Urban road traffic belongs to the roof group of road traffic, and this belongs to the group of land transport. In the handled target system, there are three essential groups depending on each other and connected to a group. These are infrastructure, means of transport or sub-structure and the user – driver or traveler, respectively. The article is based on the field of the user or the traveler, respectively, who wishes to move, reach a destination and generally satisfy his or her needs. Travellersm due to their daily essential and non-essential needs, wish to travel quickly and qualitatively. Based on these two factors, journeys begin to form in the road network of some space. As a psychological and sociological result of generation of journeys, distribution of journeys, selection of means of transport and search for a proper path, traffic engineers recognize travel habits of an individual user or a mass number of travelers with connected joint characteristics, respectively. Generally seen, a traffic habit of a nindividual is actually a living habit repeating a a pattern in traffic behaviour – the thinking of travellers. Reaching into these living habits – travel habits – from the side of a third person my cause stress and trigger different reactions of travellers.

Learning in the broadest sense of this word is a process of changing an activity under the influence of experience and with a relatively durable effect. Habits, skills and knowledge are results of learning. The broadest relevance of those are habits. [1] Travellers learn habits through their whole life based on observations of drivers, with whom they travelled from point A to point B and based on independent practical driving experiences. The greatest characteristic of habits that we learn is the resistance to changes.

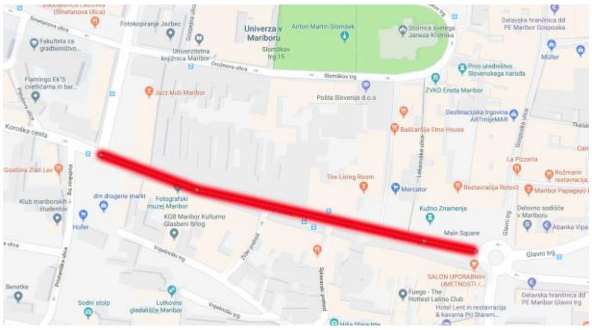
In the municipality of Maribor as an urban rad traffic system, there were already 2 experiments conducted and they gave results on the given prior statements and the description of the new driving route on an eventual change in the raod network and the measurement of actual and dynamic ractions of people to the changes. [2]. It was an experiment of introducing environmental zones I nthe centre of Maribor between October 2012 and April 2013 and the closing of Koroška cesta in 2015 between the roundabout (Stari most – Old Bridge) and another roundabout (Mariboska tržnica - Maribor Market Place).

Subject of the article is a discussion on the reactions – reactions of travelers to changes in the travelling habits caused by the canged circumstances in the raod network or infrastructure, respectively. Reactions are shown on 50 conducted partly closed opinion polls.

2 METHOD

For the preparation of the article, the descriptive method of work was used. Existing international articles on the topic of reactions to changes in road traffic were verified. For the search of databases by Science Direct, Web of Science, Directory of Open Acces Books, Prquest, University of Maribor Pres and University of Maribor Digital Libery, following keywords were utilised: travel behavior, change-travel behavior, parking habits, transportation habits and reveald preferences.

The field of collecting data was based on the experimental two-weeks closing of a part of Koroška cesta for all motorised traffice in the Municipality of Maribor in September 2015.



Source:https://www.google.si/maps/, own

Figure 1: Area of closure of Koroška cesta in Municipality of Maribor.

The opinion poll encompassed only drivers, whose travel habits were directly influenced by the changes in using the road network. Feedback information was of open type and left space for additional advice to eventual solutions in the future.

3 TRAFFIC MODELS

For the understanding and recognition of traffic habits, one has to understand the basic approaches, first, that form the elementary traffic model. In general, elementary traffic model is divided in four levels that form the start of a travel from a source point to an end point of travelling as a whole.

WE understand travelling as moving a passenger or good from an point of origin to a target point with some characteristics, with a selected means of travel, on a selected infrastructure in a certain time. Generally speaking, it is about moving into one direction from point A to point B.

A traffic model is divided into:

- generations of travel;
- distribution of travel;
- selection of means of travel;
- use of a certain route.

Generations of travel may be handled regarding some settlement or a certain group of people connected by some common characteristic.

Most frequently, at traffic planning and modelling, zoning is used that most frequently encompasses the zone of the source of travel (home) and an attractive target zone (job, providing, school) generating travels.

If we describe and analyse human mobility, then we might claim that it is composed of following basic activites:

- settlement,
- labour,
- education,
- providing,
- socializing and entertainment.

Basic activities generate trips within a certain zone or travels in another zone. Most frequent trips are connected to home (so-called home-based trips).[3] These are trips starting or ending at the traveller's home. Less frequent are those not starting or ending at home (non-home-based trips, usually business trips, providing and accidental trips). There are also transit trips, but they run thourgh a watched zone without source and target (only infrastructure is used). Mostly, trips are connected into travel chains being a collection of trips in some time (usually home – interim trips - home).

Division of trips regarding activity couples and chains [3]:

- home-home,
- home-work-home,
- home-vork.providing-home,
- home-education-home,
- home-education-providing-home-entertainment-home,
- home - entertainment (tourism)-home…

Division regarding the trveller's selection:

- obligatory trips (education and work),
- voluntary trips (not necessary).

Division regarding the time of day:

- in time or morning or afternoon peak,
- outside a time of peak and
- low-traffic time period.

The number of trips in a certain zone may be partly followed and counted, but the limit of what to count and what not has to be fixed. We have to concentrate on travellers' characterics (age, driving licence, accessibility), means of travel and distance to target zone (it's about cshort and long distance trips). The production of travel based on people is influenced by: possession of a vehicle, accessibility of public transportation, personal or family property, work activity, education and family size. If we observe traffic zones, we set the main factors of influence as: accessibility, number of households, value of real estate and number of attraction objects.

Division regarding attraction:

- number of industrial objects,
- surface of industrial objects,
- number of trade objects,
- surface of trade objects,
- pulic institutions,
- number of work places and
- accessibility.

After recognition of generation of travel, we can continue with distribution of travel telling us, where in traffic, trips actually end. The result of distribution of trips is a travel matrix in relation to timeperiods.

Selection of means of travel is influenced by three factors:

- characteristic of enquirer,
- characteristic of a trip and
- characteristic of supply (time of travel, costs, comfort, reliability, accurateness and safety).

Probability that an individual – traveler – will select some means of travel is a function of his or her socio-economic characteristics and relative attractiveness of an option. An individual decides in a way that he or she selects the offered possibility that he or she feels to be most appropriate for him or her. We say tha the individual maximizes his or her comfort [2]. There is a so-called bi-modal decision-making model between two possibilities (car or public transport) and the multi-modal model, where the traveler decides hierarchically between car, bus, taxi and train.

The last step in a traffic model is the selection of route. This step tells, on which route of travel in a traffic network – infrastructure- travelers will go or on which route they will conduct their trip. This phenomenon is also called trip assignment.

4 TRAVEL HABITS

The term »habit«, according to the Slovenian dictionnaire is something that obtains a certain form due to some human apparent characteristics. In the English transport language, this henomenon is recognized by the term travel behaviors and travel habits. Travel habits in traffic are tightly connected to travel quality, needs for geographic mobility, time of travel and a time period.

Travel habits may be divided into:

- sociologic,
- transport and
- active base studies.

4.1 Sociologic travel habits

In the framework of travel habits we seek for and exactly recognize the individual traveler or a group of people with same etimological characteristics. We can claim that sociologically related travelers take similar decisions in all four phases of a travel model.

We divide it into degrees of recognition of sociological characteristics:

1. location of residence.
2. number od inhabitants on a location of residence.
3. work active population or inactive population.
4. population culture.
5. population religion.
6. popuplation age.
7. popuplation acessibility.

4.2 Transport travel habits

Transport travel habits are habits that are divided regarding purpose, selection of means of travel and selection of traffic assignment to the road network. We speak about the last three phases of a traffic model.

Purposes were described in chapter 3 of this article.

Examples of habits of selesction of means of travel based on purpose [3]:

- work – car,
- education – bus,
- entertainment – train,
- socialising – walk.

Selection of travel assignment to the road network:

- shortest route,
- fastest route,
- simpliest route,
- weather conditions,
- extraordinary events in the network,
- knowledge of road network.

5 CHANGES IN HABITS

Reaching into human habits, in most of the cases, causes inner stress expressing in positive or negative emotions and their consequences. It is the same in changes of trvel habits, as the circumstances that can not be influenced by the traveler change. Transport policy, road traffic management, environmental standards and changes in mobility in road networks cause disturbances in a certain influence froup of travelers by their interferences, where changes are implemented. Cases in Municipality of Maribor were the introduction of an environmental zone in the centre of town, test closure of Koroška cesta, reconstruction of Ulica Pariške Komune, where we received and recognized reactions of travelers influenced by the changes.

Influence on sociologic and travel habits form feedback and reactions that may be covered through conducting certain opinion polls done as conversation on a change happening in an area used by the questioned.

Generally seen, feedback is stronger in the first moments of implementation of changes and fades in time. In a certain period of time, they totally vanish and adapt. Travelers accept a change as a renewed habit and are satisfied with it.

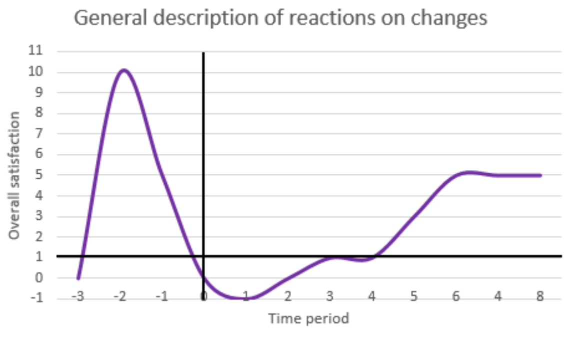


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Figure 2: General description of reactions on changes

Time spot 0 in Figure 2 is a point, where the supreme body taking care of road regulation in some area decides for a change in the road network or traffic regime, as the satus of satisfaction in a certain area is on the lowest possible level. The description of the status of satisfaction in case of a suggested new solution being generally acceptable for a location, usually is followed by high sympathy and enthusiasm (časovna točka -2). As implementation comes closer, emthusiasm starts to fall and frequently comes close to the point of 0 that was before the suggested change. In the first moments of introduction of changes, it shows that, due to the interference into the habits of the users of the former traffic system and external factors, satisfaction falls benieth the level and expresses the wish for return to the prior status. In line with the principle “time heels wounds”, after a passed time period, users accept a change at a certain point and learn it. New regulation is accepted by travelers as a new habit and general satisfaction returns to an average.

Results of such graphics may to a large extent a support for planners of urban road traffic and the leaders of transport policy in urban areas, as reactions of users of a handled area of canges may be foreseen based on experience from the past.

Data for description of a graph describing a general description of reactions on changes in a certain area has to depart from experience on a middle size pattern. A similar experiment or collection of data on travel habits was done in Belgium between 1999 and 2014, where inhabitants from the Flemish region cooperated. Researchers obtained 1780 feedbacks, by the help of which they could describe travel habits regarding a timeperiod and socio-demographic cahracteristics.

If transportation habits display large variation, if different travel purposes are habitual at different degrees, and if different moments f the day are habitual at different degrees, we expect people with difrent socio-demographic and socio-economic characterstitcs to have different levels of daily transportation habits.[4]

In the same way, socio-economic aspaects of observed travelers have to be differed. A Canadian study showed that travel habits and consequently reactions on changes of habits essentially differ from the rest of active population.

Non-workers are found to be the least sensitive to travel time in case of locations choices of restaurants for meal. Also travel time sensitivity of non-workers is low for destination choices of household responsibility type activities, e.g., drop-off and pick-up. Overall, male non-workers are less active than female non-workers. [5]

Another typical case of a socio-economic characteristic of travelers is the momental economic and financial status of some economic system. In the Peoples Republic of China, in 2011, they noticed that due to named factors, large changes of travel habits and reactions occurred on changes in assimilation to the momental economic status based on changes of transport policy that tried to increase the use of public transport in urban settlements. Their starting point for changes (increased use of public transport) was an increase of travel time of cars by change of infrastructure.

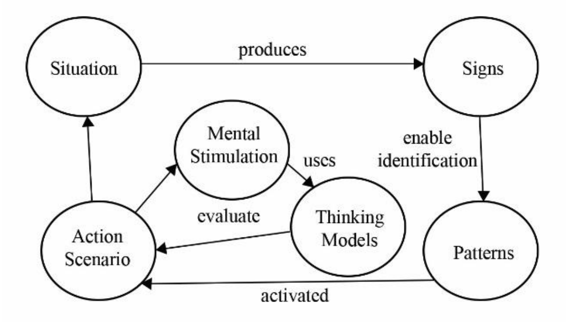
Generaly, there are two ways to promote accessibility and reduce transportaion-related social exclusion: increse proximate facilities and comtacts through land-use measures and promote physical mobility by providing feasible and efficient public transport facilities and services.[6]

5.1 Decision-Making Model

In order to predict reactions on changes, it is necessary to understand the education of a group of travelers and a decision-making model based on recognition of the situation. A well-known model based on recognition is the Klein-Model composed of three steps:

1. recognition of relations,
2. sequential assessment of choices and
3. mind simulation.

As it is not about the described model, we may use it in different fields demonstrated by the foreseen process of decision-making of travelers.[7]



Source: [7].

Figure 3: Decision-Making-Model basedon recognition

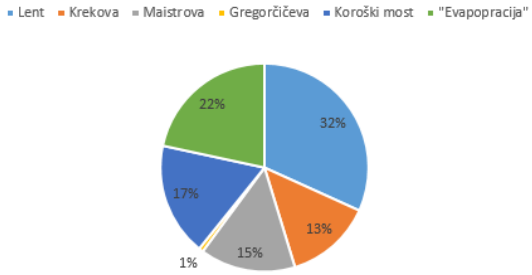
6 OPINION POLL

An opinion poll was conducted among 50 questioned, who used Koroška cesta actively or at least two times daily and at least two times per week as drivers as their primar selection for reaching their goals before and after experimental closure of Koroška cesta. All questioned passed a 20 minutes personal conversation, where they described their witnessing of the experimental closure at that time, named alternative routes they used and assessed the emotions – feelings – before closure, on the first day of closure and 14 days after closure of Koroška cesta.

The number of questioned represents 0,26% pattern of all daily travelers or vehicles using Koroška cesta before closure. The questioned were divided by following characteristics: gender, age level, employment status, community of residence and purpose of travel including Koroška cesta for reaching of the end zone.

6.1 Selection of alternative routes

During experiemental closure of Koroška cesta, the Chair for Traffic Technology and Traffic Safety of Faculty of Civil Engineering, Traffic Engineering and Architecture of University of Maribor supervised the increase and fall of traffic in the area of closed Koroška cesta and all eventual alternative routes by traffic counters: the Lent route, Maistrova ulica route, Krekova ulica route, Gregorčičeva ulica route and Koroški most route. Also, “evaporation” of vehicles was supervised.



Source: Counters of Chair for Traffic Technique and traffic safety of Fakulty of Civil Engineering, Traffic Engineering and Architecture of University of Maribor

Figure 4: Orientation of traffic in time of closure in 2015

After conducting the opinion poll, orientation towards the streets was divided into dependence in direction of driving direction from West (Maribor Market Place) towards East (roundabout at Glavni trg) and in direction from East (roundabout at Glavni trg) towards West (Maribor Market Place). It was established that drivers did not always use the same alternative route in one odr the other direction.

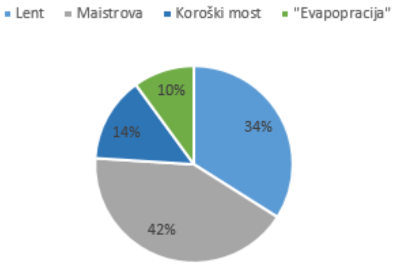


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Figure 5: Selection of alternativne routes of questioned n time of closure (direction: W towards E)

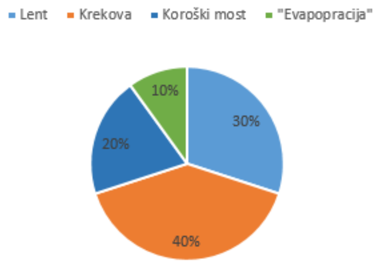

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Figure 6: Selection of alternativne routes of questioned n time of closure (direction: E towards W)

Questioned mostly decided for Maistrova and Krekova ulica for their alternative route. The streets Ob Bregu, Vojašniška ulica, Usnjarska ulica and Loška ulica in the Lent area followed and in a lower level Koroški most. None of the questioned selected Gregorčičeva ulica as alternativne route, which we conclude by the fact that in time of closure, it was used only by the inhabitants and employed in this area.

6.2 Measurement of feedback

For the obtaining of emotional reactions on experimental closure of Koroška cesta as a change in an urban area, we asked the questioned to estimate by memory the emotional moot before the change, at the change and after a part of passed time after the change. The main three questions in the opinion poll were: How did you emotionally judge trips on Koroška cesta before experimental closure? How did you emotionally judge trips on alternative routes on the first day of experiemental closure of Koroška cesta based on the made change? How did you emotionally judge trips on alternative routes after fourteen days of experimental closure of Koroška cesta based on the established change? Offered replies were of a closed type with options: 5 – excellent, 4 – good, 3 – satisfactory, 2 – bad and 1 – very bad.

Based on obtained replies, a naverage or arythmetic middle value of given replies was calculated regarding the feedback in line with common characteristics of observed questioned.

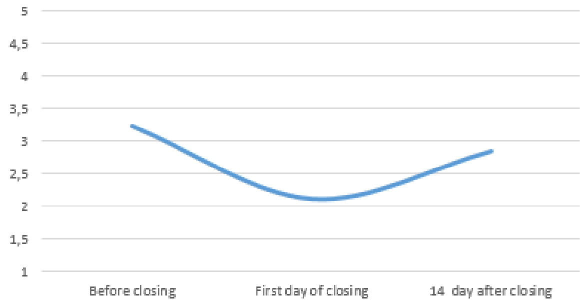

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Figure 7: Validation of average feedback of all questioned

For an easier recognition of sources of feedback or groups of travelers, who share common characteristics based on similar feedback, we prepared a comparative graph based on feedback regarding gender, age, employment status, source of place of residence and the purpose of a trip. Purposes were work, education, providing and entertainment. Residence was excluded, as none of the questioned lived in the area of Koroška cesta and its experimental closure would have immediately influenced feedback of trips in the area of residence.

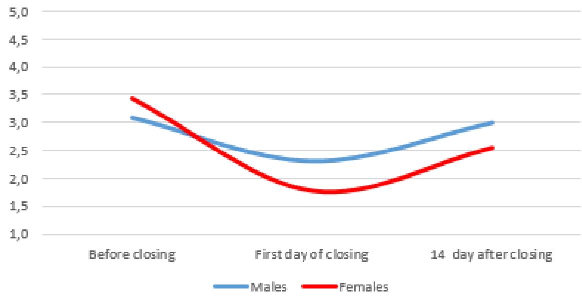

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Figure 8: Validation of average feedback of males and females questioned

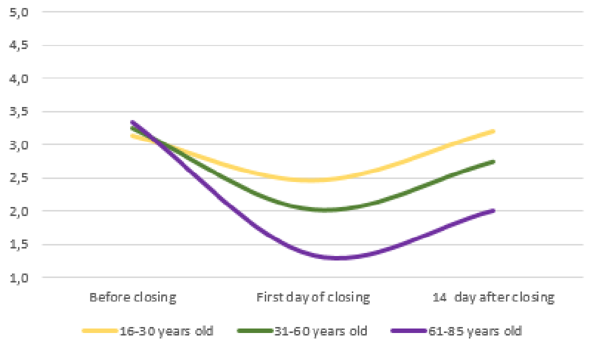

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Figure 9: Validation of average feedback by »young« questioned up to 30 years of age, by questioned of »middle age« up to 60 years of age and by »older« questioned from 61-85 years of age

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Figure 10: Validation of average feedback hy employed, of unemployed, students and by retired people questioned

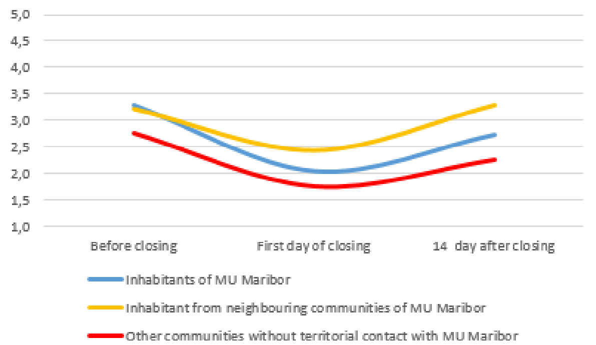

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Figure 11: Validation of average feedback by inhabitants of MU Maribor, from neighbouring communities of MU Maribor and other communities without territorial contact with MU Maribor

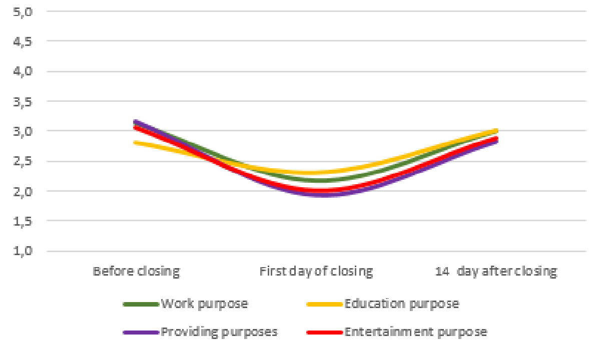

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Figure 12: Validation of average feedback by questioned with target zone for work purpose, education purpose, providing purposes and entertainment purpose

7 CONCLUSION

Feedback by questioned showed that they generally sum up the form of the graph of the general description of reactions on changes, where in a certain passed time, the assessment of satisfaction starts to rise. Rising starts right due to slow acceptance of a change and assimilation to it. The study showed in the same way that in an urban area of Municipality Maribor, female drivers are more critical and use more time to adapt to changes than male drivers. In a same way we can see that younger drivers and drivers of midde lage are less sensitive and more accepting novelties in comparison to older, who have travel habits founded in a longer period in their habits. This fact comes parallel to the employment status, as one can claim that there is a connection between the age of a driver and their employment status. Drivers living close to a place of introduction of changes seem to be more adaptale to changes, as their travel time is shorter and in most cases the changes influence their living environment in a positive way, while for drivers from distanced locations, a change is less relevant and they emotionally react in a harder way. Regarding the purpose of a trip, it was expected that the group with a purpose of work or education reacts more critical, due to use of road traffic in the tiem of peaks, but the study showed that in comparison to providing and entertainment it is low. The reason for this may be mainly the smaller pattern of questioned in comparison to all users of the travel area and in the short handling and observation of the time period.

In the running year, close to Koroška cesta there will be up to one major change in urban traffic with an essential influence on travel habits of drivers. It is about the construction of an underpass under the railway track on Ljubljanska ulica in Maribor.

Eight years after the entering into the agreement between Municipality Maribor and Ministry of Transport, at the latest at the beginning of the coming year, the construction of the underpass under the railway track on Ljubljanska ulica at Magdalenski park is goint to start. The construction of the underpass shall bring some traffic changes in the area, also the look of the whole area in the environment of the railway passing is goint to change, as well. [8]

The change will be interesting for transport engineers for observation and collection of data on reactions, as a possibility for an exact feedback by drivers for a longer time and an upgrade of immediate factors of influence, as there are media, social networks and local transport policy will open.

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DRIVING UNDER THE INFLUENCE OF ALCOHOL IN SERBIA

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ABSTRACT

The purpose of the research in this paper is to show, in the case of the Republic of Serbia, the model of data collection regarding traffic safety performance indicators which are related to driving under the influence of alcohol. The aim of the research is to determine, based on the defined traffic safety indicator, the percentage of drivers under the influence of alcohol in the traffic flow inside urban area, outside urban area, during days of the week, at daily and night time. All drivers who were at measuring points in 27 police directorates in Serbia at testing time were submitted to breath tests. In this paper 36,452 drivers were tested. The number of drivers under the influence of alcohol inside urban area has a strong positive correlation with the number of drivers under the influence of alcohol outside urban area at daily and night time. There were significantly more drivers under the influence of alcohol at night-time compared to daily time in both categories, inside urban area and outside urban area.

Keywords: safety performance indicators, road accident, drink-driving, alcohol, breath test, data quality

1 INTRODUCTION

Traffic safety evaluation is a challenge for many researchers. In order to evaluate the condition of a system it is necessary to define key elements that affect the system. Traffic safety studies have shown that the key elements that affect the system are high speed, driving under the influence of alcohol and non-use of restraint systems. Elvik and Vaa (2004) state that a key element of a system is each factor that increases the probability of traffic accident occurrence. Traffic safety can be evaluated in different ways, using direct and indirect, absolute and relative indicators (Pešić, 2012). However, it is not possible to determine key factors that lead to traffic accident occurrence based on the direct indicators. Direct indicators analysis limits the conclusions, especially in circumstances when smaller areas with less population, fewer registered vehicles, smaller number of traffic accidents and fewer killed and injured people are analyzed. On the other hand, traffic safety performance indicators show key elements of traffic accidents occurrence risk, the current traffic safety condition before the accident occurrence, and the potential for improving traffic safety condition. Traffic safety indicators represent a measure that describes traffic safety system performance and as a rule, they have a very strong relation with the final outcomes of the traffic safety system, that is, the number and the consequences of traffic accidents (Pešić at al., 2013). Gitelman et al. (2007) state that traffic safety performance indicators represent a measure of impact on traffic safety system. Hakkert et al. (2007) state that the indicators represent a connection between traffic accidents consequences and the measures for decreasing those consequences. Alcohol consumption is one of the most important factors of traffic accidents occurrence (Kim et al., 1995; Peden et al., 2004). The importance of traffic safety performance indicators related to alcohol was also emphasized in the studies Elvik and Vaa (2004), Fell and Voas (2006) and Mannetal. (2001), whereby the authors state that the number of traffic accidents with fatalities decreases if the permitted level of alcohol is lower. Similarly, Fell and Voas (2006) state that the relative risk for drivers to participate in traffic accidents is 4 to 10 times higher if they are under the influence of alcohol in the amount from 0,5‰ to 0,8‰, compared to the drivers who are not under the influence of alcohol. It has been estimated that in Europe, 25% of traffic accidents with fatalities are related to alcohol consumption (European Communities, 2013). Bartl and Esberger (2000) state, based on the research conducted in Austria, that reducing the permitted blood alcohol concentration from 0,8‰ to 0,5‰ decreases the number of drunk driving accidents by 9.4% compared to the total number of accidents.

Norström and Laurell (1997) state in their research that in Sweden in 6 years after the permitted alcohol limit of 0,2‰ had been introduced, the number of traffic accidents with fatalities decreased by 9.7%. The number of accidents where only one vehicle participated decreased by 11%, whereas the total decrease of all traffic accidents is 7.5%. Compton et al. (2002) state that the risk for drivers to participate in a traffic accident is significantly higher for drivers with blood alcohol concentration of 0,4‰ or higher, whereby drivers with blood alcohol concentration of 0,5‰ have a 38% higher risk to participate in an accident than those who are not under the influence of alcohol. For drivers with blood alcohol concentration of 0,6‰ the risk is 63% higher, whereas for drivers with blood alcohol concentration of 0,7‰ the risk to participate in an accident is 109% higher compared to the drivers who are not under the influence of alcohol.

The impact of driving under the influence of alcohol was researched by Peack et al. (2008) who came to the conclusion that young drivers under 21 have significantly higher probability to participate in a traffic accident if they are under the influence of alcohol, compared to older drivers. Therefore, Peack et al. (2008) state in their research that if drivers are under the influence of alcohol in the amount that exceeds 0,8‰, the relative risk for young drivers under 21 to participate in a traffic accident is 40, compared to older drivers whose risk is around 1, under the same conditions. Peack et al. (2008) explain the results obtained in the research by the fact that young drivers have less experience and less capability and maturity to estimate the risk and endangerment. As a reason for obtaining such results Peack et al. (2008) also state that young drivers don't have experience in alcohol consumption, which is related to probably the most important factor, that young drivers don't have experience in driving under the influence of alcohol.

Williams (2006) obtained significant research results related to traffic accidents caused by alcohol consumption. He states that the share of traffic accidents with fatalities caused by alcohol consumption in the USA decreased by 35-40% in the period from 1982. to 2003. As key reason for that success Williams (2006) marks activities of civil society and listing this problem as one of the most important social problems. Studies and experience have shown that random breath tests which are noticeable, in combination with targeted tests which are hard to notice give best effects when it comes to reducing driving under the influence of alcohol (ETSC, 1999). However, there is a question of selecting the time for random tests. For example, Mathijssen (2001) states that in most cases random tests in The Netherlands are conducted at night, most frequently on Friday and Saturday night. Several studies have shown that the percentage of drivers under the influence of alcohol increases between 22 pm and 4 am (ADV, 2012; DVS, 2011). Houwing and Stipdonk (2014) came to the similar conclusion in their research conducted in The Netherlands, where they analyzed the data regarding the number of the tested drivers and those under the influence of alcohol, which were collected during police activities in the period from January 2007 to August 2009. The research results analysis was conducted in such a way that firstly the number of drivers under the influence of alcohol at daily and night time was analyzed, then by days of the week and time of day, whereby the total period was divided into 84 two-hour intervals. The authors state that most frequently drivers are under the influence of alcohol on Sundays, then Thursdays, Saturdays and Fridays. As for the time of day, more than 2% of drivers are under the influence of alcohol from 00 to 6 am, whereby the largest percentage (4%) of drivers under the influence of alcohol is from 2 am to 4 am. Most often drivers under the influence of alcohol had blood alcohol concentration from 0.2 to 0.5 g/l (1.8%), then from 0.5 to 0.8 g/l (0.7%), from 0.8 to 1.3 g/l (0.3%) and the least common was the concentration higher than 1.3 g/l (0.2%) (Houwing and Stipdonk, 2014). Fell et al. (2014), who analyzed the number of drivers under the influence of alcohol at 300 locations at daily time and at 240 locations at night-time in the USA, came to a significantly larger percentage of drivers under the influence of alcohol. Therefore the authors state that at 12.5% of drivers at night-time the amount of alcohol is above zero, whereby 4.7% of drivers are under the influence of alcohol whose concentration is more than 0.05, whereas 2.4% of drivers have concentration larger than 0.08. An interesting fact that the authors have shown in the research is that 30% of drivers are under the influence of alcohol if they are coming from restaurants, bars, hotels and other similar commercial facilities where alcohol is used to a significant extent.

Živković et al. (2013), state that in the Republic of Serbia there has not been a significant difference in the number of drivers under the influence of alcohol who were killed in traffic accidence before and after the implementation of the new Traffic Safety Law, whereby the new Law decreases the permitted alcohol limit from 0.05 to 0.03.

In this study is present the method of data collection related to driving under the influence of alcohol indicators and the possibility of mutual comparison of the obtained data.

2 PREVIOUS RESEARCH

After analyzing the importance of traffic safety indicators monitoring, a need for international comparison and evaluation of traffic safety condition, based on the measured indicators, emerges. Defining and measuring traffic safety performance indicators related to alcohol is the most complex task for researchers in the field of traffic safety. Assum and Sorensen (2009) mention different methods for defining traffic safety performance indicators related to alcohol: according to SafetyNet Project, an indicator is defined as *% of fatalities in traffic accidents where at least one of the drivers was under the influence of alcohol*; according to ETSC (2007) *traffic safety performance indicator related to alcohol is defined as the percentage change of the annual number of fatalities in traffic accidents related to alcohol, compared to the percentage change of all traffic accidents with fatalities*; according to WHO (2008), *traffic safety performance indicator related to alcohol is defined as the number of traffic accidents related to alcohol per 100,000 inhabitants* (Assum and Sorensen, 2009).

SafetyNet Project and global experience (Assum and Sorensen, 2009) suggest that for defining indicators related to alcohol, indicators connected to fatalities at traffic accidents where at least one of the participants was under the influence of alcohol should be used, and that's precisely due to the assumption that most countries would conduct tests in cases of traffic accidents with fatalities.

In favor of it is the fact that in Germany and Great Britain it is prohibited by the constitution to randomly test drivers for the presence of alcohol (Assum et al., 2007). Also, in countries where random tests are allowed, not many countries have such data because those tests are expensive and there are problems to provide a suitable relevant sample. An additional problem is the term "a driver under the influence" of alcohol, bearing in mind that the permitted blood alcohol concentration in different countries in Europe in 2005. varied from 0.0 to 0.9 g/l (Assum and Sorensen, 2009).

There's an issue whether the data collected in that way are valid and relevant for defining indicators of driving under the influence of alcohol, whereby several important questions arise:

- What is a relevant factor for defining driving under the influence of alcohol?
- How to collect data for relevant indicators of driving under influence of alcohol?

Assum and Sorensen (2009) mention in their research the values of traffic safety performance indicators related to alcohol according to the SafetyNet Project and ETSC (2007) (Fig. 1), whereby they point out the difference regarding indicators value for Italy, Slovenia, Germany, Sweden and The Netherlands. Similarly, the authors conducted a comparative analysis of indicators values in SafetyNet Project and WHO (2008) (Fig 2), where they stress out the differences regarding indicators value for almost all the countries. In their research the authors state that the differences regarding values of traffic safety performance indicators related to alcohol between the SafetyNet and WHO data are significantly larger than the differences between the SafetyNet project and ETSC.

Assum and Sorensen (2009) state in their research that the quality of data related to alcohol indicators was not appropriate for five out of seven countries due to differences in data collection. The authors emphasize that the obtained results call into question the possibility of comparing alcohol indicators across countries. In conclusion, Assum and Sorensen (2009) state that the conclusions obtained using comparative analysis of indicators values in European countries may be unreliable, whereby if the European Union wants complete data with the possibility of comparison, a testing of all drivers who participated in traffic accidents with fatalities must be conducted, even if the driver didn't cause the accident. The authors add that the standardized procedures of data collection should be developed for all traffic safety performance indicators with the help of international activities.

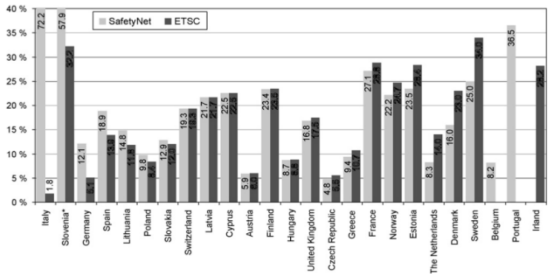

Figure 1: A comparative overview of the values of traffic safety performance indicators related to alcohol according to the SafetyNet Project and ETSC, 2007 (2004-2005) (Assum and Sorensen, 2009)

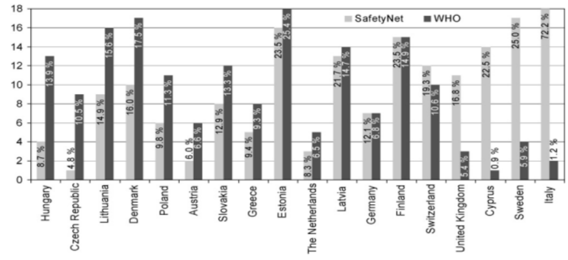

Figure 2:. A comparative overview of the values of traffic safety performance indicators related to alcohol according to the SafetyNet Project and WHO data, 2008 (2004-2005), Sourc(Assum and Sorensen,2009)

3 METHOD FOR DEFINE INDICATOR

The research has been conducted on the roads in Serbia in order to determine the number of drivers under the influence of alcohol. At the beginning of the research, fields of research were defined in 27 police directorates in Serbia (Fig. 3).

The research was conducted with the support of traffic police, using breath tests. The research was conducted on the "funnel" principle at 27 locations inside urban area and 27 locations outside urban area, in the period from Monday to Sunday, from 15th until 21th December 2015. The research was carried out in such a way that one research team tested all drivers at the research site for 15 minutes in urban area and 15 minutes outside urban area alternately. The research was conducted during all days of the week, in the period from 09 am to 03 pm and from 9 pm to 3 am.

The criteria for selection of the location include: traffic flow; that a significantly large number of drivers under the influence of alcohol is not expected (the nearness of commercial facilities, restaurants, bars etc); that there's appropriate space for forming the "funnel" that enables testing all drivers who happen to be at the research site, but also provides safety of police officers and drivers who are stopped.

All data were consolidated according to the testing site and time, whereby 26,542 drivers in 27 police directorates in Serbia were tested. Based on the conducted research, an alcohol indicator was determined: *% of drivers under the influence of alcohol in the traffic flow, which represents the ratio of the number of drivers under the influence of alcohol who had blood alcohol concentration higher than 0.3 mg/ml to the number of all tested drivers*. In time of testing, the permitted blood alcohol concentration for drivers in Serbia is 0.30 mg/ml.

Figure 3: Police directorates in Serbia

4 RESULTS

In the conducted research a total number of drivers who were submitted to breath test is 26,542. In this research blood alcohol concentration found at drivers varies from 0.00 mg/ml to 4.11 mg/ml. The division of blood alcohol concentration for the tested drivers is shown in Table 1.

Table 1: The division of blood alcohol concentration for the drivers who were submitted to breath tests

BAC (g/l)	Number	Proportion
0-0,3	26190	98,67%
0,31-0,5	133	0,50%
0,51-1,2	180	0,68%
1,21-1,6	31	0,12%
1,61-2	4	0,02%
>2	4	0,02%

Of the total number of drivers in traffic flow, 0.97% were under the influence of alcohol in the amount larger than 0.3 mg/ml.

The results of the research indicate that the largest number of drivers under the influence of alcohol is on Saturday, then on Thursday, Wednesday, Friday and Sunday. The smallest number of drivers under the influence of alcohol is on Monday and Tuesday. The number of drivers under the influence of alcohol is larger inside urban area than outside urban area. Both inside urban area and outside urban area the number of drivers under the influence of alcohol is larger at night time compared to daily time. The number of drivers under the influence of alcohol in traffic flow inside urban area is significantly larger at night, compared to daily time.

5 DISCUSSION AND CONCLUSION

This study shows that the availability of existing data on traffic safety indicators related to alcohol does not allow for international comparisons. There are many reasons for such a situation. First of all, there are three different definitions of indicators related to alcohol, which differ from one another. Not all countries collect all indicators related with alcohol, but usually one, which limits the possibility of comparison country. Comparison of the existing values of the indicator related to alcohol is shown in Figure 4, from which it can be concluded that the values of the indicators according to the ETSC, SafetyNet or WHO are the different. Namely, for a small number of countries (Latvia, Cyprus, Austria, Finland, Hungary and United Kingdom), the analyzing indicators have approximate values. Generally, the values according to the ETSC and SafetyNet show the similar values, while the WHO value is significantly different. Data collection in Serbia is the fourth different method. Results from Serbia also does not compare with ETSC, WHO or SafetyNet.

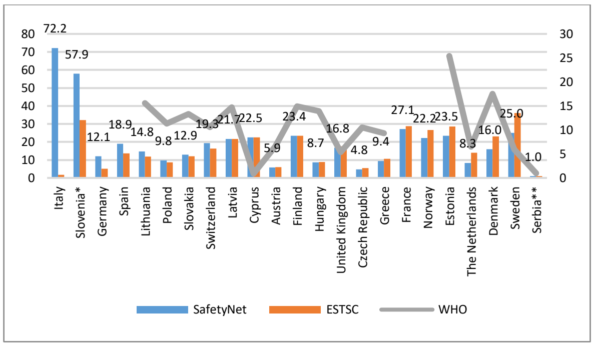

Figure 4: Comparative overview SafetNet, ETSC, WHO and method in Serbia

In February 2018, ETSC presented the data on the percentage of drivers under the influence of alcohol above the legal level. Presented data at first looks that comparisons possible (Figure 5). However, the document states that comparisons are not possible due to the selection of the sample, location and time of testing. In addition to this, it is problematic to compare these results for the reason of the legal limit.

Differences in the percentage of drivers under the influence of alcohol, presented at Figure 5, can be effect to the non-representative of causes drivers, targeted breath testing, and etc.

In different countries there are different legal limit of alcohol, which makes the comparison of drivers under the influence of alcohol above the legal, very problematic.

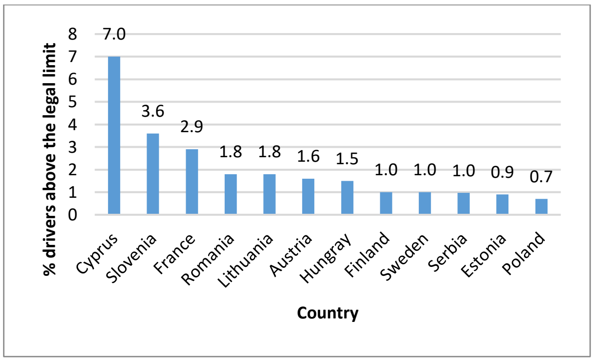

Figure 6: Proportion above the legal limit (in %) (ETSC, 2018; Serbia, 2015)[1]

In this paper we have presented the method of data collection regarding traffic safety performance indicator that is related to driving under the influence of alcohol. The mentioned method overcomes the problems concerning the validity of data regarding traffic safety performance indicator. The testing that drivers were submitted to did not require any additional funding, as the research was planned in detail and coordinated with regular police activities.

The number of drivers under the influence of alcohol at night time is three times larger than at daily time. The results of the research in this paper regarding the number of drivers under the influence of alcohol according to days of the week are similar to the results of Houwing and Stipdonk (2014) research.

A significantly larger number of drivers under the influence of alcohol in urban area, compared to roads outside urban area can be explained by the fact that drivers under the influence of alcohol more often drive short distances within urban area, whereas outside urban area a larger number of drivers takes long distances and under such circumstances they consume alcohol less. Similar explain is for differences during the day. Drivers in night times more often are drinking than daily time.

The largest number of drivers under the influence of alcohol is on Sunday inside and outside urban area, and also on Monday in urban area, which might be explained by the specificities of night life in Serbia (until the early morning), whereby drivers don't understand that even the next day their blood alcohol concentration will be above the permitted limit of 0.3 g/l.

The advantage of this paper are the new method by random breath tests, which can valid the problems representative of data. For representative data is need that the research location isn't near objects where alcoholic drinks are consumed to a great extent.

The output of this paper is the display of the model that measures traffic safety performance indicator which was called the *% of drivers under the influence of alcohol in traffic flow*. The results and the model for data collection regarding the alcohol indicator might be used in all systems where it's possible to apply road-side random breath testing, and the results of the research can be used for successful planning of countermeasures for traffic safety improvement. The results of the research can be used for a more quality planning of time and period of police activities and force on the field in Serbia.

Further research should focus on defining the relation between the traffic safety indicator obtained by the model which was developed in Serbia and traffic safety indicators defined by other researches (i.e. SafetyNet Project, ETSC or WHO), in order to provide the possibility to compare indicators values.

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GIS-BASED SPATIAL ANALYSIS OF CHILD ROAD ACCIDENTS: CASE STUDY CITY OF NOVI SAD

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ABSTRACT

There is an increasing concern in the world about the children safety. This study identifies the road hotspot traffic accident involving children in the urban area. The time period of the analysis includes the 4-year records of accidents in Novi Sad, the second largest city of Serbia. The Geographic Information System (GIS) is a popular tool for visualizing traffic accidents as well as for their spatial analysis. This paper present a methodology using GIS and Network Kernel Density Estimation to study the spatial patterns of injury related road accidents in Novi Sad. The result confirms that children are exposed to the high chance of road crashes near schools and the main city streets. The main goal of this paper was to present spatial visualization technique which provides us to note particular patterns of children road accident casualties. The results of this study showed that the major number of accidents were occured at locations with high vehicles and pedestrian exposure.

Keywords: Spatial analysis, GIS, Accidents, Children, Hotspots

1 INTRODUCTION

In the development process of European and national road safety programs, it is necessary to work in order to prevent fatalities and injuries on the road. Therefore, decision makers should adapt the traffic system to the requirements and vulnerability of its users. The analysis of the spatial distribution of accidents on the road network provides a unique approach to the observation and road safety monitoring. Identifying high density accident locations is the first step in the traffic safety management process. Road safety is one of the major problems that society faces, especially when it comes to the most vulnerable categories of participants.

About 1.2 million people die each year in accidents, and 30-50 million people are injured in the world. When it comes to the youngest road users, in 2004, it was estimated that there was about 262.000 dead among children and youth between 0 and 19 years old, which is almost 30 % of all fatal injuries among children and youth. When analyzing only children up to 14 years old, there is an indication that there are about 167,000 fatalities within this age category. The exact number of injured or disabled children at the annual level as a result of accidents is not well known, but it is estimated at around 10 million (WHO, 2004).

For people of all age groups, there are factors that increase the possibility of injuries on the road. The number of such factors has been especially increased among young participants. The impact of these factors is particularly intensified and the incompatibility of use of roads because the roads were built near schools and large residential areas. Clifton and Kreamer-Fults (2007) provided clear evidence that the presence of recreational facilities near school zones is associated with serious injuries to pedestrians in traffic accidents. Johnston (2008) also focused on the major parts of the risk assessment for children moving to and from school. Schools are places where children come every day as soon as possible and after school activities so that they represent the main places of events. Analysis the location of accidents involving children near schools and comparison with the physical characteristics of local areas can help local governments when planning infrastructure measures.

Locations of accidents can be analyzed by methods of spatial analysis which are non-parametric techniques, among them the most famous are nearest neighbor distance analysis, K-function method, and Kernel density estimation, when analyzing the network in a geographical unit. Nearest neighbor distance analysis and K-function method are similar methods that examine data grouping. In the present study, the nearest neighbor distance analysis was used to test grouped data.

When testing a location with spatial density of points in space, the most popular is the kernel density method, which has wide application for identifying locations with high density of accidents (Silverman, 1986; Xie and Yan, 2008). By using the kernel density estimation, the density of accidents can be presented as the surface at which the accidents are presented as points in space, taking into account the number of accidents at each location. For each accident occurring in a particular location, the density is defined so that the density value is greatest in the center and decreases when the density value is removed from the center (Silverman, 1986; Vemulapalli, 2015). The Kernel density method is one of the most suitable methods for visualizing traffic accidents as continuous surfaces (Chainey and Ratcliffe, 2013).

The Kernel method can be divided into two approaches: the planar Kernel method and the network Kernel method. The first approach uses the Euclidian distance to estimate the density of points. An overview of previous studies indicates that the first approach to the kernel method has wide application in the analysis of accidents in order to identify locations with high accident density (Flahaut et al., 2003; Sabel et al., 2005). However, this method has significant limitations, in the event of an accident occurring within the pavement network, the assumption of a two-dimensional space does not valid (Xie and Yan, 2008), besides which the density of the road network has been excluded. Many studies have attempted to overcome these limitations by improving planar Kernel methods in network space. Many researchers compared the planar Kernel method and the network Kernel method, where shown the advantages of using a network Kernel method (Borruso, 2008; Kuo et al., 2011; Larsen, 2010; Steenberghen et al., 2004; Yamada and Thill, 2004). The network kernel method is based on network distance and density measurements in a one-dimensional space (Timothée et al., 2010). However, the main disadvantage of both the planar Kernel method and the network Kernel method is that there is no specific statistical approach for testing locations with high density accident (Xie and Yan, 2008; Yao et al., 2015; Nie et al., 2015).

The main goal of the present study in the process of conducting spatial analysis is to visually present all locations with high density of traffic accidents involving children in the street network in the city of Novi Sad. For this purpose, the software package ArcGIS was used, which included the SANET software program designed for detection of locations with the highest density of accidents by the researchers (Okabe et al., 2006). This visualization is needed in order to apply engineering, educational and others measures in order to increase the children safety on the roads.

2 METHODOLOGY

2.1 Data preparation

In this paper, research was carried out in the urban area of Novi Sad. The municipality of Novi Sad is a central part of all events in Autonomous Province of Vojvodina. Through the urban area of the city, there are state roads and 880 city streets, which make up the total road network in this area. All of the streets in the analyzed area have been georeferenced for this research and show as lines in the space (Figure 1).

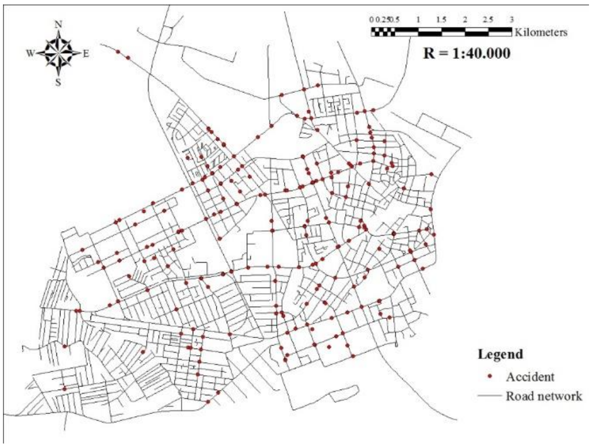

Figure 1: The visual presentation of data included in the analysis

In the urban area of Novi Sad, there were 428 traffic accidents involving children in the period from 2010 to 2013. Two data sources were used: (1) police data on road accidents (2) daily police reports. In the analysis of a geo-positioned as 367 accident so that each accident represents a point in space. Georeferencing is carried out by using ArcGIS 10.2.

2.2 Nearest neighbor distance analysis

Nearest neighbor distance analysis is used to determine whether the points are grouped in the analyzed area. In this work, accidents with children are represented as points in the space where each point has certain coordinates.

This method tests the complete spatial randomness (CSR) hypothesis in terms of the distance from every point in a given set of points on the network to its next nearest point in the set. The CSR hypothesis request that accidents are independently and identically distributed according to networks. Besides, those accidents follow the homogeneous binomial point's process on the network. The relation between distances (d) and accident (α), can be presented as a function (Okabe and Sugihara, 2012):

$$fi(d|\alpha) = 1 - \left(\frac{(|L| - |L(d|\alpha)|}{|L|}\right)^{n-1} \quad (1)$$

Where |L| denotes the length of the subnetwork, d is the distance between two accident, α is an accident which is represented by a point.

The nearest neighbor distance analysis requires defined iterations and input class for the software AcrGIS. In this research, 1000 Monte Carlo simulations were selected. The class interval is the range distance of each class of distances is selected 10 m.

2.3 Kernel density

The Kernel Density tool calculates the density of features in a neighborhood around those attribute. It can be calculated for simple linear units of points and lines.

A simplified kernel density function in a 2-D space is called a planar kernel function and is calculated on the basis of the following function (Xie and Yan, 2008):

$$\lambda(s) = \sum_{i=1}^{n} \frac{1}{\pi r^2} k\left(\frac{d_{is}}{r}\right) \quad (2)$$

Where $\boldsymbol{\lambda(s)}$ represents the density of points on the particular location **s**, **r** represents the bandwidth radius, **d** is represents the distance between locations and **k** is the Kernel function that model the distance and radius.

The extended kernel method is represented by a linear projection as a type of network space. Instead of calculating density across the surface, which is the case with the planar Kernel function, the network Kernel function calculates the density based on the linear units. The basic difference between the planar Kernel method and the network Kernel method is shown in Figure 2.

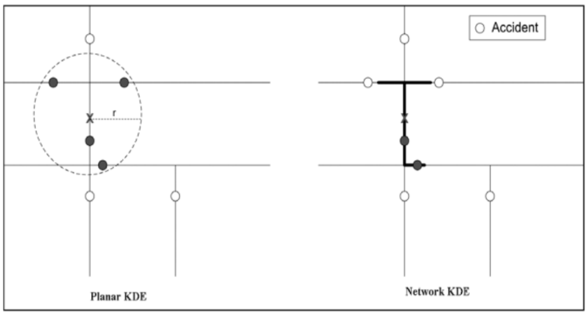

Figure 2: The basic differences between the Planar KDE and Network KDE (Xie and Yan, 2008)

In the present research, the network Kernel method for estimating the density of accidents with children on the geopositioned road network was used. As mentioned earlier, this method was applied within the framework of the SANET project developed by the author Okabe et al. (2009), in order to examine the spatial correlation of network events. The network Kernel function is defined in two cases, the first when the center of the Kernel function coincides with the intersection of two lines on the network or is located near the intersection and the other when the center of the Kernel function coincides a cross section of two lines on the network (Okabe and Sugihara, 2012.). Both cases are used to identify density accidents, in which case the function is:

$$K_q(p) = \begin{cases} \frac{k(d_s(q,p))}{(n_{i1}-1)(n_{i2}-1)\cdots(n_{ik}-1)} \\ 0 \end{cases} \quad (3)$$

For: $d_s(q, V_{ik-1}) \leq d_s(q,p) < d_s(q, V_{ik})$

For: $d_s(q,p) \geq h$

Where $K_q(p)$ represents the Kernel function, q is represents the center of the Kernel function, ds is represents the shortest distance between two points, h is the bandwidth, and n is the number of nodes of lines on the network. The Figure 3 shows a detailed view of the elements that are needed for this analysis.

The value of the network Kernel function is the same as the value of the basic Kernel function, as long as the center of the function coincides with the intersection of two lines on the network with the condition $(0 \leq d_s(q,p) < d_s(q, V_{i1})$ (Harirforoush and Bellalite, 2016)

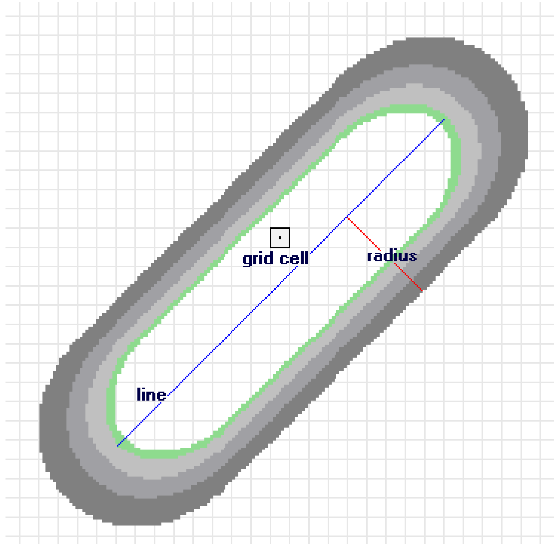

Figure 3: Application of Kernel network functions with the necessary elements (ArcGIS PRO)

The value of the network Kernel function in the case that its center is located near the cross-section of two lines is distributed to individual parts as presented in Figure 4.

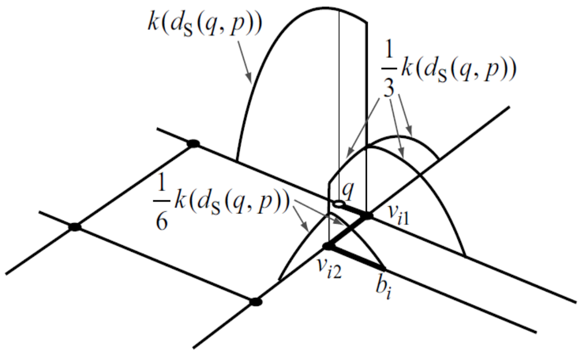

Figure 4: A network Kernel of functions that are distributed on equal parts (Okabe and Sugihara, 2012).

With the network kernel function, it is very important to select the bandwidth. The appropriate bandwidth is based on the subjective assessment of the researcher. If a large bandwidth is chosen in the analysis, the density is represented as a straight surface in the space, and therefore it is difficult to distinguish locations with high density of accidents. Many studies have so far focused on determining the bandwidth to best show the results of the analysis (Mohaymany et al., 2013; Plug et al., 2011; Silverman, 1986; Xie and Yan, 2008; Young and Park, 2014). In accordance with these studies, in this paper, a bandwidth of 300 m for the identification of the density of accidents is selected and the cell size is 30m. The size of the cells allows us to divide the analyzed section into a smaller number of cells in which the analysis is carried out.

3 RESULTS

In the urban area of Novi Sad in the period from 2010 to 2013, there were 428 traffic accidents involving children (age group 0-14). The analysis of traffic accidents involving children was done in several steps. The first step is the positioning of traffic accidents in the ArcGIS software package. In addition, the spatial randomness (CSR) hypothesis was examined in terms of the distance from each point with the method of the nearest neighbor distance. Network Kernel method was applied in order to display the exact locations on the network.

Results this the nearest neighbor distance analysis are presented as a cumulative number of points in relation to the nearest neighboring distance in software package R (Figure 5). The first line shows curves the observed values accident whereas the other three lines presented as expected values with a confidence interval of 5% above and below average.

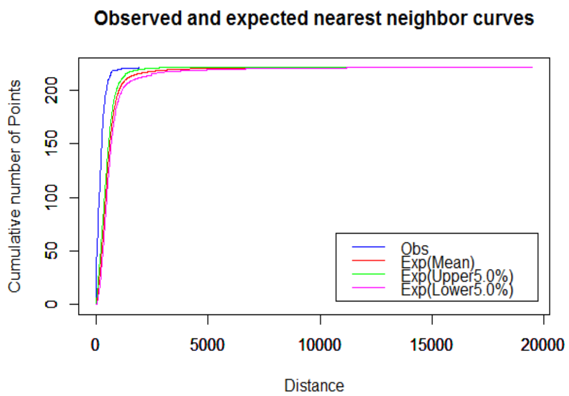

Figure 5: Curves cumulative numbers the observed and expected values

When the observed values are above the 5% level of reliability, then data set is more grouped than expected by a random point. In this paper, the accidents are more grouped than expected and CSR hypothesis is rejected. Therefore, the spatial analysis of traffic accidents is assessed as grouped.

Analysis of grouped data set is applied by methods Kernel density analysis. This method allows us to discover hot-spots locations on the urban network, where occurred a large number of accidents with children. Kernel density analysis is conducted in a software package ArcGIS according to with previous research (Larsen, 2010; Mohaymanyet al., 2013; Plug et al., 2011; Harurforoush et al., 2016.).

The results of the identification hot-spots accident with children for the total analyzed period showed that the major number of accidents were recorded at locations with high vehicles and pedestrian explosure. The largest number of accident hot-spots locations were distrubuted along major streets in the urban area. In addition, accident hotspot locations can be affect factors related to the land use, the presence of objects designed for children as well as factors related to the road infrastructure (Figure 6).

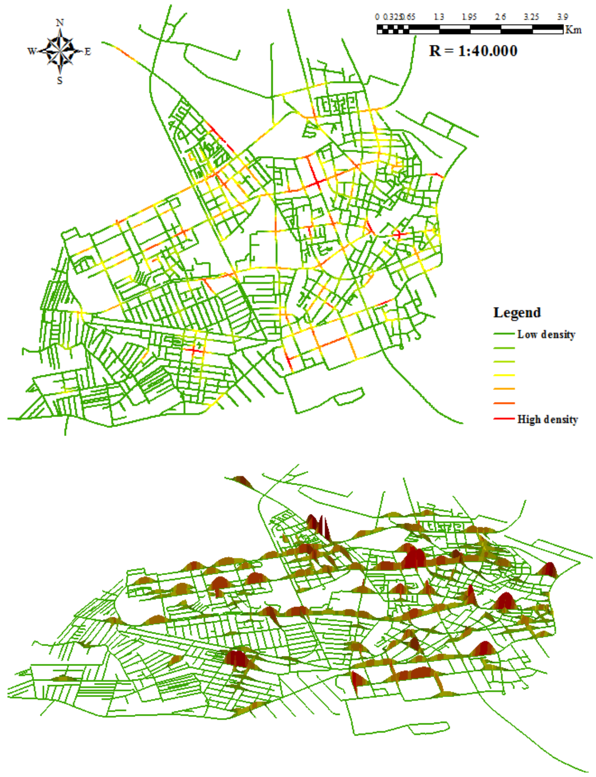

Figure 6: Visual representation of location with hot-spot points in the urban area of the city of Novi Sad.

In Figure 6, we can see that hotspots locations are located on the streets: Bulevar Oslobođenja, Bulevar kralja Petra I, Bulevar Jovana Dučića, Hadži Ruvimova Narodnog fronta, Futoška i Šarplaninska. In these streets, noticeable the presence of schools which affects children's activities leading to increased risk of an accident.

4 DISCUSION

The process of identifications hot-spots locations is the first and fundamental step in the traffic safety management process. Traffic safety in the last few years is one of the problems of the society, especially with respect to traffic accidents involving children. Although the number of traffic accidents involving children has been decreasing in recent years, this problem is still relevant and requires detailed consideration.

The application of the GIS software package enables the visualization and analysis spatial data. The most famous technique for testing data grouping is the nearest neighbor distance analysis. This analysis allows us to examine the data grouping, but it does not allow us to determine the locations of these groups. Whereas the standard error of distribution is not known, there is no simple test of the significance of this comparison (Okabe et al. 2006). The results of this analysis show that there are hot spots in the urban area of Novi Sad are related to random points. In other words, the distribution of accidents related to the expected random distribution is more concentrated than expected at random points. This result is expected because the accidents affect the characteristics of travel and the environment. Generally, more accident with children usually occurs around schools as well as at the locations where children's exposure is increased. The lack of this method terms to the positioning of hot-spots locations. In order to identify hotspot locations in this paper is applied to the network Kernel analysis.

Kernel method is the most appropriate technique for identifying locations with high density of accident on the road network. This method can be applied in two different ways, it is presented in a two-dimensional and one-dimensional space. The paper presents a network Kernel method in a one-dimensional space. The advantage of this method is that it analysis simple linear units which are related to the line and the point. The linear units involved in the realization of this work are specifically geo-positioned, where the line represents the street and the point is an accident, which is consistent with other researchs (Borruso, 2008; Larsen, 2010; Kuo et al., 2011; Harurforoush et al., 2016.; Satria, & Castr, 2016.)

In order to improve the children safety on the road, the process of identifying a segment of the road in which high accidents are expressed is of key importance. Therefore, this is necessary to implement a spatial analysis, that enables the representation of specific locations where are identification accidents with the involvement of children in the urban area of the city. This provides to consider the guidelines which give an answer to the question when and where it implements most effective to apprthe opriate measures, which provides great assistance to decision makers in road safety.

Children are especially exposed to accident risks on the road during departure and return from school and during school stay. The best practice in the field of improving the safety of children in traffic is working focused on two basic directions, the first direction is activities aimed at improving and adapting the traffic environment to children and the second direction are activities aimed at adapting children to a traffic environment.

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QUALITY AND PERSPECTIVE OF THE LOGISTICS FREIGHT FORWARDING OPERATOR'S SERVICES ACCORDING TO CURRENT TRENDS AND ENVIRONMENT

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ABSTRACT

The present global logistics market differs significantly from the traditional freight forwarding market. Traditionally speaking, the freight forwarding market was predictable and influenced by volume and intensity of global trade, dynamics growth, GDP, industrial production, actual customer and consumer expectations and other relevant indicators. Current logistics market is susceptible to hurried changes and today we can recognize many actual trends in environments which extremely define competitiveness of logistics operators on the global market. Some of them are: sustainable development, fourth industrial revolution, internet of things, digitalization, alliances, great logistics operators against small ones, new customer and consumer expectations. The mentioned terms define a new concept of the logistics freight forwarding operator's services which has a direct impact on the service quality. Therefore, the main problem in this paper is to analyze and determine the actual indicators of the logistics freight forwarding operator's service on the competitive logistics market.

The aim of this paper is to analyze and provide answers to some of the main questions such as: Which of the actual trends will determine the service quality and competitive perspective of the logistics freight forwarding operator? Which indicators will have a dominant influence on the service quality of the logistics freight forwrding operators? How can these service quality indicators be evaluated and measured? What have the logistics freight forwarding operators to do in the context of these actual trends and environment?

Keywords: actual trends, logistics freight forwarding operators, service quality

1 INTRODUCTION

The competitiveness of logistics and freight forwarding services, under the conditions of very dynamic trends on the global level and along with numerous economic factors, is also conditioned by a technological growth and the raising of the quality level in accordance with the customer's requirements. Therefore, current indicators of the logistics freight forwarding operator's services imply logistics and freight forwarding services that follow the mentioned macro trends in terms of economy and technology as well.

Consequently, the main problem in the research carried out in this paper is the survey and the analysis of the current state and the prospects of the logistics freight forwarding service and operator, the quality and competitiveness of being subordinated to the dynamic growth of technology.

As the logistics freight forwarding operators are the key partners in the supply chain, their adaptability to the changes on the global market have an influence on the total quality of the global supply chain.

In this sense, the aim and contribution of this research is to define actual trends and current operations terms that predetermine the logistics and freight forwarding service quality aimed at defining the relevant current indicators on the basis of which it is possible to measure and evaluate the quality of the logistics freight forwarding service.

The research is divided into five parts with an introduction into the analysis of the research issue. Actual trends and the competitive environment on the logistics freight forwarding operators market are analyzed in a separate part, actual quality indicators and the possibility of their evaluation are detected as well, and according to these laid facts a conclusion has been reached on the perspective and conditioning of the quality on the logistics freight forwarding service market.

2 CHARACTERISTICS OF THE LOGISTICS FREIGHT FORWARDING OPERATOR'S SERVICES ACCORDING TO CURRENT TRENDS AND ANVIRONMENT

The traditional freight forwarding service was based on offering services such as traditional transport, warehousing and contractual logistics. This part of the research deals with the analysis of the alteration from the traditional to the current logistics freight forwarding service level. The operations of an actual logistics freight forwarding operator are based on the capability of offering additional values such as: guarantee arrangements, revenues management, insurance and customs broker services etc. In order that the logistics freight forwarding service provider can act as a provider of *"services at one place",* his operations should be carried out according to the current trends and environment on the competitive logistics market.

Table 1 shows a systematic listing of the relevant traditional and current logistics freight forwarding services characteristics.

Table 1: Characteristics of the traditional and current logistics freight forwarding service

Characteristics	Traditional freight forwarding service	Current logistics freight forwarding service
Communication	Traditional use of e-mail, telephone, fax, mail Waiting for a reply	Joint venture Alliances Applications Platforms Notifications
Access to information	Handwritten files Shortage of information on Internet	Simplicity in data analysing (smart devices are able to analyze and record data by themselves)
Documents	Handwritten signature Copying documents - filing Sending documents by mail	Different on-line platforms (by using "log-in" all documents can be handed over and looked for) Electronic signature Transactions made easier (net-banking)
Knowing the market and the consumer		"Up to date" with changes on the market e-trade, Fulfillment of timetables-quicker changes in cargo delivery Risks management
Service reliability and safety (speed of the service)		Door-to-door 24/7/365, Speed, efficiency, simplicity, Just-in-time concept, Delivery "on the same day", "7PL", Cyber crime,
Available flows of cargoes	In the early '90s, two thirds of the global flows of goods moved through the top 50 routes.	Two decades later this has fallen to just over a half. Furthermore, intra-regional trade accounted for slightly over 50% of the value of total traded goods in 2014[1]
Transport capacities	Traditional use of the means of transport	„Uber" transport Overcapacity of the world's fleet Automated vehicles, ships
Sustainable development		Logistics operators as part of the supply chain affect the "greener" supply chain formation
Training, education,	Traditional freight forwarding schools	Artificial intelligence Greater possibilities to carry out researches
Technology	Traditional transport by lorries, trains, airplanes and ships Simple code readers	Robotics Sensors 3D printing Blockchain Personal Internet/Internet of Things (IoT) ICT- Track and trace

Source: made by the authors based on different sources

The existence of advanced technological solutions, that in the last 15 years have considerably contributed to the affirmation of the logistics freight forwarding services, can be clearly seen out of Table 1. For example, when referring to reliability and speed of service, it is evident that technologies that considerably facilitate business processes and contribute to strengthening the position of the logistics freight forwarding operators on the market are dominating.

It can also be concluded that all changes, that appear in the supply chain as a result of the innovative technologies application and digital transformation, will lead up to the raising of the level of „intelligent"business processes. According to the latest report of the International Data Corporation *("IDC")*, it is expected that, by the year 2020, approximately 80% of the interactions in the supply chain will be carried on by a trade network based on *"cloud"* technology which is assuming a large-scale ratio. [1]

The service offered to their clients by the logistics freight forwarding operator is a demanding one and includes a large number of complex transactions. And when a great number of entities involved in the logistics freight forwarding operations are added besides, a logical conclusion is made that operations need to be simplified.

[1] More on: http://www.scmr.com/article/freight_forwarding_market_going_through_structural_change (30.01.2018.)

In other words, if the aim is to make the consumer of the services satisfied and the payment of the executed operation effected, the use of electronic aids is a much more important precondition for a competitive and qualitative logistics freight forwarding service. Moreover, IT and the electronic data interchange (EDI) are improving [7,225]:

- service control,
- receiving reports on accidents/delays aimed at preparing corrective measures
- order alteration
- control of carriers
- planning future forwarding based on actual indexes
- e-communication with the customs and with a number of other partner sin the logistics chain

The most important structural changes by logistics freight forwardin operators take place in the digitaliation of the business processes based on "*cloud*" technology, advanced analitics ("*real-time decision making*"), "*blockchain*", "supply chain perceptibility", "artificial intelligence" and "*Internet of Thing*" ("*IOT*"). Furthermore, investments into digital platforms ("*Maersk NYSHEX*"), digital partnerships (*Alibaba, Maersk and CMA-CGM*) and e-trade (*e-biling, e-bidding*) are not to be omitted.

Apart from what is mentioned above so far, an essential characteristic of the actual logistics freight forwarding service is the more and more frequently appearance of joint venture projects in the form of a "*blockchain*" with logistics freight forwarding operators included in together with leading IT firms (for example: a "*joint venture*" between *Kuehne+Nagel and Temasek, Maersk and IBM*).

3 INDICATORS OF CURRENT LOGISTICS FREIGHT FORWARDING SERVICES

Innovativeness and transparency are preconditions for offering good quality logistics freight forwarding services. The evaluation of the service quality offered by logistics freight forwarding operators on the competitive and more and more demanding market implies a revealing insight into the actual quality indicators, which are to be analyzed further on.

3.1 Innovativeness and transparency of logistics services

According to actual market trends and demands, the quality of the logistics freight forwarding services is generally manifested in terms of innovativeness and transparency.

Generally speaking, the term "*innovative or die*" prevails in the logistics freight forwarding operations. Innovativeness, in this sense, involves applying and using new technologies and digital advances that will increase the quality of the services and at the same time meet the requirements of the consumers.

Transparency of the logistics freight forwarding services, on the other hand, means a complete insight into the management of a firm including "*end-to-end*"*data* that will be available to all parties interested in thus giving them a greater control over the whole operations and services. Transparency of the services contributes to identify problems in the supply chain, which could otherwise reduce the quality of the logistics freight forwarding services.

For example, logistics freight forwarding operators' transactions within the logistics chain are very often full of incorrect data, spreadsheets are wrongly filled in which, in dealings between the logistics freight forwarding operators and the consumers, carriers or third parties can cause confusion and slow down the operations of all those taking part in the supply chain. In this way, the quality of the logistics freight forwarding services is also reduced and if we wish to ensure a "*real-time visibility*", a more sophisticated approach is needed which will include a combination of correct technology and human resources

An example of is the fact that shipping companies require a higher level of transparency in and control over the flow of cargo, and it is, due to this fact, possible to ensure a qualitative service within the supply chain by using transparency in the real time, offering to shipping companies and other consumers an insight into the whole supply chain" [2].

3.2 Indcators of the current logistics freight forwarding service quality

The traditional logistics freight forwarding service was mainly a „very much hand operated one" depending on the experience of the employees and on the delivery of the printed documents by phone, fax and e-mail.

The market changes and, therefore, current large logistics freight forwarding operators have introduced changes into their operations implementing an electronic exchange of information, while the greatest part of medium-size operators and all small-size ones are not able to use IT systems to establish a direct communication[2].[4]

The transformation of the logistics freight forwarding service into a digital one has already brought great advantages to the operations so that a great number of logistics freight forwarding service quality indicators have just been conditioned by this type of operational transformation.

[2] More on: https://arrow.dit.ie/cgi/viewcontent.cgi?referer=https://www.google.hr/&httpsredir=1&article=1034&context=nitlart (30.01.2018)

Table 2: Actual logistics freight forwarding service quality indicators

INDICATOR/Description of the indicator
USING COMMUNICATION PLATFORMS
Communicationl platforms represent means of communication that make "evrything at one place and at real time". Based on the consumer's data, the consumer can simply connect himself to the platform and is then able to follow his cargo and to communicate with the logistics freight forwarding operator. Some platforms offer the possibility to fill in documents involving the use of electonic euipment and each platform has collected and stored previous documents if they were archived (for example SHIPNEXT)
„*CLOUD*" OPERATIONS
The advantage of using "*cloud*" technologies in busines operations refers primarily to low capital investments into hardware and the suprastructure in general. It is very simple to install and can be enlarged as business operations increase.
ARTIFICIAL INTELIGENCE
Artificial intelligence is based mainly on sensors by means of which it is possible to predict particular conditions. For example, the carrier can, by using different weather forecasting tools, predict the weather conditions and based on them organize the transport.
ROBOTICS
Advantages refer to providing assistance to people (many repeated actions are thus automized) so that they could be based on value added services, increasing in this way the productivity of the complete service offering process.
BLOCKCHAIN
Enables a detailed insight into and control over the transactions automating the information between the consumer and the logistics freight forwarding service provider. The transaction can be carried out immediately what leads to an efficient fulfillment of the remaining service and here we can immediately identify this service from the service carried out by an agent broker who used to carry out transaction services for his client.
ALLIANCE, „*JOINT VENTURE*", DIGITAL PARTNERSHIP
Logistics freight forwarding operators join together and initiate join venture projects with IT firms in order to speed up the digital process, improve the efficiency in offering services and achieve added values for the consumrs.
SEVEN PARTY LOGISTICS „7PL"
The evolution of „*3PL*" and „*4PL*" into „*7PL*" has brought many advantages, because one service provider can offer the consumer the „*3PL*" and „*4PL*" services under one roof. The advantage for the consumer is an easier way in solving the problem by using only one contract, one invoice and contacting only one person managing the whole logistics freight forwarding service.
„REAL-TIME DATA" AND ENSURING ACCURATE DATA
„*Real-time data*" represents the key indicator in measuring the logistics freight forwarding service. The advantage on the present logistics market has the one who has got a right information at the right moment. To ensure accurate information is what the logistics freight forwarding operators should aim at, as this is the way to ensure a better insight into the service offered within the supply chain. This indicator can be connected with the artificial intelligence which makes the use of accurate information at real time possible . .
„CYBER SECURITY"
Transfoming the operations into digital ones and using advanced technologies, the danger of "*cyber attacks*" increases too, worrying considerably even logistics freight forwarding operators representing thus an extra expense intended for investments into system and data security.

Source: Made by authors

The greatest part of all detected indicators, as shown in Table 2, refer mainly to technological transformations that should stimulate digital operations and thus achieve a higher quality level. A sufficient proof of how important the transformation into digital operations is, are the data from DHL, a system of three million documents - consignments delivered on a monthly basis of which 75% are exclusively in a digital form. [12]. Indicators, like *"7PL"*and support to the development of *"greener supply chain"*, are of utmost importance as they represent common public indicators that have to be borne in mind in the first place when defining the quality of the logistics freight forwarding service. *"7PL"* represents the human strength in the form of *"outsourcing",* while the *"greener supply chain"* is a general tendency of the transport policy and the society as well. In this sense logistics freight forwarding operators can considerably contribute to the *"greenification"* of the supply chain.

3.3 Evaluation of the logistics freight forwarding service quality

The logistics freight forwarding service is defined neither from the strategic nor from the geographical point of view. Therefore, the evaluation of the logistics freight forwarding service quality is based on defining the dimensions and the attributes of the quality that correlate with the above-mentioned quality indicators.

As a unique concept of dimensions and attributes for measuring logistics freight forwarding services does not exist, the logistics freight forwarding service quality indicators, as defined in this research, can be used as a basis for defining the quality evaluation model. For example: particular logistics freight forwarding service quality dimensions and attributes are common to the service quality in other similar port activities within which port service represents one of the links in the whole supply chain.

According to the available literature, the model very often used in evaluating the service quality and the logistics freight forwarding service as well is the SERVQUAL model based on the evaluation of 5 dimensions and 22 attributes. [5,287]

The logistics freight forwarding service is defined as the key factor in the competition among logistics freight forwarding operators. It includes the quality as perceived by the end consumers and the logistics freight forwarding operators. [8]

Therefore, they have pointed out the ISO 9000 standards as the fundamental standard basis in defining the logistics freight forwarding service quality. [8]

Measuring the consumer's satisfaction, one can get the best report on the operations carried out, and it is, therefore, perfectly rational to define and measure quality from the consumer's point of view. This fact can be additionally supported by the ISO 8402 standard which defines quality as a set of entities characterized by the ability to satisfy the mentioned and implicit needs. [9]

4 LOGISTICS FREIGHT FORWARDING OPERATOR'S PERSPECTIVE AND COMPETITIVENESS

The current logistics freight forwarding operator is faced up with a number of challenges and questions regarding competitiveness and survival on the logistics market.

The entire logistics freight forwarding operations represent a complex process in which the current logistics freight forwarding operator must adapt all his resources to the quick progress of technology in order to be able to compete on the competitive logistics market.

The logistics freight forwarding operator is directing, more and more, the greatest part of his operations towards the process of digitalization, imposed as a key need if operations are to be optimized on the demanding global market, although only and exclusively mega logistics freight forwarding operators can really face these challenges.

Besides transparency and competitiveness, some recommendations refer to the planning of a proper transport fleet for direct local deliveries, establishing "*joint venture"* agreements resulting in dividing transport capacities and cargoes in order to get all transport groups equally included into, using more and more available information from intelligent equipments and applications to make the data analysis a much easier one and to decrease the expenses.

It is presumed that, with all the mentioned digital devices and aids, the logistics freight forwarding service providers are not allowed to make mistakes, and that a logistics freight forwarding service should be brought to perfection.

However, if a further outlook of the logistics freight forwarding service is considered, a conclusion can be reached that these services will be intensively changing in the future according to the needs of the global market and that the future development will be based on further investments into digital systems, robotics ("*collaborative robots"*), delivery effected by drones and sustainable means of transport (…).

The development of technology implies, at the same time, a number of other questions, such as the key question of the data security and protection ("*cyber crime").* Thereby, the question and level of data security and protection becomes another qualitative service indicator posing itself as one of the great investments that must be anticipated in the optimization of the operations.

The prospects of the logistics freight forwarding operators implies the recognition of the logistics freight forwarding operator in the "3PL" (Third Party Logistics), "4PL" (Fourth Party Logistics) and "7PL" (Seventh Party Logistics). The link between the "3PL" and "4PL" logistics freight forwarding operators has evolved into "7PL"logistics freight forwarding operators who, inside the notion "*outsourcing",* have already been deeply-rooted into the logistics freight forwarding services.

The reason for the appearance of *"outsourcing"*, defined as using external services of a specialized supplier to attend to those operations and functions that are considered as of strategic importance for the realization of the mission, lies into the fact that a firm cannot be successful if it is not concentrated on providing the type of service it offers best or better than its competitors.

While being concentrated on the basic activities, the subsidiary ones are switched over to specialized service providers and in doing so numerous advantages of the operations, improvements and quality of the process are evaluated, increasing at the same time the efficiency and competitiveness of logistics freight forwarding operators on the market .[11,3]

5 CONCLUSION

Logistics freight forwarding operators offering logistics freight forwarding services are a compulsory part of the supply chain. In order to optimize the supply chains, logistics freight forwarding operators have developed from the traditional freight forwarder to the logistics freight forwarding operator – namely to the "3PL", "4PL", "7PL" operator.

In doing so, the current logistics freight forwarding services provider offers the "3PL" and "4PL" logistics freight forwarding services under one roof or, in other words, as a substitute for a certain number of employees coming from different logistics departments to perform operations, so that clients have one person to deal with, one contract, one invoice what essentially optimizes the operations.

The mentioned evolution of the logistics freight forwarding operators has been induced not only by the impulse to improve and optimize the operations and the logistics supply chain, but also, and in greater part, by the recognition of the information technologies, and, in accordance with this, by new trends and possibilities offered by competitive factors on the logistics freight forwarding service market.

The mentioned trends have changed the expectations and demands of the consumers, so that new current logistics freight forwarding service quality indicators can be detected on the logistics freight forwarding market that determine the competitiveness of the logistics freight forwarding operators.

In this sense, the evaluation and potential measurement of the logistics freight forwarding service quality needs to be actualized according to new trends and competitive environment which make new dimensions, attributes and indicators of the logistics freight forwarding services a condition of.

Besides taking into account actual logistics freight forwarding service quality indicators, it is necessary to form a unique model for the measurement of the logistics freight forwarding service quality, which will, by giving a real picture of the service and operation competitiveness, render the planning and optimization of the mentioned services on the ever more demanding global trade and logistics market possible.

ACKNOWLEDGMENTS

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THE ANALYSIS OF THE PROJECTED SEA STATE IN THE FUNCTION OF THE SAFETY OF NAVIGATION

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ABSTRACT

In the process of projecting ships and other objects it is important to foresee the probability that during its life span the ship will meet an extreme sea state, i.e. extremely high waves. For this purpose it is necessary to analyze and forecast extreme values of a certain random process. In the short-term sea state forecast significant wave height and the medium wave period are considered to be constant during the observed period. The long-term forecast of determining extreme wave height values takes into consideration two methods. The first consists of determining distribution of wave heights function by summing the part of the short-term distribution, and the other consists of determining the extreme sea state for the set return period. The results of the projected sea state obtained in this way assume that the wind in the observed area lasted for at least 3 hours. To get return periods, i.e. to get the most probable extreme value which is expected in 50 years, it is necessary to determine significant wave heights of the extreme sea state. Considering the fact that on the eastern coast of the Adriatic there are no continuous wave height measurements, as an example of the analysis of the projected sea state the observed data of the port sea state and in the open sea were taken into consideration. Considering that these are not the exact measured data of the wave height, the analysis covers also measured data of the wind direction and speed and all of this was incorporated in the case of the stranding of 3 ships in the Split area in the extreme navigation conditions on 05/03/2015.

Keywords: sea state, wind, waves, safety of navigation

1 INTRODUCTION

Sea state is the condition of a larger area of the open sea that occurs due to combined influence of wind, currents, wind-generated waves and swells. Thus, it is of crucial importance to mariners to monitor the sea state and behave accordingly. Every year there are losses of human lives, ship damages or sinking and other tragic losses, large waves being one of the main risk factors in maritime traffic and navigation. The general ″rule of thumb″ is the stronger the wind, the rougher the seas, the higher the waves. There are also other factors affecting sea state, however, wind-waves are generally speaking the most influential factor as far as the sea state is concerned.

2 METEOROLOGICAL SAFETY OF NAVIGATION

World Meteorological Organization – WMO and International Maritime Organization – IMO as executive organs of the United Nations, have set and elaborated standards and recommendations which require the member states to establish and maintain maritime meteorological services. In Croatia, this is in jurisdiction of Maritime Meteorological Center in Split which is a part of the Croatian Meteorological and Hydrological Service.

The activity of the maritime meteorological service includes meteorological reports and warnings for the open sea, coastal areas and main ports, search and rescue service as well as supervision over the ? meteorological reports from ships.

The safety of navigation, anchoring and mooring is endangered when critical meteorological requirements (minimum) are exceeded or ships, ports, navigation phases and participants in maritime traffic. Many of these minimums are not established by measures and analysis, but are determined by evaluation and officers´ experience in port authorities, i.e. ships.

The influence of weather, and especially certain meteorological parameters, is very significant for our everyday life. Hence the weather reports in general or about one of its elements (wind, waves or sea state) is very useful information for everyone who plans their activities based on the events in the atmosphere or at sea. Meteorological forecasts foresee some future time or only some of its elements.

In further text special attention will be given to projected sea state as one of the most significant meteorological elements at sea.

3 DETERMINING PROJECTED SEA STATE

A sea state is defined as a general state of free sea surface on a big body of water. The sea state values vary according to the weather and different weather conditions. On the eastern Adriatic coast the sea state is estimated according to the Douglas Sea Scale, considering that there are no installed instruments for measuring the wave height, such as buoys, radars and satellite measurements. The sea state is an oceanographic element which is closely connected to the direction, strength and duration of the wind in a certain area.

The sea state has to be monitored and estimated according to the Douglas Sea Scale which is verified and approved by the World Meteorological Organization (Table 1).

Table 1: Douglas Sea Scale

code	height in meters	description
0	0	calm*(glassy)*
1	0 - 0,1	calm*(rippled)*
2	0,1 - 0,5	smooth*(wavy)*
3	0,5 - 1,25	slight
4	1,25 - 2,5	moderate
5	2,5 – 4	rough
6	4 – 6	very rough
7	6 – 9	high
8	9 – 14	very high
9	over 14	phenomenal

A sea state refers to the wave height that is affected by local winds as well as swells. Wind speed is defined with the Beaufort scale. As far as weather observation is concerned, while sea state reporting remains a legal international practice, with modern in situ observing techniques we try to avoid using sea state or Beaufort scale as we prefer direct readings from appropriate instruments (e.g. wave buoys and anemometers respectively).

As far as forecasts and warnings are concerned, WMO does not recommend the use of sea state as it recommends using wave height; however, national meteorological services may be using sea state (e.g. Douglas scale) in some cases instead of wave height.

Ships, but other sea crafts as well, should be projected in a way that they withstand load to which they are exposed at extremely high waves. Evaluation of the limiting load values is connected to a certain probability that those values will not be exceeded during given time. For this purpose, it is necessary to analyze extreme values of a random process, which in this case would regard the maximum wave height, i.e. maximum sea state.

3.1 Extreme values

A ship's response on sea waves is a relationship between a random variable of initial probability density function *f(x)* and initial distribution function *F(x)*. The extreme value of this responses defined as the highest value for which it is expected to appear in a certain number of observations or during a certain period. Considering the fact that these elements are put in order from the smallest to the biggest, i.e.: $x_1<x_2<x_3... <x_n$, the last value in the line represents the biggest expected. That value which has its own probability density function $g(x_n)$and distribution function $G(x_n)$.

In monitoring the mutual relationship of these functions the question arises whether it is possible to set the maximum wave height in a longer period of wave monitoring. Since the functions $f(x)$,$F(x)$, $g(x_n)$ and $G(x_n)$mutually dependent, the initial density function of a value can give us extreme wave values. From the definition of the distribution function follows:

$$f(x) = \frac{dF(X)}{dx} \tag{1}$$

For extreme values:

$$g(x_n) = \frac{dG(x_n)}{dx_n} \tag{2}$$

Probability density function of extreme values $g\ (x_n)$ first derivation of the function $G(x_n)$:

$$g(x_n) = \frac{dG(x_n)}{dx_n} = \frac{d\{F(x_n)\}^n}{dx_n} \tag{3}$$

Expressions:

$$\frac{dF(x_n)}{dx_n} \approx \frac{-1}{n} \tag{4}$$

and

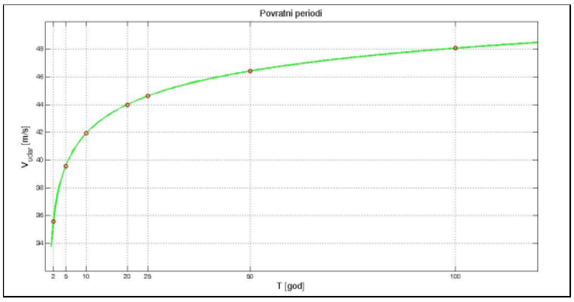
$$F(x_n) \approx 1 - \frac{1}{n} \tag{5}$$

determines that the most probable extreme value which is expected in *n* observations can be determined from the initial function $F(x_n)$.

Extreme wave or response amplitude for a longer period of time (e.g. 50 years) is determined by a return period. It is the period during which a certain value will be exceeded only once.

3.2 Example of wind and sea state correlation

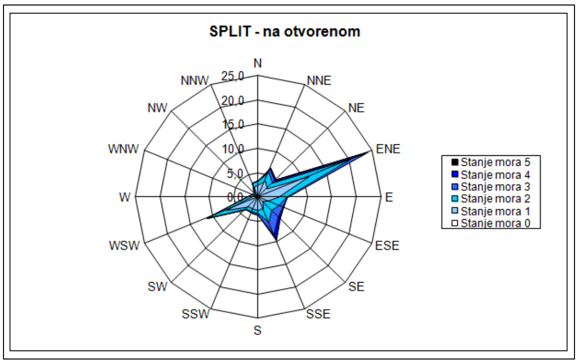
As previously mentioned, on the western Adriatic coast there are no continuous measurements of wind height and direction, so that their return periods could be made as precisely as possible based on such data. Wave height is estimated and noted as a sea state. Considering the fact that sea state is set by wave height and that waves are mostly generated by wind direction and speed (wind waves), help in determining wave height for a longer period of time gives us the return period of wind. The picture 1 shows the return period of wind for the period of 2, 5, 10, 20, 25, 50 and 100 years.



Source: authors

Figure 1: Graphic display of return periods of T years obtained by the Jenkins distribution of extremes from wind speed measurements data for broader area of Split of extremes in the period from 2006 to 2015

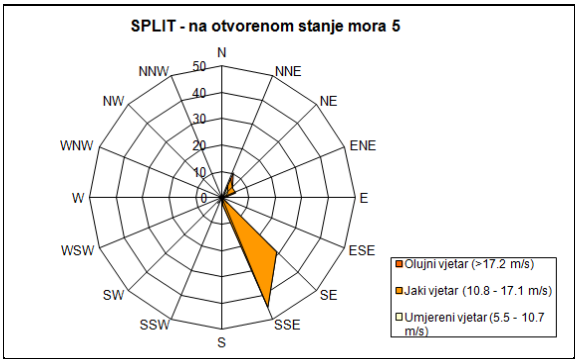
To be able to point out, as clearly as possible, what to expect from the analysis and determination of projected sea state in a certain area, according to the data of the return periods of wind and sea state, picture 2 shows ″sea state rose″ with the example of observed sea state in Split area.



Source: authors

Figure 2: Sea state rose according to the data of wind direction and sea state in broader Split area

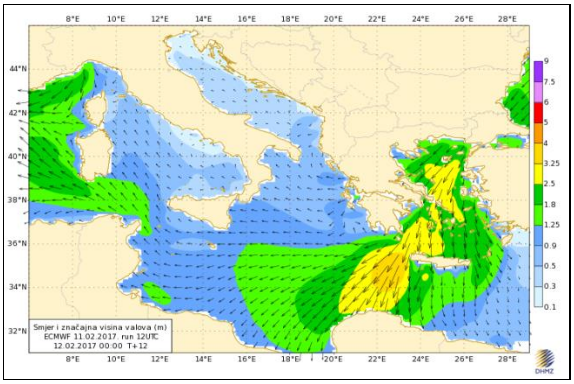
According to the picture 2, it is visible that at sea state from 0 to 5 the frequent waves were from the ENE direction, which follows the wind rose in the observed area. The second most frequent waves are from the SSE direction, followed by the waves from the WSW direction.



Source: authors

Figure 3: Wind rose with the sea state 5 in the open, in broader Split area

The wind rose with the sea state 5 in the open, in broader Split area shows the wind direction when the waves reach category 4 - moderate. It is evident that this happens during the SSE wind, which is a confirmation that the highest waves in the Adriatic occur from the second quadrant, and because of wind direction and fetch overlap. The highest measured wave from this direction was 10.8m high. Next to the projected sea state determination for a certain area, short-term information about the sea state are obtained by creating forecast maps of significant height and medium wave direction made according to the data of numerical model (ECMWF), shown in the figure 4.



Source: http://prognoza.hr/karte_e.php?id=ecmwf&param=tlak

Figure 4: Forecast map of significant height and medium wave direction made according to the data from numerical model (ECMWF) for 5 days in 3h intervals

Impact of hurricane-like wind which was noted on March 5, 2015 in Split area occasionally gained speed up to 45.5 m/s. In such weather conditions the sea state was 5, which means that the wave height was circa 4 m. in the northern part of Marjan 2 freight ships were grounded, and in Čiovo this happened to 1 freight ship. Unfavorable weather conditions were the cause of these maritime accidents.

Source: https://net.hr/danas/hrvatska/video-tri-teretna-broda-se-nasukala-na-marjanu-jedan-od-njih-pluta-prema-ciovu/

Figure 5: Freight ships grounded in the northern part of Marjan

Source: https://net.hr/danas/hrvatska/video-tri-teretna-broda-se-nasukala-na-marjanu-jedan-od-njih-pluta-prema-ciovu/

Figure 6: Freight ship grounded on the peninsula of Čiovo

4 CONCLUSIONS

Waves and winds affect ships by changing their speed and direction of navigation, outstanding leaning, stumbling, overload on ships, as well as damages. The most dangerous and evident is the sudden sinking and sudden pitching along with the direct leaning. A certain wave does not have the same influence on a big and small ship, which means that ships of different dimensions behave differently on big waves. This means that there is a certain connection between the influence of waves of certain characteristics, on a ship of certain characteristics in dependence to sea depth.

To prevent the possibility of maritime accidents caused by limiting weather conditions for a certain area, it is important, in the process of projecting sea crafts and other objects, to foresee the probability that during its life span the sea craft will meet some extreme sea state or extremely high wave.

Since in the eastern Adriatic coast there are no continuous measurements of wave height, the influence of strong and hurricane-like wind should not be neglected, as one of the generators of wave height. In that sense, research should be continued in the eastern coast of the Adriatic; especially because there is no database for this area based on which further detailed analysis could be made. This should be a priority in the system of meteorological safety of navigation.

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ODOMETRIC NAVIGATIONAL SYSTEM FOR BIOMIMETIC UNDERWATER VEHICLE

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ABSTRACT

The paper presents Odometric Navigational System for small Biomimetic Underwater Vehicle. The key element of the system is a Kalman filter supplied with traditional navigational devices like inertial and pressure sensor. Since the vehicle is not equipped with the velocity sensor, the filter is also fed with a virtual velocity sensor whose indications depend on settings of vehicle drive. Apart from an outline of the system, the paper presents also initial results of system application on a real vehicle.

Keywords: odometry, navigation, biomimetic underwater vehicle

1 INTRODUCTION

To navigate underwater, Underwater Vehicles (UV) need a system providing them at least such parameters as position (x,y,z) and orientation (usually Euler angles). In general, there are two approaches to underwater navigation. The first one is to apply external acoustic infrastructure and the second one is a dead reckoning (DR) which is based on UV own sensors. The sensors measure such parameters as velocity (log), pressure (pressure sensor - depth), magnetic field (magnetometers), accelerations (accelerometers), angular velocity (gyroscopes). Often, different sensors are combined in one device, for example, typical inertial measurement units (IMU) include accelerometers, gyroscopes, and magnetometers in one box.

All the sensors are usually combined with Kalman filter (KF) whose goal is fuse all the incoming navigational information and to estimate UV state defined by such parameters as position, orientation, velocity.

Accuracy of the DR strongly depends on quality of navigational information produced by the sensors. Usually, high-quality sensors are expensive and they are of large size. In the case of large UVs, it is possible to equip them with appropriate navigational devices which guaranty high accuracy of navigational process. However, when we deal with small UVs like the ones presented in Figure 1 which can operate in a swarm, the problem arises with determining their (x,y) location[1]. The problem is mainly due to lack of reliable speed sensor on board. The ones which because of their small size can be easily mounted inside UV hull are unfortunately very inaccurate which makes them useless for vehicles which operate on longer distances. In turn, more accurate logs are of larger size and in consequence they cannot be fit inside.

One solution to the problem of lack of speed information for DR system (KF) is to estimate speed based on state of UV drive, or in other words to apply odometry. To this end, two further solutions can be employed. The first one is to run the vehicle many times on a distance for different drive settings (operation modes) and to calculate its average speed for each mode. Then, when in action, only tested modes are permissible, and each mode refers to mode average speed.

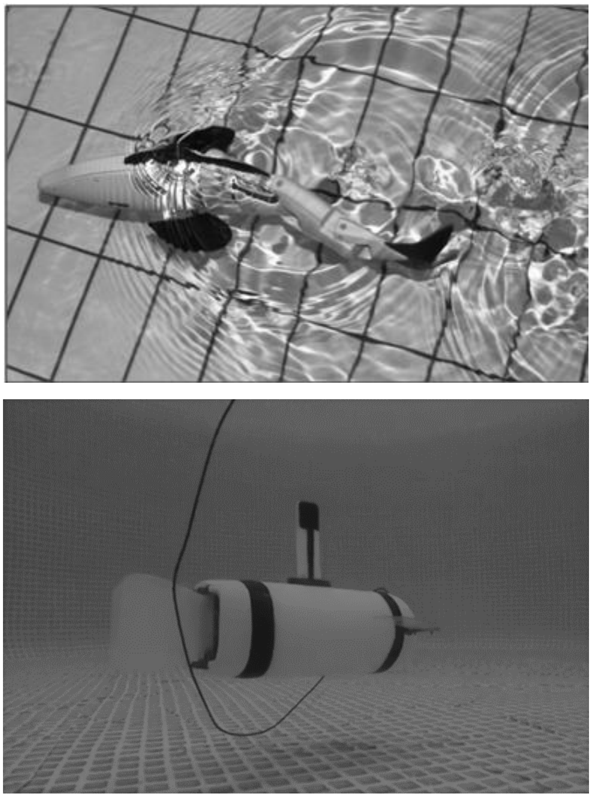

Figure 1: Example small UVs (the above vehicle is CyberFish [1])

The other solution, which is presented in the paper, is to estimate speed based on momentary state of the drive. Parameters of the drive are fed into a speed estimator whose output is treated by KF as speed measurement. The estimator has a number of parameters which decide about its performance. To determine their values different

[1] coordinate „z" is obtained from pressure sensor with a high accuracy

optimization techniques can be applied. In the paper, a solution is outlined which is based on a neuro-evolutionary method called Assembler Encoding with Evolvable Operations (AEEO) [4,5] (see Figure 2). The task of the AEEO is to adjust estimator parameters to real data recorded during tests with Biomimetic Autonomous Underwater Vehicle (BAUV)[2] [2,3,7,8] constructed within the framework of the project called "Autonomous underwater vehicles with silent undulating propulsion for underwater ISR", financed by Polish National Center of Research and Development. The recorded data include all measurable BAUV parameters along with GPS positions when the vehicle was on the surface. The GPS positions enabled the AEEO to evaluate each set of estimator parameters. Good parameters contributed to small position errors whereas the wrong ones produced high errors.

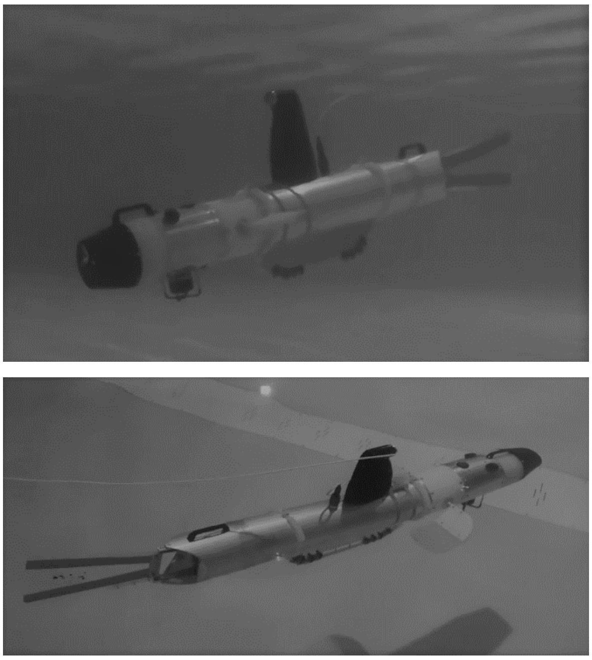

Figure 2: BAUV used in the tests

The paper is organized as follows: section 2 describes the BAUV, section 3 defines the speed estimator, section 4 outlines DR-KF navigational system, section 5 introduces the AEEO, section 6 reports experiments, and the final section summarizes the paper.

2 BIOMIMETIC AUTONOMOUS UNDERWATER VEHICLE

To test odometric DR system, BAUV depicted in Figure 2 was used. Since the current paper is focused exclusively on navigational issues, it does not contain specification of mechanical construction of the vehicle. Some details important for understanding further part of the paper are given below, whereas a complete mechanical specification of the vehicle can be found in a number of publications focused mainly on mechanical issues [8,9].

BAUV is equipped with a number of devices and sensors used for underwater and surface navigation (VN200 – inertial system integrated with GPS, digital compass OS 5000, pressure sensor), for collision avoidance (three echo sounders), and for surface and underwater reconnaissance (two cameras and sonar). To move the vehicle, the propulsion is used with two fins located symmetrically on both sides of the vehicle, in its front compartment, and one tail fin. Controlling the vehicle by means of the fins is performed by an appropriate setting of fin parameters affecting their operation. The parameters of the fins are as follows:

1. Neutral position (N) – zero position of fin, the fin moves up and down from the neutral position, $N_P \in < 0, \pm 180 >$deg. for pectoral fins, 0deg. – BAUV moves forward, 180deg. – BAUV moves backward, 90deg. – BAUV moves down, -90deg. – BAUV moves up, $N_T = \{L, C, R\}$ for tail fin, L – BAUV turns left, C – BAUV moves straight, R – BAUV turns right;
2. Amplitude of movement (A) – only for pectoral fins, in the experiments A=30 deg. was used;
3. Frequency of movement (F).

In order to generate a desirable behavior of BAUV, that is, to move it forward with a fixed speed, to turn left/right, to submerge/emerge, it is necessary to appropriately set the above parameters.

For example, in order to move forward without depth regulation, the following setting should be applied: $N_P =$ 0deg, $N_T = C, A_P = 30$deg, $F_P = 2$Hz, $F_T = 1.5$Hz. The latter three values affect speed of the vehicle and in consequence they depended on operator decisions. If the vehicle turns without depth regulation, the following example parameters can be applied: : $N_P = $ 0deg, $N_T = R/L, A_P = 30$deg, $F_P = 2$Hz, $F_T = 1.5$Hz. In turn, change of depth can be achieved as follows: $N_P = (0, \pm 90 >$deg, $N_T = C, A_P = 30$deg, $F_P = 2$Hz, $F_T =$ 1.5Hz.

3 SPEED ESTIMATOR

It seems that there are a lot of different possibilities when it comes to construction of the speed estimator. Generally, it is simply a function with the task to convert parameters of the drive into vehicle speed. In consequence, a neural network as well as manually formed function can play the role of the estimator. In the initial tests reported further in the paper, the former solution was applied in the following form:

$$V_{xy} = A(F_P, N_P, \gamma, P_{1-2}) + B(F_T, N_T, P_{3-4}) \quad (1)$$

$$A(F_P, N_P, \gamma, P_{1-2}) = P_1 F_P \left(1 - \frac{|N_P|}{90}\right) - P_2 \left|\frac{\gamma}{90}\right| \quad (2)$$

$$B(F_T, N_T, P_{3-4}) = \begin{cases} P_3 F_T \ if \ N_T = L \ or \ N_T = R \\ P_4 F_T \ if \ N_T = C \end{cases} \quad (3)$$

where

V_{xy} – is estimated BAUV speed in horizontal plane,

F_P, N_P – are frequency and neutral point for pectoral fins,

F_T, N_T – are frequency and neutral point for tail fin,

[2] In fact, the task of AEEO was also to determine parameters of Kalman filter

γ – is BAUV pitch angle,

P_{1-4} – are parameters of speed estimator.

4 DR-KF NAVIGATIONAL SYSTEM

The DR navigational system of BAUV is, in principle, the KF estimating the following state vector: $(x, y, V_{xy}, \psi, \gamma)$, where ψ means BAUV heading. The measurement part of the KF is supplied with three values, namely V_{xy}, ψ, γ. The latter two values are measured by OS5000 and VN200, mentioned above, whereas V_{xy} is produced by the speed estimator defined in the previous section. The complete definition of the KF is given by covariance matrices whose all entries are determined by AEEO – they are not fixed manually, they simply undergo optimization process together with speed estimator parameters.

5 ASSEMBLER ENCODING WITH EVOLVABLE OPERATIONS

The AEEO [4,5] is a generative neuro-evolutionary method which as its name implies is mainly used for evolving neural networks (NN). In the AEEO, NNs are represented in the form of matrices with the effect that the method can be successfully employed also to evolve other systems which can take the matrix form. Evolution of the KF and its speed estimator is exactly such a case. All parameters of KF covariance matrices and four parameters of the speed estimator can be combined together to form one entity with matrix shape and exactly such solution was applied in the tests reported in the following section.

Without going into details which can be found in [4,5], AEEO works in a number of populations in which the so-called constructive NNs (CNN) evolve. To build a single target NN (TNN) (or a matrix which represents the TNN – Network Definition Matrix NDM), each population delegates a single CNN. Then, all the CNNs from all the populations collectively form NDM of the TNN, or in other words, they modify content of the matrix which initially is filled in with zeros. Ready matrix is converted into the TNN, which is tested and evaluated. The result of TNN evaluation process is further used to evaluate CNNs contributing to the target one.

6 EXPERIMENTS

All the experiments were carried out in post-processing and they relied on real data recordings from the BAUV presented in Figure 2. In the experiments, the AEEO was applied to evolve DR-KF navigational system with embedded the speed estimator defined by (1)-(3). The task of AEEO was to produce the system capable of minimizing the distance between GPS position and DR-KF position after covering by the BAUV a distance underwater. The GPS positions were known only in points when the vehicle was on the surface, otherwise, the position was produced by the DR-KF. After covering a distance, the BAUV surfaced and GPS position was measured that was then compared to the position produced by the DR-KF. Starting position for the DR-KF was always the previous GPS position.

In order to evaluate quality of the solution defined by (1)-(3), the odometric DR-KF system was applied in which the momentary speed of the BAUV was equal to an average value for a selected operational mode. The BAUV has generally a number of operational modes and for each mode the average speed was calculated. To this end, measurements from preliminary tests were used.

All the data recordings with use of the BAUV were performed at sea, which means that, results of the recordings and later AEEO efforts to produce effective DR-KF system were severely affected by the sea current. In order to reduce the influence of the current on the results, its force and direction were estimated through the application of the procedure described in [6]. Before the data recordings and the true tests, the vehicle performed the current estimation procedure whose results were then taken into consideration in both compared speed estimation methods.

After a number of runs of evolutionary process according to the AEEO, the most accurate DR-KF system and momentary speed estimator (1)-(3) were selected. In the further part of this section, both evolved components are collectively called DR-KF1. In contrast, DR-KF system based on average speeds is called DR-KF2. Results of both systems are presented in Figures 3-8. Each figure depicts a path of BAUV which always ends in a GPS position marked with a black dot. The path always consists of two parts, the first part marked with bolded line draws positions generated by DR-KF system, whereas the second part is a narrow straight line which "jumps" from the last DR-KF position to the final GPS position, which means that the length of the line denotes position error of the DR-KF system.

All the figures below show that DR-KF1 considerably outperforms DR-KF2. The average error of DR-KF1 amounts to about 10 meters whereas the error of DR-KF2 exceeds 50 meters.

An interesting observation from all the AEEO runs is that momentary speed of the BAUV estimated by evolved DR-KFs always exceeds the calculated average value used in DR-KF2. It seems that inaccuracies of heading sensor (VN200 and OS5000) are the most likely reason of that situation. In order to reduce position error of the system which leads the BAUV in a slightly wrong direction, the AEEO is forced to increase speed of the vehicle to the value which at first glance seems to be inaccessible for the vehicle. The AEEO has simply to compensate errors of heading through application of higher speed than in reality.

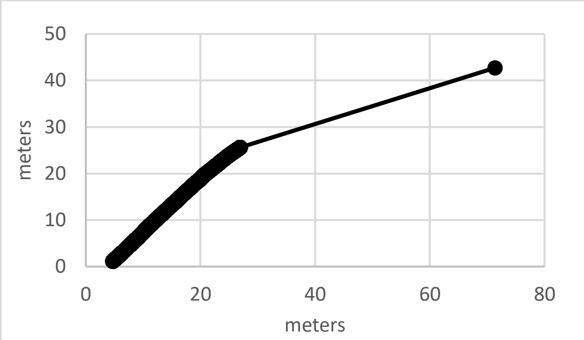

Figure 3: Underwater path no. 1 - DR-KF2

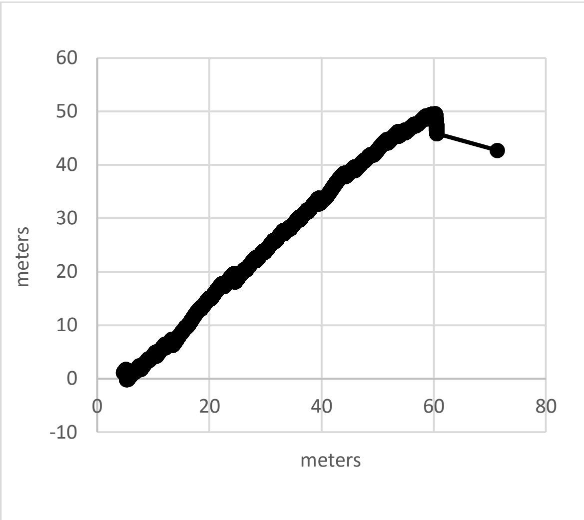

Figure 4: Underwater path no. 1 - DR-KF1

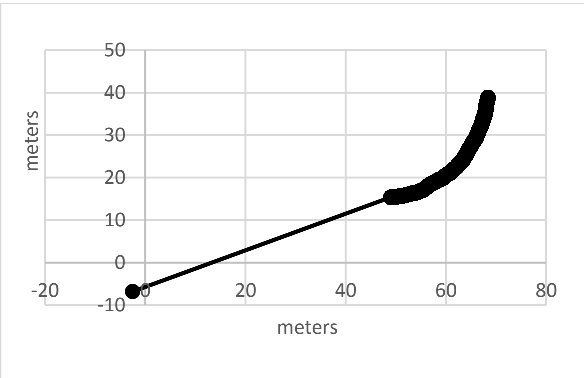

Figure 5: Underwater path no. 2 - DR-KF2

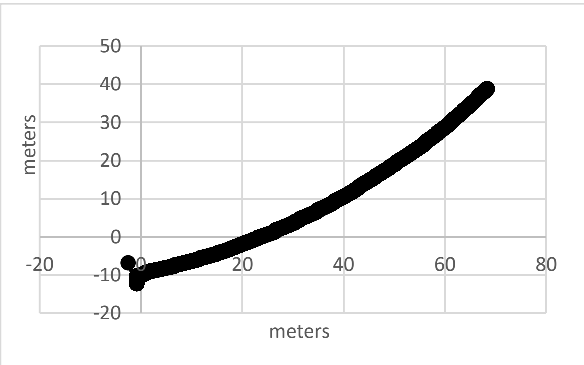

Figure 6: Underwater path no. 2 - DR-KF1

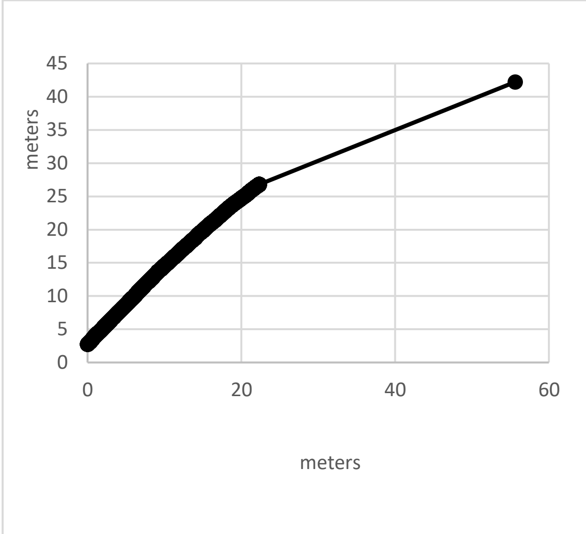

Figure 7: Underwater path no. 3 - DR-KF2

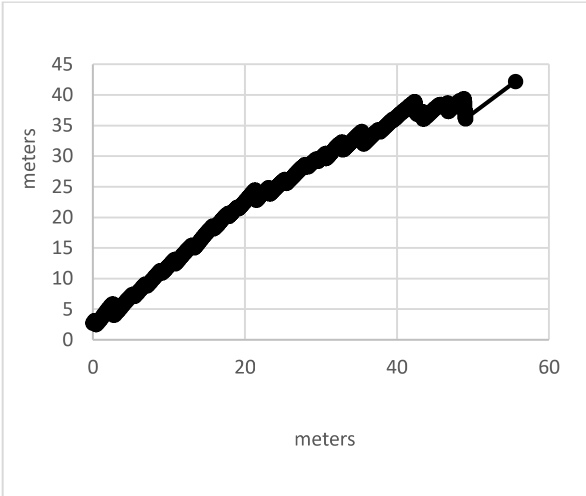

Figure 8: Underwater path no. 3 - DR-KF1

A solution to the above problem is restriction of estimated speed of the vehicle to a sensible threshold related to a true maximum speed of the BAUV. Once speed of the BAUV exceeds the threshold, DR-KF which generated such speed should obtain appropriately low fitness during evolutionary process and its chance to produce offspring is reduced. In effect, best evolved DR-KFs should not exceed vehicle speed beyond an acceptable threshold.

The other solution to the above problem is to evolve corrections for heading devices. Both them were subject to calibration process after which heading errors were reduced[3]. Unfortunately, in spite of the calibration, the level of error appeared to be still unsatisfactory and as it turned out it had influence on the tests reported in the paper.

7 SUMMARY

The paper presents initial efforts aiming at producing an accurate odometric navigational system for small underwater vehicles which because of their size are unable to carry a reliable speedometer. The core of the solution proposed in the paper is estimation of momentary vehicle speed based on the information from vehicle drive. The first tests are very promising, they showed that it is possible to effectively use state of drive to improve accuracy of navigation.

The tests revealed also some problems related to the fact that two factors have significant influence on position errors – error in course and speed, meanwhile the system evolved in the tests dealt only with one of them. The effect was that estimated speed included two different components, i.e. a true vehicle speed and compensation of course errors. In other words, it seems that the speed estimated by evolved odometric systems was inaccurate.

In order to overcome the above problem, two different solutions are proposed in the paper. The first one is simply to limit maximum estimated speed of the vehicle whereas the second one is to design the system operating on both speed and heading, its first task would be to estimate speed whereas the second one to generate corrections for heading sensors.

ACKNOWLEDGMENTS

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[3] In addition to the calibration process with the use of software provided by manufacturer, an extra calibration was also performed with the use of project team software and an accurate device for course determination: GPS-RTK

MARITIME ENGLISH TEACHERS AND MARINE ENGINEER OFFICERS – FINDING THE MIDDLE GROUND

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ABSTRACT

Between 2015 and 2017, surveys were conducted at the Faculty of Maritime Studies in Split and at Gdynia Maritime Training Centre, aiming to provide credible insights into the needs, wants, expectations and views of the seafaring marine engineer officers on English courses they attended, and to provide the answer to the key issue in this ESP (English for Specific Purposes) teaching / learning process – Is it possible to find the middle ground where general English could serve as the infrastructure for building the superstructure of specific key language competences for the marine engineers? The surveyed seafarers feel that ESP classes should focus on developing communication skills and that due consideration should be given to the proper use of tenses and other grammatical items. On the other hand, a large majority of respondents expect English teachers to have a good understanding of the career content and to be familiar with specialist terminology, ship engine systems and processes, latest technologies, regulations, safety standards etc. The results of the research imply that the various aspects of the ESP process should be harmonised and carefully metered when (re)designing ESP activities and syllabi, and may serve as the groundwork for further research.

Keywords: English for Specific Purposes (ESP), marine engineers, survey

1 INTRODUCTION

At Gdynia Maritime Training Centre[1] (Poland) and Faculty of Maritime Studies in Split (Croatia), Maritime English as English for Specific Purposes (ESP) is taught at undergraduate and graduate levels, but also as part of the courses that are specifically developed for high-school degree mariners who wish to make further steps in their career advancement. While the course programs may vary between Poland and Croatia, graduate and undergraduate levels, or in terms of syllabi designed for deck and engine officers, it is important to note that they all comply with the STCW requirements and the principles of ESP (English for Specific Purposes).

2 THEORETICAL BACKGROUND

Teaching English for Specific Purposes (ESP) is a process where teachers are focused on preparing students for their specific work environment or helping the already employed students to make a step up in their career. ESP has been widely discussed over the last few decades. Here it suffices to underline some of the basic principles developed by Hutchinson and Waters (1987), Dudley-Evans and St John, Gatehouse (2001), Harding (2007) and other scholars.[2] ESP teaching is a learner-centred approach designed to meet learner's specific needs and is related in content to particular disciplines or occupations. Furthermore, it is centred on language appropriate to those activities in syntax, lexis, discourse, semantics, etc. English for Specific Purposes (ESP) uses the same tenses and sentence structures as English as a Second Language (ESL), also known as general English, but in different ways and rates. For instance, in Maritime English as a branch of ESP, it is common to use passive constructions in reports, instructions, description of procedures and operations, because in most cases the focus is on action. As Vidak and Didović Baranac perceive, frequently used linguistic items also include verb phrases and verb-noun collocations, long compounds, adverbs and adjectives, participles and modal verbs.[3] ESP may use, in specific teaching situations, a different methodology from that of general English. Finally, flexibility is the key feature of the ESP approach: teaching is likely to be designed for intermediate or advanced students and for adult learners in a professional work situation. However, most ESP courses assume basic knowledge of the language system so that ESP could be

[1] Gdynia Maritime Training Centre refers to Ośrodek Szkolenia Zawodowego Gospodarki Morskiej S.C. Gdynia, ul. Węglowa 11, which provides STCW courses otherwise not performed at Gdynia Maritime University. Polish co-authors of this paper teach English at both institutions.

[2] For more elaborate insights into ESP principles, see: Adelija Čulić-Viskota and Sara Kalebota: Maritime English – What Does It Communicate?, ToMS, Vol. 2, No. 2, 2013; or Vesna Cigan: Teaching English for Specific Purposes at Higher Education Institutions in View of Lifelong Learning, 2012.

[3] Nives Vidak and Sandra Didović Baranac: Professional Experience and Application of English Language in the Specific Area of Shipping; Proceedings of the ILC Celje, Slovenia, 2012.

used with learners at secondary school level, or even with beginners. It is therefore important to identify the learners' specific needs and to develop a model that best integrates the specific elements with the elements of general English.

3 PRACTICAL AND SPECIFIC ISSUES

Quite naturally, the theory sets the frame and paradigms, while practice needs to find its own syntagms. The real situation in Maritime English classes attended by seafarers at the Faculty of Maritime Studies in Split (Croatia) and the Maritime Training Centre in Gdynia (Poland), is considerably different from the assumed ESP textbook situations. Student groups exhibit significant inhomogeneity in terms of size, age, present and target jobs, work environment, expectation, and proficiency level. The latter varies from basic knowledge of the language system to excellent command of English language, i.e. often an A2 student sits next to a C1 user.[4] A fifty-year-old 3rd marine engineer who has spent all his career in old traditional diesel engine rooms, weary and tired of life but fluent in English, argues with a young ambitious member of the smartphone generation, who is familiar with cutting-edge marine technologies but finds it difficult to understand the difference between "it's" and "its". A man who has served all his time on local vessels (and is now joining a foreign shipper for the first time) seems to be lost, hiding behind a cargo engineer on a multi-national LNG carrier who sits very comfortably in the front row. Some claim that the last thing they expect is to do, once again, the passive voice exercises; others complain that too much time has been wasted on learning non-essential matter such as the ship's structure and principal dimensions. Some suggest that this short course should be used for refreshing basic grammar skills, because those 3000-4000 technical terms are their problem anyway. On the other hand, there are always a number of students expecting the ESP teacher to be familiar with basic maritime technologies and engine principles (where "basic" usually refers to a variety of principles, properties, procedures, requirements, regulations, standards and conventions), so that the ESP content-based and learner-centred approach would make sense.[5]

Each group represents a specific challenge and each time the application of ESP should be well balanced. Here it is important to point out that English language is the condition *sine qua non* in the shipping trade, and that the ESP teacher should always take into consideration not only a) the specific needs, but also b) actual students' needs, and c) stay in line with STCW requirements and other international and national guidelines. In order to obtain guidelines and answers to the above described issues, the authors conducted a survey among the seafaring population of marine engineers attending ESP classes.

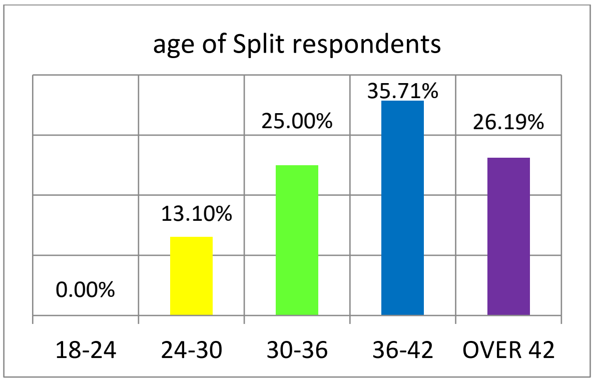
4 AIM AND METHODOLOGY

The questionnaire containing 6 questions was compiled to ascertain the role of the ESP teacher and the application of Maritime English as ESP with respect to specific terminology and basic grammar. The aim of the research was to gain insights into the specific needs, expectations and abilities of the marine engineers regarding ESP classes they attend. The gathered data will help to (re)design the teaching approach and content, (re)define the Maritime English syllabi and learning outcomes, and improve overall communication skills of both learners and teachers.[6]

The survey was performed at the Faculty of Maritime Studies in Split and Gdynia Maritime Training Centre over two years and included 84 and 69 respondents respectively. The questionnaires were completed anonymously at the beginning of the course. As the responses and desired data were supposed to produce both quantitative and qualitative value, the types of questions included rating questions, closed questions with single or multiple responses and, beyond questionnaire, individual comments and general attitude. The data of the survey were analysed by means of descriptive and inferential statistics, and descriptive and comparative analysis.

5 RESULTS

The identical questions were given to the mariners attending Maritime English courses in Split (Croatia) and Gdynia (Poland). Graphs 1-a and 1-b show their distribution by age (Question 1):



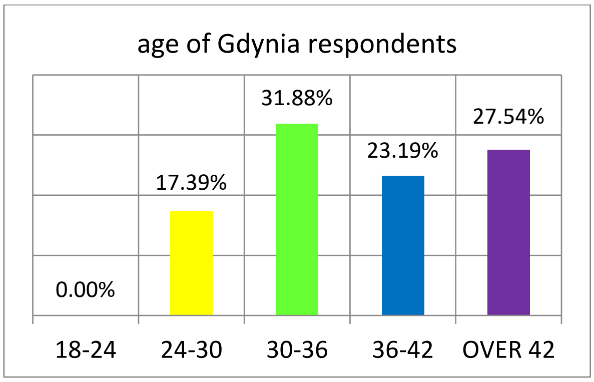
Source: Authors

Graph 1-a: Age of survey respondents in Split

[4] Assessment according to: Council of Europe, Common European Framework of Reference for Languages.

[5] For more information about seafarers' expectations and functions of ESP teacher as practitioner, organiser, advisor, etc. see Vodopija P., Skračić T. and Žanić Mikuličić J.: Marine Engineers' Views on ESP Teachers, Proceedings of the 7th IMSC 2017, Solin, Croatia

[6] There may be dilemmas and controversies regarding the content, tools and performance of ESP process, but one thing is sure: to a certain extent, a good ESP teacher is always familiar with, or at least shows genuine interest in, the specific subject matter. See more about the responsibility of teachers and students in: Lorenzo Fiorito, Teaching English for Specific Purposes (ESP).



Source: Authors

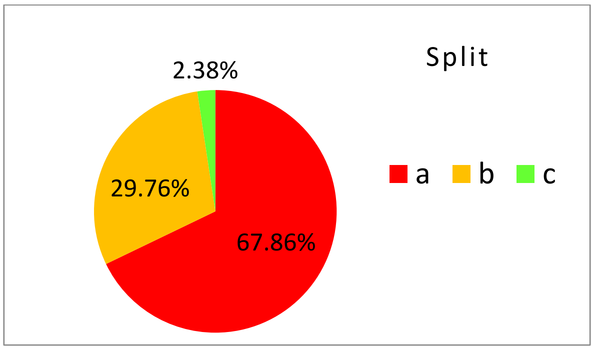
Graph 1-b: Age of survey respondents in Gdynia

Among Split respondents, the largest percentage (35.71) fell into the 36-42 year category, while most of Gdynia respondents (almost 32%) fell into the 30-36 age group. All respondents were older than 24, and more than a quarter of them, in both countries, were over 42 years of age.

The first part of the questionnaire consisted of self-assessment questions through which the seafarers confirmed the importance of English language in their work environment.

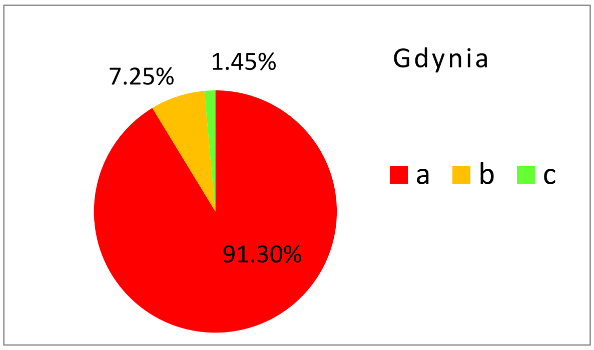
Q2: "In my job and on my ship the knowledge of English language is: a) Crucial; b) Very important; c) Reasonably important; d) Not important". 33.33% of Split respondents and 49.28% of Gdynia respondents state that, in their job and on their ship, the knowledge of English language is "crucial", followed by 57.14% (Split) and 43.48% (Gdynia) respondents who feel that the knowledge of English language is "very important". This large consensus leaves but a few respondents who feel differently.

Q3: "Insufficient knowledge of English may lead to a) Major misunderstanding, problems and accidents; b) Misunderstanding and minor problems and damage to the ship or people; c) Minor difficulties without any damage to the ship or people". Once again, by common consent, the seafarers confirm that the poor command in English may cause serious troubles at sea (option "a" in Graphs 2-a and 2-b).



Source: Authors

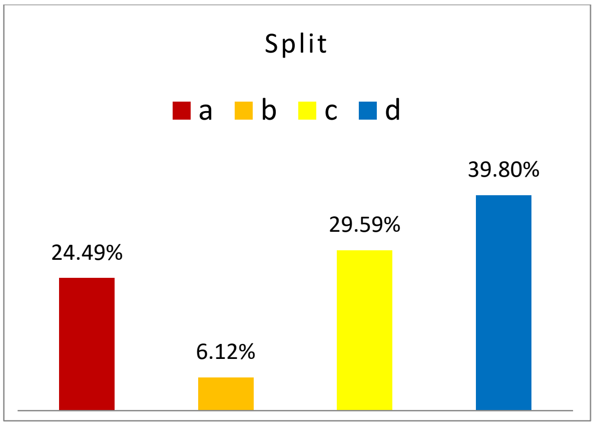
Graph 2-a: Importance of English in maritime shipping



Source: Authors

Graph 2-b: Importance of English in maritime shipping

Q4: Given the fact that English teachers are not marine engineers, the seafarers had to decide whether the teachers should: a) Teach general English; b) Teach English grammar; c) Be familiarised with the profession and teach professional English – mainly terminology; d) Be familiarised with the profession and teach professional English – both terminology and grammar. Split respondents provided a total of 98 answers, while Gdynia respondents provided 1 answer per person (69 in total).



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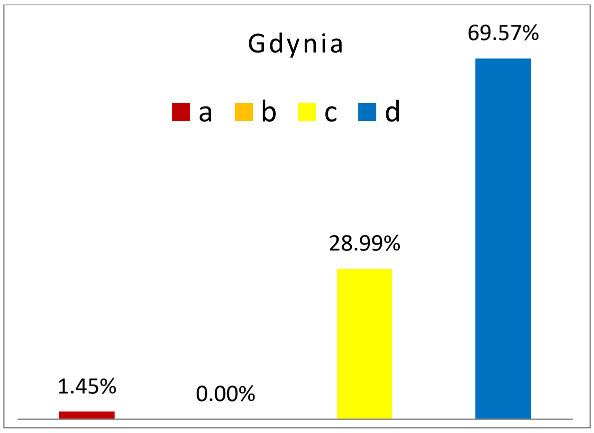
Graph 3-a: Expectations of Split seafarers – general English vs ESP



Source: Authors

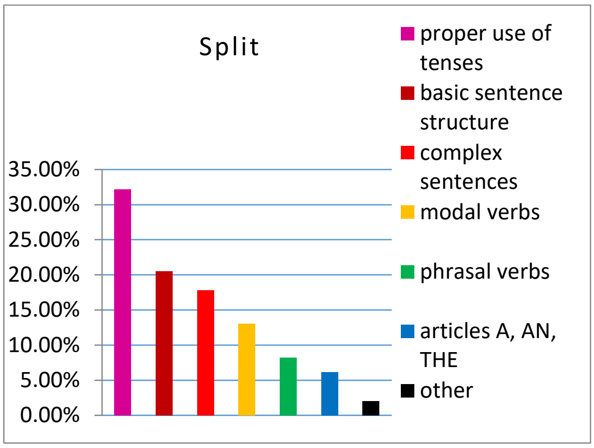
Graph 3-b: Expectations of Gdynia seafarers – general English vs ESP

The absolute winner is option d) suggesting that ESP teachers performing Maritime English courses are expected to be familiar with the marine engineering profession and specialist terminology. Before and after classes, or during breaks, the respondents were individually asked to say what "to be familiar" might imply. This triggered a variety of positive reactions and suggestions, and it was obvious that, at this point, the students realised that their responses could make a difference, and that they are more than willing to cooperate for the benefit of all sides in the process. The more or less straightforward comments led to the conclusion that "familiarity" with their profession and specialist terminology might imply the basic understanding of engine systems and processes, including engine components, material properties, compression vs spark ignition, turbo-charging, scavenging, cooling and lubricating systems, watch-keeping and signing-on procedures, in addition to the essential requirements of STCW, ISPS Code, SOLAS, MARPOL and other relevant conventions.[7]

From the standpoint of teachers, the respondents' suggestions sound more realistic in Split, where the tradition of teaching General English and ESP variants is longer than in Poland. The latter also explain the expectations of Gdynia respondents (see columns "c" and "d") who are willing to sacrifice grammar and General English for a more profession-oriented approach. Implicitly, the first (a), second (b) and fourth (d) options suggest that the ESP teachers in both countries, need to carefully strike a balance between general and vocational English, between what seafarers need and think they need, between what they need now and what will be needed in five or fifteen years, and to (re)design ESP courses and develop teaching tools and materials accordingly.

Assuming the issue of the traditional "unpopularity" of grammar across student population, the Q5 was given: "In my case, I think that learning English grammar is a) of Vital importance; b) Very important; c) Necessary; d) Not necessary. However, the obtained responses show that the assumption was wrong, probably due to the maturity of the respondents. Only two respondents at Faculty of Maritime Studies in Split (2.38%) stated that learning English grammar is not necessary. Their peers at Gdynia Maritime University in Poland were larger in number (12 or 17.39%), allowing various interpretations of this information. The authors of this paper believe that Gdynia responses were provided by older marine engineers who serve onboard all-Polish-crew ships under the Polish flag, hoping to reach their retirement age there.

As for those who considered learning English grammar as crucial, important or necessary, Q6 offered the possibility of multiple responses: "What do you think we should particularly focus on in class?" Most of the respondents from both maritime institutions (Split 32%, Gdynia 51%) feel that they have not mastered the use of tenses. Their second weakest points include sentence structure (Split, 20.5%) and modal verbs (Gdynia, 24%) (see Graphs 4-a and 4-b).



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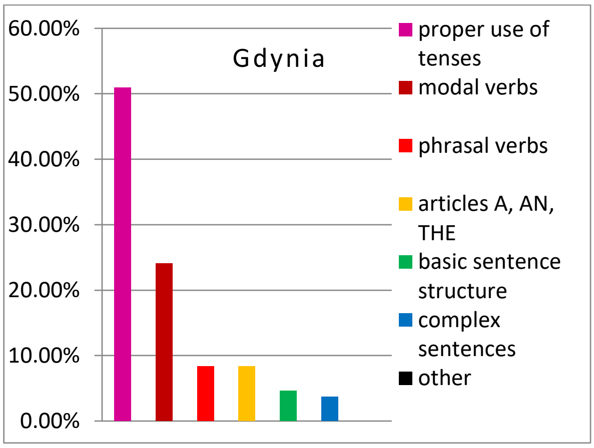
Graph 4-a: ESP should focus on these grammar items in class (Split respondents)



Source: Authors

Graph 4-b: ESP should focus on these grammar items in class (Gdynia respondents)

These graphs deserve particular attention and further analysis as they provide valuable guidelines for teachers and course designers. The multiple-response question allowed the respondents to define more than one need. 146 responses by 84 respondents in Split and 108 responses by 69 respondents in Gdynia (i.e. overall 1.66 responses per person) lead to a justified assumption that the defined learning needs, in the area of grammar, correspond to the true needs. It is rather clear where the focus should be in syllabus areas dealing with grammar and general English.

[7] As Violeta Karastateva in *Teaching Maritime English at a Technical University* points out, maritime terminology is "rich and varied […] and the process of acquiring and mastering the latter is highly dependent on the learners' specialized knowledge". It is also highly dependent on their teachers' understanding of their profession and of Maritime English as an "operational language featuring some restrictions in terms of functional characteristics", including grammar structures limited by technical text style restrictions and specialized lexis which is considerable but standardized by the International Maritime Organization's regulations, International Safety Management Code, SMCP (Standard Marine Communication Phrases) and other documents.

6 CONCLUSION

Maritime English as English for Specific Purposes (ESP) has originated out of the necessity of effective ship, ship-to-ship and ship-to-shore communication in order to ensure safety at sea. Due to globalisation and multi-national manning of ships, it has become the lingua franca of the international maritime shipping. Across the world, higher education institutions have developed ESP programmes complying with STCW and other standards, in order to enable seafarers to acquire the specific knowledge required in their profession.

Between 2015 and 2017, surveys were conducted at the Faculty of Maritime Studies in Split (Croatia) and at Gdynia Maritime Training Centre (Poland), aiming to provide credible insights into the needs, expectations and views of the seafaring marine engineer officers on English courses they attended, and to provide the answer to the key issue in the ESP process – Is it possible to find the middle ground where general English could serve as the infrastructure for building the superstructure of specific key language competences for the marine engineers?

The respondents in both institutions sent a clear message: it is absolutely necessary to find the right balance between general and ESP language. Good command of English is an absolute must in maritime shipping. Insufficient language skills may result in serious misunderstanding and errors which, in turn, may cause machinery malfunction and breakdown, delays, accidents, or threats to safety, health and life. General English and ESP should function in a complementary way, like a marriage. Teachers and students should not ignore one or the other, otherwise the marriage, i.e. the ESP course or, ultimately, ship's voyage, is unlikely to have a happy ending.

A good teacher never hides under the safe umbrella of General English; instead, to a reasonable extent, he/she is familiarised with, and shows interest in, the specific subject matter. ESP teachers need to carefully strike a balance between general and vocational English, between individuals and groups who differ in age, professional background and language competencies, between what seafarers need and think they need, between what they need now and what they will need in five or fifteen years, with regard to rapid socio-economical changes and technological developments in the world of shipping. They have to harmonise the various aspects of the ESP process and (re)design ESP courses and learning outcomes accordingly. The results of this survey will hopefully serve as the groundwork for further research.

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MARINE FOULING AND ITS EFFECTS ON VESSEL PERFORMANCE AND ECONOMIC EFFICIENCY

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ABSTRACT

The underwater surface of the hull has an important role in a vessel's operational status. Regular maintenance is very important and is a major contributor to ship performance. The vessel's underwater surface produces a drag with its motion through the water, the total vessel resistance the sum of several components such as: roughness of the surface, viscosity of the water, waves making resistance, attached parts to the underwater surface, sea waves and air drag resistance. Some parts of the vessel have a greater influence on drag because of growth, such as the bow, stern and propeller. Regarding drag as a result of the vessel's shape and other parameters, nothing can be done after the vessel has been built. Dents on the vessels hull can be repaired in dry dock, also roughness (because of rust) of the surface can be treated by sandblasting, high-pressure water blast, mechanical scraping and application of protective coating paint. Another type of roughness results from algae, bacteria, seaweed, and molluscs; these can be partly removed with special cleaning techniques while the vessel is in the water. Additionally, the underwater surface can be protected with antifouling protective coating when in dry dock, which prevents bacteria acting on the underwater surface.
The article will be discussing the consequences of hull fouling. Cumulative running costs and emissions will be calculated and presented for two approaches, classical dry-docking overhauling compared to in-between (dry-dockings) hull and propeller cleaning.

Key words: Marine fouling, resistance, anti-fouling, propulsion, fuel consumption, running costs

1 INTRODUCTION

The hull of the vessel must be treated as changeable. The hull creates resistance (friction) when moving through the water and the degree of resistance is increases as time in the water does.

Resultant vessel drag consists of the following:

R_V – drag produced because of the water viscosity and vessel shape.

R_W – drag produced by waves and differences in pressure as a result of the vessel moving, which depends on the Froude number, which includes the underwater body (specially bow-bulb and stern).

R_R – component, which includes:

Roughness of the underwater body

Drag produced by the attached parts on the underwater body (anti-corrosion anode)

Air drag

Below is the formula which includes these components:

$$R_H = R_V + R_W + R_R \ [N] \tag{1}$$

Next formula represents Froude number and Froude drag resistance, which is the part of above mentioned R_W component.

$$F_N = \frac{v}{\sqrt{g \times L_{WL}}} \tag{2}$$

$$R_F = \rho \times k \times S \times v^{1,825} \ \text{[N]} \tag{3}$$

F_N – Froude number

R_F – Froude drag resistance [N]

ρ – density of the water [kg/m³]

S – reduced wetted surface [m²]

v – speed of the vessel [m/s]

L_{WL} – length on waterline [m]

Air drag can be calculated by following formula:

$$F_D = \frac{1}{2} \times \rho \times v^2 \times A \times C_D \ [N] \tag{4}$$

F_D – air drag force [N]

ρ – density of air [kg/m³]

v – speed of the vessel relative to fluid motion [m/s]

A – windage area [m²]

C_D – drag coefficient

This article will explain only the component which produces drag related to underwater body roughness.

1.1 Vessel underwater body maintenance

Vessel underwater maintenance should be done in dry dock. The vessel hull survey is based on the following:

- Hull damage
- Hull fouling

If the underwater part of the hull has dents, then a Classification society surveyor must decide if they must be repaired. In case that damage is in the vicinity of the frame (stringers), this must also be checked. Each dent in a vessel's hull is produces additional drag.

1.2 Fouling of vessel underwater body

Vessel underwater body fouling is not the only cause of drag, but does have a significant influence on it.

An International Maritime Organisation (IMO, 1999) report observes that vessel bottoms not protected by anti-fouling systems may gather 150 kg of fouling per square metre in less than six months of being at sea. This data is based on quantitative appraisal biomass for mass fouling on a surface of 1 m^2, which is insufficient for determining drag, from a hydrodynamic point of view (Sonak S., Giriyan A., Pangam P. 2010). For determining the final evaluation two parameters are needed:

- fouling location and
- fouling type

The theory and practice regarding fouling location indicates that the main influence is on these parts of the hull (Roškar, 1991):

- Bow 13 %
- Stern 10 %
- Ship prop 32 %

The first fouling type is based on plant life (which can be found as well on structures such as oil rigs and piers): algae, slime and seaweed. The second type is based on animal life and grows on any kind of underwater surface - barnacles, mussels and oysters.

1.3 Vessel underwater body cleaning

The most common procedure for cleaning the underwater hull are mechanical scraping, high-pressure water blasting and sandblasting. Sanding is the most effective way to clean the underwater body, but is the most expensive procedure. Mechanical scraping is used for cleaning in dry dock and also when the vessel is in the water.

1.4 Use of vessel underwater protective coating

There are two different types of protection for mechanical cleaned surfaces of a vessel; biocidal and non-biocidal coatings. The protective coating has experienced chemical changes, because of environment requirements.

Biocidal coatings:

- Controlled Depletion Polymer (CDP) uses hydration and releases biocides into the marine environment, which are used for vessels which have short dry-dock intervals; they are mainly preferred for ships operating in low fouling regions. Their effectiveness lasts up to 3 years. (Atlar, 2008).
- Self-Polishing Copolymers (SPC) have good initial hydrodynamic performance, because of their smooth surfaces; hence better antifouling ability. They are used on vessels which have longer dry-dock intervals. These can remain effective up to 5 years.
- Hybrid SPC's biocide releasing method works on hydrolysis and hydration principals. Their durability ranges from 3 to 5 years (Taylan, 2010).

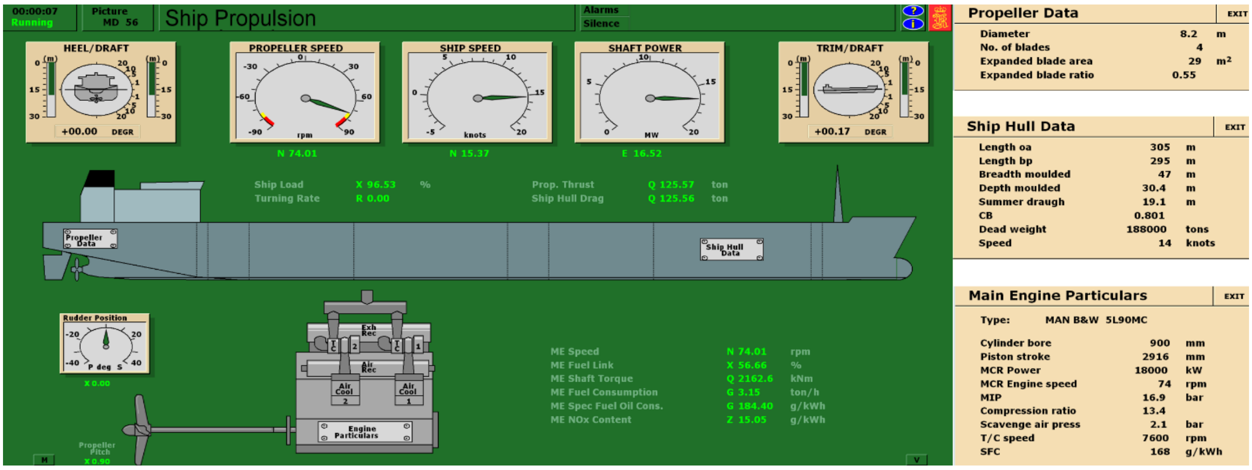
Non-biocidal coatings:

- Foul release (FR), prevents attachment of marine species on the hull. They cannot cleanse all of the slime and they are effective only above a certain speed since the releasing mechanism works by means of a particular amount of shear force to detach marine organisms. Because of this, they are appropriate for slow ships and for ships spending a long time in ports. They are expensive compared to the other types of coatings and may be damaged easily by means of mechanic effects such as cleaning.

During observation of SPC protective coating special attention must be taken the turbulent phenomenon caused by the classical type of coating. Turbulent flow has a major impact on vessel hull drag.

2 VESSEL UNDERWATER BODY DRAG AND SURFACE ROUGHNESS

Fouling of a vessel's hull reduces speed and increases fuel consumption, cause increased expense. The degree of fouling depends on the type and size of the vessel.



Source: Authors

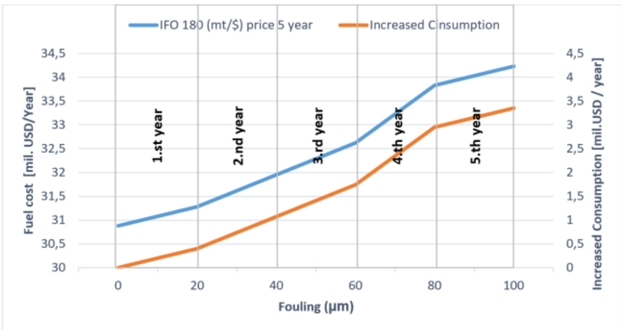
Figure 1: Propeller, hull data and main engine particulars

Figure 1 shows information about very large crude carrier. The research is based on data obtained from an engine room simulator produced by Kongsberg.

Data of the vessel:

- L_{oa} – 305 m (length overall)
- L_{bp} – 295 m (length between perpendiculars)
- B – 47 m (breadth)
- T - 19,1 m (draft)
- CB – 0,801 (block coefficient)
- DWT – 188 000 t (deadweight)
- v – 14 (Nm/h) (vessel speed)

Figure 2 shows the increase in fuel consumption for the vessel shown, assuming that the vessel is 100 % loaded (full displaced) and the telegraph is on 75 % of maximum speed. Clearly, there is a significant increase in fuel consumption observed over a 5-year period (DD dry dock period).



Source: Authors

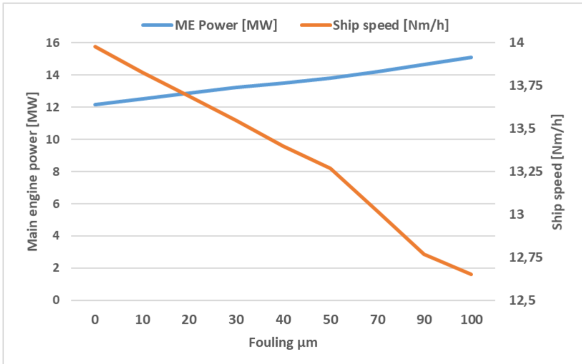
Figure 2: Fuel cost increape during fouling

The reason for this is fouling of the hull and the resultant vessel drag, which must be overcome by the vessel's propulsion system.

A vessel's drag after cleaning never reduces to the original value, increasing with each docking.

The constant increase of drag becomes more steady after 5-years in operation because of permanent changes to its underwater body (dents and surface roughness).

The following chart shows main engine power increase and speed drop in relation with fouling µm.



Source: Authors

Figure 3: Main engine power increase

The chart illustrates the same phenomenon as on the chart illustrating fuel consumption with constant speed. Fouling is the reason for increase in drag and speed drop, which results in the need for a higher rate of turn for the main engine to reach the same RPM speed.

The table in section 3 presents costs for fuel oil consumption over 5-years if the vessel is sailing 1250 days with 75 % of MCR (Maximum Cursing Rate) and assumed price for IFO 180 (mt/$) is 447.5 (global 20 ports average) (Ship&Bunker; News and intelliegence for the marine fuels (May, 2018).

3 DEFINING OPTIMAL DRY-DOCKING

The ultimate result of untreated fouling is the state where the vessel simply can no longer economically run. The other end of the spectrum is the hull in its virgin state. The question then is when to pause for dry-docking.

The following data are pertinent:

- ME fuel link position [%]
- ME Power [MW]

- Propeller thrust [ton]
- Ship Speed [Nm/h]
- Ship hull drag force [ton]
- Propeller speed [RPM]
- ME shaft torque [kNm]
- ME fuel oil consumption [ton/h]
- ME exhaust receiver temp [^{0}C]
- ME fuel oil consumption (specific) [g/kWh]

At some point (reasonable fouling condition), the underwater body must be cleaned; because of this there must be a known cost increase of a vessel's uncleaned surface to the moment when the vessel was dry-docked.

The costs related to fouling derive from reduced speed, time out of service, and the cleaning cost itself. The figures in the diagram are estimated from data obtained from similar vessels (actual pricing depends on daily freight prices). Altogether costs, that appears with underwater-cleaning are 69,200 $.

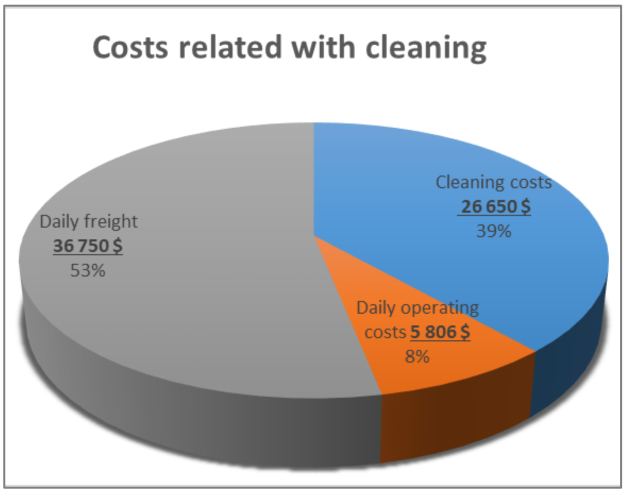


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Figure 4: Costs related with underwater cleaning

3.1 Determining the appropriate time for dry docking

Calculating the appropriate interval for dry docking of the vessel; there must be presumed a limit case where the vessel never goes into the dry dock. Based on the previous formulas, there can be established formula for situation mentioned above.

The following section will present the amount of money that can be saved according to data obtained from an engine room simulator:

With data observed from table 1, one may calculate the cost of reduced service time per nautical mile under increasing fouling conditions.

N_{mc} – nautical mile cost [USD/Nm]

v – ship speed [Nm/h]

F_C – fuel oil cost [USD]

SFOC – specific fuel oil consumption [g/kWh]

ME_p – main engine power (MW)

$$N_{mc} = \frac{1}{v} \times SFOC \times ME_p \times F_C \qquad (5)$$

Assuming that the vessel is in voyage 1250 days in 5 years and taking into account speed decreasing because of vessel fouling, one can calculated distance travelled during those 5 years.

D_{year} – 1 - year distance [Nm]

T_{Vy} – days in voyage 5 - year time (DD – time)

$$D_{year} = V_s \times 24 \times T_{Vy} \qquad (6)$$

With the results from the previous point we can calculate how much the voyage time will be extended by the decreasing speed of the vessel, which is the result of increased hull drag from fouling.

D_{year} - different state of fouling in 5 year period of time

S_{DAYS} – difference in days savings [day]

$$S_{DAYS} = \frac{\frac{D_{year\ (base\ line)} - D_{year\ (fouling\ state)}}{V_S}}{24} \qquad (7)$$

Multiplying fuel cost for one nautical mile (vessel in voyage) and distance travelled in 1 - year time produces the annual fuel cost. From table two it is clearly stated that annual costs rise because of marine fouling.

F_{ca} – annual fuel costs (end of the year)

$$F_{ca} = N_{mc} \times D_{year} \ \text{[USD/year]} \qquad (8)$$

Putting together extra voyage time influenced by higher rate of hull drag, vessel speed, and fuel cost for one Nm; there is a result lost days as propulsion cost.

T_L – lost days as propulsion cost

$$T_L = S_{days} \times V_s \times 24 \times N_{mc} \ \text{[day]} \qquad (9)$$

Assuming similar vessel operation costs per day is $43,000 and multiplying this number by the extended voyage time lost days, of course, can be calculated as lost income.

T_{Li} – lost days as loss of income [USD]

V_{oc} – vessel operation cost per day (43,000 USD)

$$T_{Li} = S_{days} \times V_{oc} \qquad (10)$$

Table 1 shows increasing annual fuel cost as result of marine fouling. Assuming that vessel is never cleaned underwater and DD in 5-year service. Observing the annual increase in fuel cost because of marine fouling explains the difference in consumption.

Table 1: Parameters impact on vessel fouling condition

Source: Authors

		Vessel loaded 100 %; speed 75 %				
		Annual marine fouling				
Parameters	**Base line**	1-st. year	2-nd. year	3-rd. year	4-th. year	5-th. year
ME fuel link position (%)	45,86	46,21	47,22	48,19	49,86	50,47
ME Power [MW]	12,15	12,53	12,88	13,22	13,52	13,81
Propeller thrust	101	107,99	115,02	121,91	128,5	134,47
Ship speed (knots)	13,98	13,83	13,69	13,55	13,4	13,27
Ship hull drag force (ton)	101	108,37	115,41	122,15	128,5	134,97
Propeller speed (RPM)	67,16	67,16	67,16	67,16	67,16	67,16
ME shaft torque (k/Nm)	1757,4	1808,5	1859	1905	1951,5	1991,9
ME fuel oil consumption (ton/h)	2,3	2,33	2,38	2,43	2,52	2,55
ME fuel oil consumption (specific) (s/kW)	180,47	180,42	179,45	178,75	178,77	179,14
Me exhaust receiver temp ^{o}C	335,74	336,78	337,5	339,34	342,18	343,68
ME exhaust Nox content final (g/kW)	11,92	12,14	12,8	13,45	14,55	14,93
Increased Resistance	0	7%	14%	21%	27%	33%
Increased Power	0	3%	6%	9%	11%	14%
Increased Consumption	0	1%	3%	6%	10%	11%
Reduced Speed	0	-1,1%	-2,1%	-3,1%	-4,1%	-5,1%
1 Nautical mile cost	70	73	76	78	81	83
1 Year distance (Nm)	83880	82980	82140	81300	80400	79620
Difference in days	**0,0**	**2,7**	**5,3**	**7,9**	**10,8**	**13,4**
Annual Fuel Costs (end of the year ($))	5.887.428	6.069.879	6.205.883	6.344.856	6.489.566	6.642.484
Lost days as propulsion cost ($)	0	65.834	131.461	201.350	280.892	355.400
Lost days as lost of income ($)	0	116.594	227.721	341.144	465.299	575.170
Difference in fuel cost ($)	**0**	**-91.226**	**-250.454**	**-387.942**	**-529.783**	**-678.597**
Cleaning costs (2 per year ($)) = diff. in days	0	69.200	69.200	69.200	69.200	34600
Dry-dock cost ($)	0					400.000
Saved money ($)		**22.026**	**181.254**	**318.742**	**460.583**	**243.997**

When the ship is re-floated from DD this presents the base line minus each year - in which marine fouling is greater (fouling state). The increase in fuel cost is significant.

F_{CD} – difference in fuel cost [USD]

$$F_{CD} = \frac{F_{ca\,(base\ line)} - F_{ca\,(fouling\ state)}}{2} \qquad (11)$$

Assuming that underwater cleaning costs and loss of income when the vessel is not in service (while the underwater body is cleaned) the cost arrived at is $69,200. The estimated time for the underwater hull cleaning procedure is roughly estimated between one and one and a half days. This, again, shows that cleaning costs combine with lost days to increase loss of income and suggests the time when the vessel should be cleaned to achieve lower consumption and lower No_x emissions, (a great concern for future generations). Figure 5 shows the increase of No_x content (g/kWh) during a vessels fouling effect over a period of time.

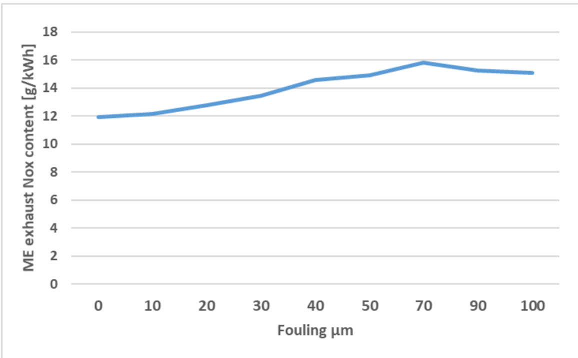
Cleaning cost (2/year [USD]) = S_{DAYS} [USD] (12)

Based on the formula the underwater cleaning should be done twice a year. Calculating saved money based on fuel cost difference and cleaning costs for each year.

The values are assumed if the vessel is never cleaned underwater. Less money is saved for the vessel's fifth year in operation because the vessel is obligated to be in DD, which adds extra expenses estimated at $400,000 and this year vessel will need to be underwater cleaned just once. Saved money will be equal to:

C_C - cleaning cost

$$S_M = F_{CD} - C_C \quad \text{[USD / year]} \qquad (13)$$



Source: Authors

Figure 5: ME exhaust No_x content (g/kWh)

4 CONCLUSIONS

The solution to the problem of higher fuel costs, lost service time, and increasing No_x emissions is the development of STC (Surface treated composite protective coating system), which would be applied once during the lifetime of the vessel; it improves smoothness with in-water cleaning and at most would require minor touch-ups when the ship is in dry-dock as a result of class requirements.

Regular underwater cleaning with STC protective coating will help to minimization fuel costs and greenhouse gasses. The required frequency of underwater hull cleaning shows that developing and improving underwater cleaning technology is significant. What is necessary is:

Faster, more effective and affordable underwater cleaning

- Automatization of underwater cleaning systems when the ship is in port for cargo manipulation
- Each vessel could have an integrated system for underwater cleaning

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ORGANIZATIONAL PERFORMANCES AND STRATEGIES IN THE CHAGEABLE ENVIRONMENT OF THE MARITIME INDUSTRY - OFFSHORE COMPANY

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ABSTRACT

The maritime industry brings together a large number of specialized companies. One part of it is offshore maritime company. The business concept of offshore maritime companies is to provide services to the business market (B2B), so these corporations operate within a chain that begins at the state level and ends with delivering energy supplies to end users. In the event of the exploitation of natural gas or oil resources, offshore maritime companies provide resources (platforms) and services for testing sites, drilling, transportation, raw material processing. Although those are high value jobs, industry's sustainability is dependent on the oil price created on the stock market. This fact points to the dynamic and changeable environment of the task. Offshore maritime companies implement control of market risks into a business strategy. The issue explored in this paper is the adaptation of the strategy of leading offshore maritime companies to changeable market conditions. The measuring instrument of the starting point is the financial result of the business being examined in relation to the oil price at a given time interval. The results indicate that companies with better performance indicators are those that have adapted the strategy of changeable business conditions.

Keywords: Strategy, changeable environment, maritime industry, offshore maritime companies

1 INTRODUCTION

Oil offshore maritime companies (and the oil industry in general) have recently faced advances of a new trend of alternative (renewable) energy sources. On the one hand, these companies face the challenge of their own maintaining, and on the other hand, there is the price of crude oil that varies in the world market. Businesses in a changeable environment, offshore maritime companies should retrieve answers to three questions: (1) who are the customers, (2) which products and services to offer, and (3) how to offer products and services in an efficient and innovative way [1].

The business concept of offshore maritime companies is to provide services on the business market (B2B). In the B2B market, interactions between participants are occasional and contracted for a longer period. Business environment is a process of several stages, and it involves [2]:

Finding out the problem, internal and external incentives. Internal incentives can be exhausted supplies, lower (or higher) market prices, threats, etc. External incentives are, for example, supplier activities etc.

- Defining an order type, quantity, price, deadlines etc.
- The order specification is shown through the procurement value analysis.
- Finding a supplier happens most commonly through a database, catalogue, address book, chamber, and the like.
- Collecting offers is a prerequisite for evaluating offers in the choice of suppliers (ranking and selection of offers, choice of key supplier, selection of ancillary suppliers).
- Contracting.
- Performance assessment

If the performance assessment is positive after the completion of the contracted activities, the contract is repeated or extended. In this way, both sides of the B2B market achieve mutuality and stability. The problem arises if the value of the concerned service is linked to the price of the final product to which no party has any influence. Such situation happens when it comes to crude oil. The price rise of crude oil on the world market directly affects the degree of utilization of capacity and profitability of offshore maritime companies. The issue explored in this paper is the adaptation of the strategy of leading offshore maritime companies in changing market conditions.

2 ORGANIZATIONAL PERFORMANCES

Organizational performance and business strategy are multi-dimensional and ambiguous features or characteristics of a business subject. The task environment affects the company's strategy through challenges of stability, complexity, diversity and rivalries. The stability of the environment may vary from stable to dynamic; the complexity of the environment can be from a simple environment to a complex one; diversity manifests in the range from integrated to diversified markets, and the rivalry of a pleasant and adventurous environment to a very hostile one [3].

The strategy can be key to distinguish the effective company from the ineffective, beneficial from unbeneficial, prosperous from unprofessional. The strategy formation process is based on techniques and methods of continuous monitoring of the environment. Companies rely on internal and external environment analysis, SWOT analysis, defining mission and vision, strategic goals and defining processes, programs and projects that enable strategy implementation in a given environment and conditions. The overall success of these processes affects organizational performance, which, as well as the success of strategy implementation is led by known control mechanisms for assessing and questioning the same.

Taking into account the life cycle theory of companies, it is worth mentioning the existence of several phases during the development and growth of companies that are themselves carriers of internal crises. The strategy in the given context has the importance of preserving and improving the performance of the company in an organizational and business sense and includes strategic management of internal resources and processes in the context of the task. The result is the company's health and its strength to fight crises (external and internal). In other words, in practice it is necessary to take into account both dimensions and strategy should be combined with company performance (and vice versa).

When dealing with the performance of the company there is a kind of division of attitudes towards a deterministic and stochastic approach [4]. Deterministic approaches emphasize company’s growth and concentration process through corporate behavior and noticeable industrial features. The stochastic approach begins with the assumption that in the world where there is no initial difference between companies in profitability, size and market share, the differences in their performance happen suddenly [5]. Stochastic models of company growth are based on a law of proportional effect, which in its strict form claims that the expected growth rate of the company in any specified period is equal to all companies regardless of their size at the beginning of the period [6]. The assumptions of the formulated Gibrat's law are not sustainable if the rate of growth or growth variance correlates with the size of the company. The stochastic approach is given contribution based on so-called Jovanovic learning model. The same is based on passive learning [7]. Furthermore, the mechanic approach sees the company through a quantitative dimension and believes that growth is unlimited, while the holistic approach sees it through a qualitative dimension. Business performance is also seen through the dimension of efficiency, effectiveness and sustainability. The assumption is that success will support growth, that is, success is a characteristic of a dynamic harmony with the environment.

3 STRATEGIES IN CHANGEABLE ENVIRONMENT

The lack of strategy can be very good for businesses that operate in a particularly changeable environment. An adaptive strategy is characterized as the absence of clearly defined goals and the behavior of the company is only reflection on the influence of particular interest groups in and / or outside the company. In addition, in this scenario, there is no central place of political power and unified goals and access is justified for mediation activities or in service programs of narrow specialties directed towards end use. In organizations in the B2B market that manage high value assets and broad-spectrum experts that bear high risks of specific business activities, the strategy is a key element in building an entity's identity in the business environment. At the same time, the positioning of industry entities globally implies market partitioning among the main "players", which are the companies that lead and create the industry on international and intercontinental determination.

Very often, there is a company that is recognized as a leader. It usually has the largest market share, so the price, advertising, distribution intensity, coverage and technological solutions, determines the nature, timing and basis of the competition [8]. Market leader is the company with the largest share in a particular business [9]. The leader's strategy relies on a proactive approach, improving efficiency and developing new products and processes. Market leaders are companies that continually increase their competitiveness by using market research and trend analysis. These companies carefully manage business performance indicators and give community extensive and transparent reports to point out their stability in the leading position. Companies in the second, third or lower place in the industrial branch are positioned as emerging companies. The strategy of these companies can be twofold. Either it will attack leaders and other competitors in an aggressive struggle to expand their market share (market challengers), or will cooperate and work without risk (market followers). The market challenger is the second-ranked company that uses various strategies for progress. They are [8]: an attack on a market leader, an attack on companies of the same strength, an attack on small local or regional companies. In practice, some of the tactics of these companies allow progress to leading positions. The characteristics of these companies are high set goals and high levels of management with all their resources.

Market followers are using the strategy of copying the already tried recipe based on the leader [8]. These companies retain their position and existing relationships, which dictate market itself, have a high degree of uncertainty or significant growth constraints. The main feature of these companies is to avoid unnecessary risk. Dangers for these companies are market challengers, so companies that are positioned as followers have to take care of the costs and quality of their output so they do not lose customers.

Smaller companies lack the capacity to lead or to challenge or even follow-up. A small market where a company provides a highly targeted product or service is a strategy of orientation to a particular niche. A market niche is a business opportunity that is marketable and can be a combination of circumstances that creates the need for a new product, service or business idea. This strategy implies offering products and services on markets that are not covered by products or services, and defense against competition is achieved by special delivery politics, quality and price.

Within each industry, there are all kinds of relationships between companies, enterprises and corporations. In some cases, the corporation acts as a market leader, but at the same time, it is a challenger or a follower in another branch of market relations or in geographical understanding of the global market.

Complexity of business is found in all industries, including maritime one where there is a high level of division of work and specialized services and / or products.

4 MARITIME INDUSTRY

The term maritime refers to all activities and skills at sea and in relation to the sea. Activities include the exploitation of the sea as a waterway, exploitation of marine resources (fisheries, fishing, mariculture, oil and gas exploitation) and exploitation of ports, shipbuilding, maritime economics, maritime sports and more. Maritime science is set of activities, skills and social facilities at sea and in relation to the sea. Thus, maritime science is a complex system, segmented into the activities of various economic, technical and technological processes [10].

The maritime industry brings together a large number of specialized companies. One part of it is an offshore maritime company. The exploitation of mineral resources from the seabed becomes more and more important and there are different opinions about it. The social purpose of marine technology is to find new energy potentials and exploit the seabed world because of the growing shortage of raw materials and energy in the world. The development of marine technology is based on the technical and technological capabilities of exploitation the seabed for oil, gas, minerals and submarine energy.

Looking at the world's production of liquid fuels and their worldwide consumption in the period from 2011 to 2017, there is a continuous increase and a positive trend. The same shows that the world's population and economy need increasing amounts of liquid fuel at an annual level. However, oscillations are due to global economic and other changes resulting in surplus stock, which affects the correction of the price of liquid fuels (oil), which creates a change in the market supply and demand for services of offshore maritime companies (Fig. 1).

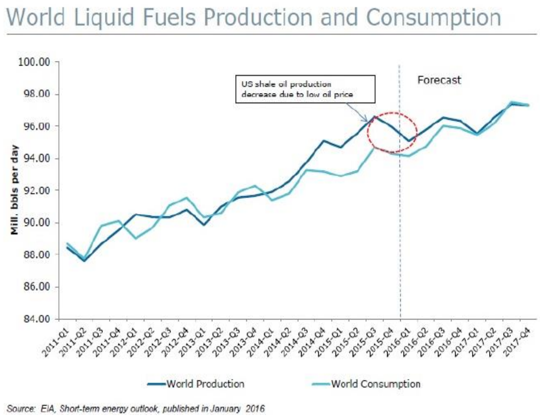

Figure 1: World Liquid Fuels Production and Consumption

It should be emphasized that the activity of offshore companies is highly specialized and that these companies are continuously investing in new technological and technical solutions that enable safe operation in difficult and unpredictable conditions at sea, providing that high ecological standards should be respected in the natural environment. Mistakes in operational activities are accompanied by the risks of negative and long-term consequences for the ecosystem of the seabed, air and land. Therefore, the oil and gas exploitation system from seabed is a highly specialized activity and is the most developed part of maritime technology. The intensity of the development of infrastructure and technology of offshore companies stems from the fact that around one quarter of the stock of oil and gas stocks in the world are found in seabed. When drilling it, the experience of land-based technology is applied. Specific technical plant is equipped with submersible and semi-submersible platforms, self-propelled platforms, specialized vessels and drilling barges [11]. The specialization and ability of these companies to comply with safe service in high-risk conditions is divided into a separate category under the common name of the maritime offshore company.

5 MARITIME OFFSHORE COMPANIES

The offshore company was mentioned for the first time in history in 1891, in Grand Lake St. Mary, Ohio. Until today, offshore maritime industry developed in two directions: an offshore gas and oil industry and an offshore wind power industry.

Offshore oil and gas exploitation and offshore wind power are activities performed at sea and seabed.

Business specificity is in its fleet and job structure that are carried out on platforms installed on the sea. Modern offshore maritime companies network three production factors: offshore platforms, offshore vessels and offshore jobs. These three factors are specific to maritime offshore companies. Investing in resources and maintaining business sustainability depends on world supply and demand for liquid fuels. The oil price cannot be predicted with the efficiency that could be the basis for forecasting and projection of business performance, growth and development of the company, because the environment is unpredictable and often unequal in terms of the known and foreseeable destruction that arises during the financial crisis. Namely, in times of financial crises, oil prices are at level that ensures positive business of offshore companies, which is a kind of step forward in looking at the operations of these companies in times of crisis or stability. (Fig. 2).

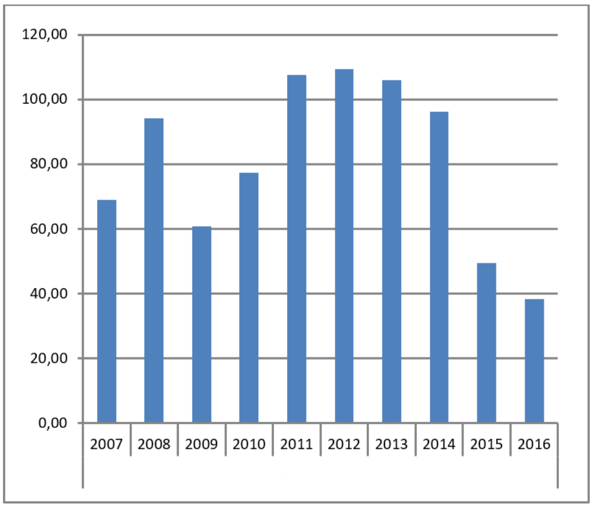

Figure 2: Oil price for specific year (according to the OPEC)

The financial and oil crises are not equated, and it is often claimed that after the fall in oil prices, the financial crisis occurs [12]. The crisis always reflects on the transfer of power, and so on the repositioning of offshore maritime companies. Repositioning occurs in a variety of ways, most often through the takeover of part of the market by companies that are not ready to meet new business conditions (low oil prices and demand in countries entering the market). Although companies are active for more than a decade, it should be noted that their development and current position in the offshore maritime market are the result of growth and development strategies or adaptation to changeable business conditions. It is also important to consider the technology that requires continuous service development and high sensitivity to ecological requirements and risks to the open sea.

In order to examine the consistency of offshore company strategy, the following five profiles are presented in the business analysis from 2011 to 2015. This period of time is reflecting the fluctuations in crude oil prices.

5.1 POSH

PACC Offshore Services Holdings Ltd. (POSH) is an offshore maritime company headquartered in Singapore. In 60 years of oil and gas exploitation, the company has developed a fleet of over one hundred offshore vessels serving the markets of Asia, Africa, the Middle East, North and Latin America. POSH operates through four business units: Offshore Supply Vessels (OSV), Offshore Accommodation (OA), Transportation & Installation (T & I) and Harbor Services & Emergency Response (HSER) [13]. Business results for the period from 2011 to 2015 indicate a rise in gross profit and the end of the observed period with a negative result. For the observed period the assets of the company increased by 24.7%, and company's capital by 43.9%.

The POSH performance indicators are presented in Table 1.

Table 1: POSH: ROA, ROE 2011 -2015

Year	ROA	ROE	Oil price
2011	0,042	0,044	107,46
2012	0,044	0,081	109,45
2013	0,041	0,085	105,87
2014	0,031	0,044	96,29
2015	0,033	-0,123	49,49

Source: Authors

Table 1 shows that return on assets (ROA) in the observed period is higher in years with average higher oil prices, while return on equity (ROE) cannot be deduced.

5.2 BOURBON

The BOURBON maritime company has undergone transformation and adaptation to market conditions in its 40 years of activity. Initially oriented to commercial and geographic diversification, the early 90s of the last century focused on maritime activities and the merger of maritime companies for cargo transportation. The BOURBON Group operates in 45 countries with a modern and standard fleet of more than 513 vessels and 37 business partners. The Group is a leading provider of offshore oil and gas industries [14].

Business analysis in the period from 2011 to 2015 showed results indicating that the company had gross profit for the observed period, but concluded 2015 with a negative sign. For the observed period, the company increased its total assets by 7.1% and increased its share capital by 23.5% compared to 2011. The BOURBON business performance indicators are presented in Table 2.

Table 2: BOURBON: ROA, ROE 2011 -2015

Year	ROA	ROE	Oil price
2011	0,003	0,003	107,46
2012	0,018	0,038	109,45
2013	0,038	0,097	105,87
2014	0,034	0,061	96,29
2015	-0,004	-0,028	49,49

Source: Authors

Table 2 shows that return on assets (ROA) was significantly oscillated in the observed period as well as the ROE indicator.

5.3 Tidewater

Tidewater company has built vessels adjusted to offshore oil and gas industry at sea since 1956. Around the world, it provides crews and stockpiling services, pulling and anchoring mobile platforms, assisting in offshore projects and carrying out various specialized maritime support services. Tidewater has the largest fleet in the industry and operates in more than 60 countries [15].

Tidewater has started to show business losses since 2014. Over the observed period, the company increased asset value by 18.6%, but its share capital fell by 9.8% in 2015 compared to 2011.

TIDEWATER performance indicators are presented in Table 3.

Table 3: TIDE WATER: ROA, ROE 2011-2015

Year	ROA	ROE	Oil price
2011	0,027	0,035	107,46
2012	0,047	0,059	109,45
2013	0,035	0,052	105,87
2014	-0,014	-0,026	96,29
2015	-0,028	-0,070	49,49

Source: Authors

Table 3 shows that in the observed period the profitability of the asset and capital changed to a negative one at the time of the fall in oil prices.

5.4 SEACOR Marine

SEACOR Marine is a company that in its quarter-century business provides operational, technical and security services in offshore maritime business. It specializes in providing crew, platform supply, maintenance support, security services and the ability to berth and anchor in shallow and deep waters worldwide [16].

SEACOR did business with a positive financial result in the observed period, which did not happen in 2015. In 2015, the company's assets fell by 22% compared to 2011. The company's core capital decreased by 2.4% in the observed period.

SEACOR MARINE performance indicators are presented in Table 4.

Table 4: SEACOR MARINE: ROA, ROE 2011-2015

Year	ROA	ROE	Oil price
2011	0,014	0,033	107,46
2012	0,015	0,047	109,45
2013	0,022	0,026	105,87
2014	0,050	0,072	96,29
2015	-0,010	-0,054	49,49

Source: Authors

From the data in Table 4 it can be seen that for the observed period ROA and ROE are positive except in 2015.

5.5 Siem

Siem Offshore has been operating since 2005 in the maritime offshore oil and gas industry. The corporation has a modern, environmentally friendly and technically advanced fleet of 45 vessels. Siem Offshore operates in Norway, Brazil, Germany, the Netherlands, Poland, USA, Canada and Australia [17].

Business results of SIEM pointed to instability in business because the gross profit of the company from 2011 to 2015 alternately increased or went into loss. The company increased its asset value in 2015 compared to 2011 by 8.5%, but decreased its share capital by 21.7% in the same period.

SIEM's performance indicators are presented in Table 5.

Table 5: SIEM: ROA, ROE 2011-2015

Year	ROA	ROE	Oil price
2011	-0,002	-0,008	107,46
2012	0,011	0,019	109,45
2013	0,009	0,027	105,87
2014	0,032	0,090	96,29
2015	-0,094	-0,311	49,49

Source: Authors

The SIEM company reported a negative ROA and ROE indicator in 2011 and 2015.

5.6 Comparative analysis

For similar companies, Table 6 shows the results of descriptive statistics on cumulative gross profit. The sum shown in the table is also a company-ranking indicator according to the above criterion.

Table 6: Descriptive statistics (profit before tax)

	Sum	Arithmetic Mean
SEACOR MARINE	308.033.000	61.606.600
POSH	304.103.000	60.820.600
BOURBON	284.232.303	56.846.461
TIDE WATER	273.261.000	54.652.200
SIEM	-84.483.000	-16.896.600

Source: Authors

According to the cumulative gross profit shown in Table 6, Seacor Marine is the most and SIEM the least successful company.

Chart 3 shows the ROA indicator of offshore companies in the observed period.

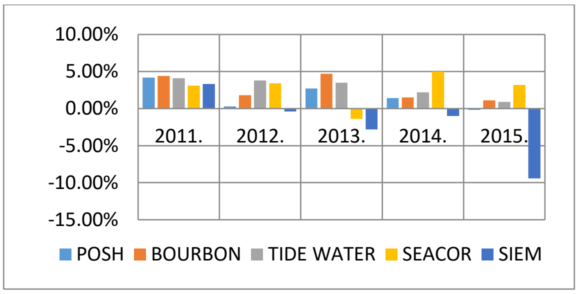

Figure 3: ROA indicator 2011-2015

The SIEM company is showing a rebuttal of asset profitability in 2015 when the oil price is the lowest in the observed period.

The decline in profitability of SIEM assets in the observed period stems from the consolidation and growth process because of the strategy geared towards reaching the leading position of the operator in supplying and servicing vessels globally. The company is focused on strengthening the fleet of oil and gas activities at sea, and striving for competitiveness and positioning with advanced and modern vessels and technology. The most favored ranked offshore company in Table 6 is Seacor Marine. This company is focused on achieving as much market share as possible and making better profit rates. In other words, the company has defined its profile and strives to achieve the best results, which is due to the realization observed from the point of view of financial performance indicators.

6 CONCLUSION

From the analysis it can be concluded that selected companies have similar characteristics in terms of generating gross profit in the observed period. Although only one of the selected companies reported negative business outcomes and dropped ROA and ROE out of the larger extent than reported by other companies, it went through the growth and development process and that consolidation had the effect and financial result. By reviewing the annual reports of selected companies, it can be concluded that they took the stand towards market risk controls implemented in business strategies. Changeable environments and market conditions ultimately have no significant impact on the financial results of the business, although the oil price reached a very low level in the observed period. The premise of maintaining offshore companies is the fact of long-term engagement in oil and gas exploitation. What differentiates them is their geographic positioning, where resources are directed to efficiently and effectively achieving goals and realization with the highest guarantee of risk control and fulfillment of contractual clauses with the client. Those are also companies competing with each other, but their position allows them to control their position for a longer period and to use their potential and power to take over the markets of their challengers and followers in crisis. With a certain reserve, the oil price is a "trigger" which affects the regulation of market relations through expelling those companies that have no capacity to overcome the internal or external crisis, whether it is an external fact of the financial crisis or the fact of oil price falling. The realization of the business goes on with losses and the survival of the market guarantees the profits when stability is established. The biggest problem, however, is the oil price forecast. Still, this fact is less important to companies that have diversified activities within the maritime industry. Maritime industry encompasses a whole range of services and production of specialized vessels, enabling maritime companies to align their operative, tactical and strategic activities. Organizational performances and strategies in the changeable environment of the offshore maritime industry reflect the qualities that the market prefers. In subjective self-determination, they uniformly and continuously show monitoring of the environment, analysis of internal weaknesses and forces, external opportunities and threats, mission and vision and set goals that are combined with a common denominator that embraces security, quality, expertise and modern equipment. It accomplishes complex services and activities in conditions and activities beyond the control of human opportunities in the open sea. In order to continue performing high efficiency it is necessary that the growth and development strategy are covered by growth and development activities, which is an integral part of all reports. Maritime offshore companies are predestined for positioning through affirmation of quality and safety, and their sustainability depends on two strategic goals: high specialization or vertical integration that can be achieved by merging companies in the chain of value.

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SIMPLIFICATION OF EVALUATION METHODOLOGY FOR SHIP'S PLANNED MAINTENANCE SYSTEM DATABASE

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ABSTRACT

This paper describes testing of simplified evaluation methodology for ship's computerized Planned Maintenance System database. The simplified evaluation methodology is developed using the efficiency analysis of the evaluation methodology for ship's computerized PMS database.
Evaluation methodology for ship's Planned Maintenance System database is designed to enable shipowners and their responsible persons for control the PM system development of correct computerized database. The evaluation methodology is used for the development and analysis of computerized databases in nine shipping companies, where it showed to be useful tool for the process of developing new databases and checking existing databases as well. Analysis of the process indicated that the methodology can be simplified with maintaining a high degree of accuracy. An improvement of the evaluation is suggested in three cases, consisting of the simplification of the evaluation grades. Two grades should be used for evaluation, 0 and 1, instead of 1 to 5. Grade 0 should be used when database quality is not satisfactory and 1 when database quality is in order. The analysis of the application of the simplified database evaluation methodology has determined elimination of the subjectivity of a person who evaluates the database that increases the accuracy of the evaluation system. The usability of simplified evaluation methodology is determined by analysis of the results of the evaluation obtained by the testing.

Keywords: Evaluation methodology, database, Planned Maintenance System, questionnaire, quality evaluation

1 INTRODUCTION

Although first appearance of Planned Maintenance System (PMS) is not recorded, it is known that the system is in use in the shipping industry for over one hundred years. It evolved together with the industry and become important part of the entire maintenance process. Planned Maintenance System today is mainly computer based system and there are varieties of programs designed for the purpose. Main part of each PMS program is well designed and high quality database (DB). Creating a database is process that determines its quality and shipowner is the most important part of the process. Shipowners and their responsible PMS personnel must supervise and control DB development process and establish control of inserted data (Tayi & Ballou, 1998) which is the key to good DB quality. "*In spite of the importance of having correct and adequate data in a company, there seems to be a general agreement in literature that poor quality data is a problem in many companies*" (Haug et al., 2011). The control of inserted data in DB is a complex task requiring specific knowledge of computerized PMS as well as maintenance of ship and ship's systems. A specialized tool was created to facilitate the task, i.e. the evaluation methodology for ship's PMS database (Stazić et al., 2017). It is designed according to the DQA (Data Quality Assessment) methodology (Batini et al., 2009). The methodology is developed with the intention to be used on any PMS program without any prior adaptation, by a person familiar with the computerized PMS program and the company's maintenance process. It consists of the questionnaire (Table 1), guidelines for database evaluation and guidelines for the interpretation of evaluation grades. The DB evaluation guidelines recommend a grading system consisting of grades from 1 to 5.

Grades should have the following meaning:

- Grade 1 – Fully negative evaluation result, very few positive findings
- Grade 2 – Mostly negative evaluation with a minor number of positive findings
- Grade 3 – Mostly positive evaluation with a significant amount of irregularities

- Grade 4 – Mostly positive evaluation with a minor amount of irregularities
- Grade 5 – Fully positive evaluation with a neglectable amount of irregularities

The "traffic light principle" (red, yellow, and green) is used to describe the importance of the question. According to the evaluation guidelines, the questions evaluated by grades 1, 2 and 3 are not satisfactory and DB improvement action should be arranged. Questions evaluated with grades 4 and 5 are in order and no further action is required.

Table 1: Computerized PMS DB evaluation questionnaire (Stazić et al., 2017)

Area	Imp.	Question	Grade
Machinery and equipment		01. Is all machinery and equipment included in the database?	
		02. Is all included equipment marked properly and uniquely, according to their shipboard location and markings?	
		03. Is all necessary machinery divided to subcomponents (to smaller subsystems) in logical manner?	
		04. Does machinery or equipment have larger number of subcomponents then necessary?	
		05. Is there equipment or machinery listed in the database more than once, or do they have same markings or names?	
		06. Is the data about the manufacturer, the type and the serial number entered to all relevant items?	
		07. Do all equipment and machinery entries have the same style, abbreviations, and markings?	
Jobs inside DB		08. Do all devices in the DB have linked maintenance plan according to manufacturer's recommendation?	
		09. Are manufacturer's recommendations grouped according to devices, periods and company maintenance rules?	
		10. Are all jobs required by company policy included in the DB? (e.g. SSM – Safety Management System)?	
		11. Are all jobs based on manufacturer's recommendation changed due to the company policy (if exists)?	
		12. Are all jobs required by flag state rules and regulations included in the DB?	
		13. Are all jobs required by class society included in the DB?	
		14. Is there a number of smaller jobs which can be grouped together?	
Special jobs, and rules - DB jobs general		15. Is fire detection sensor list inserted into the DB together with the testing plan?	
		16. Is the alarm system and its testing program entered in the DB?	
		17. Is PMS self-improvement program inserted into the DB, and is there control mechanism for PMS DB self-improvement program?	
		18. Is critical equipment marked according to company SMS?	
		19. Are job descriptions written clearly and straightforward?	
		20. Are jobs created and grouped according to multiplier principle?	
		21. Are all the same type jobs, coming from different sources, synchronized?	
		22. Are all the same jobs, resulting from different requirements (sources), merged?	
Spare parts		23. Are all required spare parts included in the database?	
		24. Are spare parts distributed to proper equipment and machinery?	
		25. Are all spare parts properly marked, do they have sufficient data for ordering?	
		26. Is company critical spare parts list inserted in the DB?	
		27. Do all spare parts have the same style, abbreviations, markings…?	
		28. Are there spare parts entered several times?	
Misc.		29. Are all users inserted in the DB, are all access rights defined in order?	
		30. Is there any other deficiency noted in computerized PMS database?	

The evaluation methodology from its creation was used for the development and analysis of computerized databases in nine shipping companies, where it proved to be a useful tool for developing new databases and checking existing databases as well. The authors of the methodology established the user feedback system Hattie & Timperley 2007) with the intention of controlling and improving the performance of the methodology (Basili et al., 1994). Improvement is proposed in three cases, consisting of the simplification of the evaluation grades. The simplification of the grading system is based on the outcome of the interpretation of the evaluation grades where the grades from 1 to 5 should be replaced by 0 and 1.Evaluation grade 0 should be used when the database quality is not satisfactory and database correction is recommended, while evaluation grade 1 should be used when the database quality is in order and no further action is required. In other words, grades 1, 2 and 3 will be replaced with grade 0 and grades 4 and 5 with grade 1.

The initial analysis of the proposal has shown that a simplified grading system will facilitate database evaluation and help to reduce or eliminate the subjectivity of a person who evaluates the database. This will increase the accuracy of the evaluation system and consequently help to improve the methodology. Testing of improvement is carried out to determine the usability of a new system of evaluation grades in practice.

This paper presents the process of testing a simplified grading method for evaluation methodology. New evaluation grades are presented together with results of analysis of evaluation grades and the interpretation of results. Determination of the usability of the simplified grading system is performed by comparing the results of the normal grading system with the simplified system. The usability recommendation is formulated in the conclusion in regards of results of analysis and the comparison.

2 EVALUATION OF DATABASES

Evaluation methodology testing was conducted from July 20th to 25th, 2017 (Stazić et al., 2017) in the offices of local companies. Five databases were evaluated (Table 2) using the questionnaire (Table 1), the grades are shown on the left side of Table 2. Simplified system grades are product of substitution, they are derived from a normal grading system by replacing grades 1, 2, and 3 with grade 0, and grades 4 and 5 with grade 1. Simplified system grades are shown on the right side of Table 2.

Table 2: Databases grades in Normal/Simplified system

	NORMAL system grades					SIMPLIFIED system grades				
Question	DB1	DB2	DB3	DB4	DB5	DB1	DB2	DB3	DB4	DB5
01.	5	4	5	5	4	1	1	1	1	1
02.	4	4	4	4	4	1	1	1	1	1
03.	5	5	5	5	5	1	1	1	1	1
04.	5	5	5	5	5	1	1	1	1	1
05.	5	5	5	5	5	1	1	1	1	1
06.	4	4	3	4	4	1	1	0	1	1
07.	4	4	4	4	4	1	1	1	1	1
08.	5	5	5	5	5	1	1	1	1	1
09.	5	5	5	5	5	1	1	1	1	1
10.	1	1	1	1	2	0	0	0	0	0
11.	1	1	1	1	2	0	0	0	0	0
12.	3	3	3	3	1	0	0	0	0	0
13.	5	5	5	5	5	1	1	1	1	1
14.	4	4	4	4	3	1	1	1	1	0
15.	5	5	2	2	5	1	1	0	0	1
16.	5	5	5	5	4	1	1	1	1	1
17.	4	4	4	4	4	1	1	1	1	1
18.	5	5	5	5	4	1	1	1	1	1
19.	4	4	4	4	4	1	1	1	1	1
20.	4	4	4	4	5	1	1	1	1	1
21.	1	1	1	1	2	0	0	0	0	0
22.	5	5	5	5	5	1	1	1	1	1
23.	4	4	4	4	3	1	1	1	1	0
24.	4	4	4	4	4	1	1	1	1	1
25.	4	4	4	4	4	1	1	1	1	1
26.	1	1	1	1	1	0	0	0	0	0
27.	5	4	5	5	4	1	1	1	1	1
28.	5	5	5	5	5	1	1	1	1	1
29.	5	5	5	5	5	1	1	1	1	1
30.	5	5	5	5	5	1	1	1	1	1

3 ANALYSIS AND COMPARISON

Analysis of the simplified evaluation grading system is performed to determine if and when the method can be used. Several methods were used for the analysis; the results of both grading system are compared to reach conclusion of usability.

3.1 The summation of grades and the average grade value

The first part of the analysis is the calculation of the summation of grades and the average grade value of each database. The average grade in the normal grading system is the value that needs to be taken into account with a particular reserve, it is calculated for information purposes and represents an indicator of the general state of data in the database. Conversely, the average grade value of the simplified grading system is the absolute value of grades where the DB is in order.

The results of the average grade value of simplified grading system will show different values and have different patterns (Table 3) from the normal grading system. The deviations from the results of the two evaluations are significant, so the conclusion based on the assessment of the simplified grading system will not be the same as for the normal grading system. **Therefore, the average grade value for a simplified grading system should not be calculated nor taken for any further consideration.**

Table 3: Summation of grades and average grade value

	NORMAL system					SIMPLIFIED system				
	DB 1	**DB 2**	**DB 3**	**DB 4**	**DB 5**	**DB 1**	**DB 2**	**DB 3**	**DB 4**	**DB 5**
Summation of all grades	122	120	118	119	122	25	25	23	24	23
Average grade value	4.067	4.000	3.933	3.967	4.067	0.833	0.833	0.766	0.8	0.766

3.2 Assessment of major deficiencies

An assessment of major deficiencies defines the areas where DB can and should be corrected. Assessment of major deficiencies is shown as an excerpt (Table 4). All questions that received lower evaluation grade are marked in red. The red areas in Table 4 for normal grading system are identical to those of the simplified system. This suggests that **this analysis** will yield the same results for both grading systems and therefore **can be used in a simplified system.**

Table 4: Questions with major deficiencies

Question	NORMAL system					SIMPLIFIED system				
	DB1	**DB2**	**DB3**	**DB4**	**DB5**	**DB1**	**DB2**	**DB3**	**DB4**	**DB5**
10.	1	1	1	1	2	0	0	0	0	0
11.	1	1	1	1	2	0	0	0	0	0
12.	3	3	3	3	1	0	0	0	0	0
14.	4	4	4	4	3	1	1	1	1	0
15.	5	5	2	2	5	1	1	0	0	1
21.	1	1	1	1	2	0	0	0	0	0
26.	1	1	1	1	1	0	0	0	0	0

3.3 Resemblance analysis

Resemblance analysis is performed by calculation (Stazić et al., 2017) according to formula 1. Results of resemblance calculation are given for a normal and simplified grading system (Table 5):

$$S = 100 - \frac{100}{nQ}\sum\left|Ri_{bj} - Ri_{bk}\right| * \frac{1}{nG-1} \quad [\%] \qquad (1)$$

where is: S – resemblance of grades of two databases, nQ – total number of questions, Ri–answer on i^{th} question (i = 1, 2 ... n), bj – j^{th} evaluated database, bk – k^{th} evaluated database (j, k = 1, 2 ... m, j ≠ k), nG – total number of grades.

Table 5: Resemblance of databases evaluation grades (%)

	NORMAL system					SIMPLIFIED system				
	DB 1	DB 2	DB 3	DB 4	DB 5	DB 1	DB 2	DB 3	DB 4	DB 5
DB 1	100	98.33	96.66	97.50	90.00	100	100	98.33	99.16	98.33
DB 2	98.33	100	95.00	95.83	90.83	100	100	98.33	99.16	98.33
DB 3	96.66	95.00	100	99.17	86.66	98.33	98.33	100	99.16	96.66
DB 4	97.50	95.83	99.17	100	87.50	99.16	99.16	99.16	100	97.5
DB 5	90.00	90.83	86.66	87.50	100	98.33	98.33	96.66	97.5	100

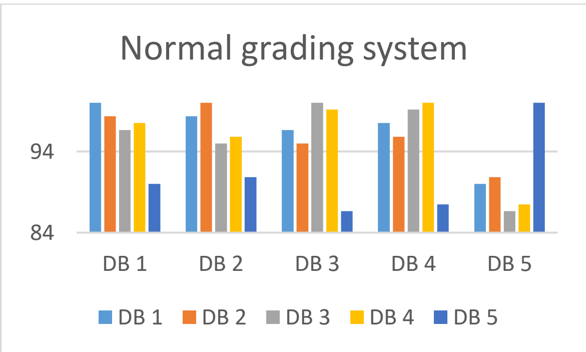

Figure 1: Graph of normal grading system resemblance

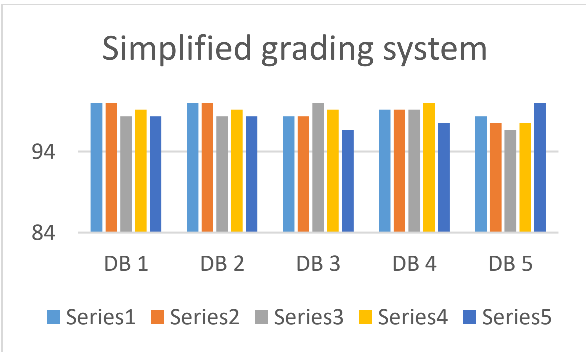

Figure 2: Graph of simplified grading system resemblance

Comparison of resemblance analysis results is shown in Figures 1 and 2, where it is clear that obtained results are different. The analysis of the resemblance of the grades of a normal grading system can be the source of data for further research, while the analysis of the resemblance of the grades of the simplified grading system does not provide enough data and has a different pattern. Therefore, any **resemblance analysis calculated on simplified grading system** will not be accurate, and this analysis method **is not recommended** for simplified grading system.

4 CONCLUSION

The simplified grading system for the evaluation methodology for ship's computerized PMS DB has shown its advantages and disadvantages. The main advantage is the simplicity of use, there is no need to check DB too deep to formulate the grade. Another advantage is to reduce the subjectivity of a person evaluating DB, which increases the accuracy of the evaluation system. The shortcomings of the simplified grading system are the lack of precision (descriptive capabilities) and inadequacy of the average grade value for further use. Also, the resemblance calculation of grades in the simplified grading system will not produce credible results and should not be performed.

If all above is considered, the simplified grading method for the evaluation methodology for ship's computerized Planned Maintenance System DB should not be used for complex analysis of company databases. At the same time, the simplified grading method should be considered for use for the evaluation of newly-built databases or databases under construction, where only one database will be evaluated at a time, and there is no need for any further analysis of the results.

If used that way, a simplified grading system will provide good and precise results and will be good improvement of evaluation methodology for ship's computerized Planned Maintenance System DB s.

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INTEGRATION OF FATIGUE RISK MANAGEMENT IN AVIATION SAFETY MANAGEMENT SYSTEM

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ABSTRACT

The aim of the presented research is to elaborate the hazard of fatigue in air transport operations. Besides a summarized overview of bibliographical sources, a correlation between fatigue and safety management is discussed, as well as fatigue risk assessment and mitigation tools. The targeted research task refers objectification of the crew fatigue on the sample of flight operations and preliminary results interpretation of referent indicators measuring.

Key words: Air transport, fatigue, risk, safety management system, crew fatigue objectification

1 INTRODUCTION

The rise in global long-haul, regional, night cargo and domestic short-haul air traffic requires a 24-hour working time. Supporting such flight operations includes shift work, night work, work in several time zones, and a changeable and unpredictable crew roster. Such working hours and specific working environment and workload (aircraft cockpit or cabin, long duty hours) may cause disturbance of circadian rhythm and loss of sleep or sleep disorder, which may result in fatigue of flight crew and have impact on the safety of flight operations. Fatigue affects various cognitive abilities such as alertness, memory, getting around in space, learning, problem-solving, decision-making, and more. A very important role in reducing fatigue risk, besides the restrictions defined in flight time limitations, lies in the Fatigue Risk Management System (FRMS) that presupposes some methods for fatigue quantification. This paper describes the method of measuring the fatigue of professional airline pilots using special measuring psycho-diagnostic equipment which was used to perform the measurements. The construction of these tests is based on a chronometric approach to measure cognitive functions.

2 HAZARD OF FATIGUE IN AIR TRANSPORT OPERATIONS

Fatigue is the result of personal and business factors (1). Personal factors are related to age, chronotype (morningness, eveningness) (2), gender, genetic predisposition and personality that have an impact on tolerance towards shift work (3). In addition to this lifestyle in terms of physical activity or inactivity - the time spent in front of a television or computer has effect on the length and quality of sleep (4) (5). For flight crew, job factors mean shift work that includes early/late/night duties (6), unpredictable monthly crew roster (duties are usually being changed because of operations reason, sickness and other reasons), time zone crossing, standby duties and other.

The listed factors with two major biological mechanisms affecting periods of wakefulness and drowsiness (circadian rhythm, homeostatic sleep pressure and sleep inertia) can lead to sleep loss and sleep debt.

Fatigue has physical (general feeling of fatigue, decrease alertness and an irresistible desire for sleep, microsleep[1], lethargy, prolonged reaction time, etc.) and mental (difficulty with memorizing and forgetting information and actions, lack of concentration, slow understanding, the bad will and decisions, apathy) manifestations. Where in flight operations, some but not all included, fatigue effects are:

- Inaccurate flying and Missed radio calls;
- System warnings missed or slow to pick up;
- Routine tasks performed inaccurately or forgotten;
- Loss of situational awareness;
- Microsleeps and task fixation;
- Poor communication between crew members.

Also, fatigue has effect on reduced possibility of judgment/performance in the critical phases of flight (take-off/landing), and difficulty remaining alert in terms of reduced workload (cruise).

Some of identified causes of fatigue hazard in short-haul operation (7):

- Restricted sleep due to early duty report times;
- Multiple high workload periods across the duty day;

[1] Microsleep - short episodes of complete perceptual exclusion from the outside environment and stimuli that may last several seconds or shorter.

- Multiple sectors;
- Long-duty days;
- Restricted sleep due to short rest breaks;
- High density airspace.

Factors that may be considered to manage fatigue in flight operations are:

- Length of duty;
- Total flying time;
- Number of legs;
- Rest period duration;
- Time of day;
- Pattern of duty;
- Rest facilities (management of sleep during layover period);
- Number of time-zone transitions;
- Number of consecutive duty days.

Traditional fatigue management and the way to protect the crew members from excessive fatigue levels has been the Flight Time Limitations (FTL). But restrictions on working hours are different from country to country and in various ways restrict the permitted flight duty, length of rest period and other FTL elements (8) (9). Also, the prescriptive nature of these limitations prohibits some elements of crew rosters, but also allows others that can be very fatigue-inducing while all regulatory provisions are complied with at the same time. Although the new regulation from 2014 (EU OPS FTL) promotes active fatigue risk management systems (FRMS), it does not oblige airlines to apply FRMS except in certain specific cases (e.g. the use of reduced rest operations, etc.).

At the same time, EU OPS FTL also, among other, requires the following from the airlines[2]:

- Ensure that flight duty periods are planned in a way that enables crew members to remain sufficiently free from fatigue so that they can operate to a satisfactory level of safety.
- Appreciate relationship between the frequencies and pattern of flight duty periods and rest periods and will give due considerations to the cumulative effects of undertaking long duty hours interspersed with minimum rest.
- Allocate duty patterns which avoid such undesirable practices as alternating day/night duties or the positioning of crew members so that a serious disruption of established sleep/work patterns occurs.
- Provide rest periods of sufficient time, especially after long flights crossing many time zones, to enable crew members to overcome the effects of the previous duties and to be rested by the start of the following flight duty period.

The question that arises is how it can be determined that an airline complies with the above regulatory requirements? The only possible way is to quantify and monitor fatigue risk. In this paper, the quantification of fatigue phenomena is discussed.

3 BIBLIOGRAPHICAL RESOURCES

Sleep is human biological need, with its main mechanisms of homeostatic sleep pressure and circadian rhythm. One of the recent studies of fatigue phenomena won the Nobel Prize for the year 2017 for discovering molecular mechanisms controlling the circadian rhythm (10). Small sleep debt is needed to fall asleep – "The probability of falling asleep means a combination of two opposing forces: our burden of sleep minus the level of excitement" (11) but great sleep debt can lead to falling asleep while driving. Also, performance measured by the reaction time and the number of mistakes is worse as result of sleep deprivation (12). One study showed worsening of the reaction time and performance of motorcycle driving (13). One of the main data sources for fatigue research, especially in in-flight operations are subjective fatigue scales that flight crew use in fatigue reporting. The application of subjective measures in pilot fatigue research and the effect of time, length of duty, and time of day can be found in the most recent studies (14) (15) where pilots reported subjective fatigue level at ToD[3] point using Samn Perelly fatigue scale. Other studies involved actigraphy, sleep diaries, performance vigilance test (PVT) and biomathematical predictive model (SAFE[4]) where fatigue correlation was studied regarding different methods of its quantification (16) (17) (18). One research showed that there is high correlation between certain biomarkers in saliva and fatigue levels (19). One research outlined the problems of crew fatigue management in airline operations (30).

In addition to the methods of quantifying the fatigue of flight crews, cognitive abilities that deteriorate with fatigue increase can be measured with a chronometric approach to measuring cognitive functions. For this purpose, an electronic CRD[5] system of standardized chronometric cognitive tests is used. CRD series have been used in various studies from 1969. The instruments, methodology, measuring parameters and other information are well explained and documented in the university book (20). CRD series has been used for the study on psychomotor disturbances of scuba divers (21). One study showed differences between the working ability of the driver, train operator and dispatcher during day and night shifts (22). In doctoral dissertations CRD series have been used for evaluating psychomotor abilities of military pilots (23) and in some older studies CRD series have been used for researching workload and work efficiency during time periods (24) (25) (26).

4 CORRELATION OF FATIGUE AND SAFETY MANAGEMENT

ICAO defined a Fatigue Risk Management System (FRMS) as "a data-driven means of continuously monitoring and maintaining fatigue related safety risks,

[2] Commission Regulation (EU) No 83/2014, ORO.FTL.110
[3] ToD – Top of Descent
[4] <http://www.frmsc.com/the-safe-suite/the-safe-model/ >(30.11.2017.)
5 CRD – Computerized Reactionmeter Drenovac

based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness". (27)

Information and reports data related to crew alertness are routinely collected and analysed by means of an effective FRMS. FRMS helps to control the risk associated with fatigue.

FRMS can be established as a standalone system or as part of the Safety Management System (SMS). (27)

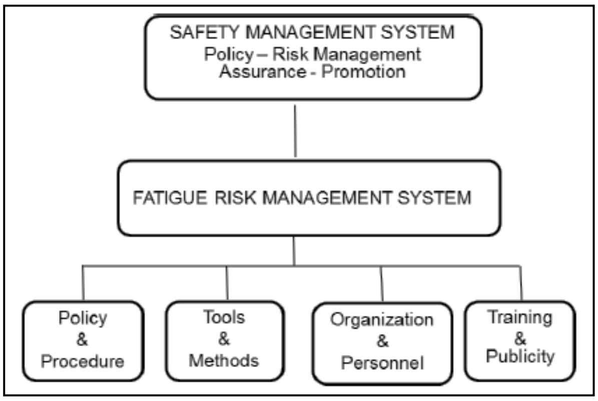
FRMS aims to ensure that flight crew members and cabin crew are sufficiently careful to work at a satisfactory level of performance. The principles and processes from the Safety Management System (SMS) are applied to manage the specific risks associated with the crew member's fatigue (27). Like SMS, FRMS seeks to achieve a realistic balance between safety, productivity and costs. It seeks to proactively identify opportunities to improve operational processes and reduce risk, as well as to recognize disadvantages after adverse events. The structure of FRMS is modelled on the SMS basic framework. Basic activities are Safety Risk Management and Safety Assurance. These basic activities are governed by FRMS policy and supported by FRMS promotion processes (27).

SMS and FRMS rely on the concept of an effective reporting culture, where staff are trained and constantly encouraged to report any dangers (hazards) whenever recognized in the working environment (27, 30).

The FRMS goals are to "manage, monitor and mitigate the effects of fatigue to improve flight crew members' alertness and reduce performance errors" as well as to balance safety and productivity (31).

The use of SMS to manage fatigue is fundamental. Fatigue is recognized as aviation hazard and as such, it creates risks, for which it is essential to maintain a solid SMS. Because of this, the basic SMS elements must be established (31).

Incorporation of an FRMS works in parallel with the elements of the Safety Risk Management component of the organization's SMS. Further, FRMS supports the Safety Assurance component of SMS by providing, among other things, performance monitoring and a system of employees' reporting. Finally, Safety Promotion component of SMS needs to establish safety as a core value with a sustained Safety Culture (31).



Source: (31)

Figure 1: SMS and FRMS

Safety Risk Management (SRM) methodology is used to identify hazards, analyse identified hazards, conduct the safety risk assessment using the safety risk matrix, and to propose the risk mitigation measures in order to reduce, mitigate or eliminate risk. The objective of safety risk management is to assess the risks associated with identified hazards and develop and implement effective and appropriate mitigations. Safety risk management is therefore a key component of the safety management process.

Fatigue is identified hazard to safety of air transport operations. Due to this fact, fatigue hazard is analysed and recognized as potential danger to the safety of air operations. Paragraph 5.1 describes relevant fatigue measurement which shows and confirms the existence of fatigue.

The next step of SRM is Safety Risk Assessment. In order to obtain the risk level, it is necessary to evaluate Risk Probability (Table 1), i.e. how often the fatigue occurs, for example in relation to time of the day; and it is necessary to evaluate Risk Severity (Table 2), i.e. what the severity of risk occurrence could be, for example in relation to the time of day.

Table 1: Risk probability of the fatigue hazard

Likelihood	*Meaning*	*Value*
Frequent	Likely to occur many times (has occurred frequently)	5
Occasional	Likely to occur sometimes (has occurred infrequently)	4
Remote	Unlikely to occur, but possible (has occurred rarely)	3
Improbable	Very unlikely to occur (not known to have occurred)	2
Extremely improbable	Almost inconceivable that the event will occur	1

Source: ICAO Doc 9859

Table 2: Risk severity of the fatigue hazard

Severity	*Meaning*	*Value*
Catastrophic	— Equipment destroyed — Multiple deaths	A
Hazardous	— A large reduction in safety margins, physical distress or a workload such that the operators cannot be relied upon to perform their tasks accurately or completely — Serious injury — Major equipment damage	B
Major	— A significant reduction in safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of an increase in workload or as a result of conditions impairing their efficiency — Serious incident — Injury to persons	C
Minor	— Nuisance — Operating limitations — Use of emergency procedures — Minor incident	D
Negligible	— Few consequences	E

Source: ICAO Doc 9859

Once the Risk Probability and Risk Severity are defined, the Risk Level is obtained from the Safety Risk Assessment Matrix (Table 3), and by obtaining the Risk Level, the Tolerability (Acceptability) Area of the risk can be determined.

Table 3: Safety risk assessment matrix

Risk probability		Risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E

Source: ICAO Doc 9859

Due to the fact that fatigue hazard happens occasionally, and the severity of the occurrence may be major, i.e. it might end in a significant reduction of safety margins, a reduction in the ability of the operators to cope with adverse operating conditions as a result of an increase in workload or as a result of conditions impairing their efficiency, and/or serious incident and/or injury to persons (Risk Level 4C); risk level is considered to be in Tolerable (Acceptable) Area (Table 4).

Risks defined in the Tolerable Area are called Moderate Risks. Moderate Risks are only acceptable if the Risk Mitigation is conducted, i.e. it is necessary to implement risk mitigation measures to bring down the risk level to the low range (acceptable, green) if viable.

Table 4: Tolerability of the risks

Tolerability description	Assessed risk index	Suggested criteria
Intolerable region	5A, 5B, 5C, 4A, 4B, 3A	Unacceptable under the existing circumstances
Tolerable region	5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	Acceptable based on risk mitigation. It may require management decision.
Acceptable region	3E, 2D, 2E, 1B, 1C, 1D, 1E	Acceptable

Source: ICAO Doc 9859

Considering that the fatigue hazard represents, at least, Risk Level 4C, i.e. Moderate Risk, it is mandatory to ensure Risk Mitigation measures in order to reduce the risk level to the acceptable.

Therefore, further research, to find and define appropriate mitigation measures to reduce fatigue risk level to the acceptable, should be conducted.

5 OBJECTIFICATION OF THE CREW FATIGUE

The most commonly used methods for objectification of the crew fatigue include:

- Subjective fatigue scales (Samn Perelli fatigue scale, Karolinska Sleepiness Scale);
- Psychomotor vigilance test (PVT);
- Actigraphy;
- Predictive models (biomathematical algorithms in software applications like SAFE);
- Sleep diaries.

Subjective objectification of fatigue is also commonly found in fatigue reports and fatigue reporting (27) that are used as the main data collection tool. Predictive models can be found in modern crew management software applications and they can warn crew planners of fatigue risk (usually warning messages and colour schemes – from green as no risk to red – high fatigue risk). Other objective methods are used in fatigue studies for specific cases when required by airline (e.g. for certain type of flight operation of an airline).

5.1 Referent indicators

This paper describes a study of fatigue objectification using CRD instruments.

The purpose of the research is to find correlation between cognitive, psychomotor and functional mental disorders, measured with electronic tests of the CRD series and workload parameters of flight crew (pilots). Personal assessments on the current state of fatigue (subjective scales) were also used. The aim of the research is to identify and quantify elements that affect the risk of fatigue.

Independent categories or criterion variables were:

- Workload (flight hours, duty hours, rest periods, number of sectors, etc.);

- Time of day (when CRD tests were done, used to study circadian rhythm influence);
- Subjective scales of self-assessment (four short questionnaires) (28).

Dependent categories were:

- CRD indicators (measures or results from solving the tests of CRD series);
- Subjective scales of self-assessment (they can be both independent and dependent categories).

The task design in the CRD series tests is based on the concept of reaction time measurement. These tests are intended for chronometric measurements of the efficiency of performing mental and psychomotor functions, as well as the determination of dynamic characteristics and functional interferences in the process of mental processing. Efficiency of solving tasks in most CRD tests is expressed by time indicators:

- Total Test Solution Time - UKT - the lower value indicates a higher level of efficiency and vice versa.
- The shortest time to solve the task - Tmin - lower value indicates higher processing speed and vice versa.
- Number of errors - UP - the number of errors mostly points to the form of compliance of speed and accuracy in mental processing or attention. The error number also carries information about the weight of tests.
- Total lost time due to the fluctuation of the speed of solving the same tasks in individual tests as the representativeness of mental processing stability or total ballast - UB - an indicator of individual stability as the dynamic characteristic of mental processing. Lower value indicates greater stability and vice versa.
- Final ballast and initial ballast ratio – ZB/SB – derived indicator of the speed change (acceleration or deceleration) of the task-solving in the function of performing a test. If the final ballast (ZB) is greater than the starting ballast (SB), the ratio will be greater than one, meaning that the subject is slowing down in test solving (deceleration).

5.2 Measuring

Measurements were made involving four male pilots of an average age of 42 years (+/- two years), who have been professional airline pilots for the last 11 years (standard deviation 4.7 years) and an average of 6,305 flight hours (standard deviation of 2,532 flight hours). The pilots were familiar with the method (process and dynamics of the study) and the metering CRD equipment and tests to be used. The pilots first had a training for 10 iterations and in a single iteration they did five CRD tests, since a later measurement aims to avoid the effect of learning how to do tests better because the goal was to measure the drop of mental potential due to fatigue. The five CRD series tests that were used in this research were:

- CRD2-41: Identifying progressive series of numbers;
- CRD2-3: Complex convergent visual orientation;
- CRD1-3: Spatial visualization test;
- CRD3-24: Actualization of short-term memory; and
- CRD4-22: Operative thinking with sound stimuli.

Measurements, during which the pilots did full battery of tests and filled subjective survey, were done before and after the flight duty period. The tests were done in an improvised CRD laboratory, a room at the International Airport Zagreb where the pilots had the check-in and the check-out (pre and post-flight duty).

Source: Prepared by authors

Figure 2: CRD laboratory

In total, the goal was that every single pilot has at least 30 series of full test battery, not including 10 training series. That goal was reached.

5.3 Results interpretation

After the measurements have been completed and data collected, the statistical data processing started. In the first step it was necessary to convert the original CRD measurement results from the time indicators (milliseconds) to standardized T scale indicators for the purpose of normalizing data.

The need for transposing the original measures into standardized metrics results from the fact [20] that the chronometric data are distributed asymmetrically and it is necessary to normalize their distribution because later analytics uses standard statistical procedures that presuppose normal distribution. This process included the data of UKT, T_{min} and UB originally expressed by time indicators (milli-seconds), and the total number of errors (UP) and the relationship between the final and start ballast (ZB/SB) are in the original values.

In the second step, statistical processing was started. In this paper the analysis (t-test) of the small part of the whole study is presented – the comparison of the start of the working shift (Check In – CI) and the end of the working shift (Check Out – CO) of pilots, and the dependent variables:

- UKT - total test time, transposed into T scale;
- T_{min} - the shortest time to complete the test, transposed into T scale;
- UB - total ballast, transposed into T scale;

- UP - the number of errors when solving the test, the original value;
- ZB/SB ratio - relationship between final and initial ballast.

The hypothesis checked in this paper is as follows: "The start and end of the shift affects the effectiveness of mental processing of pilots in cognitive testing."

For the purpose of testing this hypothesis, the statistical analysis of independent variables (CI and CO) and dependent variables is presented below. The statistical method used is a standard t-test. The presented indicators relate to CRD test 422 - operative thinking with sound stimuli. The signal-command system of the CRD422 includes, along with the main signaling board, the connecting elements: headphones (speakers) and pedals. In this test, one of the two predefined sound signals is broadcasted in different tasks. At high volume, at the same time, a large key in the left corner of the control panel must be pressed by left hand and the right foot pedal must be pressed with the right foot. When low sound is broadcasted, the required response is to press at the same time, the large key in the right-hand corner of the control panel with the right hand and the left foot pedal with the left foot.

The reason for choosing CRD 422 test for research in this paper is the complexity of the test (sonic and visual stimuli) and its measurement sensitivity. The number of measurements at CI was N=113 and CO was N=115.

Table 5: Analysis of dependent variables relative to CI and CO

	CI – Average	CO – Average	Delta Average	p
UKT (T scale)	47.63406198	52.32479127	-4.690729295	**0.00035458 ***
T_{min} (T scale)	49.12543896	50.85935128	-1.733912321	**0.19213582**
UB (T scale)	47.47799569	52.47814336	-5.000147672	**0.00013624 ***
ZB/SB (original value)	1.380578009	1.390902262	-0.010324253	**0.86927242**
UP (original value)	3.274336283	1.390902262	1.778684109	**0.00001092 ***

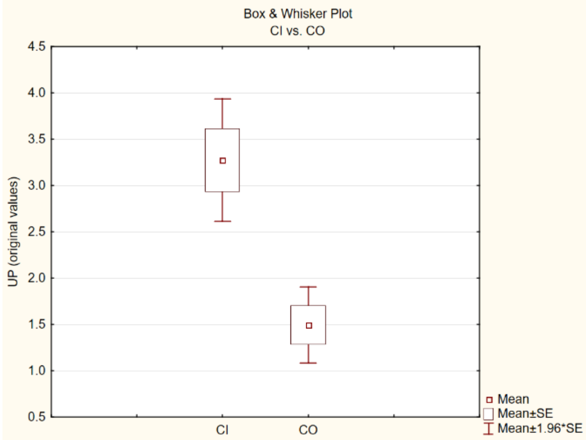
*Source: authors by software application Statistica 10 *Significance of differences at the level of prommiles*

From Table 5 it is apparent that UKT difference is statistically significant at the level of prommiles and shows that after the end of the shift the mental processing of the pilots slows down, which means that they need more time to solve the same number of tasks in the test, compared to the time of the task solutions at the beginning of the shift.

The shortest time to complete the test T_{min} increases at the end of the shift, but this difference is not statistically significant.

Similarly, the UB difference is statistically significant at the level of prommiles. It shows increasing of the fluctuation of time for solving certain tasks at the end of the shift relative to the fluctuation of solving these same tasks at the beginning of the shift.

The difference of ZB/SB ratio according to the analysis in Table 5 is not statistically significant.



Source: authors by software application Statistica 10

Figure 3: UP (original values) in relation to the beginning of the shift (CI) and the end of the shift (CO)

From Table 5 it is apparent that this difference is statistically significant at the level of promilles and shows that attention, measured as the number of errors – UP, is lower at the beginning of the shift compared to the homogeneity of attention at the end of the shift, meaning that the pilots at the end of the shift sacrificed the processing time in favour of the accuracy of processing.

6 CONCLUSION

The aim of the targeted research is to identify the critical causes in flight crew scheduling and workload of pilots that affect the increased risk of fatigue. The results of cognitive test were analyzed in relation to the elements of work schedule (rest period before duty, time of day, etc.) and workload (number of sectors, length of flight duty, etc.). Besides, the pilots gave the subjective scale of fatigue estimation, so the indicative comparison results of subjective self-assessment of the pilots and the objective findings of their cognitive testing are also expected.

In this paper the fatigue aetiology is presented and the correlation of fatigue risk management and safety management in air transport operations elaborated.

As a result of the presented part of the research, it can be concluded that there are serious changes in the pilots' mental processing relative to the start and the end of the work shift, which confirms the justification of the continuation of the study targeted to more precise determination of correlation between cognitive, psychomotor and functional shortages and mental processing.

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MEASUREMENT SYSTEM OF BIOMIMETIC UNDERWATER VEHICLE FOR PASSIVE OBSTACLES DETECTION

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ABSTRACT

In the recent times, we may notice some new designs of underwater vehicles, which imitate living underwater organisms, e.g. a fish, a seal, a turtle, etc. These vehicles are called biomimetic. They are driven by undulating propulsion, imitating wavy motion of fins, which was created during many years of evolution.

In the paper, a measurement system of Biomimetic Underwater Vehicle (BUV) called CyberSeal for passive obstacles detection using hydrophones is presented. The main objective of the system is to detect and then to determine the bearing on the movable objects generating noise. At the beginning of the paper, an introduction to the research area and a structure of the measurement system is described in general and then, all the elements of the system are presented in details in the following sections. At the end of the paper, an initial research on obstacle detection and a schedule of the future research are inserted.

Keywords: biomimetic underwater vehicle, passive obstacles detection, hydrophones

1 INTRODUCTION

In the recent years, a dynamical development of underwater robotics has been noticed. One of the latest innovative constructions in this field are autonomous biomimetic underwater vehicles (BUVs) [1][2][4][11]. They imitate underwater living organisms, e.g. fishes, marine mammals, etc. They can imitate both the construction and kinematics of motion. BUVs are driven by undulating propulsion imitating real fins, e.g. of a fish – Fig. 1 [4] or of a seal – Fig. 2 [9].

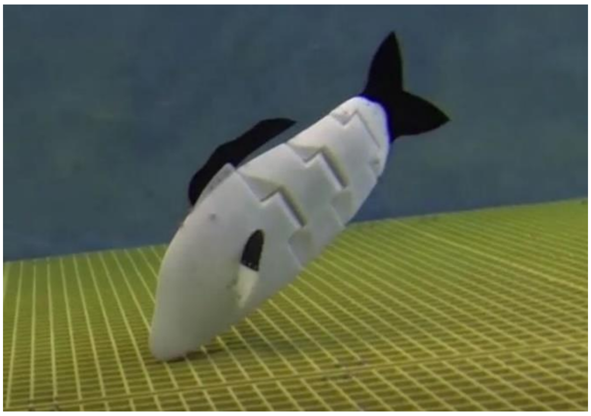

Figure 1: BUV CyberFish ver. 5 in a swimming pool [4]

The BUVs are driven by undulating propulsion consisting usually of two side fins and one (Fig. 1) or two (Fig. 2) tail fins. This propulsion system is usually supported by an artificial swim bladder, i.e. a ballast tank for changing buoyancy of the BUV. Additionally, the BUVs are equipped with different sensors and communication and navigation devices. One of the sensors are hydrophones. They are used for hydro acoustic signal registration.

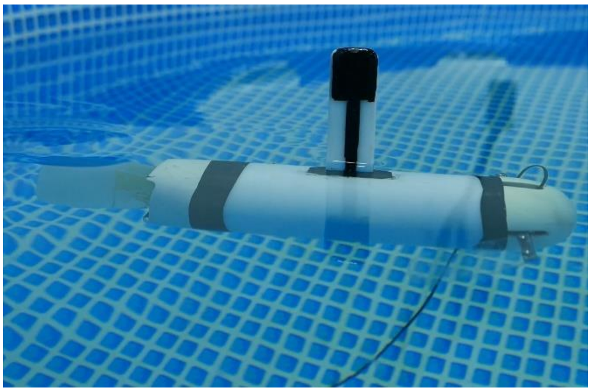

Figure 2: BUV mini CyberSeal in a swimming pool [9]

The basic function of hydrophones is to capture signature of different objects. The additional function of the hydrophones can be to detect and to track noisy and movable obstacles for avoiding possible dangerous object in the area near a surface of water (Fig. 3).

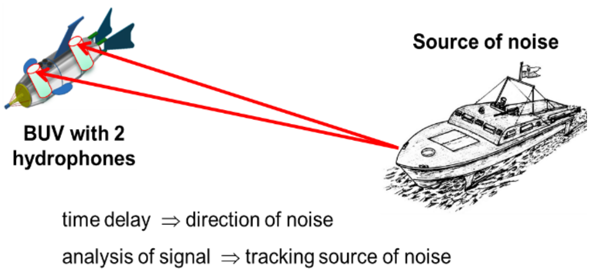

Figure 3: Conception of using hydrophones for tracking noisy obstacles

The idea of determination a bearing β on a source of signal are quite simple and refers to the mechanism of echolocation used by real animals, e.g. bat and dolphins, which use echolocation for obstacle detection [10]. The bearing on a source of signal is understood as an angle between BUV's longitudinal axis of symmetry and a source of noise, e.g. a small boat (Fig. 3). According to the right-hand screw rule, the source of signal located on the right side of the BUV is on the bearing equal to (0,180) [deg], while the negative values of bearing (0,-180) [deg] means that source of signal is on the left side of the BUV. The bearing equal to 0 [deg] means that the source of signal is in the front of BUV and consequently the bearing equal to 180 [deg] means that source of noise is behind the BUV. In the proposed solution with hydrophones, no signal is transmitted by the BUV, only signals generated by the noisy object are used. In this case, passive detection of obstacles is obtained. At the beginning, only one noisy obstacle is assumed to be taken into consideration. Presence of more than one noisy obstacle will demand analysis of their frequency signatures, what will be the objective of the further research.

Knowing a value of velocity of a sound in water and a time shift between received signals from two hydrophones, an absolute value of bearing on the source of signal can be determinated. The absolute value of bearing means that it is not possible to determine if the source of signal is on the starboard or on the port side after analysis of a single measurements from two hydrophones. Having additional third hydrophone mounted on one of the BUV's sides, a value of the bearing can be determinated based on the strengths of signals received from three hydrophones, e.g. if the third hydrophone is mounted on the starboard and the signal received by this hydrophone is stronger than signals received from first and second hydrophones mounted adequately on the bow and the stern, the noisy obstacle will be on the starboard.

However, also having two hydrophones, the determination of bearing is possible, i.e. knowing own changes of position in time, especially a course, the value of the bearing can be calculated after analysis of several samples of received signals from two hydrophones, especially in the case of undulating propulsion characterizing with an oscillation of motion. Moreover, taking into account analysis of several samples of signals, it can be also calculated whether the source of noise is approaching or moving away.

It is worth mentioning that calculation of time shift between signals received from two hydrophones mounted on the bow and the stern allows to determinate only a bearing, but not a position.

In general, the points with the same absolute difference of distances Δd from two hydrophones, i.e. with the same time shift lie on the hyperbola with the foci in the position of the two hydrophones. If the source of noise is located in long distance from the two hydrophones comparing to the distance between hydrophones h, it can be assumed that the source lies on a straight line. In that case the cosine of the bearing β is equal to the fraction of the absolute difference of distances Δd and the distance between the two hydrophones h.

The interesting approach for underwater object detection using hydrophones is included in [3]. In this case, the objects are marine mammals, which communicate using hydro acoustic signals. During tests [3] two hydrophones were mounted on the left and right wings of an underwater glider. There are also other different approaches used for tracking marine mammals by means of hydrophones [5][6].

This paper undertakes problem of using two hydrophones for passive obstacle detection by the BUV (Fig. 3). In this case, noisy and movable obstacles are assumed to be detected.

This paper includes results of initial research using hydrophones installed outside the BUV2's hull. In the research, the National Instruments hardware platform with LabView application were used.

In the next section, the structure of the measurement stand for passive obstacle detection is included.

Then, the application for obstacle detection written in LabView is described. The application uses the functional blocks with implemented algorithms of data processing. The analysis of different methods for obstacle detection performed by the Authors is included in [7].

The next section contains results of initial research using the mentioned below LabView application.

At the end of the paper, the summary with conclusions from the carried out research and schedule of the future research is presented.

2 STRUCTURE OF MEASUREMENT STAND

The measurement stand of the BUV for passive obstacle detection consists of:

1. Two hydrophones HTI-96-MIN from High Tech, Inc. mounted on the bow and stern of the BUV (Fig. 4),
2. Microprocessor system sbRIO-9636 from National Instruments installed inside the BUV's hull.

The HTI-96-MIN hydrophone has omnidirectional characteristics and sensitivity equal to -165 [dB] with respect to [1 V/ μPa], i.e. 5.6 [mV/Pa]. The hydrophone sensitivity refers to the ratio the sensors scales the pressure to the voltage. Taking into consideration 12 bit analog to digital converter with 0-5 [V] range, i.e. 1 bit is equal to 1.22 [mV], measurement of pressure on the level of 0.2 Pa is possible. Moreover, the HTI-96-MIN has additional advantage connected with its small size, i.e. its length is 6.35 cm and diameter 1.9 cm.

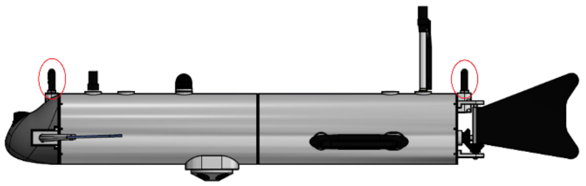

Figure 4: 3D design of BUV2 with two HTI-96-MIN hydrophones marked by red circles [9] (designed by Maciej Chmielak)

The sbRIO-9636 is equipped with 400 MHz processor, 512 MB nonvolatile storage, 256 MB DRAM for deterministic control and analysis. Moreover, it has sixteen 16-bit analog inputs and four 16-bit analog outputs. The signals from hydrophones were connected to the two first analog inputs. The sbRIO-9636 platform can be integrated with other microprocessor system using 10/100BASE-T Ethernet, RS232 serial, RS485 serial, USB, CAN, and SDHC ports.

3 APPLICATION FOR OBSTACLE DETECTION

The application for obstacle detection AOD was written in LabView 2017 environment.

In the Fig. 5, Front Panel of this application is visualized, while in the Fig. 6 Block Diagram with the graphical code is presented.

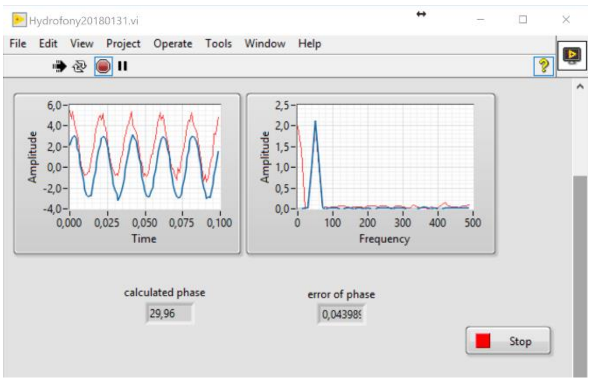

Figure 5: Front Panel of the application for passive obstacle detection

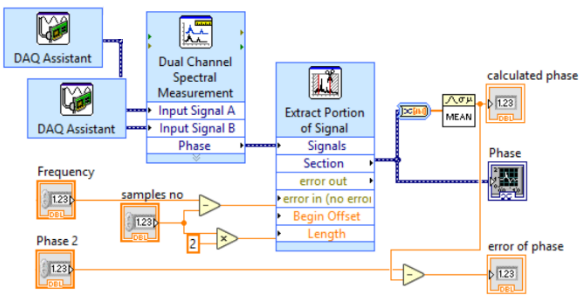

Figure 6: Block Diagram of the application for passive obstacle detection

The principle operation of the application is based on two functional blocks: *Dual Channel Spectral Measurement* DCSM Express VI and *Extract Portion of Signal* EPSE Express VI. The first block DCSM measures the frequency response of the input signals received from hydrophones using *DAQ Assistance* blocks. *DAQ Assistance* block allows to register real signal connected to the input/output module from the National Instruments company. Moreover, DCSM Express VI block measures the coherence based on the current and previous input signals. The DCSM Express VI returns results such as *Magnitude*, *Phase*, *Coherence*, *Real*, and *Imaginary*. In the application, the *Phase* output is used. The *Phase* is calculated for the following frequencies. The best results are received for the frequencies closest to the basic harmonic of the input signal. Therefore, the *Phase* output is connected to the second block EPSE Express VI. This block extracts portions of data from the input signals and returns the extracted data. The data is extracted by index from *Begin Offset* value to the *Length* value (Fig. 6). During research value of *Length* in the range from 3 to 20 was selected in the experimental way. The precise value of *Length* was depended on basic frequency of the input signal. The dependence between the frequency of the signal and selected value of *Length* will be examined in the future research.

Then, the extracted portion of *Phase* is used for mean value calculation illustrated in the Front Panel as *calculated phase* numeric indicator. The *error of phase* numeric indicator shows the result of difference between phase shift of the second input signal relative to the first input signal and the *calculated phase*.

The input signals are illustrated in the Front Panel in the domain of time and frequency (Fig. 5).

4 INITIAL RESEARCH

The initial research was carried out in two stages:

1. Application testing in simulated mode (for simulated signals),
2. Application verification in real condition (for harmonic signal generated by an underwater speaker in a small swimming pool).

In the Fig. 7, the Block Diagram of application in simulated mode is presented. The input signals are generated by the *Simulate Signal* blocks. These blocks enable to simulate the following waves: sine, square, triangle, sawtooth or noise signal with the set amplitude, frequency, phase and offset. It enable to test different signals.

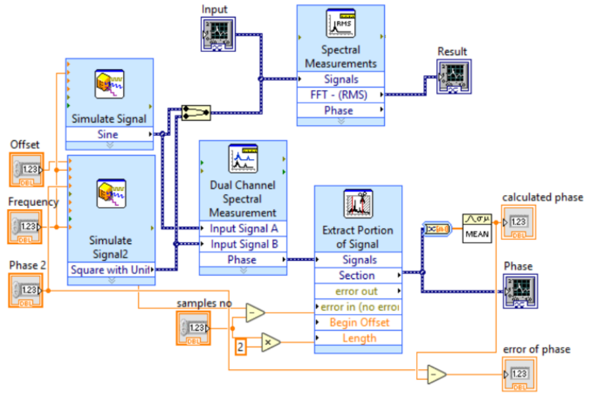

Figure 7: Block Diagram of the application for passive obstacle detection in simulated mode

In the Fig. 8, Front Panel of the application for simulated input signals as a sinus wave with added uniform white noise (Fig. 9) is presented. In this case, phase shift *Phase2* between input signals was set on 90 [deg], and the application precisely calculated this value of phase – *calculated phase* (Fig. 8).

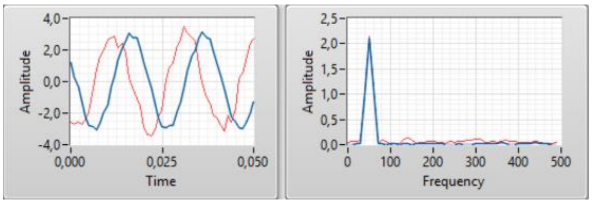

Figure 8: Front Panel of the application for passive obstacle detection in simulated mode (input no 1 and 2: sinus waves with added uniform white noise with noise amplitude 0.2)

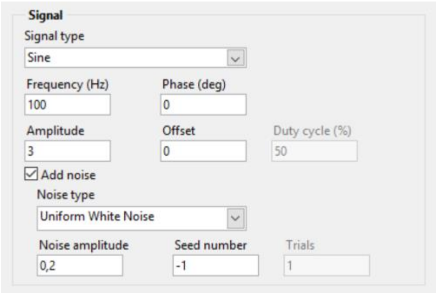

Figure 9: LabView window for selection of input signal's parameters

In the Fig. 10-13, the more complicated situations are illustrated than in the Fig. 8. In the following Fig. 10-13, the second input signal is changed to be more distorted in comparison with the first input signal:

1. The second input signal wass changed into square wave with added uniform white noise with the noise amplitude 0.2,
2. The noise amplitude was added to the second input signal is increased to 0.6,
3. The offset equal to 2 wass added to the second input signal,
4. The amplitude of the second input signal was decreased to value 2.

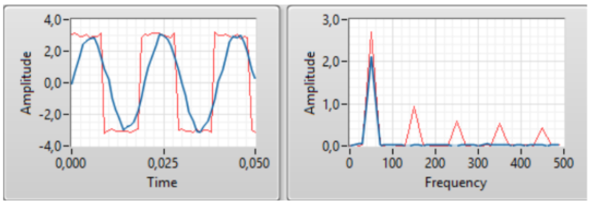

Figure 10: Front Panel of the application for passive obstacle detection in simulated mode (input no 1: sinus wave, input no 2: square wave both with added uniform white noise with noise amplitude 0.2)

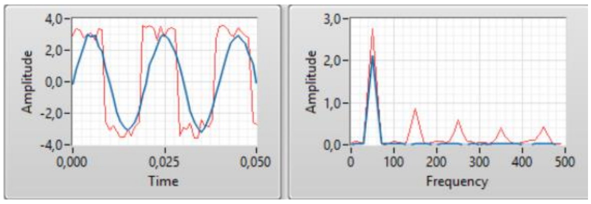

Figure 11: Front Panel of the application for passive obstacle detection in simulated mode (input no 1: sinus wave with noise (amplitude 0.2), input no 2: square wave with noise (amplitude 0.6)

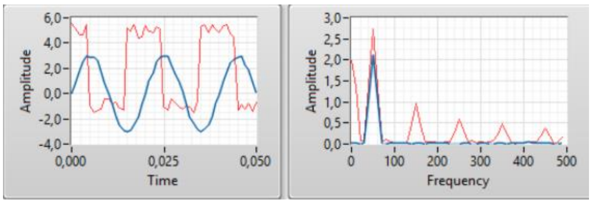

Figure 12: Front Panel of the application for passive obstacle detection in simulated mode (input no 1: sinus wave with noise (amplitude 0.2), input no 2: square wave with noise (amplitude 0.6) and offset equal to 2

As it can be seen, the changes of second input signal do not influence significantly on the result of the application. In most cases, *error of phase* equal to several [deg] was achieved. In one case (Fig. 12), *error of phase* equal to approx. 9 [deg]. The achieved value is not a problem assuming that obstacle detection system of the BUV has a define resolution usually equal to 30 [deg]. Higher resolution than 30 [deg] creates problems for high-level control system, i.e. the system has to process too much data.

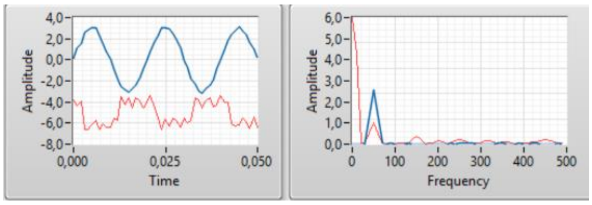

Figure 13: Front Panel of the application for passive obstacle detection in simulated mode (input no 1: sinus wave with noise (amplitude 0.2), input no 2: square wave with decreased amplitude equal to 2 and additional noise (amplitude 0.6) and offset equal to 2

In the second stage of the research, the real signal generated by the underwater speaker in a small swimming pool was received by two hydrophones (Fig. 14).

As it can be observed, two signals close to the sinusoidal were received. Representation of the input signals in a time domain enabled to determine graphically the phase shift between input signals, i.e. the phase shift equal to approx.

110 [deg] was received. It is important for the AOD operation estimation, especially in the case that you are not sure if the desired phase shift was obtained.

In this case, only distortion of shape of sinusoidal waves and their amplitudes can be seen. The distortions are lower than in the simulated mode. The AOD application should calculate without any problems the correct phase based on these signals.

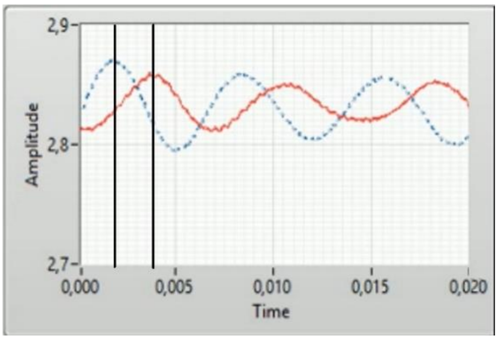

Figure 14: Front Panel of the application for passive obstacle detection, real harmonic signal equal to 500 Hz received by two hydrophones in a time domain

5 SUMMARY

In the paper, the measurement stand with the application for the phase shift calculation between two signals received from hydrophones were presented. The application was tested in the simulation mode, and then it was verified using the simulated real environment, i.e. the small swimming pool. Good results have been obtained so far, but future improvement likely is needed during tests in real environment, e.g. signals filtering.

Currently, the measurement system based on two hydrophones is mounted inside the BUV2 which is being built within European Defense Agency project category B called SABUVIS [9]. The project is carried out by the consortium consisted of the following scientific and industrial Polish partners: Polish Naval Academy AMW – the leader, Cracow University of Technology PK, Industrial Institute of Automatics and Measurement PIAP, Forkos Company, and also Bundeswehr Technical Center for Ships and Naval Weapons WTD 71 in Eckernförde from Germany.

After starting the BUV, tests of the measurement system will be carried out in real environment, what should result in further improvement of the AOD application.

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RESEARCH OF HUMAN RESOURCES IN THE FUNCTION OF IMPROVING MARITIME EDUCATION: EXAMPLE OF THE MARITIME FACULTY OF KOTOR

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ABSTRACT

Contemporary maritime companies operate in the conditions of intensive competition, which is the reason for exploring the sources for gaining competitive advantage either by means of lower costs or by providing superior (different) service for customers. Knowledge, skills and competencies of human resources are, among others, recognized as an essential tool for achieving business success and the productivity of maritime companies, which means that they could be the basis for strengthening competitive performance of the companies in the market.

Human resources have been explored in the context of finding ways to create an effective organizational structure of maritime companies, improve the social climate in maritime collectives, integrate into a multinational work environment, and adequately respond to technological and security challenges, etc. This paper tends to emphasize that the strategy of improving the maritime education needs to be built on the basis of the results obtained by investigation of the maritime labour market.

The research subject is the supply and demand of human resources in the wide range of maritime sectors/activities, that is, the employment of personnel with a common educational background. Namely, the paper aims to indicate that there is a notable demand for the candidates who graduated from the University of Montenegro, Maritime Faculty of Kotor. Furthermore, these candidates are expected to become more competitive in the international market, based on their proven competencies, knowledge and skills.

The purpose of the paper is to create improved models of education system based on continuous research and the measurement of the factors of human resources competitiveness in maritime industry.

Keywords: maritime industry, education, knowledge, skills, competencies

1 INTRODUCTION

In contemporary maritime business, companies invest greater efforts in raising the awareness of the importance of human resources, as well as security, safety and multiculturality. The concept of managing the quality of human resources is, above all, based on the investigation and knowledge of the human nature, human way of thinking and functioning. Also, managing human resources is a function directed towards recruitment, training, evaluation and rewarding. Traditional attitude that a human error is one of the main causes of maritime accidents stems from numerous case studies, whose result is almost identical: modern maritime technologies have remarkably developed. In addition, security, profit, reputation in the labour market and other business performances can be achieved through better understanding of human factor in the system of maritime operations [2].

Growing competition and constant changes of the labour market, to which the employees need to adapt and by enhancing their skills and knowledge, are a typical picture of the environment in which present-day companies are established and developed further. The material resources of a company are very important, but the employees' skill to manage and increase the company's worth gains significance, as well. Human resources are actually a basis upon which a company's strategy is built, since the employees are the creators of technical, economic and cultural values.

Knowledge can be defined as interaction between intelligence, that is the capacity to learn, and a given situation, that is the opportunity to learn [6]. Knowledge normally includes theoretical knowledge, but also the knowledge gained as a result of the experience in performing certain tasks. It is indicated that skills can be defined as a combination of mental and physical qualities which require certain practice and training. However, the notion of skills refers, above all, to the level of performance, that is to the accuracy and speed in performing particular tasks [6].

Recent literature analyses a great number of definitions of competencies and states that competency is an ability to fulfill the requirements of the workplace and specific work tasks (European Training Foundation), or competency is also the ability to achieve the required occupational standards in various conditions (British national body for qualification development and certification (QCA). Finally, competency is the application of knowledge, skills and behavior which result in performance [3]. It can be concluded that competencies represent our knowledge, skills and attitudes which create our behavior at the workplace.

The research topic of this paper is exactly the basic skills, knowledge and competencies of human resources with a common educational background – the students who graduated from the Maritime Faculty of Kotor, University of Montenegro, employed within a vast spectrum of maritime sectors/activities. The research aim is actually the enhancement of the education system based on the continuous research and measurement of the factors like knowledge, skills and competencies, which are the primary factors of the human resources competitiveness in maritime industry. Many authors addressed this topic and explored the challenges such as professionalization of the shipping industry via postgraduate education, career path mapping in the maritime industries as well as students' profiles, motivation and expectations in maritime affairs [1; 4; 5].

The research goals are specified according to the defined research topic and aim, and, in that sense, the main goals of this research conducted in the context of the Maritime Faculty of Kotor, University of Montenegro are the following: a) to measure the knowledge, skills and competencies quality of the students who graduated from the faculty in question, b) to investigate whether such students can find employment in the leading maritime branches, and c) to confirm that the respondents can become important partners in developing strategies for quality improvement of the education process at the faculty in question.

2 RESEARCH METHODOLOGY AND SAMPLE

This research was based on the results of the primary research for the purposes of which the survey method was applied. A structured questionnaire was designed and administered online. A sample consisting of 31 respondents was created out of 50 sent questionnaires.

The target group were maritime companies from the following sectors: maritime transport, shipbuilding and services; maritime tourism; ports; maritime monitoring, safety and supervision; energy; seafood and bioproducts; public sector; P&I clubs, classification societies.

Respondents were chosen according to the following criteria:

- Respondents who were continually involved in the „Modernizing and harmonizing maritime education in Montenegro and Albania – MarED" project,
- Respondents who occasionally participated in specific workshops of the project.

The respondents were employed in managerial positions and/or were the company owners.

The questionnaire was divided into two parts: a) general information on the researched maritime companies and the employees who graduated from the faculty in question, and b) the measurement of knowledge as well as general skills and competencies possessed by the employed graduates of specific study programs of the Maritime Faculty of Kotor.

The questions asked were as follows:

- In regard to knowledge: "With a number from 1 to 5 please assess the knowledge that your employees who graduated from Faculty of Maritime Studies Kotor have." The assessment concerned the knowledge of Nautical Sciences, Ship Engineering, Maritime Electrotechnics, Maritime Management.
- In regard to general skills and competences: "With number from 1 to 5 please assess the skills and competencies of your employees who graduated from Faculty of Maritime Studies Kotor." The items considered were: communicative skills, interpersonal relations, entrepreneurial skills, managerial skills, scientific research, information and communications technology, and the English language proficiency.
- The scale was: Absolutely unsatisfied (1), Unsatisfied (2), Partially satisfied (3), Satisfied (4), Very satisfied (5).

3 RESEARCH RESULTS

3.1 General results analysis

Out of 31 respondents, 21 stated that the graduate students of the Maritime Faculty of Kotor are employed in their companies. Considering the Bachelor degree, the majority has graduated from the Department for Nautical Studies, as for the Specialist degree, the majority graduated from the Department for Maritime Management, whereas for the Master degree, only one person is employed and has graduated from the Department for Maritime Sciences. The results are shown in Table 1.

Table 1: Employment of the students graduated from the Maritime Faculty Kotor

Degree	Department	The total number of employed graduates in all organizations
Bachelor	Nautical Sciences	171
	Marine Engineering	137
	Maritime Sciences	24
	Maritime Management	98
Specialist	Maritime Management	18
	Maritime Sciences	4
	Marine Polytechnic	17
Master	Maritime Management	0
	Maritime Sciences	1

On the basis of the answers given by maritime companies and ship recruitment agencies, it can be seen that in the last ten years, the most frequently employed are the personnel who have a degree in Ship Engineering and a) who graduated from the Maritime Faculty of Kotor (239 people), b) who graduated from the Maritime High School in Kotor (147 people), and c) who completed a course (33 people), respectively.

The total of 21 respondents stated that the vocational training programs included candidates who graduated from the Maritime Faculty Kotor, the majority of whom studied Ship Engineering (10), Nautical Sciences (7) and Maritime Management (7), whereas the ones who studied Maritime Sciences were the least included (3). Out of the 21 respondents, 17 pointed out that, after the internship, they retained those candidates in their companies and extended their period of employment. The respondents qualitatively declared that it is very difficult to find qualified personnel with a Chief Engineer profile, 2nd engineer and, finally, a Master profile.

3.2 The analysis of knowledge, skills and competencies

3.2.1 Nautical Sciences

When it comes to the knowledge in the field of nautical sciences, the average mark of the graduated students' knowledge was 3.82. In order to increase the mark, the respondents additionally qualitatively expressed their attitude concerning the fields of nautical sciences which should be developed further during the education, and the fields are: practice, the English language, safety at sea, work on simulators, ship rules, regulations and administration, collision avoidance, VTS service, CleanSeaNet Service - CSN, Long Range Identification and Tracking -LRIT, procedures and navigation on bridges.

Furthermore, the respondents think that, when it comes to nautical sciences, the following fields should be introduced to the maritime education program, since the current system is deficient in them: interpersonal relations, general knowledge, ISM & ISPS codes as a separate subject, ship chartering, business correspondence, maritime inspection and expertise, VTS, CSN, LRIT, SafeSeaNet - SSN.

3.2.2 Ship Engineering

Satisfaction with the knowledge of their employees - who obtained their bachelor degree at Department for Ship Engineering of the Maritime Faculty of Kotor - was qualitatively expressed with an average mark of 3.86. In order to improve the quality of the students' education at the Maritime Faculty of Kotor, the ship engineering fields which should be further developed are the following: ship and coast protection, general knowledge and identity, work on simulators of main and auxiliary engines, the English language, practice, automation (electrical control engineering), ship rules, regulations and administration.

Special subjects that should be introduced are: people care, ship navigation in risky situations, the analysis of causes and troubleshooting, class and flag regulations, effective writing in maritime industry.

3.2.3 Maritime Electrotechnics

Average mark of the knowledge of maritime electrotechnics candidates was 3.67. In order to improve this kind of knowledge, it is necessary to introduce the following fields: work on simulators, ships' electrical systems – safety and maintenance, ship rules, regulations and administration, the English language, electric drive, practice, IT systems, electric schemes, troubleshooting, Dynamic Positioning (DP) field of navigation equipment maintenance.

3.2.4 Maritime Management

The average mark in this field was 3.74. The respondents were asked to name the fields of maritime management which, according to them, should be especially developed for the purpose of improving the quality of education at the Maritime Faculty of Kotor. The answers are the following: ship chartering, ship finances, accounting, maritime companies' economics, the English language, security and safety in maritime affairs, marine business, human resources management, maritime law, charter companies' leadership, the management and marketing of marinas.

3.2.5 General skills and competencies

The following fields were investigated in the category of general skills and competencies: a) communicative skills, b) interpersonal relations, c) entrepreneurial skills, d) managerial skills, e) scientific research, f) information and communications technology, and g) the English language proficiency. The average mark for all of the above-mentioned skills was 3.62.

The respondents were asked to name which types of general skills and competencies, according to them, should be developed for the purpose improving the quality of education at the Maritime Faculty of Kotor. The answers are the following: interpersonal relations, scientific research, information and communications technologies, the English language, managerial skills, team work, entrepreneurial skills.

4 CONCLUSIONS

This paper begins with the research of the relevant literature and the basic assumption that human resources are the most important resource of a company, which means that effective HR management is important for achieving both organizational and personal goals and interests. The research proved that the people, with their knowledge, skills, competencies and development potential, coupled with the help of techniques and technology, represent the most important resource of a company, as well as a factor of its competitive ability and advantage in the labour market. Having their importance and specificity in mind, human resources should be managed effectively, in order to achieve both organizational and personal goals and interests.

On the basis of the results obtained, certain conclusions concerning the set goals can be drawn.

Considering all the above-mentioned quantitative data, a straightforward conclusion can be drawn - there is a demand for candidates who graduated from the Maritime Faculty of Kotor, and the diploma from this faculty is recognized and valued in both economic and non-economic maritime activities.

Regarding all quantitative data previously obtained, as well as average knowledge, skills and competencies marks, it can be concluded that the respondents are satisfied with the knowledge, skills and competencies their employees possess, but that there is space for improvement, as well. Candidates were assigned the highest average mark for knowledge in the field of nautical sciences (3.82), which was followed by maritime management (3.74). The difference between ship engineering (3.68) and ship electrotechnics (3.67) was very small. General competencies and skills in diverse collectives in maritime sciences were assigned the lowest average mark in comparison to the previous marks (3.62). This indicates that the skills (planning, organization, leadership, management, coordination, team work, motivation, communication, work in multinational collectives) should be developed, along with the better application of information and communications technologies and the English language.

Furthermore, it can be concluded that the respondents can be significant partners for improving the strategies for developing the competitiveness of the personnel graduating from the Maritime Faculty of Kotor. Namely, better knowledge quality has an effect on the better productivity of an employee in the labour market. This is clearly indicated by the research results, on the basis of which it is obvious that employers hire a higher number of personnel with a university degree in comparison to the ones who finished high school or completed a course.

Analysing the results obtained in this research, it is possible to define directions for future research. One of the primary goals is to repeat this research after a certain period of time and determine the differences in relation to the present results. Future research could be, among other things, directed towards analysing and measuring the quality of knowledge, skills and competencies of the personnel graduating from other vicinal faculties. On the basis of those results, as well as the results obtained in this research, a benchmarking analysis could be done. In that way, it would be further confirmed which fields and work processes in education should be improved at this faculty, as well as at the other faculties. Everything mentioned would enable a clearer and better positioning of the Maritime Faculty Kotor in the market of maritime higher education services.

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COMPARISON OF GLOBAL AND CROATIA AIRLINES PREMIUM AIR TRAVEL TRENDS

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ABSTRACT

Demand for airline premium travel has an influence on some airlines' pricing and operational strategies out of proportion to the number of travellers, thus supporting airline financial performance. The size and trends of word premium air travel and its dependence on economic changes for main traffic route areas are examined in the paper and compared with size and trends of Croatia Airlines premium air travel over the period of last decade. Also, the innovations in first and business class seating to further improve a flight experience are investigated and a trend of premium class seating moving upmarket is recognized. The paper reviews forces that affect demand for premium air travel and recovery patterns after recession and financial crises and assess the widely accepted assumption that premium travellers are inelastic with respect to fares. Analyses of premium air traffic data from IATA shows that whilst international long-haul premium traffic recovered quickly and robustly from the financial crisis - particularly that connecting advanced to emerging markets - short-haul travel demand has been more lagging. The paper brings some specific guidelines for airlines to keep and increase their premium travel volumes and improve their financial performance.

Keywords: Premium class travel, business passengers, low-cost airlines, passenger yield, Croatia

1 INTRODUCTION

With an increasingly globalized and financially integrated world economy, air transport services are essential for moving people and goods swiftly within and between nations, and the increased liberalization and deregulation of international air transport markets has facilitated this. Premium air travel is an important aspect of international trade and economic development. Over the period of last decade airlines have experienced many financial challenges, especially around 2008 when oil prices outstripped $130/barrel causing a worldwide economic slowdown. Demand for airline premium travel is a key source of revenue and profit for many scheduled carriers and has an influence on some airlines' pricing and operational strategies out of proportion to the number of travelers.

Traditionally, airlines identify different segments of air travel market and offer appropriate fare products to each of them according to their price and time sensitivity. To achieve the required demand segmentation in practice, airlines physically differentiate their fare products by offering clearly identifiable different products with different quality of service, such as first class, business class, economy class and premium economy class.

The quality of business class products has increased in recent years while first class capacity is diminishing. At the same time passengers are benefitting from airlines which invest more in premium economy amenities. Today's typical business class seat is lie-flat, often with direct aisle access, previously the main characteristics of traditional first class. The world's leading airlines are reducing first class space on their aircraft in favor of more business class and premium economy seats. A typical long-haul aircraft configuration with first, business and economy class is replaced by cabin arrangement with business, premium economy and economy class on numerous routes.

The aim of the paper is to examine and analyze trends in premium air travel and its dependence on economic changes for main traffic route areas are examined in the paper and compared with size and trends of Croatia Airlines premium air travel over the period of last decade.

2 RECENT CHANGES IN AIRCRAFT CABIN CONFIGURATIONS

Flexible aircraft cabins (the concept allows for seat pitch to be quickly increased), removal of overhead bins, foam seat cushions that allows passengers to adjust the firmness of their seat with the push of a button, introduction of in-flight social zones, suites with double beds, a smart seat which remembers passenger preferences are new trends in the evolution of aircraft cabin design that make air travel more comfortable and familiar. Icelandair's Boeing 757 Hekla Aurora aircraft, Thomson Airways' 'Beach Snack Bar' concept, KLM's Boeing 787-9 business class, and Finnair's A350 XWB serve as insightful examples of how inventive cabin design can be used to enhance the in-flight experience [1].

2.1 First class

Number of revenue passengers who traditionally travel premium class is diminishing, as corporate and government travel policies approve travelling in higher classes for journeys under a certain length. Premium class passengers increasingly choose lower-cost options or travel by private jet. First class is often used for frequent flyer redemptions, or complimentary upgrades and it mostly exists not for direct revenue contribution, but for marketing purposes and boosting wider airline brand's credibility. In response, many airlines are shrinking their first class cabins to two rows or phasing out first-class cabins entirely. At the same time, carriers are offering more luxury facilities like world-class gastronomic experiences and improved sleep quality to differentiate between first class and business class. However, some airlines like Singapore Airlines, whose luxurious first-class service has long been part of its marketing, stick to first-class cabins, and make them even richer. Their large suits look like flying hotel rooms but their number is significantly reduced. Singapore Airlines markets its highest class on its A380s as "suites", with the tagline "A class above first." Etihad Airways introduced a three-room suite called "The Residence" in December 2014 when it added the Airbus A380 to its fleet.

But, even Emirates decreased the number of first class seats, although persisting with first class. Qatar Airways, known for its premium position, has first class only on its small A380 fleet but its business class product is more like first class product of other airlines.

2.2 Business class

The group of passengers travelling in the business class cabin is not uniform and a careful market segmentation is essential to understand passenger demands. According to Claussen and O'Higgins (2010), five distinct groups can be identified as potential clients for business class travel:

1. Upgraders -i.e., leisure travelers likely to switch from economy to business class, highly sensitive to prices and less time sensitive,
2. Affluent individuals who are looking both for attractive pricing and schedules,
3. Self-employed who are looking for a good quality/price trade-off and would change their schedule preferences for cheap offerings,
4. Corporates I – medium to high level executives who require frequency, a strong network, a high-quality product, and are insensitive to price,
5. Corporates II – low level executives who travel in the business class cabin only if the price is especially reasonable [2].

Doganis (2002) clustered five groups of factors important in the value propositions of the business class target group: price, schedule, comfort, convenience, and image [*3*].

Traditionally, business-class cabin is separated from the economy class cabin and equipped with more comfortable and functional seats, from cradle seats with around 150-160 degrees of recline, which are still common on shorter routes, to fully flat seats and separated cabin seats on long haul business class flights.

Business class has started to disappear from some short/medium haul routes, to be replaced with full fare economy and discount economy. On these routes, the seats are the same for all passengers, only the flexibility of the ticket and the food and beverage service differs. On shorter routes (less than one hour) many airlines have removed business class entirely.

2.3 Premium economy class

Although premium economy class is part of the economy class, some important advances related to that travel segment are further considered. Airlines bring business-class service elements to premium economy class to attract more travellers and to maintain competitive advantage in today's air transportation market. It provides a larger and more comfortable seat than standard economy class and is cheaper than business class. On international flights, premium economy usually amounts to what business class used to be.

Hugon-Duprat and O'Connell (2015)'s findings show that the unit costs to produce a premium economy seat is only 1.6 times more expensive than an economy seat but it generates revenues that are 2.3 times higher than its cost of production. Premium economy generates the highest marginal revenues over its cost of production when benchmarked against the other cabins [4].

The study conducted by Kuo and Jou (2017) used spike model to investigate how much extra air travellers are willing to pay to upgrade to premium economy class. Three flight distances, short, medium, and long hauls were separately estimated to investigate the effects of flight distance on willingness to pay. Travelers' willingness to pay to upgrade from economy class to premium economy class round-trip was US$138, US$309, and US$545 for short-haul, medium-haul, and long-haul, respectively [*5*].

3 PREMIUM TRAVEL DRIVERS

Since international air passengers travelling on premium seats represent 8% of traffic but 26% of passenger revenue, the premium travel segment is broadly recognized as an important travel market segment, particularly for hotels and network airlines, but also for others in the travel and tourism value chain. [6].

According to research done by IATA [6], there is a positive relationship between the number of premium passengers travelling between a country pair and the size of the economies at either end of the route. Still, some interesting country-pairs are found as outliers to that relationship: those with a relative small number of premium passengers but large economies at both origin and destination (such as United States - Russia) and those with a high number of premium travellers but small economies (such as United Arab Emirates-Bahrain).

The same research identified the following factors as the most important business travel drivers determining the size of premium travel markets between country pairs:

- the relationship between travel and distance (business travel, all other things being equal, tend to diminish with distance)
- historical relationship (for example, premium travel market between Australia and the United Kingdom is about 3 times larger than Singapore - United States)
- regulatory framework of a country (how well property rights are protected and the cost of setting up a business)
- the quality of the information communication and technologies infrastructure
- price competitiveness (purchasing power parity, airfare ticket taxes, taxation level in the country.

Many countries have a great potential to increase the number of business travellers over and above the flows implied by economic size and distance, by improving one or several of these drivers. Basic findings of IATA's research could be summarized as follows [6]:

- economic size at both origin and destination is the most significant factor in explaining differences between country-pairs
- all other things being equal, if GDP rises by 10%, number of business passengers will increase by 6%
- any 10% improvement in policy rules and regulations, ICT infrastructure and price competitiveness would lead to an increase of 4.5%, 2.2% and 13.8% in number of business travellers
- for every 10% increase in distance between economies, premium travel markets, all other things being equal, will be 9% smaller.

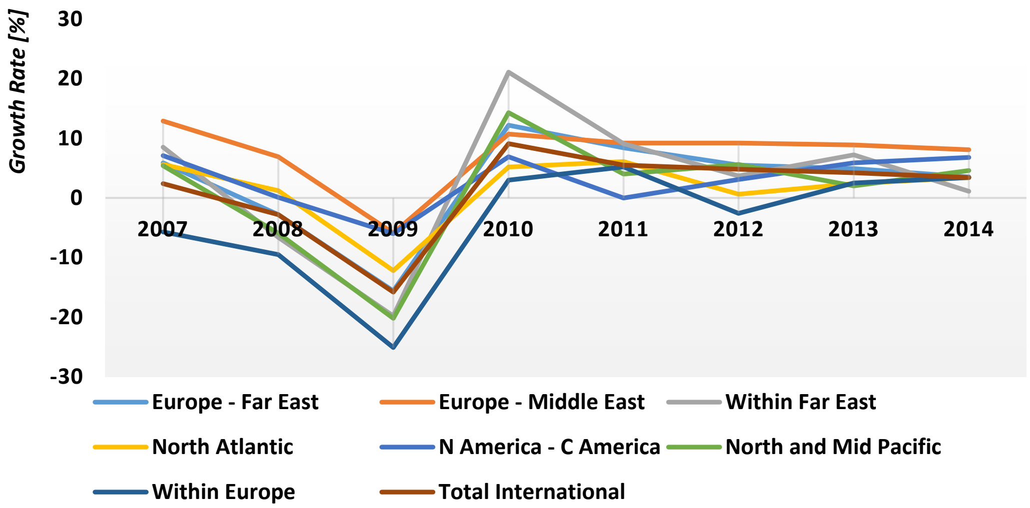
4 ANALYSIS OF PREMIUM TRAFFIC TRENDS OVER THE PAST DECADE

This chapter provides an analysis of high-yield traffic growth based on IATA Premium Monitor reports from January 2008 to December 2015 and IATA Airlines Financial Monitor reports from 2014 to 2018.

4.1 Premium traffic trends over the period 2007-2014

The slowdown in premium travel was widespread across the world even through most of 2007 especially in markets linked to the troubled US economy. It was partially neutralized with the impact of Open Skies across the North Atlantic which provided the introduction of new services and brought increased competition resulting in premium revenues slowing more sharply than volumes. Another boost to the premium travel market was provided by the services offered on many long-haul markets by the Middle Eastern airlines and Middle Eastern hubs [7].

According to IATA, international premium traffic began to fall in July 2008 and the monthly traffic decline has been particularly steep since November 2008, leading to a 21% fall in premium passengers worldwide in February 2009 compared with February 2008 [8]. Premium passenger traffic data provided by IATA Premium Monitor reports from January 2008 to December 2015 were deeply analysed and growth rates for major routes over the 2007-2014 period are illustrated in Figure 1.



Source: Airlines Premium Traffic Monitor, January 2008-January 2015

Figure 1: International Traffic Growth by Route 2007- 2014

Premium travel fell sharply from September 2008, as the Lehman Brothers bankruptcy marked the start of the collapse in the banking sector. Business travel, being highly sensitive to economic growth and developments in international trade and investment was so far less sensitive to fare levels. The fact that average premium fares were falling faster than discounted economy fares on some markets, e.g. within Europe, witnessed about severity of the downturn in business travel during 2008. For network airlines, focused on serving this passenger segment, the decline in premium revenues damaged overall profitability [9].

The year *2009* saw a 16% fall in premium travel numbers. The decline in premium travel matched very closely the decline in world trade so when world trade started to pick up at a robust pace from the middle of 2009, premium passenger numbers followed that upturn very closely. A steady shift of business travelers from premium to economy seats on the within-Europe market was recorded, but this was less evident on long-haul markets. There were large geographical differences in passenger growth. Very strong growth was recorded in Within-Far East and Asian markets, while the weakest large premium market was within-Europe where premium travel numbers were down on the previous year by 25% [10].

Over the 2010, premium travel continued to grow and premium travel markets expand by 9.1% [11].

During the 2011, premium travel markets grew slowly by 5.5%. While first 8 months sow a nearly flat trend, premium travel strengthened at the end of 2011 [12]. Growth on all the larger routes continued at a robust pace with no significant areas of weakness.

During 2012, expansion in economy and premium travel numbers slowed from the faster growth trend seen in late 2011. For the whole year, premium travel expanded 4.8%. Among the major markets, air travel across the North Atlantic and within Europe experienced largest decline in 2012. Recession in many European economies contributed to premium travel numbers expanding for only 1.0% within Europe. By contrast, Far East contributed more than any other market to overall growth in premium travel in 2012 [13].

The growth trend continued in 2013 with number of passengers travelling in premium seats on international markets expanded by a solid 4.2% mostly due to positive developments in the business environment in the second half of the year. The largest share of the rise in premium travel in 2013 was attributed to the within Far East market which expanded 7.2% in 2013 [14].

In 2014, annual growth was 3.4% for premium international air travel and 3.5% for economy class. While in 2013 and during first months of 2014 premium travel expanded at a faster pace than economy travel, in 2014 there has been no further gain in premium's share of total traffic [15].

The impact of the global recession of 2008 – 2009 on premium and economy travel was remarkably different. Premium traffic started to fall before economy traffic, as corporations anticipating the recession started to cut travel budgets. While economy traffic recovered strongly a year after the worst negative growth rates were recorded, premium traffic needed years to stabilize growth rates and grew slower than economy traffic for many years. Economy travel regained its pre-recessionary levels in early 2010, but premium traffic did not recover to these levels until late 2012.

4.2 Premium traffic trends over the period 2015-2017

In 2013 and early 2014, premium travel was expanding at a faster pace than economy travel which was positive for airline yield growth and revenues. That trend reversed in 2015, with relatively stronger growth in economy class travel. Premium traffic volumes grew by an estimated 3.7% in 2015 thanks to upward trend recorded in the first months of 2015. The easing in the upward trend of premium traffic over the second half of 2015 relates to broad-based weakness in the drivers of premium travel demand, including the ongoing uneven pattern of global economic growth and the emergence of key economic risks. Comparatively strong economic performance in advanced economies has supported premium traffic on the North Atlantic, but slowing growth in a few large emerging markets such as China and Brazil, has weighted on premium traffic growth in many markets [16].

According to IATA Airlines Financial monitor issued in February 2017, premium's share of revenues increased on many key routes thus supporting airline financial performance. Still, average passenger yields have trended downwards since late-2014, and fell by 8.8% in 2016 compared to the previous year. The main reason for these developments lies in upward trend in oil and jet fuel prices and rising labor costs in some key markets. Industry-wide passenger yields have trended downwards since late-2014, and fell by 8.8% in 2016 compared to the previous year [17].

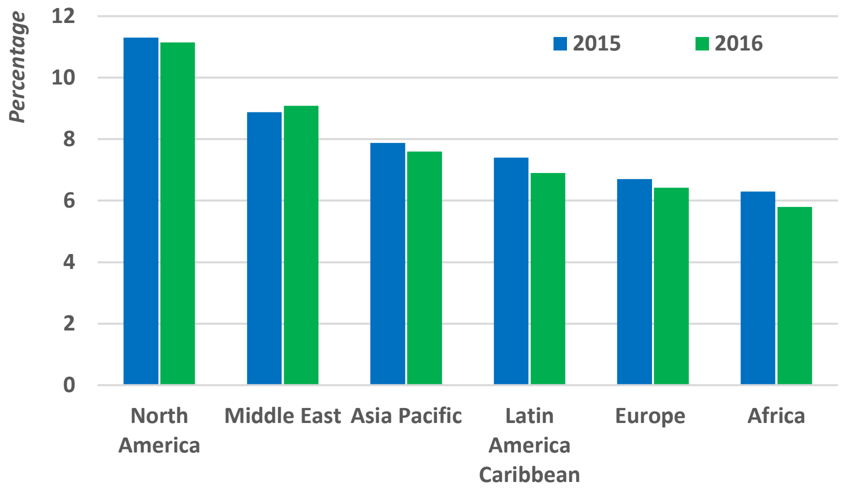
International passenger traffic by cabin class and geographic region for 2016 are reported in Table 1. Figure 2 shows how the share of premium international traffic varies by region.

Passenger and freight volumes grew by 7.6% and 9.0% respectively in 2017 as a whole and are both carrying solid momentum into 2018. The passenger load factor posted a record high for a calendar year in 2017 (81.4%), while the freight load factor climbed by 2.5 percentage points compared to 2016. Stronger global trade conditions have helped to support premium-class demand. Premium's share of total international passenger revenues increased to 27.0% in the first 11 months of 2017, up from 25.9% for the same period in 2016 [18].

Table 1: International Passenger Traffic by Cabin Class

Region of Airline Domicile	RPKs[1] (millions)					
	Premium Classes[2]		Economy Classes		Total	
	2016	% Growth	2016	% Growth	2016	% Growth
Africa	8,059	0.7	128,787	10.7	136,846	10.1
Asia/SW Pacific	100,905	5.3	1,215,024	10.9	1,315,929	10.4
Europe	109,757	1.4	1,582,658	5.8	1,692,414	5.5
Latin America	13,596	2.0	179,427	8.8	193,023	8.3
Middle East	60,634	12.6	597,108	11.7	657,743	11.8
North America	64,488	1.1	508,380	4.1	572,868	3.7
Industry	357,438	4.2	4,211,384	8.1	4,568,822	7.8

Source: IATA WATS (World Air Transport Statistics) 2017, IATA, Montreal 2017, p. 47

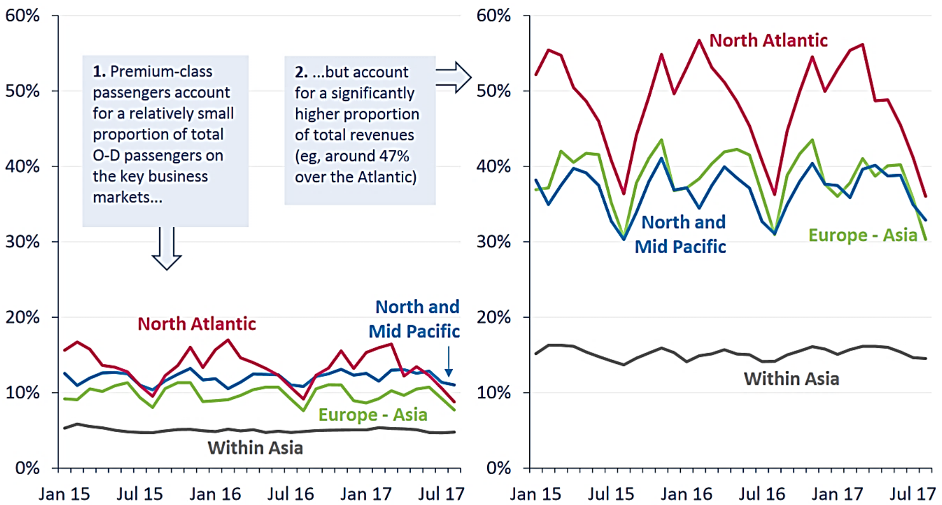


Source: IATA WATS (World Air Transport Statistics) 2017, IATA, Montreal 2017, p. 48

Figure 2: Share of Premium International Traffic, 2015–2016

Before the recession, premium passengers represented around 9.5% of total passengers, while in the 2016 it was around 7.8 %. Given that premium fares are much higher than economy fares, the loss in revenue is significant.

Figure 3 highlights the differing importance of premium - class demand over time on four key markets, which together account for more than 60% of all international premium revenues.



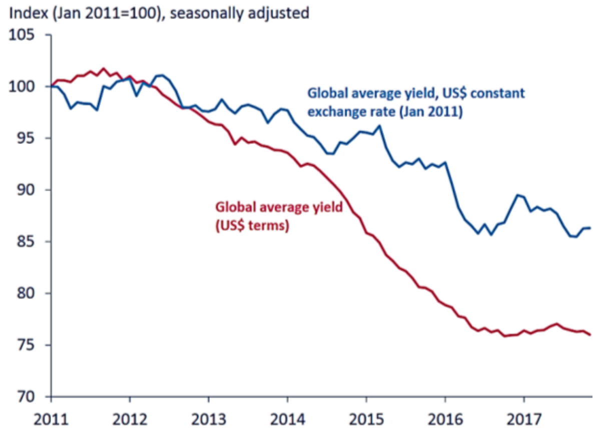
Source: IATA Economics' Chart of the Week, 10 November 2017, available at: http://www.iata.org/publications/economics/Reports/chart-of-the-week/chart-of-the-week-10-Nov-2017.pdf

Figure 3: Premium class share of total passengers and revenues

[1] RPKs-revenue passenger kilometres

[2] Traffic for the premium classes refers to the combination of First Class and Business Class. Premium Economy (or similar) classes are included under Economy Class.

As shown in the left - hand graph, the premium cabin's share of total passengers ranges from around 5% on international routes within Asia to nearly 13% across the North Atlantic. As the right - hand graph shows, premium travel accounts for close to 15% of total revenues within Asia, around 37% between Europe and Asia and across the Pacific, and almost 47% across the North Atlantic [19]. The long-standing downward trend in passenger yields started to level off during the middle of 2016 (Figure 4).



Source: Airlines Financial Monitor December 2017 – January 2018, IATA, Montreal 2017, p. 2

Figure 4: Airlines' Global Average Yield

Source: Airlines Financial Monitor December 2017 – January 2018, IATA, Montreal 2017, p. 2

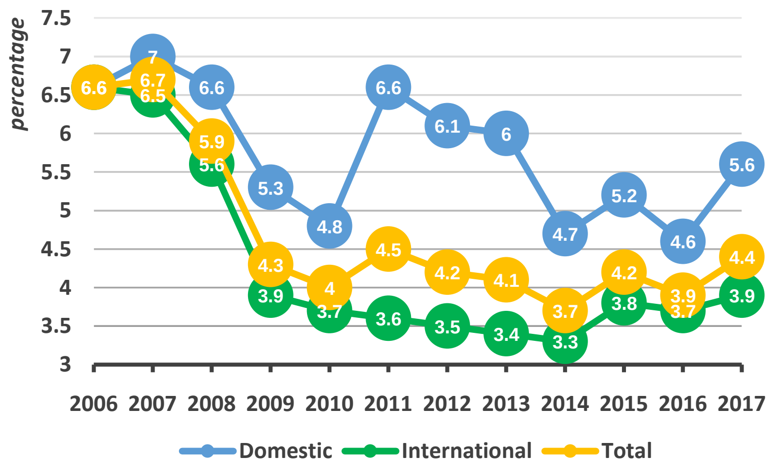
Yields in exchange-rate adjusted terms trended downwards modestly during the second half of 2017, but the key point is that yields remain broadly unchanged in year-on-year terms. The change in trend in the yield series has come alongside a strengthening in the global economic backdrop, as well as upward pressure on some key input costs, including oil and labor [18].

5 CROATIA AIRLINES PREMIUM AIR TRAVEL TRENDS

Croatia Airlines does not offer first class travel on any of their flights. Business class is available on all Croatia Airlines flights. Its fleet consists of Airbus A320, Airbus A319, Q400 aircraft, as well as Bombardier CRJ-1000 aircraft that are wet-leased from Air Nostrom and operated during busy summer months. Business class is dedicated to the first three rows of the aircraft, however, it may be contracted or expanded depending on demand. Although Business class seating has the same seat pitch as Economy (32 inches), the airline blocks out the middle seat in rows of three to create additional space.

On all Croatia Airlines flights passengers are offered free food and beverages which vary depending on the class of travel, the flight duration and the part of the day. As of 30th November 2016, in the scope of the project "Inspired by Croatia", traditional food is offered to business class passengers. In cooperation with their partners, Croatia Airlines offers its business class passengers the possibility to rest in comfortable lounges at all its destinations.

Figure 5 shows share of premium class domestic and international passengers over the 2006-2017 period. Share of premium class passengers is higher among domestic passengers than among international passengers for considered period. Comparison of Croatia Airlines and European scheduled airlines premium travel data show that Croatia Airlines premium travel lags behind its European counterparts.



Source: Croatia Airlines, Controlling and Internal Audit

Figure 5: Croatia Airlines premium passengers share

6 CONCLUSIONS

Passenger air travel is expected to maintain positive growth rates, despite a number of challenges faced by the industry. The rapid growth of passenger numbers across the world is likely to influence the way airlines consider their class distinctions. As premium economy and business classes improve, airlines will have to do more for their first class customers to make it worth its price.

Airlines are competing for premium class passengers throw better differentiation of premium class products, advanced cabin designs and better airport amenities. Premium travel demand tends to be highly correlated with world economic performance. The 2008-2009 slowdown in the economy has led to a reassessment of the assumption that business or time sensitive passengers are inelastic with respect to fares and that they would be prepared to pay high fares for *attractive flight* schedules and *frequencies*, flexibility and comfortable seats. Analyses of IATA premium air traffic data shows that whilst long-haul (intercontinental) premium traffic recovered quickly and robustly from the financial crisis short-haul travel demand has been much more sluggish.

To avoid decrease of premium passenger travel and improve their financial performance airlines should understand and recognize all relevant factors that drive demand for premium market segment, stop taking premium class passengers for granted, capture rich data about passengers' preferences at each point of interaction between the passenger and the airline to better understand their expectations and ensure their loyalty. Recent trends show that premium's share of revenues increased on many key routes thus supporting airline financial performance. When compared premium travel statistics in Croatia Airlines and in Europe, it is evident that Croatia Airlines premium travel lags behind its European counterparts with higher share of premium class passengers among domestic passengers than among international passengers.

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CITY LOGISTICS PROBLEMS AND SOLUTIONS OF THE CENTRAL ZONE

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ABSTRACT

Central city zone (CCZ) is a highly popular area both for the citizens and the tourists. Due to the large concentration of urban functions and activities, central urban zones generate a significant part of logistics activities, primarily freight transport. Different objects generate a large number of small-size deliveries, which requires the engagement of a large number of delivery vehicles. These vehicles generate negative effects on society and the environment, such as congestion, pollution, noise, higher levels of energy consumption and risks of accidents. In addition, these zones have different limitations such as narrow streets, lack of the spaces for storage, loading/unloading and parking, as well as the different access regulations. The aim of this paper is to analyze all the problems and potential logistics solutions of the CCZs. Solutions must be in accordance with the characteristics of the zone, but also with the requirements and goals of the city logistics stakeholders.

Keywords: city logistics, central city zone, problems, solutions

1 INTRODUCTION

Cities are places with the most intense production and consumption of material goods, as well as logistics activities. Logistics in urban areas needs to provide all the activities in order to satisfy demands for goods. (Dablanc, 2011). Since number of inhabitants is in direct correlation with the volume of goods and transportation flows, significant growth of number of demands for logistics services is expected, especially in urban areas (Tadić & Zečević, 2016). Cities are centers of numerous events, and the places of their realization most often are CCZs. These zones are characterized by a high density of construction and concentration of different urban functions and tourist attractions (Tadić & Zečević, 2016). Due to this reasons, cities represent magnets for people, citizens, daily migrants and tourists, and therefore commodity flows, primarily for the objects of trading and catering activities. Also, residents generate demands for moving and home delivery, which is growing alongside with the growth and popularization of e-commerce. In addition, objects in urban areas occasionally require different types of services such as computer servicing, cash registers, washing and dry cleaning services etc. The number of services flows for a facility depends on its activity, size, equipment etc. (Zečević & Tadić, 2013).

Besides high density of generators, inherited infrastructure is also typical for central historical city zones. Narrow streets are often reserved only for a particular type of traffic (e.g. pedestrian zones). Traffic infrastructure is overloaded, and possibilities of its expansion are limited by the lack of space. The morphology of central city areas, the need to preserve their authenticity and attractiveness for tourists opposite to presented intensity of commodity flows pose a great challenge for logistics and urban freight transportations planners.

The rise of environmental awareness and need for sustainable development in order to benefit city and its inhabitants makes this task more difficult. In this paper the review of problems concerning realization of logistics activities in CCZs is given, as well as some of the solutions that could be/are successfully implemented in certain cities. At the end of the paper, the city logistics performances of central zone of Belgrade are shown. The analysis of performances that describe existing condition can be used for identification of problems and potential solutions.

2 PROBLEMS OT THE CENTRAL CITY ZONE

Since there is large number of different functions and generators, city logistics is very complex (Behrends 2016). Most of the economic and social activities include the delivery and/or collection of goods, which generates complex logistical processes and significant growth of number of freight delivery vehicles on the streets (Benjelloun & Crainic, 2009). Urban freight transport produces more negative environmental effects compared to long-distance transportation and the reasons are following (Tadić, 2014): vehicles structure in realization of commodity flows (starting more vehicles with lower capacity creates more negative effects than starting heavy vehicles), the age of vehicles, conditions and operating mode (street congestion, light signaling, frequent stops, acceleration and deceleration), and environmental characteristics. High density of construction (densely built objects, especially multi-floors ones, significantly slow down mixing of exhaust gases with „cleaner“ air) and minor participation of green areas also contribute to the increase of negative impacts go transport.

Prices of land, housing and business properties in CCZs are higher, so the size (surface area) of logistics generators, are often smaller than those from other urban areas. For these reasons, the storage space for supplies is disappearing from CCZs, changing the way of supply of generators. Shipments are smaller and more frequent which leads to the engagement of larger number of delivery vehicles, often half-empty, but also creates congestion, and make other traffic more difficult and slower. On the other hand, infrastructure constraints and the lack of space in CCZs reduce accessibility and have negative impact on efficiency of logistics activities (Hesse and Rodrigue, 2004). Street congestion and the lack of space for handling operations often lead to delivery delay, growth of logistics costs and thereby increased prices of products, services, while delivery vehicles negatively affect environment and quality of life.

Emissions of harmful gasses are responsible for generating 70% of carcinogens and other hazardous substances in the air (Silva & Ribeiro, 2009). Huge problem is traffic safety (Russo & Comi, 2010). In European cities, light delivery vehicles participate in accidents with fatal outcome with 5-10%, heavy delivery vehicles participate with 10-15% (Schoemaker et al., 2006), and mostly vulnerable category are pedestrians (Tadić & Zečević, 2016). The first problem that citizens observe is noise, and the main source is transport – primarily road. Not only does it create unpleasant sensation, noise is also involved in creating many health issues, such as tension (psychological disorders), cardio-vascular diseases and hearing damage (Tadić & Zečević, 2016).

Traffic congestion is typical for urban areas, and discontinuous and slow traffic with frequent stops increases transportation time, fuel consumption, emission of harmful gasses and noise, as well as the risk of traffic accidents. The dimensions of delivery vehicles create additional problems related to congestion, safety and traffic jam and maneuvering difficulties. The largest share of freight vehicles is recorded in historical and central zones with narrow streets and lack of parking space. (Tadić & Zečević, 2016). Studies have shown that the biggest number of deliveries is provided in morning hours, between 6 and 12 hours, often during morning rush hours (Allen et al., 2008b). Recent research doesn't show significant differences in delivery times during day regarding different business and supply systems (Cherrett et al., 2012).

For the realization of loading and unloading operations it is necessary to engage part of urban space (public or private parking areas, along or outside the street). In the absence of these areas, these operations take place on the street or sidewalk (double, illegal parking). Illegal parking has negative effects on the capacity and safety of other traffic (motorized and pedestrian), but also on the costs and service quality of the logistics providers (Aiura & Taniguchi, 2006).

Due to all these problems, reliability and accuracy of deliveries are reduced, which can lead to decrease in service quality, and thereby loss of market share (Tadić & Zečević, 2016). Still, although urban freight transport has significant negative impacts on sustainability, it also plays an important role in economic position of the city (Navarro et al., 2016). And while on the one hand it is necessary to respond to all demands in urban areas, on the other hand, it is important to reduce all negative impacts that are directly related to providing logistics services (Benjelloun & Crainic, 2009).

3 POTENTIAL SOLUTIONS FOR CENTRAL CITY ZONE

The spatial and infrastructural constraints of the CCZ and the characteristics of demands of the generators require defining specific city logistics solutions. These solutions should be defined according to aforementioned demands of all stakeholders, but also harmonized with the overall city logistics concept and urban plans (Tadić et al., 2014). In this section of the paper solutions such as the application of eco-vehicles, zones for loading and unloading operations, micro-consolidation schemes, as well as regulatory measures of city administration are presented.

3.1 Implementation of eco-vehicles

With the growth of awareness and concern regarding impacts of transport on the ecological, economic and social sustainability of cities, the interest in implementation of eco-vehicles is also growing. Vehicles that could replace road vehicles in the delivery in CCZ are cargo bikes, e-scooters, drones and Cargohopper.

E-scooter and cargo bikes can be used for deliveries of small and medium sized shipments. Bicycles are already in use for transport of food, documents, and even for selling products, while most common examples of using e-scooters are for food and pharmaceutical products. Companies have already recognized benefits of using these vehicles in realization of „first and last mile“, since bikes are cost-effective and time efficient, while e-scooters can provide fast delivery (Daggers, 2013). The research shows that 19-48% of distances travelled by road vehicles in courier industry could be transferred to cargo bikes (Gruber et al., 2013). In addition, it is estimated that 51% of all tours travelled by motorized vehicles can be transferred to cargo bicycles (Schliwa et al., 2015), without increasing total costs (Conway et al., 2011). However, given that these vehicles have smaller dimensions and capacity, it is necessary to analyze conditions when their application is justified (Kunze, 2016).

Within PRO-E-Bike study, Italian pilots tested (Noceriono et al., 2016), usage of clean vehicles in four cities. Examples of Genoa and Milan show environmental benefits. Delivery of letters and small shipments in central zone of Genoa has shown that e-scooter can replace the traditional one without any negative effects on service quality. In Milan, the use of e-bikes instead of vans for delivery in city center was tested. This solutions required implementation of temporary warehouse near the reception points. The results have shown that e-bikes can entirely replace vans, and the company has adopted a new operation mode. In both studies, savings in CO2 emissions (160 kg and 17, 901 kg) and costs (131 € and 9,366 €) were achieved.

Drones are solutions that could ease the traffic infrastructure by moving part of the traffic up in the air (Heutger & Kückelhaus, 2014), and unlike the previous ones, they don't require driver (but do operators). Drones can have built-in loading and unloading devices (Kunze, 2016). The use of drones in congested city areas can lead to improvement of service speed (lead time), network flexibility and environment. Using GPS (Global Positioning System) data from user's smart phone allows finding him even when he changes the location (Heutger & Kückelhaus, 2014). However, problems related to safety of goods (e.g. collision damage) and the safety of people and objects located below the drone's path, are present. Since this technology gained its attention recently, certain problems regarding regulations are present and aren't developed sufficiently (Kunze, 2016). Drones can be used as a good solutions for home delivery, as well as unscheduled and/or emergency smaller sized shipments (e.g. pair of shoes to boutiques), which would otherwise be realized by delivery vehicle, taxi or private vehicle.

Cargohopper, electric vehicle with three trailers carrying mini-containers loaded with goods, is used for distribution in city center, even during time restrictions in pedestrian zones. The use of these vehicles requires logistics consolidating center on the outskirt of the city, where the containers are being loaded, as well as a logistics center in city center, where containers are being transferred onto Cargohopper (Browne et al., 2012). Cargohopper 2, electrical truck with lightweight trailer equipped with solar panels, has greater capacity than its predecessor. Cargohopper 2 also delivers goods to city center, but directly from distribution center. Their use can help reduce street congestion and improve quality of life (Daggers, 2013).

Eco-friendly supply of CCZ can be achieved by using cargo trams (e.g., in Dresden, Zurich and Amsterdam). Benefits are decreased emission of harmful gasses and noise through reduced number of road vehicles and street congestion, but additional cost of handling goods are present (Taniguchi et al., 2016). Company Yamato Transport uses a tram system for delivering goods to Arashiyama, Kyoto. From the station Arashiyama to end users, deliveries are realized by electric bikes. This system has reduced CO2 emissions and number of delivery vehicles by 50% (Taniguchi et al., 2016). Moreover, the subway is in use for express courier deliveries in Japan since recently and system operates during afternoon hours avoiding crowd (Kikuta et al., 2012). In study conducted in Turkey (Gorçun, 2014), impacts of cargo trams have been evaluated in terms of costs and benefits for deliveries in urban areas. Urban rail transport produces lower costs than road vehicles (external costs also), and it is eco-friendly solution. However, it is necessary to mention that rail can't provide „door-to-door" delivery, but it can be combined with small eco-vehicles.

3.2 Loading/unloading zones

The problems regarding the lack of space and accessibility in CCZs can be solved by defining loading and unloading zones, reserved especially for handling goods. Their application can have positive effects on delivery companies, but also receivers, residents and tourists (Russo & Comi, 2010).

According to some authors, parking policy and infrastructure offer are one of the most powerful solutions authorities can offer in order to manage demands for transportation (Pendyala et al., 2000; Shiftan & Burd-Eden, 2001). Due to this, as well as fast and simple implementation, loading and unloading zones are often used in practice, especially in CCZs (Tadić & Zečević, 2016). Transport companies willingly use these zones even if their use is being charged, because parking and loading/unloading are often problematic part of their business (Ishida et al., 2006). Research of the drivers' opinions and experiences show that increased number of loading-unloading places has priority compared to all other city policy measures (Debauche, 2008).

Loading and unloading zones should be defined according to demands and conditions of delivery/collection of the goods (Tadić & Zečević, 2016). These zones can be public (e.g. parts of the sidewalks or spaces outside the street) or private (near big commercial objects or street) (Zečević & Tadić, 2013). Most frequently, the existing infrastructure is used (taxi stops, parking lots for private vehicles, bus stops etc.) (Tadić & Zečević, 2016). The use of these zones decreases the time that drivers spend on searching for a free parking space as well as stress (Odani & Tsuji, 2001). However, there are certain problems, such as access control. Studies have shown that between 47 and 54% of loading/unloading zones is taken by parked passengers' cars (Aiura & Taniguchi, 2006).

In Rome, authorities are developing new city plan and implementation of 700 new areas reserved for handling goods, that would be efficiently managed with information and communication technologies, while in Stuttgart there are examples of successful electronic management of these zones (Russo & Comi, 2010). In Barcelona, 44 parking spaces have been transformed to loading/unloading zones during certain hours. During peak hours, these lanes are used for public transportation vehicles (buses), while during night lanes are used for parking private cars. In some examples, accessibility and usage of zones is conditioned, for example in Goteborg with load factor (greater than 65%) (Russo & Comi, 2010).

3.3 Consolidation

Among analyzed and applied city logistics concepts, cooperative logistics systems and logistics centers are very popular, and often integrated implemented. The concept of cooperative logistics systems is based on consolidation of commodity flows, as well as the cooperation of logistics providers, transportation companies, senders or receivers. These concepts allow servicing larger number of facilities with one integrated or multi-integrated logistics system (Tadić & Zečević, 2015). Cooperation and consolidation can be carried out with our without directing flows to logistics centers (Zečević & Tadić, 2005), and the most popular solution is urban consolidation center (UCC).

According to Ogden (1992) UCC are suitable for deliveries in densely populated areas. Also, UCC are especially suitable for the supply of zones with diverse constraints and delivery problems such as central and historical city zones (Browne et al., 2005). Consolidation centers can help creating the balance between modes of transportation. UCC enables achieving sustainability goals from the social and environmental perspective due to reduction of traffic congestion, number of vehicles and travelled distances, as well as emission of harmful gasses (Tadić & Zečević, 2015).

Lately, the focus is on micro-consolidation initiatives - solutions that bring goods closer to reception points (Browne et al., 2011; Conway et al., 2011; Janjevic & Ndiaye, 2014). One of these initiatives is micro-consolidation center, that is logistics platform or city terminal that resemble traditional consolidation center, but with focus on smaller limited space (Zečević & Tadić, 2016). In these centers, goods are consolidated directly before the delivery to recipients. Focus is on smaller and lightweight deliveries with promoting cleaner delivery vehicles (such as cargo bikes) and delivering goods on foot from center to receiver. Considering that the most deliveries in CCZs are smaller in size and weight, consolidation and application of smaller eco-vehicles is justified (Janjevic & Ballé Ndiaye, 2014) and can have positive impact on environment (Benjelloun & Crainic, 2009). These centers are mostly privately owned by specialized logistics companies (Janjevic & Ballé Ndiaye, 2014). Although unknown, it is assumed that the most significant business costs are the space and manpower costs (Conway et al., 2011).

In London, a solution with micro-consolidation center and electric vehicles for delivery to end-consumer has been tested. Research show that the total travelled distance was reduced by 20%, emissions of CO2 by 54 % (Browne et al, 2011). In cities in Frances, such as Bordeaux, Paris, Lyon, Montpellier implementation of logistics points known as “Espaces Logistiques de Proximité“ (ELP), enable realization of logistic activities in the heart of the city. Servicing end-users from ELP with electric vehicles (two or three wheels) has led to reduction of circulation of big delivery vehicles in city center, as well as congestion and pollution (Browne et al, 2012). There are also mobile micro-consolidation centers. Company TNT Express has developed “Mobile Depot”, a trailer that represents mobile base inside city from which first and last mile are realized with electric cargo bikes. The application of this system has resulted in reduction of emission of harmful gases and kilometers travelled by road vehicles (Verlinde et al., 2014). One of the solutions of micro-consolidation initiatives includes usage of parcel lockers that do not require presence of receivers in delivery area. This enables consolidation of goods for several recipients into one reception point, reducing the number of tours in urban areas. Lockers can be used by both companies and residents, and example of successful usage can be found in post in Belgium (Janjevic & Ballé Ndiaye, 2014). Also, they can be used for home delivery, or the delivery of smaller „unexpected” shipments to generators.

3.4 Regulations related to means of transport

The regulations and limitations related to road vehicles are one of the city logistic solutions. Although most common initiative, it definitely should not be used as independent solution, but as support and addition to other solutions.

There are many limitations related to vehicle characteristics and negative emission around the world. These limitations tend to change the structure of delivery vehicles used in city centers, and their aim is to reduce traffic congestion (vehicle space occupancy limitations) and air pollution (emission related restrictions). The limitations may be related to the weight of vehicle (e.g. in Milan and Rome the limit is 8.5 tons), the length of vehicle (e.g. Milan and Brescia with limits of 7 and 6 m) or width (Piacenza where the limit is 2.2 m). In European cities, limitations related to vehicle dimensions are very common measure, and one of the reasons is tendency to introduce smaller delivery vehicles (Russo & Comi, 2010).

Low emission zones (LEZ) promote cleaner vehicles and reduce the number of older vehicles in CCZs (Taniguchi et al., 2014). Increasing number of cities controls access to central areas, providing access only to vehicles that don’t emit harmful gasses, low emission electric or hybrid vehicles (Russo & Comi, 2010).

One of the new initiatives is load factor control. The goal of this initiative is to encourage the increase of load factor, which has positive economic and environmental effects (Zečević & Tadić, 2013). Weight or volume utilization can be expressed as the average value over a certain period. However, defining the limits of the value of load factor is problematic as this value varies over time even for one vehicle. Also, it is necessary to determine the size of area on which this factor would be calculated – whether it is the area where the limits will apply or wider (Russo & Comi, 2010). This initiative is one of the newest, and the reason for growing interest is the decrease in the size of the delivery, which results in low load factor, and often empty vehicles.

Despite positive goals, application of regulations often creates more problems than benefits. Therefore, it is important to determine when it is justified to implement restrictions, and what its limits are.

4 PROBLEMS OF CENTRAL ZONE IN BELGRADE

In order to identify problems of supplying central zone of Belgrade, a study of city logistics parameters was conducted in three streets: Kneza Mihaila, Uzun Mirkova and Studentski trg. Kneza Mihaila St. is central pedestrian zone, shopping center and main touristic attraction of Belgrade. Streets Uzun Mirkova and Studentski trg also belong to CCZ and are parallel to St. Knez Mihaila. St. Studentski trg has turntables for busses and trolleybuses, taxi station, and one part of the street is intended only for public transportation vehicles. In Uzun Mirkova St., traffic is one-way, which additionally complicates access to facilities.

In research area, 75 generators of demands for logistics services have been identified. Due to the specificity of the business, the objects of financial and legal activities are excluded from the analysis, so the presented parameters refer to 46 facilities that could provide required information. The dominant activity is trade (38 generators), followed by catering (4 objects), culture and art (3 objects) and education and science (1 object). Among trading facilities, clothing and footwear shops are dominant (over 80% of trade objects), while the offer of other activities is significantly lower.

Over 55% of generators in this part of central zone have a surface area less than 90 m^2, and 11 of them less than 30 m^2 (Figure 1). However, 14% of objects have a surface area larger than 400 m^2 (faculty, hotel, museum and 2 major trading objects). Considering that the participation of these objects in the rest of the central zone is significantly lower, the fact that the objects in CCZs are predominantly smaller is confirmed.

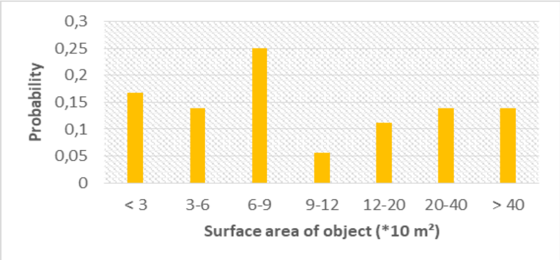

Figure 1: Probability distribution of surface area of the objects

Regarding the restriction of access to vans, over 60% of deliveries are realized until 10h. Other time intervals are less frequent, and over 20% of the deliveries are realized anytime during the day (Figure 2).

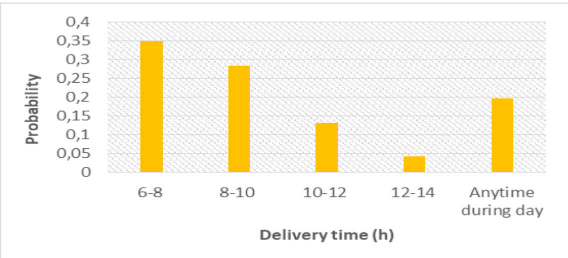

Figure 2: Probability distribution of delivery time

The deliveries are performed by vans (62% of objects) and pick-up vehicles (37%), and in certain cases with a passenger car (to the gallery in St. Studentski trg, the authors transport piece of art with their cars). These data confirm the presence of smaller vehicles in CCZ. Unfortunately, in Belgrade they are not the eco-friendly.

Over 20% of analyzed generators don't own storage space, and for the third the surface is up to 20 m^2 (Figure 3). This is in line with the fact that companies apply new business strategies with minimum stocks and frequent deliveries. Besides, the price of the spaces in these zones is too high to be used for stocks.

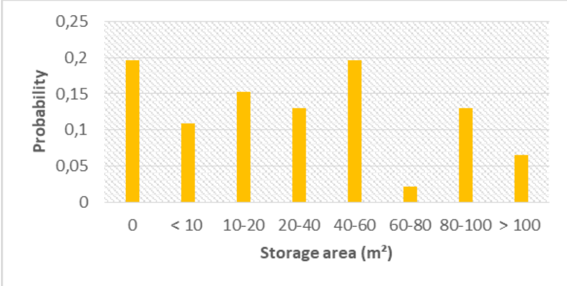

Figure 3: Probability distribution of storage area

For over 25% of generators, the size of delivery is less than 0.1 m³ and for over 30% of generators, the size of delivery is between 0.1 and 0.5 m³. However, for 15% of generators, size of the delivery is between 1.5 and 2.0 m³ and this is typical for large clothing and footwear stores (Figure 4).

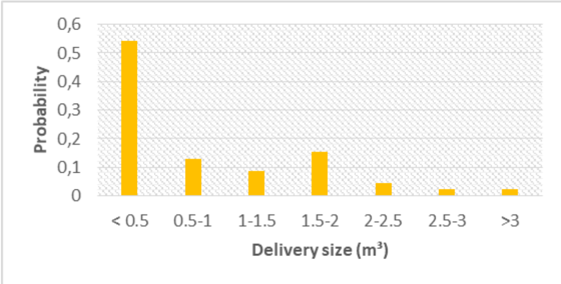

Figure 4: Probability distribution of delivery size

Seven facilities receive goods more than twice a day, while 10 facilities receive goods once or twice a day (mostly catering facilities and footwear shops). Also, for 37% of generators, the delivery is realized once or twice a week (Figure 5).The fact that over 80% of trade objects are clothes and footwear stores can influence on frequency, as well as the size of the delivery.

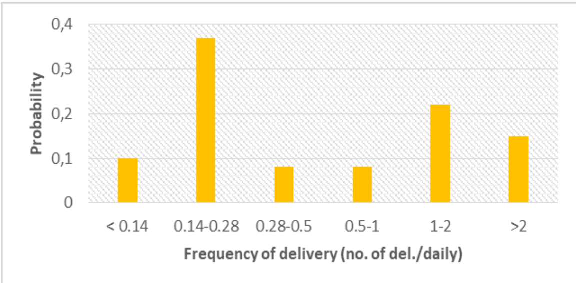

Figure 5: Probability distribution of delivery frequency

During loading and unloading operations, vehicles most often (over 50%) stop in one of the neighboring streets, and 43% in front of the generator. Only 2 objects have their own parking spaces that vans can use (one street parking place and parking place in hotel garage in St. Uzun Mirkova).

Since Knez Mihaila St. is a pedestrian zone with delivery vehicles restrictions, vehicles stop in nearby streets, from where goods are transported on foot with our without cart. In streets Uzun Mirkova and Studentski trg, vehicles often stop in front of the objects, on private parking spaces, or due to their occupancy on the road itself. This leads to traffic jams, reduced safety and increased risk of penalty. For these reasons, loading/unloading of goods must be realized very fast despite all difficulties.

The results show that city logistic parameters of the central zone of Belgrade mostly confirm mentioned characteristics, problems and limitations. The fact that clothes and footwear dominate in the structure of goods, as well as small size of the shipment enable the use of eco-vehicles that often do not provide special temperature conditions necessary for some food products. In addition, the dominance of the trade sector supports the concept of consolidation, since they are products with similar characteristics. However, the justification of afore mentioned solutions in the central zone of Belgrade requires additional analysis, concerning wider city area, since the solution for the central zone must fit in with the city logistics concept of the whole city.

5 CONCLUSION

The CCZs are centers of diversity of events, but also generators of big economic problems, with impact on quality of life. Most of the problems are related to urban freight transport, so the most popular solutions are the application of eco-vehicles, loading/unloading zones, as well as the UCC. However, at the moment, the greatest attention is given to political initiatives that force changes in behavior. Such initiatives provoke resistance, which further requires conditionalization of their applications in order to achieve operating in practice (Tadić & Zečević, 2015).

Defining sustainable and acceptable solution requires extensive research, knowledge of the characteristics of the city, of demands, goals, as well as interaction of stakeholders, integrated planning, and cooperation of participants. The precondition of all these activities is raising awareness and „logistics" way of thinking where it lacks. Urban authorities often don't have the knowledge and capacity for managing and controlling logistics activities and processes as a whole, and the holistic understanding of their impact on sustainability is also lacking. On the other hand, logistics providers, in order to achieve competiveness and grater market share, offer shorter lead time and greater reliability of delivery, what creates additional problems of sustainability. The best results could be achieved by combining these solutions. This requires creating „bigger image" and defining a common goal – city center that is still center of all activities and events, but in such a way that decreases or eliminates all negative effects.

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ENVIRONMENTAL FRIENDLY TRANSPORT AND NAVIGATION IN THE REPUBLIC OF SERBIA

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ABSTRACT

One of the categorical imperatives of legal order represents the healthy environment. Danube river basin region is today inhabited by more than 100 million people. Although today the world is threatened with new risks due to the climate change and global warming, it is clear that the application of the concept of the green economy, i.e. the use of renewable natural resources, as well as reducing greenhouse gas emissions is necessary. Countries around the world are trying to find the best way to reduce greenhouse gas emissions and protect the country from further pollution. Serbia as a state party to the Paris Agreement has established national targets for reducing emissions of greenhouse gases by 2030.

The most suitable environmentally friendly mode of transport is the Danube waterway transportation. At the end of the 19th century navigation through Đerdap sector was regulated. The Strategy of water transport development of the Republic of Serbia from 2015 to 2025 *(“Official Gazette RS“ no. 3/15)* has the function of promoting water transport as the most cost-effective and environmentally friendly mode of transport. With improved infrastructure and transport means Serbia would be able to compete with the traffic of European countries. Water traffic can be integrated in a multimodal network which would effectively connect a comprehensive network of roads and railways at the national level with the TEN-T Corridor Rhine - Danube.

Keywords: environment, protection, Danube, Serbia

1 INTRODUCTION

Many countries in the world are thirsty, and every drop is considered valuable so European commissioner for agriculture and rural development has suggested the establishment of the Special Fund for financing of the Program for adaption on climate changes, water management, use of the renewable sources of energy and preserving of biodiversity.

Pollution of living environment is seen in different shapes. Undesirable consequences of human activities disrupt natural living frame, and water, as one of the most important structural elements of different eco systems is most frequently under an impact of polluters. Although the permanent concern for the protection of the clean water is present, never stops pollution of our rivers. The cooperation between the nations that live along the Danube catchment is very important for realization of common target: decrease of present pollution and prevention of the future one.

While nature represents a priceless cultural and natural heritage of each country, traffic is a major source of local, regional and global environmental problems. However, traffic, industry, agriculture, trade and tourism represent advantages of the entire Danube region in Serbia. The high concentration of settlements and population, the rich historical heritage, the developed economic infrastructure and the natural attractions are distinct advantages for the development of tourism with good outlook in this part of Serbia.

2 ENVIRONMENTAL PROTECTION ISSUES AND NAVIGATION

The EU Directive on the conservation of natural habitats (Habitats Directive) is one of the most relevant transnational legal tools for nature protection in Europe. In many ways a man intervened in the natural courses (regulation of the Danube, water economy, hunting, fishing), but the basic ecological conditions remained preserved. In 1978, for example, a part of the National Park "Danube Valley" which stretches 47 km between Vienna and Bratislava, was declared the biosphere reservation by UNESCO, while in 1996 Austria and Slovakia have passed laws and regulations on the establishment of the national park.1 In June 1999. Danube basin countries signed the Danube River Protection Convention, with aim to protect one of the greatest eco-systems in Europe. Collaboration of all countries Danube flows through is needed. On the 30th of January 2003 Federal Republic of Yugoslavia ratified Danube River Protection Convention (Convention on Cooperation for the Protection and Sustainable Use of the Danube River). There are also Directives of the European Union (EU), such as the Directive on nitrates and the Directive on superficial waters which have the aim to prevent rivers's poluttion. Member states are obliged to apply in practice the plans of the river's basins protection and to carry out the sustainable policy of water prices.

[1] The union of Danube as a mountain river with western lowland river March (Morava) represents a cause of exceptional wealth of flora and fauna.

The Strategy of water transport development of the Republic of Serbia from 2015 to 2025[2] in the part concerning the organized collection of ship waste on Danube, Sava, Tisa and the network of canals in the Republic of Serbia includes monitoring and acceptance of all guidelines from the Strategy of waste management for the period from 2010 to 2019 [3], i.e. harmonization with EU legislation in the area of waste management.

In Serbia, ecologists often raise their voices to protect biodiversity. At the confluence of the Tisa is the realm of unspoiled nature, a protected zone with complex of branches and puddles, where even 103 kinds of birds that are on the list of natural rarities stay. Shipyard Bomex 4M in Zrenjanin was built despite the fight of environmentalists against the construction of the shipyard near the nature reservation Carska Bara, due to the impact on the world of birds that has its habitat in this region.

The potentials of the rich cultural heritage on the banks of our rivers are not sufficiently recognized during the planning of traffic of passengers and recreational tourism on the waterways of the Republic of Serbia. The geographic location is convenient, especially for tourists from the neighbouring regions of Central Europe and the Balkans. The rich plant and animal wildlife spurs the development of tourism, while in the field of environmental protection a lot of work still remains to be done and a continuous effort is necessary to prevent the further pollution of the region. Danube region, at the same time, still needs a number of infrastructural-technical and marketing steps for a better quality tourism development in the coming period, to be able to compete with leading tourist destinations in Europe.

Non-Governmental Organization "Give back the beauty to the rivers" was established as an ecological center of Danube and Sava rivers fans, in order to protect and take care of rivers, coast, parks and change the awareness of all citizens of Serbia.

One of the categorical imperatives of the legal order represents a healthy environment. Although today the world is threatened by the new risks because of climate change and global warming, it is clear that the application of the concept of the green economy, i.e. the use of renewable natural resources, as well as reducing greenhouse gas emissions are necessary. Serbia as a state party to the Paris Agreement has established national targets for reducing emissions of greenhouse gases by 2030.

Improving waterways means respecting the principles of environmental protection which relate to ecological corridors of international importance in the Republic of Serbia, which represent navigable rivers with its coastal belt: the Danube, Sava, Tisa, Drina, Velika Morava.

3 NAVIGATION IN SERBIA – ONCE AND TODAY

Since the time of the ancient Greeks the navigation on the Danube has been performed. During the reign of the Byzantine Empire, at the time of the Crusades, army was traveling by Danube. With the arrival of the Turks navigation has stopped and again was renewed by the Belgrade peace, in 1739, when the Turks have recognized the freedom of navigation. Later, by the Paris peace of 1856 the Danube was declared the international river with free navigation.

Modern inland shipping in Serbia began to develop in 1862, when by the decree of Prince Mihailo Obrenovic, the steamer "Deligrad"[4], which was built in France in 1851, was bought from Russia. In 1895 the steamboat was converted into the modern passenger ship and from then until 1914, it sailed on Danube from Belgrade to Radujevac.

By Treaty of Paris from 1921, the Kingdom of Serbs, Croats and Slovenes received larger number of ships (which happened to be from 1918 after the end of the First World War in the newly formed state SHS) so that with the existing navigable park had the largest fleet on the Danube. In addition to freight traffic, there were more and more passenger ships[5] which sailed from Belgrade to Prahovo.

At the end of the 19th century navigation was regulated through Đerdap sector, more precisely dissatisfied with the solutions of the Austrian government and the Austrian-Turkish commission, in 1879. Hungary has formed the Commission for organizing the navigation through Djerdap. The project was completed in 1883. The works on the regulation of the Djerdap sector were conducted by the Hungarian technical administration in the period from 1889 to 1900. The channels up to 60 meters wide and 2 meters deep have been cut out under the water, at zero water level in Oršava for the upper Đerdap section and 60 meters wide and 3 meters deep for lower section of Đerdap, with the exception of Sipski channel, where a width was 73 meters.

Danube is tamed by the formation of Sipski channel[6] and from then more than 120 years passed, and by the opening of the channel safer sailing for ships has been achieved. It is cut into the right bank and built for 6 years, from 1890 to 1896. This was a monumental work of the 19th century, 2.133 meters long, 73 meteres wide and 3.9 meters deep. Upstream the navigation has lasted for 24, and downstream about 5 minutes. The powerful River Danube whose river flow speed was 18 kilometers per hour, required to find a new solution for ships, and therefore in 1899 the steamship traction was introduced. Thus, the shipping was developing until 1916, when the vessels were replaced by three

[2] "Official Gazette RS" no. 3/15.
[3] "Official Gazette of the RS", number 29/10.
[4] Steamboat was named by the trench from Deligrad in the First Serbian Insurrection. Capacity was 275 tons and and it sailed by Danube, Sava and Tisa for more than 50 years. During the year 1859 this steamer drove the last Ottoman commander Ali Riza Pasha down the Danube from Belgrade.
[5] They were the steam ships using the coal as fuel, and later crude oil.
[6] Village Sip was flooded after the construction of the dam.

locomotives and these German locomotives [7] (there were 11) pulled vessels upstream by the cord. And so until 1969, when a large artificial lake was created by construction of the first power station Djerdap. Thus, the complete tracks and two locomotives "berliner" remained under the water.

So called „locevi" or pilots on ships, i.e. captains of river navigation have safely escorted the ships in that part of Djerdap called "Iron Gate", and there were 29 of them who did this risky, responsibile and hard job. There are many stories remained from that period that I learnt thanks to my grandmother, who was legal adviser to former JRB, i.e. Yugoslav River Shipping.

Ports and piers in the Republic of Serbia are the property of general interest.[8] Water routes of international importance represent the primary resource of waterway network on the territory of the Republic of Serbia, which besides Danube make rivers Sava and Tisa.

Convention regarding the Regime of Navigation on the Danube was signed at Belgrade on 18 August 1948 and the regime established by this Convention shall apply to the navigable part of the Danube River between Ulm and the Black Sea through the Sulina arm, with outlet to the sea through the Sulina canal.[9] In Serbia, the Danube reaches its full strength and the entire stream is navigable, and passing through two national parks[10] in Serbia. River Danube achieves 8% of European turnover of goods, but unfortunately this river is considered to be the most blocked in Serbia. Danube throughout its length within the Republic of Serbia of 587,6 kilometers is the international waterway with free navigation for all flags. Part of its course forms a natural border with the Republic of Croatia (which is not yet defined) and Romania. Danube waterway is fully marked in accordance with current international regulations. In the period from 2009 to 2013 on the rivers Danube and Sava the most modern River Information Services (RIS) were implemented. The coastal Network of base stations (15 on Danube and three on Sava river) was established, what completely covered with a signal the flow of these rivers. Electronic Navigation Charts (ENC) are provided for the entire course of the Danube, Sava and Tisa through Serbia. Beginning with 1 January 2014, the obligation of locating and monitoring of vessels using this system was introduced, as well as the issuance of electronic communications for shipping.

Tisa River with 164 kilometers of the international waterway, with a network of local channel Danube - Tisa - Danube from a total of 600 kilometers, has the potential to become an international waterway which will be used by all Danube countries.

The need for urgent action in the field of maintenance of waterways was confirmed by Luxembourg Declaration, because the well maintained waterway is prerequisite for safe and cost-effective internal traffic, especially during rainless periods.

By Governmental Decision on determining the piers for international traffic[11], as ports open for international traffic are proclaimed: Apatin (port operator: Port "Napredak"), Belgrade (port operator: Port "Beograd"), Bačka Palanka (port operator: Port "Bačka Palanka"), Beočin (port operator: "BFC Lafarge"), Novi Sad (port operator: Port "Novi Sad"), Pančevo (port operator: Port "Danube" Pančevo), Prahovo (port operator: Port "Prahovo"), Smederevo (port operator: "Ironworks Smederevo"), Bogojevo (port operator: Port "Danube Bogojevo") and on the Tisa Senta (port operator: Port "Senta").

Today Serbia is the country that has no exit to the sea, but it is very rich in rivers.

Velika Morava, main Serbian river, the right Danube's tributary, arising of the South and West Morava that meet at Stalać; South (with its right tributary Nišava) and West Morava, with its tributary river Ibar (its tributaries are: Sitnica, Raška, Jošanica, Studenica) which flows near Kraljevo.

Sava (207 km) the longest river in the former Yugoslavia, flows into the Danube near our capital Belgrade. Since the beginning of the last century area of Petnica (near Valjevo) in the upper river basin of Kolubara river, the right tributary of the Sava is classified as a terrain rich with subterranean waters of high quality, so the water factory was built on that field and started to work in March 2003. According to the Regulation on the quality and other requirements for natural mineral, natural spring and table waters[12] this water satisfies requirements for natural spring water.

Tisa is left tributary of the Danube, rises in the Carpathian Mountains, but only in our country is navigable for larger river boats from Senta to Slankamen; Tamiš, river in Banat, also left tributary of the Danube River, which rises in Romania, and is navigable at the mouth of the river, with the main pier Pančevo, while the gold-bearing river Pek, left tributary of the Danube, in eastern Serbia, is characterized by a river basin rich with ores. Left tributary of the Danube is the river Nera in Banat; Timok is a right tributary of the Danube, part of the border between Bulgaria and our country**.**

The biggest problem of Serbian fleet is the lack of new modern vessels of inland navigation and a constant increase in the age of the existing vessels. Records from July 2014 show that in Serbia there were 292 registered vessels in all types of purposes, of which 190 freight vessels. For comparison, data from 2006 show that the

[7] In the coastal embankment of channel Germans have built the railway 1,800 meters long and these small tracks were featured in all railway maps in the world.

[8] *Article 203, paragraph 1. of the* Law on navigation and ports on inland waters ("Official Gazette RS" no.73/2010, 121/2012).

[9] Article 2. of the **Convention regarding the Regime of Navigation on the Danube**, "Official Gazette of FNRY", no. 8/49, "Official Gazette of FRY", International Contracts, no. 6/98.

[10] Fruška Gora, a region of exceptional natural characteristics and cultural-historical sights and Carska Bara, special nature reservation, an area of about 1.600 hectares, which is registered in UNESCO's list of wetland areas of international importance.

[11] "Official Gazette RS", no. 51/05, 14/10.

[12] "Official Gazette FRY" no. 53/2005.

number oscillated between 900 and 1000 vessels and that it covers all vessels that were not deleted from the Register of Ships, while the number of registered vessels was half the size, means 450-500.

For the purpose of effective implementation of the Strategy of water transport development of the Republic of Serbia from 2015 to 2025[13] on 31st of March 2015 Action Plan for implementation, monitoring and improvement of this strategy was adopted by the Government. The Action Plan will determine appropriate activities aiming at implementation, their holders and participants in the implementation, as well as the manner of implementation and sources of funding. The obligations of the state bodies and organizations which, in accordance with authorities established by law, have jurisdiction in the field of water transport, as well as of the organs and institutions whose competences can influence on the development of this branch of traffic are set by the Action Plan. Until now, responsibility for rivers was split among several state and city institutions, and the city of Belgrade for performance of water management activity established the public water-economic company "Beograd vode" that carries out activities in order to protect the city from floods. Otherwise, on the territory of Belgrade, there are 1.783.6 kilometers of land reclamation channels and 33 pumping stations where "Beograd vode" performs activity of general interest.

Serbia has a considerable potential of waterways and the long-term strategy of the state is to divert the flow of goods from road to river transport as much as possible.

4 CONCLUSION

The possibilities for utilization of the Danube and its water are limited and determined by the geographical and hydrological factors. The Danube is an international navigation route, which is passing through nine countries. Due to its length and very bifurcated catchment the Danube has got also a great military, geographical and strategic importance. Rhine-Danube corridor is one of nine European corridors of TEN-T network which passes through the Republic of Serbia and the TEN-T network is part of transport policy which aims to reduce 60% of greenhouse gas emissions, caused by traffic by 2050 ('Transport 2050' White Paper 2011).

Transport on inland waterways has significant advantages compared to other modes of transport, such as lower gas emissions that pollute the air.

It is clear that maritime and inland transportation are real competing alternative to land transportation. This transportation is reliable, economical, usually clean and quiet, but their capacities are still unused. Better use of capacities is possible especially in the transportation on inland navigation routes. Although the main infrastructure problems remain, and these are unsuitable cross sections, heights of bridges, lack of equipment, etc.

The advantages of water transport for certain types of cargo compared to other modes of transport in regard to environmental protection are not sufficiently recognized in the Republic of Serbia. Closing the gap between knowledge and reality in environmental protection is needed.

Our vision is to achieve European standards of safe navigation on the entire network of international waterways of the Republic of Serbia, with full respect for ecological corridors of international importance in our country.

Among the strategic objectives of the Republic of Serbia is also the preservation of favorable status of ecologically important areas and improvement of deteriorated state of parts of the ecological network consisting of ecologically important areas, ecological corridors of international importance and protective zones in the Republic of Serbia.

The goal of improving the state of the waterways in the period from 2015 to 2025, i.e. the creation of conditions for water traffic to become safer, more reliable and more efficient mode of transport with respect of the modern environmental standards in planning and design, is attainable and realistic. Maintenance and development of infrastructure on the waterways of the Republic of Serbia for the needs of navigation is based on a clearly defined European standards and adopted international and bilateral agreements on the path towards European integration fully direct the national policy and commitments. Conditions of navigation on Danube, Sava and Tisa have to be improved in accordance with European development plans of the European water transport and taken international obligations.

The most suitable environmentally friendly mode of transport is the Danube waterway transportation. The Strategy of water transport development of the Republic of Serbia from 2015 to 2025 has the function of promoting water transport as the most cost-effective and environmentally friendly mode of transport. With improved infrastructure and transport means Serbia would be able to compete with the traffic of European countries. Water traffic can be integrated in a multimodal network which would effectively connect a comprehensive network of roads and railways at the national level with the TEN-T Corridor Rhine - Danube.

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HANDING OVER THE BRIDGE WATCH – CRITICAL SPAM PERIOD OF BRIDGE RESOURCE MANAGEMENT

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ABSTRACT

The notion of hand-over on board ships is not completely defined by legislation or regulations. Indeed, the content of the hand-over is described by the ship procedures that are part of the International Safety Management Code (ISM), Ship Safety Management System (SMS) and Master's Standing Orders etc. However, there is not a single document defining the duration of the hand-over. The development of marine technologies has made handing-over procedures more complex and time consuming. Meanwhile, the organizational structure of the navigation watch has remained the same, resulting in the hand-over practice being shorter than needed.

Handing over the bridge navigational watch depends on a number of factors, including the type and size of the vessel, quality of the company and ship SMS, ships trading area, traffic density, weather conditions, state of the sea and seaworthiness of the vessel, experience and qualifications of the officers.

A survey was conducted to 30 deck officers in order to gain insights into the variations of duration of handing over the bridge watch with regard to the prevailing conditions.

Keywords: Hand-over, bridge navigational watch, checklists, safety, officer of the watch, Safety Management System, simulator

1 INTRODUCTION

The hand-over is a maritime term referring to handing over and taking over the navigational and engineering watch. The same expression is used for taking over the duty at the beginning of the watch and when joining the ship, i.e. signing on. During the hand-over period, the joining officer or rating is familiarized with the relevant information's that are important for the safety of navigation.

Previous and present research has revealed that handing over process is an important safety factor. The hand-over period is typically short due to reduced time that vessels spend in ports. The reduced ship's turn-round time has been considerably affected by the development of marine technologies. In addition, research results have proved that the hand-over procedure heavily depends on the education level and qualifications of officers [1].

With regard to the ways of duty handover on board ships, the handing/taking over the duty may be performed:

- between crew members in charge of the same duty, and between crew members (same rank) signing off and signing on,
- at the beginning or end of the watch.

The handover between off signing and on signing crew member (same rank) is carried out periodically, when boarding and leaving the vessel. Unfortunately, due to the fast turn-rounds in ports, the handover is performed within a limited time period that is shorter than necessary.

While at sea, handing over is carried out at the beginning or end of the navigational or engine watch, or when the master or the chief engineer takes the command due to maneuvering or emergency.

Considering the place where the hand-over occurs, there are three types:

- bridge navigational watch (24 h),
- cargo control room/deck watch,
- engine watch.

Handing over the bridge or engine watch between two officers is performed according to ship Safety Management System (SMS) procedures/checklists.

With regard to ship operations, there are differences among:

- handing over the watch when under way,
- handing over the watch in port,
- handing over the watch at anchor,
- handing over the watch during maneuvering.

Handing over the watch when the vessel is underway, in port, at anchor and maneuvering is performed in line with the procedures/checklists defined by SMS, Master's Standing Orders and Master's Night Orders.

In respect of the light conditions, there is a considerable difference between:

- daytime watch hand-over, and
- handing over the watch at night.

Completing checklists for hand-over the watch during a night watch implies the monitoring of equipment and devices in low light conditions and, at the same time, carrying out the procedures. Alterations of the dark (look-out) and light (writing) requires frequent vision adaptation (light-dark-light), i.e. increased period needed for completing the paperwork and temporary inability to perform a proper lookout.

Considering the prevailing circumstances, there are two types of hand-overs:

- while under regular circumstances,
- while under exceptional circumstances.

Regardless of the prevailing circumstances, the two procedures must be performed at all times: Handing Over the Bridge Watch and ECDIS Setup Checklists. Depending on prevailing conditions, SMS Code provides additional procedures/checklists for specific situations such as: reduced visibility, meting heavy weather, helicopter operations, navigation in coastal waters, navigation in ice, etc. Given the complexity of navigation, it is likely that vessels may meet a number of these circumstances which require completion of large number of procedures/checklists.

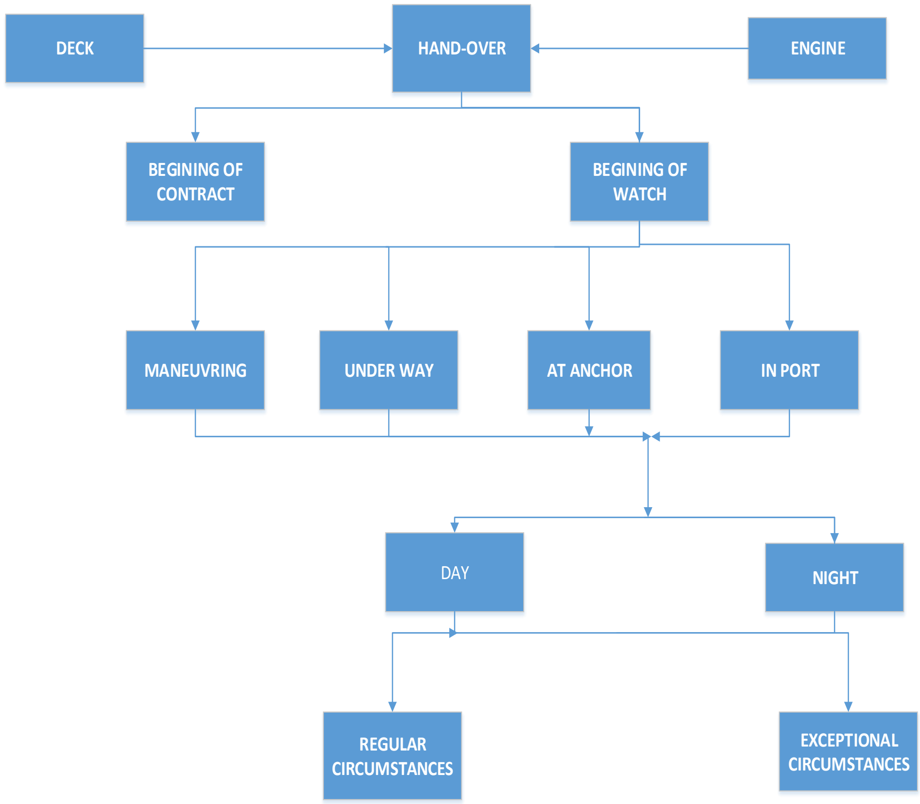

Figure 1: Simplified diagram of watch/duty hand-over on board vessels (Source: Authors)

The Officer of the Watch (OOW) has to comply with the rules of SMS Navigational Policy prescribed by the shipping company, perform the Bridge Resource Management (BRM), carry out the watch hand-over in an efficient and safe way, be familiarized with the bridge procedures, execute the passage planning, monitor the ship movements at all times, etc. A proper hand-over of the bridge navigational watch is carried out when all relevant information has been exchanged between the outgoing and ingoing OOW [2, 3]. The ship's Safety Management System (SMS) defines numerous procedures/checklists aimed at enhancing the safety and quality of the watch hand-over. The number of these procedures vary with the purpose and type of the vessel. The procedures laid out by the SMS which are in practical use [2, 3] include:

- Handing over the bridge watch checklist
- ECDIS setup checklist
- Restricted visibility checklist
- Heavy weather checklist
- Anchoring and anchor watch
- Navigation in coastal waters checklist

- Navigation in ice.

Owing to the development of technology, automation and digitization of the ships the number of crews have been reduced. Today, officers have less manual work but more tasks involving the bridge equipment monitoring [4, 5]. The ingoing watch officer does not have a specified time period for familiarizing with the situation on the bridge and in the vessel's environment. He or she has to complete numerous SMS procedures, which extends the period necessary for efficient taking over [6].

An example is the report on ship collision issued by the Japan Transport Safety Board on 26th May 2017. The collision of a container ship and a fishing vessel resulted in death of one crew member [7].

Conclusions and recommendations arising from this and similar sea accidents state that all deck officers have to strictly comply with the all standards regarding Watch keeping, defined by ISM, STCW and COLREG (Collision Regulations) conventions, ship's Safety Management System (SMS), Master's standing orders and Master's night orders.

The procedures laid out by the ship's SMS strictly define the actions that a deck officer must take prior to taking over the bridge navigational watch. However, as it has been already emphasized, the maritime legislation and regulations fail to define obligatory hand-over time period necessary to complete all required procedures so that handing over the bridge navigational watch would be carried out in a proper way.

Researches show that the handing over period on the same vessel largely depends on the prevailing sailing circumstances, e.g. weather conditions, traffic density, area of navigation, navigating with the pilot on board, navigation at night, and so on. Obviously, the complexity of the circumstances implies that the hand-over period should be much longer than it actually is in practice. Studies have proved that the human eye adaptation to the reduced light, i.e. night watch is around 15 minutes [8, 9]. Naturally, the hand-over period will be much longer, considering the time needed for completing procedures required for safe and efficient taking over the bridge navigational watch. Just a brief exposure to light will result in the repeated process of eye adaptation and additional extension of the handing over procedure.

2 HYPOTHESIS

Advances in marine technologies have increased the ship safety and made navigation easier, on the other hand, the development has increased the number of devices that require monitoring (AIS, ECDIS, BNWAS etc.).

In practice, handing over the bridge navigational watch lasts 15-20 minutes. Neither the convention on Safety of Life at Sea (SOLAS) nor any other conventions, have provided guidelines regarding the duration of the watch hand-over. Given the changing illumination (day/night) and eye adaptation period, hand-overs may be extended. In addition, extraordinary circumstances, such as navigation in ice, reduced visibility, heavy weather, etc., the handing over procedure can be even more difficult and longer.

Considering the amount of compulsory procedures, 15 to 20 minutes is an insufficient hand-over period, especially when under way in difficult circumstances or in dense sea traffic areas.

3 METHODOLOGY

Thirty seafaring deck officers with sea-time experience of at least 36 months have been surveyed in order to find out relevant insights. They all attend the Special Education Program for seafarers for acquiring certificate/license for Chief Mate on ships of 3.000 GT or more.

The research was performed at the Faculty of Maritime Studies in Split through the years 2016 and 2017 with the aid of Transas Bridge 5000 simulator. A variety of sailing and meteorological conditions were simulated.

Prior to the research, the seafarers ran through a 60-minute familiarization with the devices featured in the simulator / navigation bridge. The procedures prescribe by ISM and Bridge Procedure Guide, used in the survey, are compatible with simulator.

Each seafarer attending the Special Education Program was timed, i.e. time measurements were performed to find out how much time each seafarer needs to complete all the required procedures/checklists and carry out the hand-over in a proper and safe way, as described by international conventions. The timing was performed for hand-over bridge watch during daylight. Fifteen minutes have been added for hand-overs at night for eye adaptation to the reduced light.

To make the presentation of the gathered results easier, the applied procedures have been marked as abbreviations, as follows:

- C/L 1 - Handing over the bridge watch Checklist,
- C/L 2 - ECDIS Setup Checklist,
- C/L 3 - Restricted visibility Checklist,
- C/L 4 - Heavy weather Checklist,
- C/L 5 - Anchoring and anchor watch,
- C/L 6 - Navigation in coastal waters Checklist,
- C/L 7 - Navigation in ice.

The respondents were marked by numbers 1 – 30. The time necessary for completing all 7 procedures was measured for each respondent.

4 RESULTS AND DISCUSSION

The tables below show the results obtained by measuring time for each procedure completed by each respondent separately. Furthermore, the times for completing all procedures were added to obtain the total day watch time. Supplementary 15 minutes were added to obtain the total night watch time for each respondent.

Table 1: Times needed for completing C/L 1-7 (day/night watch)

Candidates	Time required for completing checklist (h:mm:ss)							Total time / day watch	Total time / night watch
	C/L 1	C/L 2	C/L 3	C/L 4	C/L 5	C/L 6	C/L 7		
1	0:12:49	0:08:37	0:03:47	0:03:41	0:03:24	0:03:38	0:04:34	0:40:30	0:55:30
2	0:12:24	0:05:25	0:03:57	0:05:16	0:02:35	0:03:55	0:04:08	0:37:40	0:52:40
3	0:15:41	0:05:00	0:04:16	0:04:49	0:03:59	0:05:06	0:04:10	0:43:01	0:58:01
4	0:15:11	0:09:52	0:05:20	0:04:04	0:03:55	0:06:51	0:03:49	0:49:02	1:04:02
5	0:15:04	0:05:48	0:05:39	0:03:49	0:03:50	0:03:52	0:04:48	0:42:50	0:57:50
6	0:14:28	0:05:21	0:03:44	0:03:39	0:02:48	0:03:32	0:03:43	0:37:15	0:52:15
7	0:12:34	0:06:10	0:04:14	0:04:21	0:02:44	0:06:50	0:04:55	0:41:48	0:56:48
8	0:13:48	0:05:08	0:03:58	0:05:10	0:03:14	0:04:04	0:04:18	0:39:40	0:54:40
9	0:09:36	0:07:16	0:05:50	0:05:22	0:03:32	0:06:46	0:03:31	0:41:53	0:56:53
10	0:12:56	0:09:49	0:04:39	0:04:24	0:02:55	0:06:41	0:04:22	0:45:46	1:00:46
11	0:11:46	0:08:50	0:05:16	0:04:10	0:03:51	0:04:35	0:04:03	0:42:31	0:57:31
12	0:11:39	0:06:43	0:05:34	0:03:23	0:02:30	0:05:00	0:04:13	0:39:02	0:54:02
13	0:10:20	0:05:07	0:05:48	0:03:19	0:02:56	0:03:41	0:03:37	0:34:48	0:49:48
14	0:11:34	0:07:53	0:04:09	0:05:57	0:03:29	0:06:52	0:04:06	0:44:00	0:59:00
15	0:09:37	0:09:19	0:05:06	0:04:48	0:03:33	0:03:45	0:03:32	0:39:40	0:54:40
16	0:14:57	0:06:56	0:05:37	0:04:03	0:03:46	0:04:00	0:04:54	0:44:13	0:59:13
17	0:09:03	0:08:14	0:05:40	0:04:07	0:03:02	0:06:26	0:03:30	0:40:02	0:55:02
18	0:10:45	0:05:14	0:05:43	0:05:05	0:02:58	0:04:46	0:03:41	0:38:12	0:53:12
19	0:15:39	0:06:35	0:03:30	0:03:14	0:03:27	0:04:01	0:03:42	0:40:08	0:55:08
20	0:09:42	0:08:19	0:04:36	0:05:27	0:03:21	0:05:20	0:03:55	0:40:40	0:55:40
21	0:14:16	0:09:34	0:05:21	0:04:08	0:02:37	0:05:22	0:04:19	0:45:37	1:00:37
22	0:15:16	0:07:57	0:03:15	0:04:09	0:02:52	0:05:47	0:04:52	0:44:08	0:59:08
23	0:15:45	0:06:19	0:05:59	0:05:26	0:03:44	0:06:11	0:03:52	0:47:16	1:02:16
24	0:11:38	0:06:15	0:05:04	0:04:35	0:02:40	0:04:54	0:04:39	0:39:45	0:54:45
25	0:13:26	0:06:45	0:04:22	0:04:57	0:02:49	0:05:35	0:04:35	0:42:29	0:57:29
26	0:10:08	0:09:06	0:04:33	0:05:56	0:03:00	0:04:02	0:04:57	0:41:42	0:56:42
27	0:13:35	0:05:36	0:05:22	0:04:14	0:03:28	0:03:59	0:04:14	0:40:28	0:55:28
28	0:09:24	0:06:48	0:03:14	0:03:30	0:02:31	0:04:15	0:03:38	0:33:20	0:48:20
29	0:09:26	0:05:16	0:03:34	0:04:42	0:03:26	0:03:36	0:03:57	0:33:57	0:48:57
30	0:14:43	0:08:01	0:04:21	0:03:11	0:03:41	0:03:30	0:04:16	0:41:43	0:56:43

The results displayed in Table 1 indicate that the minimum time needed for handing over the bridge navigational watch by completing all 7 procedures amounted to 00:33:20 for day watch and 00:48:20 for night watch. The maximum time for performing the same task was 00:49:02 for day watch and 01:04:02 for night watch. In both cases, the period of time needed for hand-over was over 30 minutes, which is longer than the period of time for actual handing over on board ships.

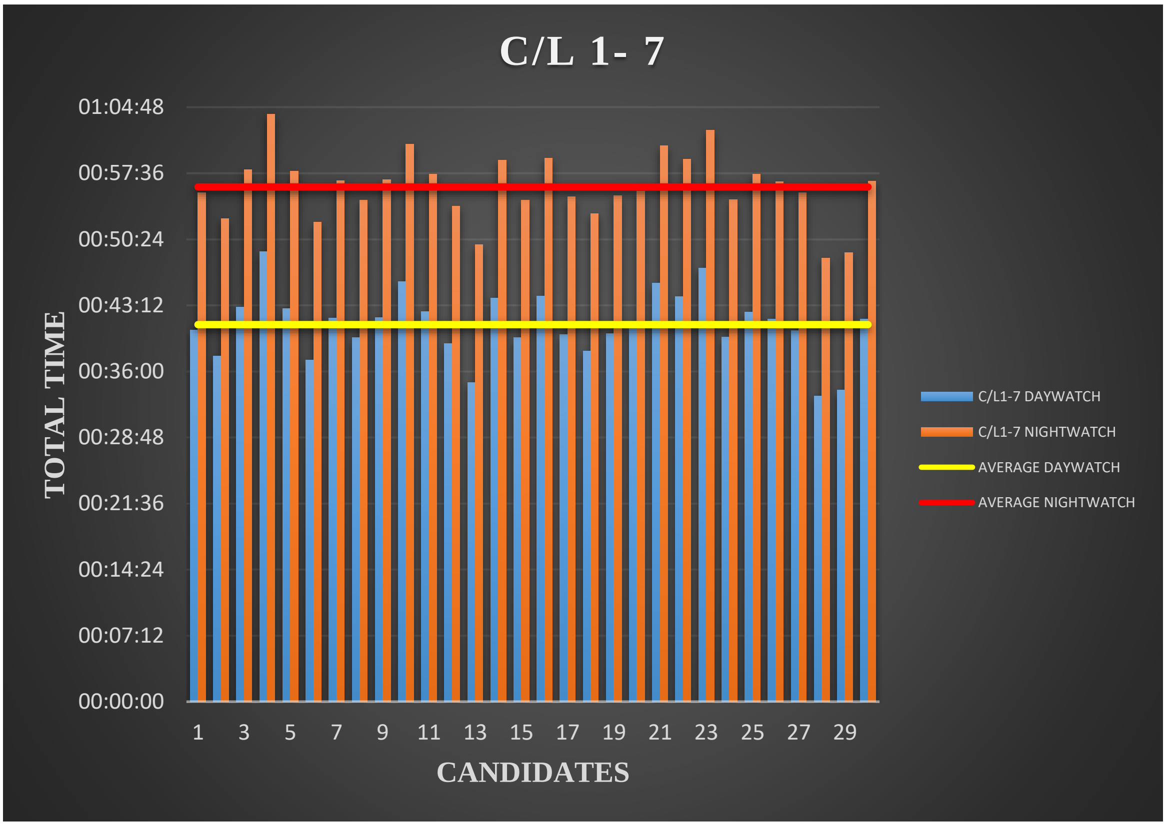

Figure 2: Time for completing C/L 1 - C/L 7 (day/night watch), n=30 (Source: Authors)

Figure 2 shows the periods of time needed for carrying out the handing over the bridge watch by applying all 7 procedures. In reality this situation is not impossible. Completing all procedures required 00:41:06. This value was increased by 15 minutes (eye adaptation to darkness during night watch), producing the average night hand-over time of 00:56:06. Over 24 hours, the handing over workload of a deck officer would amount to over 90 minutes. Despite the limited sample of respondents (n=30), it can be noted that the time needed for carrying out the handing over the bridge watch in an efficient and safe manner does not correspond to the actual hand-over time in practice.

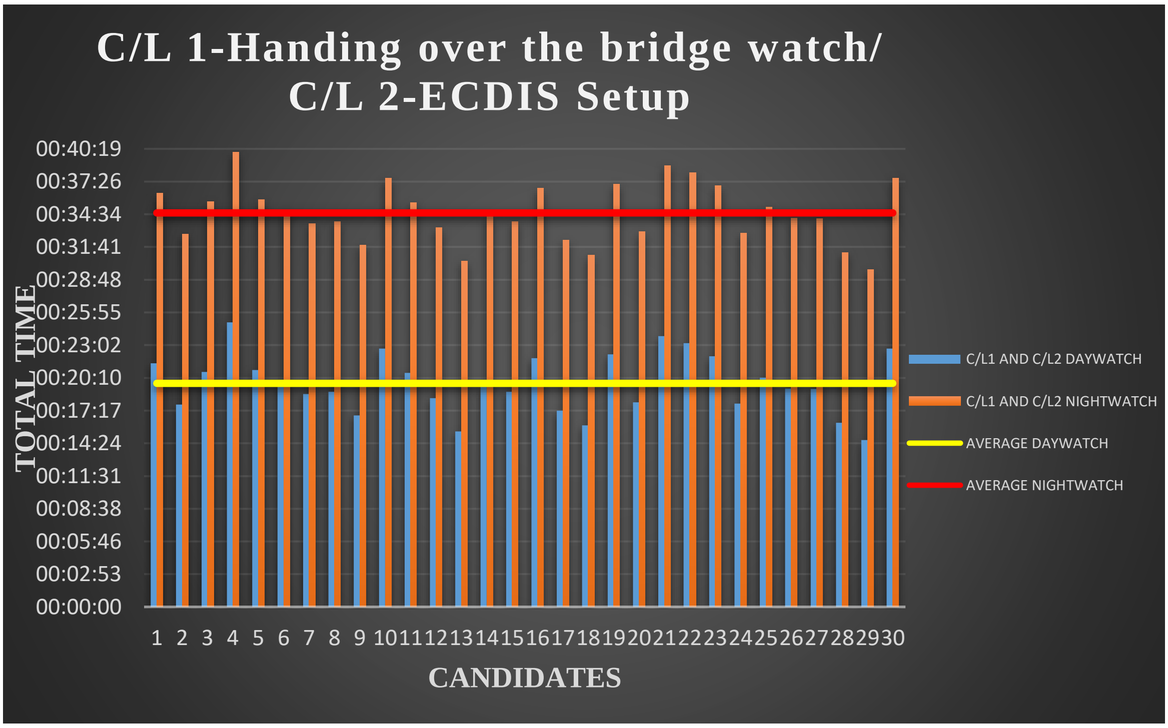

Figure 3: Time for completing C/L 1 & C/L 2 (day/night watch), n=30 (Source: Authors)

Figure 3 shows the times needed for carrying out the handing over the bridge watch by applying the procedures C/L1 and C/L2 under normal circumstances. These two procedures are compulsory both in day watch and night watch hand-over. Considering the average time necessary for handing over the bridge watch by day (00:19:41), it can be concluded that the simulated situation corresponds to the real-life situation. When supplementary 15 minutes are added, allowing for the dark adaptation, it can be concluded that the time needed for handing over the watch exceeds 30 minutes.

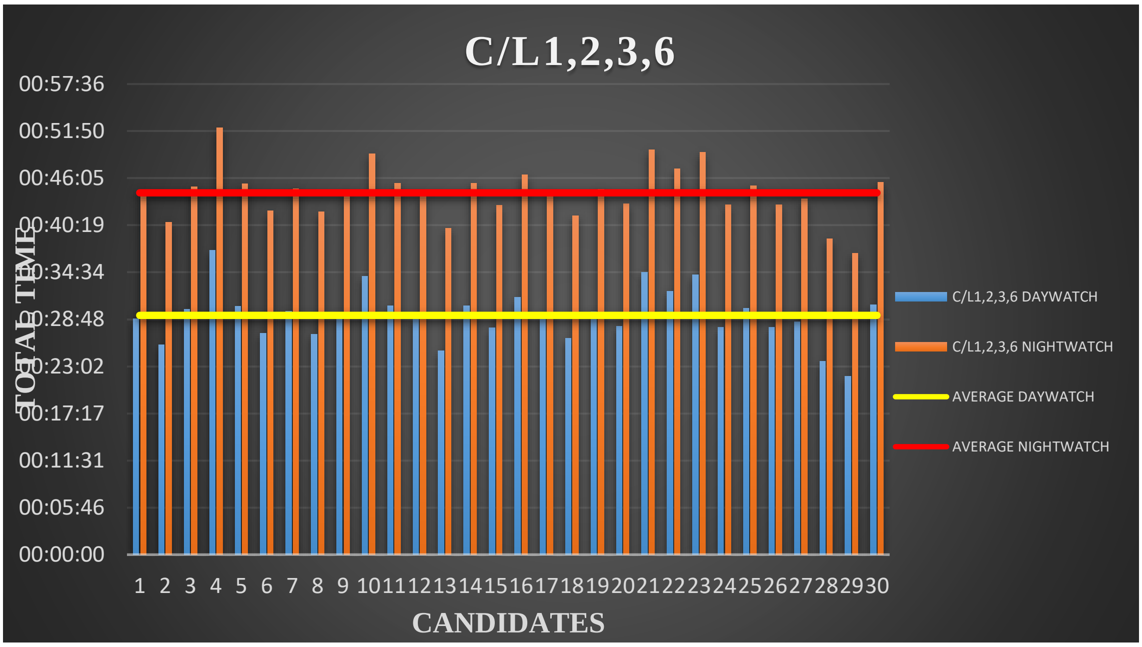

Figure 4: Time for completing C/L 1,C/L 2, C/L 3 & C/L 6 (day/night watch), n=30 (Source: Authors)

Figure 4 shows the times for handing over the bridge watch in coastal water navigation in reduced visibility. In addition to the time required for performing the compulsory hand-over duties (C/L 1 and 2), the specific navigation conditions require supplementary time for completing procedures C/L 3 and 6. Under the circumstances, the hand-over period is 00:29:17 for day watch and 00:44:17 for night watch.

This is the time when a deck officer has to be well concentrated because of the vicinity of the coast, reduced visibility and typically increased sea traffic. After performing such a demanding watch, the officer has to perform the hand-over in a proper way as well. The handing over period is clearly extended because of additional procedures and may affect the due diligence of the tired officer of the watch.

5 CONCLUSION

Although the international conventions SOLAS, STCW and COLREG [3, 10] define that the officer of the watch (OOW) may use the watch keeping time only for performing safe navigation, the research has revealed that a deck officer spends up to 50 minutes for continuous completing the compulsory procedures during and after the hand-over of the navigational watch. The time dedicated to satisfying ship procedures reduces the officer's concentration, otherwise necessary for observing potential hazards in the vessel's environment. Moreover, navigation under complex circumstances (reduced visibility, heavy weather, etc.) tends to increase the procedures related to data checking and recording, thus extending the period of time necessary for completing the procedures and carrying out the hand-over of the bridge navigational watch.

The interviews with the surveyed seafarers who participated in the research confirm that, in practice, the formalities are fulfilled by carrying out ship procedures retroactively. In this way, the focus is on lookout duties and navigation itself, but the procedures are not properly satisfied.

The checklists are typically completed under more favorable circumstances (reduced sea traffic, improved visibility, calmer seas, and the like), to meet the requirements on keeping records and evidence. This practice is not desirable and is not in line with the legal assumption of due diligence.

The results of this research suggest that the ISM Code should be partly revised with reference to the checklists. Their use could be simplified to allow the implementation of their real purpose, i.e. reduction of human errors. Special attention should be given to the periods of time needed for completing the checklists and other forms of documentation.

It is also suggested that the ISM Code should have a digitized e-version connected with the instruments on the bridge and in the engine room. A large amount of data such as ship's position, speed, radar operation mode, ECDIS etc., can be entered automatically, allowing the flow of information from a detecting device directly to the computer. In this way the OOW can be informed without searching through the information presented by each individual device, and precious time may be spared for writing and eye adaptation (paper / screen), particularly during navigation at night. The very purpose of the ISM checklists include the informing of the officer of the watch, reminding him/her of the duties, simplified communication etc., all of which should result in increased safety at sea.

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IOT IN LOGISTICS: EFFECTS OF DECREASING NUMBER OF WASTE BIN SENSORS ON COLLECTION LOCATIONS

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ABSTRACT

Internet of Things – IoT is a new concept that is based on the most contemporary information and communication technologies (ICT) that enable marking, identification, communication and intelligent management of things. Different things equipped with identification devices become smart objects that have the possibility of identification, communication and mutual interaction. IoT enable virtual model of reality, providing ability for real-time management of different processes based on timely information on its current status.

The paper describes the concept of specific category of IoT, waste bin sensors, which are used to provide real-time information about the quantity of waste in bins on certain location. Usual concept is in installing one sensor in each of waste bins. However, because the waste quantity sensors are relatively expensive devices, the main idea of the research presented here is in assessment the effects of decreasing number of sensors installing them in every second waste bin, every fourth waste bin, etc. Assessment of the waste quantity is based on simulation modeling approach. The idea of determining effects of decreasing of waste bins equipped with sensor, is tested on numerical examples.

Keywords: Reverse logistics, Waste collection, Internet of Things, Simulation

1 INTRODUCTION

In this paper we consider application of IoT in a municipal solid waste collection systems. Municipal solid waste (MSW) collection can be seen as one of the most important challenges in today's big cities. Waste quantity follows constantly increasing trend as a consequence of population growth, urbanization and economic and technical development. The main objectives of MSW management systems are monitoring, collection, treatment, reuse and finally, safe, economical and societally acceptable waste disposal. From the logistics point of view, MSW collection is of special importance because it includes loading-unloading and hauling operations, which are responsible for 50 to 70 percent of total waste management costs. This means that even a small improvement in collection process may provide significant savings in the overall system cost (Tchobanoglous and Kreith, 2002). Similarly, Hannan et al., (2015) stated that cities are faced with solving waste collection vehicle routing problems which have direct impact to the collection efficiency, costs and environmental pollution.

Traditional approach to routing of MSW collection vehicles is based on historical data and experience, where vehicle routes are fixed, at least in certain season or the day of the week. Because of that vehicles need to break off route realization, whenever the waste quantity, after visiting certain number of collection nodes, reaches vehicle capacity, or, when waste quantity is lesser than expected, result with only partially loaded vehicles hauling waste to the destination.

However, development of technology, particularly different wireless sensors, has given additional opportunity for remote monitoring of waste bin status and increasing collection efficiency through dynamic vehicle routing. Those advances are based on Internet of Things – IoT which is a new concept based on the most contemporary information and communication technologies (ICT). IoT application can be found in different areas, from the everyday life situations to logistics, traffic control, smart cities concept, futuristic applications, etc., where one possible application is in so called "smart waste management service". This concept includes sensors embedded into bins, so that information about the waste quantity are forwarded to dispatching center, where they can be used for dynamic routing of waste collection vehicles (Zanella, A. & Vangelista, 2014). More details about the configuration of such a system can be also found in Kumar et al., (2016). However, in opposite to the potential improvements which result from the information provided by bin's fill level sensors, this concept increase operational cost due to the sensors and communication technologies price. Those costs are fairly large, particularly when they are embedded in every collection container.

The previous sentence hides in itself the main idea of the research presented. In this paper we analyze effects of decreasing number of sensors installed in collection containers on the location. More precisely, we analyzed inaccuracy i.e., expected errors in the estimated waste quantity on location in cases when not all of waste bin on location are equipped with sensors, but only some of them. In this way it is possible, based on simulation experiments results, to make trade-off between number of sensors per container and accuracy of the real-time waste quantity estimation. In other words, our idea is to give answer to the question of necessity equipping all waste bins with sensors. It is worth to be noted, that similar situation should be expected even in cases when all bins are equipped with sensors, because some sensors might get broken at waste discharging, stay with drawn batteries or at least with their abilities degraded, and thus showing those as having true status only in a limited number of bins, incorporates quite a big additional source of information noise.

The remaining part of the paper is organized as follows. The second section is devoted to description of the MSW collection system based on IoT that provide real-time waste quantity monitoring. In the section three we introduced concept of the simulation model and simulation scenarios used to answer research question given. Section four presents numerical example designed to enable simulation experiment realization, and results obtained for different scenarios. Next section concludes the paper.

2 MSW COLLECTION SYSTEM BASED ON IOT THAT PROVIDE REAL-TIME MONITORING OF THE WASTE QUANTITY

Municipal solid waste (MSW) collection is important logistics task which exists in all cities in the world with the main objective of collecting generated solid wastes in a cost effective and environmentally friendly manner. Efficiency of the waste collection has direct impact on the quality of life because of pollutants emission, from one side, and to economy from the another, due to high costs. In the same time, so high collection process related costs represent huge rationalization potential which may be achieved through optimal routing of collection vehicles. Hence, through past decades, significant effort has been made in order to improve routing decisions. An excellent example, more than forty years old, is a booklet (Shuster and Schur, 1974) which proposes heuristics and practical instructions for routing of waste collection vehicles. Since then, many researchers have been worked on vehicle routing problems in MSW collection, and reverse logistics. More details about the problems in this area can be found in Beullens et al. (2004), the book chapter devoted to those problems.

Until recent development in ICT, collection vehicle routes were usually static, based on long term estimation of waste quantities, and as such, didn't respect uncertainty of the waste quantity. Static routing approaches, in turn, resulted with necessity for braking off the route realization when waste quantity is larger than expected, or with only partially loaded vehicles when the waste quantity was smaller than expected. However, more intensive IoT application, particularly waste bins fill level sensors, supported by ICT, has provided real-time information on the waste quantity, and have given opportunity for dynamic routing of vehicles, dependent on the actual waste quantity. This concept enables "smart waste management service" (Zanella, A. & Vangelista, 2014), which includes continuous waste quantity monitoring and data transfer to dispatching center where information can be used for dynamic routing of collection vehicles. Basically, as it is stated by Anagnostopoulos et al., (2017), smart waste management system comprises three main categories:

- The physical infrastructure,
- The IoT technology and
- The software analytics.

The physical infrastructure includes waste bins, collection vehicles, vehicles' depots and landfills. The IoT technology includes sensors and communications, while the software analytics comprises data processing and real-time dynamic routing algorithms and software. From there, the main difference between traditional and so called smart waste collection systems is in IoT and ICT technologies embedded, although, of course, certain differences also exist in data processing, routing algorithms and software.

Sensors - IoT devices are the main components of the smart waste collection systems which monitor certain physical characteristics. Data observed by sensors are then transferred by short range communication systems (ZigBee, Wi-Fi, Bluetooth) to Wireless Sensor Networks (WSN), and through Long range communication systems (GSM/GPRS, VHFR) to the waste collection vehicles dispatching center. The most general concept of such a system is shown in the Figure 1.

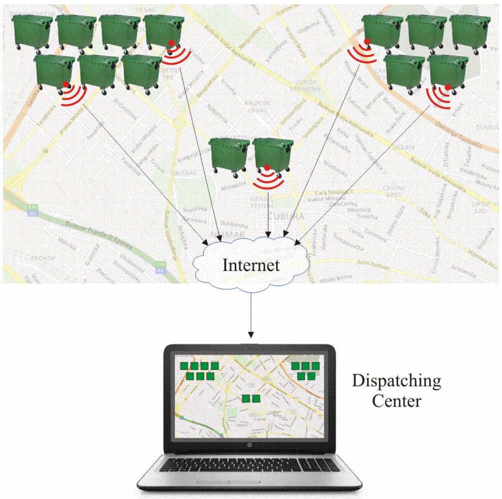

Figure 1: General concept of the smart waste management system

Waste bins fill level assessment can be based on different principles (image based sensors, weight sensors,...) but the most used concept is ultrasonic sensor (Figure 2) which send a high-frequency sound wave into the container and measures time for sound reflected back.

There are lot of companies on the market which offer ultrasonic sensors for the waste bin fill level detection, but the main shortcoming of those devices is its price, which is approximately one half of the price of $1m^3$ waste collection container. This is the reason why some of producers mention that not all containers should be equipped with fill level sensors, although they do not give exact information on the ratio of containers equipped by those devices.

Figure 2: Example of ultrasonic sensor for the waste bin fill level assessment

The previous sentence contains, also, the main idea and the objective of this research. An arbitrary waste collection location usually includes not only one, but few containers. During the period between two successive collections, waste is brought and put into the containers. It is known from the experience that containers are filled randomly, where sometimes customers use "strategy" of disposing waste to the least filled containers. When all waste containers positioned on a certain location are equipped with fill level sensors, exact quantity of waste on location is known in every moment. However, this information is costly and requires that number of fill level sensors be equal to the number of containers. Therefore, intriguing question is how accurate would be information about the waste quantity on the location, if sensors are installed not in all containers, but in every second, third, ..., or only in one container positioned on the location? In other words, our intention is to analyze effects of decreasing number of sensors have been built-in in containers on a certain collection location.

To find answer to this intriguing question, which potentially hides considerable rationalization potential, we deploy simulation modeling approach. The model proposed in this research simulate different containers' filling strategies, based on expected users behavior, monitors and estimates waste quantity on the location for different variants: every container is equipped by sensor, every second container is equipped,...etc.

3 SIMULATION MODELLING APPROACH

To simulate the process of waste disposal and filling containers, let consider the set N of waste collection locations $i \in N$, where each location includes sebset n_i of waste collection containers $j \in n_i$. Without loss of generality, it is assumed that all collection containers have the same capacity Q. Number of collection locations $|N|$, in each simulation experiment, corresponds to the number of locations are visited in one collection route which is random variable, and vary between $N_{\min} \le |N| \le N_{\max}$ in accordance to the known probability distribution, where N_{min} and N_{max} are based on historical data related to a certain collection zone. Similarly, number of containers $|n_i|$ on a certain collection location depends on the expected quantity of the waste generated by users oriented to that location, is also random variable and vary between $n_{\min} \le |n_i| \le n_{\max}$ in accordance to known probability distribution, where n_{min} and n_{max} are based on historical data related to certain collection zone.

Filling containers on a collection location is the stochastic process in which random number of users bring random quantity of the waste and dispose it into the containers. This process is simulated by multiple generation of the random variable q_d, with known probability distribution, and expectance $\bar{q}_d$, that describes waste quantity in one disposal, which is also the quantity of the waste brought by user. Total expected waste quantity $\bar{Q}_i$ disposed on collection location $i \in N$ should correspond, with some safety coefficient $\xi < 1$, to the capacity of all available containers on the location, i.e. $\bar{Q}_i = \frac{D_i \bar{q}_d}{\xi}$. In the model we fixed number of disposals, and while simulating random quantity of waste in one disposal, we allowed containers overloading when happened.

Because the waste quantity in any particular collection container $j \in n_i$, depends on the users' behavior when making choice on the container being used for disposal. To simulate users' behavior, in the model we considered three strategies:

- random choice strategy
- smallest quantity strategy
- probabilistic strategy

First strategy assumes random choice between containers available on the location. Second strategy is based on the concept in which choice of the container will be used for disposal depends on the current quantity of the waste in container. Accordingly to this strategy, on each disposal user choose the container with the smallest current quantity of waste. Third strategy is also based on the concept in which choice of the container depends on the quantity, but at the moment of disposal, to every container on the location is associated probability to be chosen, inversely proportional to the current quantity of waste inside. Lesser quantity - more preferably. However, for the case of the second, and the third strategy, disposal preference is considered only when containers are filled to $2/3$. Until then, container choice is based on random filling strategy.

The simulation model considers five variants for the number of sensors n_{si} have been built-in in the containers on an arbitrary collection location $i \in N$:

- one sensor for every two containers on the location ($s=1$)
- one sensor for every four containers on the location ($s=2$)
- one sensor for every six containers on the location ($s=3$)
- one sensor for all containers on the location ($s=4$)
- each container on the location is equipped with sensor ($s=5$)

Number of sensors n_{si} on the location, for the first three variants $s=1,2,3$ is determined by ceiling function which rounds up ratio of the number of containers on the location

$|n_i|$ as shown in (1). Number of sensors n_{si} on the location $i \in N$, for the variants $s=4,5$ is obvious: $n_{4i}=1$, $n_{5i}=|n_i|$. Assignments of sensors to particular containers in variants $s=1,2,3,4$ is random.

$$n_{si} = \begin{cases} \left\lceil 0.1 + \frac{|n_i|}{2s} \right\rceil, & s=1 \vee s=2 \\ \left\lceil 0.2 + \frac{|n_i|}{2s} \right\rceil, & s=3 \end{cases} \tag{1}$$

Estimation of the waste quantity on the location is based on waste quantities disposed to containers equipped with fill level sensors. The quantities in containers that were measured are averaged, and this average value is used as estimate for waste quantity disposed in one container. That is, if Q_{si}^M is the total waste quantity that were measured in all containers equipped by sensors on location $i \in N$, in variant s, then the estimate of the waste quantity in one container is, and estimated waste quantity on the location is $|n_i| Q_{si}^M / n_{si}$. Calculated estimates for all defined number of sensors variants $s=1,2,3,4$ compared with the variant s=5 give opportunity for assessing effects of number of sensors decreasing.

The main structure of the simple simulation model used to examine effects of decreasing number of sensors on collection locations is presented in the form of pseudo code in the Figure 3.

```
for simulation h=1,...,h_max
# create collection network configuration
|N|  |n_i|
for location i=1,..., |N|
for number of sensor variants s=1,...,4
# random assignment of sensors to containers
n_is sensors to |n_i| containers
for number of containers j=1,..., |n_i|
# random filling containers up to 2/3
for number of disposals d=1,...,D_i
if "random choice strategy"
# random filling containers following random strategy
if "smallest quantity strategy"
# filling container with the smallest quantity
if "probabilistic strategy"
# roulette wheel filling container
# simulation statistics collection
```

Figure 3: Pseudo code of the simulation model

4 NUMERICAL EXPERIMENT AND SIMULATION MODEL RESULTS

Simulated waste collection network is based on the New Belgrade's network characteristics, where each simulation experiment corresponds to one collection route realization. In New Belgrade, collection route visits between 12 to 20 collection locations with 2 to 12 containers of 1.1m^3 capacity on each. Quantity of waste per disposal is considered as a percentage of the collection container capacity, so that 1/3 of the capacity is filled after $D=5$ disposals, while it is also assumed that the number of containers are dimensioned so that 80% of its capacity accepts total expected quantity of waste on a location ($\xi = 0.8$). Based on that, in simulation we used following inputs:

- number of collection locations $|N| \sim U(12,20)$
- number of collection locations $|n_i| \sim U(2,12)$
- percentage of 1/3 of total containers capacity on the location $q_d \sim N(80/3, \sigma)$ - standard deviation is varied $\sigma = 3,7,15$

Total number of simulations for defined variants of standard deviation, and for each defined container filling strategy was 500, where each simulation corresponds to one collection route realization. Results of simulation experiments are shown in Tables 1,2 and 3. As a estimates of the effects of decreasing number of sensors on collection locations, for each variant of number of sensors we calculated average absolute relative error, standard deviation of the error, and minimal and maximal errors observed through the simulation.

Table 1: Errors in waste quantity estimations for the case of random choice strategy

ERROR σ=3	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	1.1313	1.9187	2.2441	2.6836
StDev.Rel.Err [%]	0.9756	1.5426	1.7378	2.0169
Max.Rel.Err [%]	7.7206	10.9586	11.7429	11.7429
Min.Rel.Err [%]	0.0002	0.0003	0.0023	0.0030
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	0			
ErrLocation (s=2)	0.0251			
ErrLocation (s=3)	0.0628			
ErrLocation (s=4)	0.2261			

ERROR σ=7	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	2.6688	4.5444	5.2250	6.1777
StDev.Rel.Err [%]	2.2818	3.6306	4.1059	4.7458
Max.Rel.Err [%]	19.8195	24.4450	25.0673	26.5056
Min.Rel.Err [%]	0.0008	0.0002	0.0002	0.0002
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	1.2718			
ErrLocation (s=2)	8.4165			
ErrLocation (s=3)	13.0175			
ErrLocation (s=4)	20.1247			

ERROR σ=15	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	5.7176	9.7311	11.2616	13.4323
StDev.Rel.Err [%]	4.8321	7.8258	8.7779	10.2503
Max.Rel.Err [%]	39.9837	56.3471	56.6022	62.6550
Min.Rel.Err [%]	0.0015	0.0028	0.0002	0.0002
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	16.1977			
ErrLocation (s=2)	39.7037			
ErrLocation (s=3)	47.3730			
ErrLocation (s=4)	55.1668			

Table 2: Errors in waste quantity estimations for the case of smallest quantity strategy

ERROR σ=3	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	0.9358	1.5850	1.8301	2.1870
StDev.Rel.Err [%]	0.7965	1.2042	1.3074	1.4200
Max.Rel.Err [%]	5.5336	6.8653	6.9996	7.1164
Min.Rel.Err [%]	0.0004	0.0000	0.0006	0.0006
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	0.0000			
ErrLocation (s=2)	0.0000			
ErrLocation (s=3)	0.0000			
ErrLocation (s=4)	0.0000			

ERROR σ=7	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	1.1281	1.8788	2.1711	2.6060
StDev.Rel.Err [%]	0.9704	1.4486	1.6095	1.7806
Max.Rel.Err [%]	6.7400	9.2417	10.7849	11.4846
Min.Rel.Err [%]	0.0003	0.0000	0.0003	0.0000
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	0.0000			
ErrLocation (s=2)	0.0000			
ErrLocation (s=3)	0.0250			
ErrLocation (s=4)	0.1123			

ERROR σ=15	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	1.6016	2.6385	3.0493	3.6139
StDev.Rel.Err [%]	1.4046	2.1547	2.4064	2.7010
Max.Rel.Err [%]	14.0358	18.7881	18.7881	18.7881
Min.Rel.Err [%]	0.0000	0.0007	0.0005	0.0007
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	0.0749			
ErrLocation (s=2)	0.9607			
ErrLocation (s=3)	1.6719			
ErrLocation (s=4)	2.9195			

Average absolute relative error, in tables 1, 2 and 3 denoted as *Avg.Rel.Err*, is calculated in accordance to the expression (2).

$$Avg.\mathrm{Re}l.Err = 100\frac{|ExactQ - EstimatedQ|}{ExactQ} \qquad (2)$$

In the expression (2), *ExactQ*, denotes real quantity observed in case that all containers have a sensor, while *EstimatedQ* denotes calculated estimates for all defined number of sensors variants $s=1,2,3,4$.

Table 3: Errors in waste quantity estimations for the case of probabilistic strategy

ERROR σ=3	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	4.0555	7.3206	8.8571	11.5133
StDev.Rel.Err [%]	3.6300	6.7426	8.3127	11.2655
Max.Rel.Err [%]	26.7713	46.7769	48.1980	48.1980
Min.Rel.Err [%]	0.0007	0.0007	0.0007	0.0007
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	7.8402			
ErrLocation (s=2)	27.2899			
ErrLocation (s=3)	34.8159			
ErrLocation (s=4)	42.2541			

ERROR σ=7	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	4.6401	8.1786	9.8266	12.8095
StDev.Rel.Err [%]	4.0288	7.3630	9.0258	12.3311
Max.Rel.Err [%]	33.7415	49.1617	52.1312	56.6403
Min.Rel.Err [%]	0.0009	0.0016	0.0016	0.0004
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	10.8169			
ErrLocation (s=2)	31.2405			
ErrLocation (s=3)	38.1493			
ErrLocation (s=4)	45.2597			

ERROR σ=15	s=1	s=2	s=3	s=4
Avg.Rel.Err [%]	6.2307	11.1019	13.2591	17.1680
StDev.Rel.Err [%]	5.2663	9.7192	11.7819	15.1097
Max.Rel.Err [%]	50.5696	68.1720	69.7838	76.5627
Min.Rel.Err [%]	0.0013	0.0007	0.0007	0.0016
Percent of locations with Max.Abs.Rel.Err >10 [%]				
ErrLocation (s=1)	20.5625			
ErrLocation (s=2)	43.6875			
ErrLocation (s=3)	49.8875			
ErrLocation (s=4)	56.5000			

As additional measure of the effect that could be expected from decreasing number of sensors built into the containers on the location, we calculated percents of locations where the maximal relative error (*Max.Rel.Err*) is larger than 10% (*ErrLocation*). The idea is to more precisely show maximal expected error, since this error itself may corresponds to only one realization of the simulation experiment. The results reported in tables 1,2,and 3 show that the idea of decreasing number of sensors on the location, by installing sensors in every second, third,...etc. container may have practical application, particularly when the stochasticity level of the quantity of disposed waste is not so big. Obviously, errors observed by simulation are not so huge, even when standard deviation from the expected disposed waste quantity is close to 30%. Illustration of the average absolute relative errors, observed in simulation experiments for the random choice strategy, is given in the Figure 4. Diagrams on the figure 4 show that "controlled" disposal, when containers with smaller quantity are filled first, gives more accurate estimation of the waste quantity, what is expected. However, disposal order based on probabilities give the worse waste quantities estimates, probably because of introducing more stochasticity to disposal process.

Particularly for the case when sensors are installed in every second container, errors estimated by simulation are very small, while in the same time needed investments into the sensors are 50% lesser.

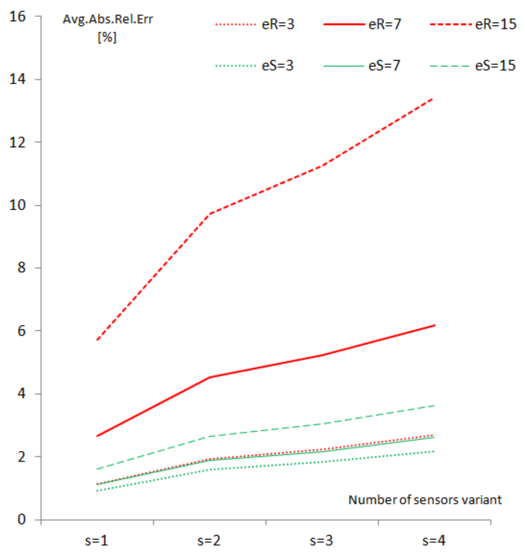

Figure 4: Average absolute relative errors for random choice strategy (R) and smallest quantity strategy (S)

5 CONCLUSION

In this paper we tried to find answer to the intriguing question of decreasing number of sensors for real-time measuring quantity of waste. Use of wireless sensors for remote monitoring of waste disposal containers is relatively new technology based on advances in ICT and IoT application, used to increase waste collection efficiency through provision the opportunity for dynamic routing of collection vehicles which potentially hides considerable rationalization potential

To analyze effects of decreasing number of sensors we deployed simulation model based on three strategies intended to imitate user behaviour in choosing the container for waste disposal: random choice of the container, choice based on the smallest quantity of waste in the container, and probability based choice.

We considered four variants for decreasing number of sensors installed in group of containers on the location: one sensor for every two containers, one sensor for every four containers, one sensor for every six containers, and a variant in which only one sensor is installed on the location. To compare effect, we also simulate variant in which all containers are equipped with sensor.

The results of the simulation modeling approach show that the idea of increasing number of sensors may have potentials for application, since the estimated errors in collected quantity seem to be inside acceptable limits.

However, results of the research presented we consider only as a first step and begining of some wider research which should include not only adoption of the simulation model, but also empirical investigation of user behaviour and disposal dynamics.

Additionally, it is needed to analyze some advanced concepts in IoT development which include analysis of IoT fusion concepts which easily become important research direction which includes combining few different, but cheap sensors instead use of pretty expensive concept of ultrasonic devices.

Finally, it could be concluded that presented results are promissing and that are shown certain rationalization potentials.

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APPLICABILITY OF NOVEC 1230 SYSTEM ON BOARD, IN TERMS OF ITS ENVIRONMENTAL FRIENDLINESS AND SUSTAINABLE DEVELOPMENT IN MARITIME TRANSPORT

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ABSTRACT

Due to the ever-growing world economy, increased demand for freight space and the growth of maritime traffic itself, there is a need for safer ships from the view of fire protection.
Release of different media into the atmosphere for the purpose of extinguishing fires, in different places, on land and sea, presents a serious problem for the human health and ecosystem due to long-term disintegration of the media into the atmosphere.
Due to the above-mentioned facts that directly affect ecology, economy, development of plant and animal organisms, needs for environmental conservation have emerged. Efforts to obtain a media that will meet all demanding standards and requirements have been made in order to obtain an adequate solution.
Comparison of the Novec gas with other most prominent fire extinguishers will be presented, in areas of safety margins, ozone depletion coefficient and required degradation time in atmosphere.

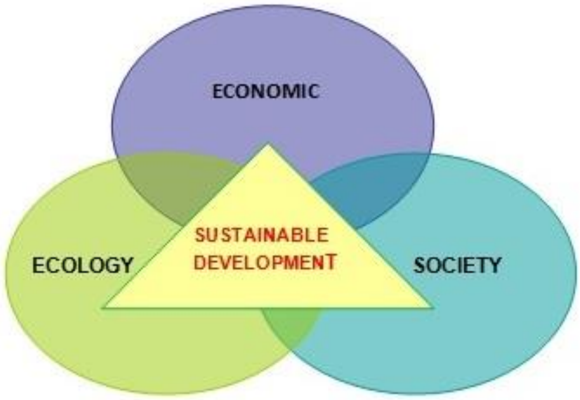
Keywords: NOVEC 1230, sustainable development, ecological acceptability

1 INTRODUCTION

Maritime industry, as a key component of the global supply chain, is expected to safeguard life and ensure safe operations at sea and at the same time protect the marine environment. All involved parties must administer between regulatory framework which is constantly evolving, driven by geopolitical events and technological advances.

According to the available data 90% of EU foreign trade and 40% of trade between EU member states take place by sea. More than 3.7 billion tons of cargo is transported in EU ports annually, and more than 400 million passengers pass through European seaports and these figures are growing [1]. Further increase in maritime traffic is to be expected. One of the basic principles of maritime transport in the EU is freedom of movement of services with a high level of safety, good working conditions and high ecological standards.

Ecological standards are correlated with sustainable development. The concept of sustainable development was presented in 1987, by the World Commission on Environment and Development (Brundtland Commission). At the United Nations Conference on Environment and Development (UNCED) in 1992, worldwide attention was focused on the increasing problems related to the issues of development and environment at local and global level. During the last 20 years there were a lot of activities on the issue. The United Nations Conference on Sustainable Development (UNCSD) 'Rio + 20', held in Rio de Janeiro in 2012, has set a comprehensive framework for sustainable development. One of the most significant decisions of the Conference is to define the future Sustainable Development Goals -SDGs, which will include three dimensions of sustainable development: economical, social and environmental (Figure 1) that need to be linked to the development policies contained in the Millennium Development Goals-MDG’s and to represent the global development agenda for the post-2015 period.



Source: authors

Figure 1: Concept of sustainable development

Maritime industry is also trying to keep pace. From conventions and regulations, set by the International Maritime Organization, insight about the cost to achieve legal compliance and the issues affecting enforcement are of great importance for ship-owners, shipbuilders and equipment suppliers.

2 FIRE SUPPRESSION SYSTEMS

Fire suppression systems are commonly used in areas that require reliable fire protection and in highly hazardous areas that have critical uses such as engine room, control rooms, storages containing hazardous materials etc.

In response to the ban on Halon 1301 production, the fire extinguishing industry responded with the development of alternative ecological means, so called clean agents, which represent smaller threat to the ozone layer. The clean agents are gases which can flood protected area completely allowing rapid extinguishment of fire and leaving no residues after discharge.

As replacements various agents have emerged: carbon dioxide (CO2), inert gases, halocarbons gases and latest Novec 1230.

Carbon dioxide (CO2) is odorless, colorless and electrically non-conductive gas, which is very effective as a fire suppressor. His high expansion rate enables to function quickly. His advantage lies in efficient fire suppression of most materials, with the exclusion of active metals, metal hydrides and materials containing their own oxygen source, such as cellulose nitrate [2]. Inert gas, as firefighting agent, contains one or more primary components such as the helium, neon, argon or nitrogen gases, and extinguishes fire by reducing the oxygen content below 15% [2]. The halocarbon agents[1] are carbon-based compounds when activated work on principle of chemical reaction and extinguish the fire by absorption of heat.

In practice, marine extinguishing systems are divided in two broad categories: sprinkler systems and gas systems. The first can suffer leakage or cause potentially high damages and data loss for electrical systems or control rooms when applied. On the other side CO2 systems can cause catastrophic effect given its physical pressures. Advantage of halocarbon gases lies in fact that their use does not high pressure [3].

Overall, the value of the marine assets that fire systems protect is increasing, but the competitive nature of the free market in the marine and fire industry places great pressure on it to deliver systems which often minimally comply with the regulations and deliver the protection at the most economical cost [4].

3 FIRE SUPPRESSION AGENT - NOVEC 1230

Since the beginning of development Novec 1230 fire extinguishing agent is intended to completely replace the former Halon in a way that is safe, effective and present a long-term solution in situations of firefighting on ships [5]. At the same time have certain advantages over other fire extinguishing media on ships regarding its low toxicity coupled with high efficiency in fire extinguishing. The gas is stored in a liquid state in tanks under pressure of 25-40 bars at 21 ° C [6]. In order to guarantee the efficiency of the extinguishing system, it is necessary to have a precisely defined design solution. Also, it is important to note that the discharge time of the media must be no longer than 10 seconds. Under these conditions it successfully extinguished all types of fire within ten seconds from the moment of activation and most important, it is completely harmless to people [7].

When activated, it is quickly dispersed, enabling it to be used in all areas, like in sensitive electronic and navigation equipment areas, especially in those where people are present. In relation to the other fire extinguishing systems, which use foam or dry powder, it leaves no residues that need to be subsequently cleaned, which allows the usage without damaging the ships equipment.

During the development and emergence of Novec 1230 gas for fire-fighting, special attention is devoted to the prevention of environmental pollution in order to meet the stringent requirements of modern society. This gas, as completely clean fire extinguishing agent, represent the first serious alternative to the current media, particularly regarding the preservation of the ozone layer and preventing climate change.

Emphasis of Novec 1230 system is an extremely slight influence on the environment and the ozone layer. With great efficiency and speed in extinguishing the fire, it's most important characteristic is a short decomposition time in the atmosphere of five days [8, 9].

Since it does not damage the ozone layer, it quickly breaks down into the atmosphere and has a very low coefficient of Global Warming Potential (GPW = 1) and very good Ozone Depletion Potential Index (ODP), placing it in the lead position for Halon replacement. These characteristics make it the most environmentally friendly gas of today [10].

The media that were used before demanded tens, hundreds or even thousands of years to degrade after release. In contrast, Novec 1230 quickly degrades after being discharged into the atmosphere. Exposure to natural sunlight causes cracking of the material in the next few days. However, this material remains stable under normal storage conditions, such as in a fire extinguisher system [8].

As electrically non-conductive it is ideal for protecting machinery spaces, cargo pumps rooms, cargo compressor rooms, IT rooms, server rooms, telephone exchanges, electronics [6].

4 COMPARISON OF FIRE SUPPRESSION AGENTS

Comparison of fire suppression agents will show risks and benefits associated with them. National Fire Protection Association - NFPA issued the Standard for Clean Agent Fire Extinguishing System for Halon substitutes- NFPA

[1] In literature also known as Sythetic/Chemical agents

2001, edition 2012. National Fire Protection Association –NFPA deals with two types of fire suppressors, inert gas and halocarbon agent. Associated health and environmental risks with those agents are different [11].

It is a general recommendation that for areas that cannot be abandoned for less than one minute is defined by No Observed Adverse Effect Level- NOAEL, and for those areas which can be evacuated within one minute the permitted concentration is defined by Lowest Observed Adverse Effect Level - LOAEL [11]. Since the Novec 1230 offers a much wider safety margin than other carbohydrate or inert gas based agents, their use does not exceed the safety boundaries in ship systems- table 1.

Table 1: Comparison of fire suppressant agents regarding human health

	Halon 1301	CO2	Inergen (IG-541)	Argonite IG-55	FM 200 (HFC-227)	**FE 25 (HFC-125)**	**Novec 1230**
Designed concentration	5 %	34 %	34,2 % - 38,5 %	37,9 % - 42,7 %	5,2 % - 6,7 %	8,7 % - 9.0 %	4,4 % - 4,7%
NOAEL	5 %	< 7 %	43 %	43 %	9 %	7,5 %	10 %
LOAEL	n/a	n/a	52 %	52 %	10.5 %	10 %	>10 %
Safety margin	11 %	0 %	7 %	7 %	14 %	0 %	82 %

Source: authors as per [3, 11, 12]

Use of firefighting agents presents a potential danger to the environment.

In table 2 comparisons of agents, in terms of environmental concerns, is carried out.

Table 2: Comparison of environmental features of Novec 1230 and other media used for fire protection

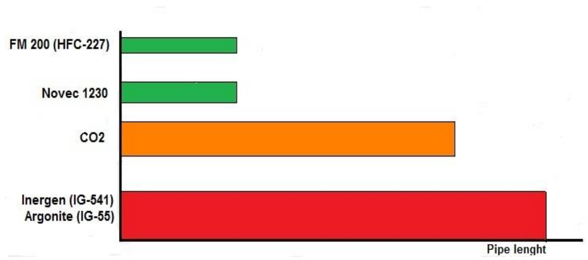
	Halon 1301	**CO2**	**Inergen (IG-541)**	**Argonite IG-55**	**FM 200 (HFC-227)**	**FE 25 (HFC-125)**	**Novec 1230**
Ozone Depletion Factor (ODP)	12.0	0	0	0	0	0	0
Global Warming Potential (GWP)	7140	0	0	0	3220	3500	1
Atmospheric Lifetime (years)	65	0	0	0	37	29	0.014

Source: authors as per [2, 5, 11]

As indicated in table 2, CO2 and inert gases have no impact the environment. On the other side, halocarbons gases have great impact on the environment. Novec 1230 gas is exception with low GWP and short atmospheric lifetime.

According to Material Safety Data Sheet-MSDS for FE 25 (HFC-125) which states that agent is not flammable in air under ambient conditions of temperature and pressure. But, when pressurized with air or oxygen the mixture may become flammable [13]. Considering that fact agent will be eliminated from further comparison.

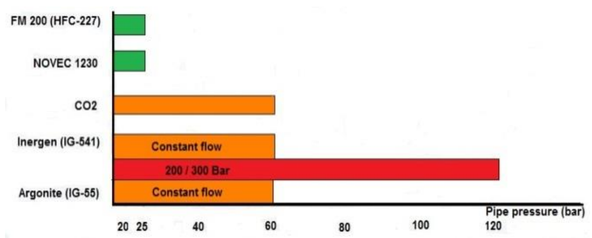
Complexity (pipe length) and required time for installation are issues which must be dealt with. Although IG agents are excellent for environmental issues, installation complexity and required time pose a great obstacle for marine use, as shown in graph 1.



Source: authors as per [14, 15, 16, 17, 18, 19,20]

Graph 1: Comparison of firefighting agent's complexity and installation time

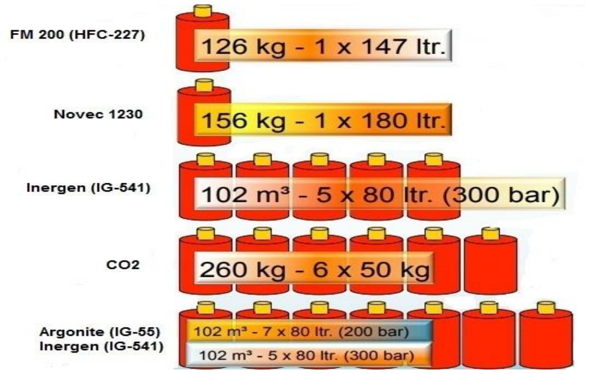
Working (pipe) pressure is also crucial for fire systems. Graph 2 indicates required pipe pressure for each agent. Inert gases and CO2 are lagging behind other firefighting agents because they require a significantly higher working pressure.



Source: authors as per: [14, 15, 16, 17, 18, 19,20]

Graph 2: Comparison of firefighting agents working pressures

Amount of required firefighting agent also have an important role. To extinguish a fire in average room of 200 m3 different amount per selected agent is required- graph 3.



Source: authors as per [15]

Graph 3: Comparison of firefighting agent's cylinder footprint

5 DISCUSSION

According to available data, agent with the widest safety margin between design concentration and LOAEL is Novec 1230 with safety margin of 82%, followed by FM-200 with safety margin of little above 10%. On the other side Inert gases present a hazard due to fact that their safety margin is around 7%.

Inert Gas systems discharge the agent under high pressure which will displace up to 40% of ambient atmosphere in order to sufficiently reduce oxygen level. Displaced atmosphere requires vent system in order to avoid over pressurization.

Other disadvantage is that Inert Gas systems require six times more storage space than a clean agent system followed by a high pressure discharge pipe and fittings. On the other side Inert Gas systems are cheap to refill compering them with clean agent systems which are more expensive to refill due to fact that the extinguishing gas is more expensive.

Clean Agent systems require smaller number of cylinders under lower pressure. Negative side is they tend to cause breakdown if exposed to temperature above 500°C which can be near the hazard area or in an adjoining room. By installing and designing the system properly this issue can be solved easily.

CO2 is most commonly used system on of the ships. Maintenance of the same is allowed only for certified service companies, which place the lowest bid for the job. Due to fact that ships are available only for few hours while alongside, quality of inspecting and servicing comes to question. Common procedure for inspection of only one component of CO2 system is to dismantle and weight each cylinder separately. In past, average time for dismantling, weighing, recording and re-assembling was around 40 minutes. Using modern instruments, like type approved ultrasonic liquid level reader, cylinder level condition can be checked in 30 seconds which gives average time of 1-3 minutes to record and validate readings. Considering that CO2 system comprises from two hundred to six hundred CO2 cylinders per ship, it still requires a considerable amount of time for proper inspection. Often, marine service companies may not have the enough time to perform detailed inspection. Furthermore, there are some marine service companies who are said to randomly check cylinders and place sticker "tested" on the rest [4]. Following this allegations interviews with professional seafarers were carried out on the topic. No one could confirm them, with certainty, but the time used for the inspections and servicing left some doubts.

Question which arises after analyzing difficulties and associated risk during inspections is why these systems are not permanently monitored using the benefits of modern technology, instead of leaving them unsupervised until next annual inspection. Accidental discharge or slow seepage from cylinders is a real possibility. According to some marine service companies estimations is that at one time 20% of all CO2 cylinders on ships have partially leaked or have discharged their contents into atmosphere. Estimation is that at any time 55,000 commercial vessels are present at sea [4].

The precise number of ships which have partially filled or empty CO2 cylinders and cases of accidental discharges or leakages are kept undisclosed and unknown. In other critical industries, like nuclear and airline industry, cases of errors or faults are quickly and openly distributed between operators, authorities and engineering organizations. In shipping industry situation is often opposite. Public is informed only in cases when fatality occurs. Numerous tragically events and accidents, related with CO2, did occur in near past [2, 4, 21].

6 CONCLUSION

Loss of machinery and equipment, complete shutdown of operations and lost data are risks that pose a major threat to shipping companies. Business operations with unique, highly technical and information devices depend on the safety and availability of this equipment.

Therefore, it is inevitable to expect a growing demand for increased fire safety. It is necessary to choose such a type of firefighter that will quickly and efficiently extinguish the fire without leaving any major consequences on the equipment.

Novec 1230 is toxicologically harmless agent that will extinguish fire class A (solid), class B (flammable liquids) and class C (energized electrical equipment) within 10 seconds. Since it has a high safety margin such media is ideally for extinguishing fires in areas where people are present. In addition to compliance with strict environmental criteria of the Kyoto Protocol and the short decomposition time in the atmosphere, benefits of Novec system compared to other media are substantial.

Based on the above it can be concluded that Novec 1230 is a long-term solution that meets all safety, ecological and technical standards, and its installation should be applied especially in new buildings. The cost of installing this type of fire protection probably has a significant impact on its low representation, but by mass production cost will be corrected and will become more acceptable. Fire protection in shipping industry must address the safety of people, property and environment.

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COMPARISON OF CLIMATE CHANGE COST OF FREIGHT ROAD, RAIL AND MARITIME TRANSPORT

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ABSTRACT

Among various types of external costs in the transport sector, climate change costs are easily followed and studied in a certain period, as they are expressed only through carbon cost summarizing the impact of all greenhouse gases released in traffic. Considering incomparable research data in a ten year period, expressed in different units they are harmonized in order to become comparable. In this shape, the freight road transport shows better results in this category than freight rail and maritime transport. Rail and maritime transport are marked as more sustainable transport modes having low external costs, but it needs to recall that a large capacity and absence of accidents and congestion are mainly responsible for such characteristics. The comparison points to stagnation in the implementation of possible reduction of impacts of these modes of transport on climate changes in the observed period.

Keywords: external cost, climate change cost, CO_2, freight transport

1 INTRODUCTION

External costs in traffic express monetary value of damage caused by traffic to the environment and human health. Although the research had existed earlier, INFRASS/IWW study in 2000 founded the modern research of external costs and provided first systematic results with a comprehensive approach in terms and methodology (Banfi et al., 2000; Doll, 2001). Many approaches, opinions, methods of calculations and policies have been changed since then. All efforts have been made in order to make external costs as less as possible. Technological improvements of engines and fuels, “green” logistics in transport, tax policy, intermodal transport and other measures, more or less, influence the external costs. The values, expressed in various units, can be found in handbooks published periodically and supported by the European Union. Comparing the data from handbooks one can find out the trends of external costs in traffic in some observed period. Generally, total external costs in road transport are 10 to 20 times larger than in rail and maritime transport. Showing the trends in climate costs of various modes of transport is the objective of this paper.

2 CLIMATE COSTS

Climate costs are the type of external costs that measure the impact of traffic on climate changes. The climate change is generally described as global warming as a result of greenhouses gases (GHG) emissions. In 2015, the transport sector was responsible for 25.8 % of total EU-28 greenhouse gas emissions (EEA, 2017). The costs have been calculated either as the avoidance, damage or opportunity costs (Korzhenevych et al., 2014). Although the impact on global warming of some individually GHG, as methan (CH_4) or nitrous oxide (N_2O), is 25 to 298 times larger than the same amount of CO_2 (Parry et al., 2007), the final amount of all GHG is negligible related to the amount of CO_2. This is the reason why the methodology of calculation of climate changes caused by traffic was changing. Today, the avoidance costs are calculated by multiplication of the total tonnes of CO_2 equivalent GHG emission by external cost factor dependent on the actual carbon cost (Van Essen et al. 2008). The share of climate costs in total external cost can reach up to 30%, so determining the carbon price is not only economic but also a political problem (Schreyer et al., 2004).

Despite the problems mentioned above, as well as the sensibility and uncertainty in climate change research, the calculation of climate costs is relatively simple in relation to the calculation of other types of external costs. It enables relatively easy comparison of climate impacts of various modes of transport. So, it is possible to follow that impact during the time as well as the results of improvements applied in each individual transport mode to decrease both climate costs and external costs in total.

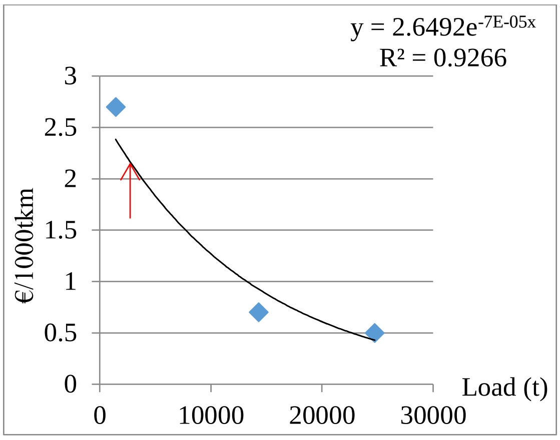
3 PREPARING THE DATA AND CALCULATION

The research of climate costs of three freight transport modes in the 15 year period was performed using data from three most important handbooks of external costs in transport sector published 2004, 2008 and 2014 (Schreyer et al., 2004; Maibach et al., 2008; Korzhenevych et al., 2014). The data from three periods have been compared to show the behavior and trends of costs and results of the efforts to decrease them.

The values expressed in €/1000 tkm, €ct/tkm, €ct/trainkm, €ct/vehiclekm and €ct/shipkm have been converted into €ct/tkm using loading factor (LF) 32 t per vehicle, LF 348 or 500 t per rail and LF 3000 t per ship (bulk carrier) as noted in the sources. Loading factor for road transport in 2004 was not defined. The data from 2004 were available in variants of low and high scenario as usually in that time.

Only the values of low scenario have been used in the calculation (Schreyer et al., 2004).

The values for diesel train on the non-urban route as well as for rigid truck on the motorway have been considered. Electric rail transport is not comparable in this research. EURO V emission standard for road traffic did not exist until 2008. Since 2013, EURO VI standard was established but, as not applied on a large scale so, it has not been considered (Dieselnet, 2016). There was no value of external cost in maritime transport until 2008 in the handbooks used. The presented value in 2004 is related to inland waterway transport. This has been compared with the same value in 2008 as well as with the value of maritime transport from another source (Maibach et al., 2008; Maffii et al., 2007). The appropriate value for maritime transport, (bulk carrier, LF 3000) in 2014 has been defined by exponential regression (Figure 1) using available data from the handbook (Korzhenevych et al., 2014). Everything was done to get comparable data for all the periods.



(calculation value-red arrow)

Figure 1: Regression analysis of climate costs of bulk carriers in 2014 considering capacity changes

The values of cost of CO_2 have been taken from the same sources of data and used for further calculation. The external costs expressed in €ct/tkm have been divided with the costs of CO_2 in €/t used by each individual handbook to bring the data to the final common denominator and become comparable. The obtained results have been multiplied by 1000 to get whole numbers. The input data taken from handbooks before they have been processed are shown in Table 1.

Table 1: Climate cost data and units taken from the handbooks

Transport mode	INFRAS/IWW 2004 (20 €/tCO_2)	CE Delft 2008 (25 €/tCO_2)	RICARDO AEA 2014 (90 €/tCO_2)
Maritime LF 3000 t	0.6 €/1000tkm*	2.05 €ct/shipkm*, 0.29 €ct/tkm**	2.7€/1000tkm, LF 1440 t
Rail	0.5 €/1000tkm	28.9 €ct/trainkm, LF 348 t	0.26 €ct/tkm, LF 500 t
Road, LF 32 t EURO II EURO V	1.8 €/1000tkm*** /	2.0 €ct/vehiclekm 1.9 €ct/vehiclekm	7.9 €ct/vehiclekm 6.7 €ct/vehiclekm

*inland waterways data

**75€/tCO_2 (Maffi et al., 2007)

***LF unknown

The value of 2.7€/1000tkm was converted to 2.2€/1000tkm as a result of equation from Graph 1 for LF 3000. Each individual handbook presents the data in different measurement units. All values have been converted to the unique unit, €ct/tkm. Their overview is shown in Table2.

Table 2: Climate costs of freight transport by modes in three observed periods in €ct/tkm

Transport mode	INFRAS/IWW 2004 (20€/tCO_2)	CE Delft 2008 (25€/tCO_2)	RICARDO AEA 2014 (90€/tCO_2)
Maritime	0.06*	0.07*, 0.29**	0.22
Rail	0.05	0.08	0.26
Road EURO II EURO V	0.18 /	0.0625 0.0593	0.2468 0.2093

*inland waterways data

**75€/tCO_2, (Maffi et al., 2007)

In this form, the values have not yet been comparable as they had been calculated with different carbon cost inputs. The data have finally been divided with the carbon prices used in sources to get the units by the cost of 1 €/tCO_2 (0.1€ct/kgCO_2) (Table 3).

Table 3: Climate costs of freight transport by modes during three periods in €ct/1000 tkm (1€/tCO_2)

Transport mode	INFRAS/IWW 2004	CE Delft 2008	RICARDO AEA 2014
Maritime	(3)*	(2.8)*, 3.9	2.4
Rail (diesel)	2.5	3.2	2.8
Road EURO II EURO V	 9 /	 2.5 2.4	 2.7 2.3

*inland waterways data

The numeric results, as well as Figure 2 show decreasing of climate costs in all three transport modes in observed period.

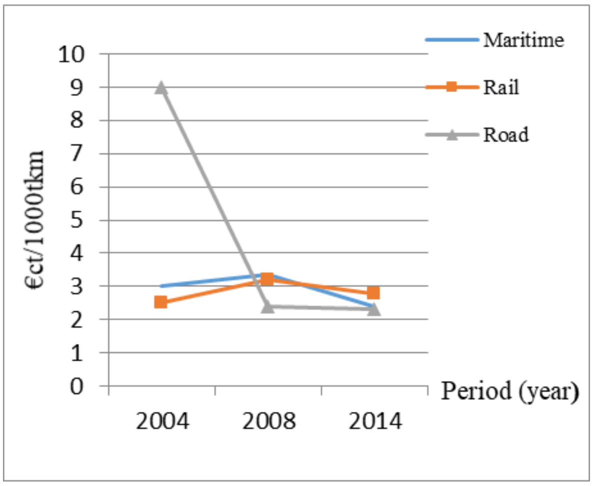


Figure 2: Changes of the results during the observed period

4 DISCUSSION

Current European Union transport policy supports shifting the freight off the road to decrease the damage of transport on the environment and human health (White Paper, 2011). By promoting the intermodal, maritime-rail transport, it advocates for decreasing the external costs as much as possible. Such policy resulted in increased awareness of the ecologically negative impact of transport. According to research, some approaches were radically changed in last twenty years. In the beginning, the impact of maritime traffic on climate change was presumed as negligible, but today it is marked as the main factor coming from the traffic, responsible for 3.5-4% of all climate change emission (Vidal, 2009). The premise based on the electric railway in resolving that negative impact failed by increasing the trains' speed (and emissions consequently) and especially, calculating the external costs of infrastructure and upstream and downstream processes. It is estimated that about 30% of the external costs of these processes are climate cost (Maibach et al, 2008). It shows that only change of traffic mode is not enough. Technological development of both the engine and fuel improved the results of all three transport modes. The comparison of those improvements is not easy, and inappropriate presentation of results is an important reason for it. The presentation of results, e.g., in total amounts of external costs in € is useless for the comparison equally as the absence of necessary parameters. There is also a problem of current carbon cost, necessary for climate costs calculation that changes during the time resulting in calculations with various values. Finally, there are prejudices that the expected results cannot be different as they used to be. It was necessary to find all data in this research, including various carbon cost values, and bring them to a common denominator to become comparable. This complex procedure shows the level of a confusion of presented data in handbooks. The results show similar or equal values in all three transport modes but the best improvement in road traffic in the observed period as well. It is important to point out that results obtained in the research are sensitive, so little difference between them multiplied by the real carbon cost can make that difference to become significant. This wide span excludes the possibility of a wrong conclusion. Even the uncertain loading factor in 2004 cannot significantly change the presented result because the span of data dependent on load is not so wide in road transport. Moreover, given that the EURO VI standard has not been taken into calculation, real results would be even better for road transport. It is evident that European Union transport policy encouraged mainly road sector to make and apply improvements to be held on the market of transport services. The absence of accidents and congestion as well as the large capacity of rail and maritime transport modes make them sure the first choice, particularly in intermodal transport variant. They are less motivated in the implementation of modern and expensive technological achievements. The research shows how the results of a pure academic calculation can be different and unexpected in regard to analysis in a practical transport sector where other elements influence on them (accidents, congestion, capacity). Although the change of direction of freight movement among transport modes is not expected, the improvements applied in freight road transport represent the positive sign, knowing that some demands of transport service can be realized only by road transport (e.g. door-to-door service).

5 CONCLUSION

Contrary to the well-known findings of the dominant share of road transport in the total external costs, comparison of the data of climate (external) costs of freight road, rail and maritime transport in 15 year period, bringing them down to a common denominator, currently show same or similar values for all transport modes. The decreasing trend of climate costs was most evident in the road transport while stagnated in other transport modes.

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COMPARISON OF IACS CLASSIFICATION SOCIETIES PROPELLER STRENGTH CALCULATIONS

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ABSTRACT

Marine propeller is the essential ship propulsion system component from the functional point of view. It can also become a safety component in case of storm and heavy weather. For this reason all of the world wide recognized marine classification societies acting within the International Association of Classification Societies, IACS (among them Croatian Register of Shipping) prescribe their requirements for minimal propeller blade thickness from strength point of view and the procedure for its calculation in their Classification Rules.
Though IACS societies base their calculation procedures for other propulsion system components (e.g. engine crankshaft, marine gears, shafting, etc.) upon common approach prescribed in the IACS Unified Requirements publicly available and developed together by participation of all IACS societies, this does not apply to the propeller strength calculation procedures. Each IACS society has its own approach, though all of them are modelling the same physical phenomenon: ship propeller in water stream.
The aim of this paper is to compare the propeller calculation procedures by various IACS calculation societies, focusing on their results validated on a few selected propellers that have been proven in practice. The analysis presents the results in a way that it can be concluded whether a certain society underestimates or overestimates the propeller blade thickness. These results show that calculation procedures of different IACS societies really provide significantly different results for the required thickness of propeller blades, concluding that it will be really important for IACS to put additional effort trying to harmonize these calculations, possibly in a form of an IACS Unified Requirement.

Keywords: Marine propeller strength, IACS Classification Societies, IACS Unified Requirements

1 INTRODUCTION

In any ship propulsion system the propeller performs the essential function of the system itself: transformation of torque, produced by the prime mover, into thrust force. Marine propeller, as the most important part of the ship propulsion system, is also its essential component from the functional point of view, meaning the ship class component. The propeller becomes an important safety component of the ship in case of storm and heavy weather. For these reasons the marine propeller is to satisfy the strength criteria. All of the world wide recognized marine classification societies gathered in the International Association of Classification Societies (IACS), prescribe their requirements for the minimal propeller blade thickness from strength point of view and the procedure for its calculation in their Classification Rules and Guidelines. Each society has its own approach, although all of them are modelling and verifying the same physical phenomenon: ship propeller in water stream.

The aim of this paper is to compare the propeller calculation procedures prescribed by various IACS calculation societies, focusing on their results validated on a few selected propellers that have been proven in practice, in order to find out in what amount different IACS classification societies procedures really provide different calculation results for the required thickness of propeller blades. The basic idea was to provide a basis for the consideration of this fact on IACS Machinery Panel and the possible need of introducing some more order into this topic by developing a future IACS Unified Requirement for the marine propeller blade strength calculations, resolving thus an unpleasant situation that the same engineering component operating in the same physical surrounding according to the same physical phenomenon has presently to meet so different strength criteria from one IACS classification society to another IACS society. The proposed unified approach, tidying up the present somewhat chaotic approach, will certainly contribute to the IACS basic reason for existence, aiming to *safer and cleaner shipping* [1].

The task is to develop the computer program able to check whether the selected designed propeller on the basis of its design form, given dimensions, material properties and service loading (maximal continuous power and rpm) meets the strength criteria of each IACS classification societies. These criteria are provided in the Technical Rules of these societies, [2]-[14], mostly in the form of minimal required thickness of the propeller blade section at various propeller blade radii. The approach by each classification societies in form of the formulae from the Rules has also been briefly described. The program has been developed in Microsoft Excel implementing Visual Basic for Applications within it. The reasons for the selection of this approach have also been explained. Some important issues in the methodology of program developed have also been mentioned and briefly explained.

The next task is to select the proper actual propeller examples to test the program and then verify and validate the program results. The verification examples are used to compare the designed propeller blade thickness at certain propeller blade radii with the ones required by the Technical Rules of each classification society. For the validation example a propeller designed and built half a century ago (in 1956) and still operating on the same medium size passenger ship has been taken, owing to the fact that its strength has successfully been proven in practice, no matter what any Technical Rules say about this. The verification examples are the propeller of a large oil/chemical tanker newly built in accordance with the Rules of DNV (Det Norske Veritas) and CRS (Croatian Register of Shipping) a decade ago (dually classed DNV/CRS) and the propeller of a small patrol boat built several years ago and classed by the CRS. Both these propellers could also serve as validation examples, however the one that has actually been selected for the validation is four to three times longer in service without any reported problems with respect to the propeller strength, performance reduction or even damage. All the input data for the propeller blade required thickness calculations have been taken from the propeller technical documentation (i.e. its classification drawing)

The results have been obtained by means of the developed program and have been showed in a tabular form for each of the three ships (the oil/chemical tanker, the patrol ship and the passenger ship) separately. The reference is always the designed blade thickness, because each of the ships has been built in accordance with some classification Technical Rules.

The oil/chemical tanker actual propeller blade thickness satisfies rules requirements of five IACS classification societies, being significantly over dimensioned by two of them.

The next example of the small patrol ship meets the blade thickness criteria of eight IACS classification societies, but different ones compared to the previous case. Four of the remaining ones consider it under dimensioned by a significant amount. The obtained results cannot be even compared to the previous ones.

Validation example of the old medium size passenger ship propeller does not meet criteria of only two IACS societies. The amount of over dimensioning is found to be very high according to the rules of six of the remaining IACS societies. Comparison of results with the two verification examples appears also to be practically impossible.

It can be concluded that, though modelling the same physical system, calculations of required blade thickness in order to meet the stress criteria in accordance with various IACS classification societies give significantly different results. The results of the required thickness vastly vary from one society to another. There is no way to prove which one is right and which one is not. Consequently, it is concluded that more calculation results for more different propellers shall be needed, even in a form of a round-robin tests by submitting the same set of propeller documentation to various IACS classification societies. This would be the recommended way to start the work in the development of the propeller blade strength IACS Unified Requirement if and when the IACS Machinery Panel finds out that this is necessary. Until that time, the situation may happen that e.g. several sister ships, being exactly the same in every aspect, but classed by different IACS classification societies are to meet different criteria for the propeller blade strength based upon its thickness. This situation would certainly not be a contribution to IACS *safer and cleaner shipping*.

2 MARINE PROPELLERS AND THEIR BLADE STRENGTH CRITERIA

In propulsion systems of modern ships, the propeller is the most common means for the conversion of the rating power of the ship prime mover (Diesel engine, steam turbine or gas turbine) at the relevant shaft speed (commonly expressed in the number of revolutions per minute, rpm) into thrust force, which enables the ship to move in fore or aft direction, overcoming the ship resistance. There exist the three design forms of ship propellers [5]:

- solid propellers;
- propellers with attached blades; and
- controllable pitch propellers.

The first two forms are commonly referred to and denoted as FPP (fixed pitch propeller), while the last form is denoted as CPP. A typical 4-bladed solid fixed pitch propeller of a large ship during the outfitting phase of the newly built ship in a shipyard has been presented in Figure 1.

The propeller dimensions that play an important role in the calculation of the propeller blades strength are the following ones [5]:

- diameter of the propeller, D [m]
- mean pitch, H [m]
- number of blades, Z
- expanded area ratio, A/A0
- rake at blade tip, m [m]
- length of blade sections at 25%, 35%, or 60% radius, b0,25; b0,35; b0,60 [m]
- maximal thickness of blade sections at 25%, 35%, or 60% radius, $s_{0,25}$; $s_{0,35}$; $s_{0,60}$ [m]

Technical rules of certain IACS classification societies require also rake angle, skew angle and blade section axial area moments of inertia at 25%, 35% and 60% radius to be defined for the propeller strength calculation.

Figure 1: Typical solid 4-bladed fixed pitch propeller immediately after its fitting on its shaft [15]

Regarding material properties and manufacturing procedure it can be pointed out that the material is commonly cast aluminum bronze or manganese bronze that can be considered homogenous and isotropic for the purposes of strength calculations. For this reason, the important material properties are Young's module of elasticity, Poisson's coefficient and its tensile strength.

Service loading and calculation model can be described rather simply, regardless of the complex nature of the pressure distribution itself. Thrust force originates from the pressure distribution on the suction and pressure side of the propeller blade. Actually, difference of these pressures integrated over each of the propeller blades gives non-uniformly distributed surface loading along the blade. The strength calculation model of the blade reduces thus basically to the bending cantilever beam model with a non-uniform pressure distribution and non-uniform section properties distribution along the blade, which is easily solved in any case. Loading is determined upon the power transmitted to the propeller and the pertinent propeller speed of rotation. No IACS class society requires a more detailed model than this one. On the other hand, dimensioning of the propeller reduces to determination of the propeller blade thickness in the blade root (at 20% or 25% of propeller radius for a fixed pitch propeller, at 35% of radius for a controllable pitch propeller, as well as at 60% of radius in both cases). The section width is always given, due to the fact that it originates from the hydrodynamic design of the propeller. It is to be noted that the bending stresses are proportional to blade thickness squared, as well as the safety factor in this simple model.

The safety factors are not explicitly expressed, as they are included in the reduced material strength that is used in the calculation.

3 METHODS

Methods are also rather simple, similarly to the calculation model itself: take the required thickness formulae from each of the IACS classification societies technical rules and prepare MS Excel worksheets based upon the rules by entering the formulae into Excel, using named variables as well as VBA code if necessary. The most important part is to prepare and organize the common input data form the propeller documentation, as well as to find a way how to calculate sectional moments of inertia from the propeller profile where needed.

For illustration only, the Croatian Register of Shipping (CRS) calculation formula [5] is briefly described hereafter. Propeller blades and their relevant sections are presented in Figure 2. Other class societies implement very similar formulae, publicly available in [2-4] and [7-14], with no need to repeat them hereafter.

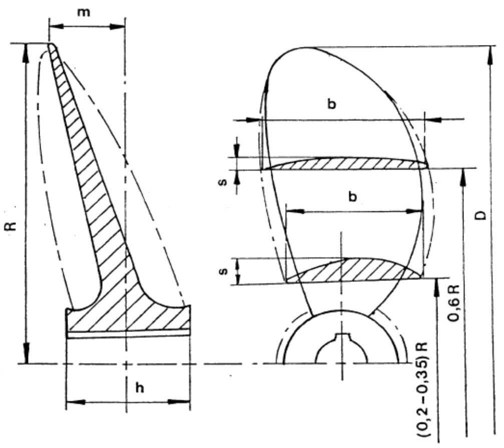

Figure 2: Propeller blade sections and basic influence quantities in accordance with the CRS rules [5]

Blade thickness is calculated based upon the following formula [5]:

$$s = 3{,}67\,A\sqrt{\frac{k}{z\cdot b}\cdot\frac{P_p}{R'_m\cdot n}} + \frac{c\cdot m\cdot 9{,}81}{R'_m}\left(\frac{D\cdot n}{300}\right)^2 \tag{1}$$

where:

A - coefficient to be determined from the Table 1

D - propeller diameter, m

H - propeller mean pitch, m

m - rake at blade tip, mm

k - coefficient of ship type and propeller material (7,8 to 9,2 for ships without ice strengthening)

z - number of blades

b - width of the expanded cylindrical section, m

c - coefficient of centrifugal stresses (0,30 to 0,35 at blade root, 0,00 at 60% radius)

D - propeller diameter, m

R'_m = 0,6R_m +175 N/mm² but not more than:
570 N/mm² – for steel blades,
608 N/mm² – for blades of non-ferrous metals.

R_m - tensile strength of blades material, N/mm²
P_p - shaft power at rated output of main engine, kW

n - revolutions per minute of the propeller, rpm

Table 1: Values of coefficient *A* for the propeller strength calculation according to the CRS rules [5]

Coefficient *A*, for		*r/R* =			
		0,20	0,25	0,35	0,60
H/D =	0,5	152,6	147,3	134,1	85,9
	0,6	143,5	138,8	126,7	82,0
	0,7	135,2	130,9	120,0	78,4
	0,8	127,7	123,8	113,7	75,0
	0,9	121,0	117,4	108,1	71,8
	1,0	115,0	111,8	103,0	68,8
	1,1	109,9	106,8	98,6	66,0
	1,2	105,5	102,5	94,6	63,5
	1,3	101,8	98,9	91,3	61,2
	1,4	99,0	96,1	88,5	59,1
	1,5	96,9	93,9	86,3	57,3
	1,6	95,6	92,5	84,7	55,7
Note: For controllable pitch propellers *H/D* shall be based on the designed service operation.					

The remaining IACS classification societies implement similar formulae for the dimensioning of propeller blades, i.e. determination of blade thickness at blade root and at 60% blade radius, but with different designation of particular quantities, their values and units. The calculation procedures and the formulae are specified in [2]-[4] and [7]-[13], so there is no need to present these formulae and procedures here.

Det Norske Veritas (DNV) uses a different approach, as specified in [6]. Their calculation has been based upon determining of the safety factor as the ratio of fatigue strength amplitude and the dynamic stress amplitude. This approach does not provide explicit values of required blade thickness, so it is not convenient either for dimensioning of the propeller, or comparison with other IACS classification societies required values.

Microsoft Excel has been selected for the development of the calculation program, owing to the fact that it is easy to prepare a formatted report with input and output values. In addition to this, implementing named variables provides additional functionality, enabling the developer to check the entered formulae easily and correctly. VBA code has been used to implement formulae that contain e.g. polynomial approximations with the relevant coefficients.

4 RESULTS

The developed Excel/VBA program, denoted with the name S01PropDim_IACS has been prepared and tested by the second author within the scope of his work on his diploma thesis. The propellers of the three different ships have been used to test the program, verify and validate the results and comment the difference among all the IACS classification society results, except DNV. The basic data of the selected ships and their propellers are as follows:

- Ship A: coastal patrol ship, length 15,48 m; gross tonnage (GT) 50; propeller type: solid, 5-bladed; diameter 0,83 m; mean pitch 1,08 m; MCR power 610 kW at propeller speed 1034 rpm;
- Ship B: oil/chemical tanker, length 187,3 m; gross tonnage (GT) 30638; propeller type: solid, 4-bladed; diameter 6,00 m; mean pitch 4,04 m; MCR power 9650 kW at propeller speed 123 rpm; and
- Ship C: passenger ship, length 37,60 m; gross tonnage (GT) 191; propeller type: solid, 3-bladed; diameter 1,53 m; mean pitch 1,20 m; MCR power 450 kW at propeller speed 400 rpm.

All of the three ships have presently been in service for a long time without any reported problems about their propellers, so they can all be considered as validation examples. However, owing to the fact that the Ship C has been longest in operation, for more than a half of a century, it has been decided to take ships A and B as verification examples and the ship C as validation example.

The calculation results for all of the three ships (A, B and C) have been presented in the following Tables 2 to 7 in terms of the actual propeller blade design thickness (in mm) at various specified blade sections, as the reference to compare required blade thickness by each classification societies. This comparison has been presented in absolute values (mm) and relative values (per cent deviation from the designed thickness).

5 DISCUSSION

The absolutely required thicknesses of propeller blades by the IACS classification rules, that have been calculated for each of the three ships and each classification society rules, has been selected as the basis for the comparison of the rules requirements.

The example of the small patrol ship shows that meets the criteria of eleven class societies, i.e. all but RMRS. This situation may seem correct, however the fact is that IRS and LR consider the blade thickness by 29,3% and CCS by 18% over dimensioned. On the other hand ABS, GL, PRS and RMRS rules find the blade thickness at 60% blade radius by some 22,6% to 28,2% under dimensioned. These results cannot be even compared to the previous ones by any means.

The oil/chemical tanker actual propeller blade thickness at 25% and 60% of blade radius satisfies rules criteria of eight class societies (CRS, ABS, CCS, GL, IRS, NKK and RINA), being significantly over dimensioned by ABS (18,4%) and CCS (19,5%). The remaining four societies find the propeller thickness under dimensioned (e.g. LR by 19,7% and KRS by 12,3%), showing an extremely large variation of the IACS societies requirements in this case.

Table 2: Absolute propeller blade thickness, mm, as designed and required for ship A (patrol ship)

Absolute thickness, mm	Section at		
	0,25 *R*	0,35 *R*	0,60 *R*
Designed, *t*	**35,2**	**29,0**	**13,6**
Required, *t*	mm	mm	mm
CRS	33,7	27,2	**14,6**
ABS	30,3	28,6	**17,5**
BV	31,4	24,0	**13,6**
CCS	29,9	24,9	13,0
GL	30,6	24,1	**14,1**
IRS	27,2	20,4	-
KRS	31,7	29,0	11,7
LR	27,3	24,8	**24,3**
NKK	30,2	24,7	11,7
PRS	31,9	27,0	**14,5**
RINA	31,4	23,9	**13,6**
RMRS	**39,1**	**33,5**	**18,9**

Table 3: Relative propeller blade thickness, %, required compared to designed for ship A (patrol ship)

Relative thickness, %, designed to required	Propeller blade section at:		
	0,25 *R*	0,35 *R*	0,60 *R*
CRS	4,7%	6,7%	**-7,0%**
ABS	16,4%	1,5%	**-22,6%**
BV	12,2%	21,2%	**-0,1%**
CCS	18,0%	16,3%	4,2%
GL	15,2%	20,3%	**-3,6%**
IRS	29,6%	42,0%	-
KRS	11,2%	0,0%	15,6%
LR	29,3%	17,0%	**-44,1%**
NKK	16,8%	17,4%	15,9%
PRS	10,4%	7,3%	**-6,8%**
RINA	12,2%	21,4%	**-0,2%**
RMRS	**-9,8%**	**-13,5%**	**-28,2%**

Table 4: Absolute propeller blade thickness, mm, designed and required for ship B (oil/chemical tanker)

Absolute thickness, mm	Section at		
	0,25 *R*	0,35 *R*	0,60 *R*
Designed, *t*	**273,6**	**228,4**	**126,1**
Required, *t*	mm	mm	mm
CRS	264,8	214,0	116,3
ABS	231,0	164,9	110,4
BV	248,1	189,7	110,1
CCS	229,0	187,0	99,0
GL	242,3	190,7	112,1
IRS	273,2	192,8	-
KRS	**311,8**	**254,8**	**126,8**
LR	**340,8**	**270,8**	**138,2**
NKK	266,1	219,4	114,1
PRS	**280,6**	**238,2**	**130,0**
RINA	248,1	185,2	108,2
RMRS	**280,1**	**235,6**	122,3

Table 5: Relative propeller blade thickness, %, required compared to designed for ship B (oil/chemical tanker)

Relative thickness, %, designed to required	Propeller blade section at:		
	0,25 *R*	0,35 *R*	0,60 *R*
CRS	3,3%	6,7%	8,4%
ABS	18,4%	38,5%	14,2%
BV	10,3%	20,4%	14,6%
CCS	19,5%	22,1%	27,3%
GL	12,9%	19,8%	12,4%
IRS	0,2%	18,5%	-
KRS	**-12,3%**	**-10,4%**	**-0,6%**
LR	**-19,7%**	**-15,7%**	**-8,8%**
NKK	2,8%	4,1%	10,5%
PRS	**-2,5%**	**-4,1%**	**-3,0%**
RINA	10,3%	23,4%	16,5%
RMRS	**-2,3%**	**-3,0%**	3,1%

Validation example of the old medium size passenger ship propeller shows that the propeller designed blade thickness does not meet LR (by max. 25,3%) and RMRS (by max. 9,6%) rules criteria. Though almost all the other societies criteria have been met, the amount of over dimensioning is about 7,0% by KRS to even 34,6% by CCS. This outcome cannot be compared at all to the previously presented verification examples either.

Table 6: Absolute propeller blade thickness, mm, designed and required for ship C (passenger ship)

Absolute thickness, mm	Section at		
	0,25 *R*	0,35 *R*	0,60 *R*
Designed, *t*	**62,1**	**54,9**	**33,3**
Required, *t*	mm	mm	mm
CRS	**67,2**	54,9	30,7
ABS	52,3	41,0	26,8
BV	56,9	44,9	27,6
CCS	46,1	40,1	24,0
GL	54,0	45,4	30,4
IRS	50,9	40,9	-
KRS	58,1	50,6	27,7
LR	**83,1**	**67,5**	**37,2**
NKK	49,2	42,2	22,9
PRS	57,2	50,6	31,0
RINA	56,9	44,9	27,6
RMRS	**68,7**	**61,2**	**37,7**

Table 7: Relative propeller blade thickness, %, required compared to designed for ship C (passenger ship)

Relative thickness, %, designed to required	Propeller blade section at:		
	0,25 *R*	0,35 *R*	0,60 *R*
CRS	**-7,5%**	0,0%	8,3%
ABS	18,8%	34,0%	24,1%
BV	9,2%	22,4%	20,4%
CCS	34,6%	36,7%	38,8%
GL	15,1%	21,0%	9,6%
IRS	22,0%	34,2%	-
KRS	7,0%	8,5%	20,4%
LR	**-25,3%**	**-18,6%**	**-10,4%**
NKK	26,2%	30,0%	45,4%
PRS	8,6%	8,4%	7,6%
RINA	9,2%	22,4%	20,4%
RMRS	**-9,6%**	**-10,3%**	**-11,6%**

6 CONCLUSION

The aim of present paper is to investigate whether the same real physical system of ship marine propeller has to meet different strength criteria with respect to the propeller blade thickness when it is calculated in accordance with different IACS classification societies and it what amount this applies.

The task was to develop an Excel/VBA program based upon the technical rules of each society, within the scope of one diploma thesis at the university marine engineering master study, as well as to select proper examples to test the program.

The program has been prepared and tested on three selected actual real propeller examples of a patrol ship propeller, oil/chemical tanker propeller (as verification examples) and a passenger ship propeller (as the validation example). This was the basis to compare the propeller calculation procedures prescribed by the rules of various IACS calculation societies, as well as for verifying and validating the program results

One classification society (DNV) had to be left out from this analysis, because their technical rules do not present stress criteria in a form feasible to dimensioning of the propeller based upon its blade thickness.

In general, the results show a very large variation from one ship type to another, as well as from another IACS classification society to another. The selected ship types are not mutually comparable, but some of the calculated required thicknesses show over dimensioning, while the other show under dimensioning even for the same ship type, but for different section positions. So, it can be concluded, even on this small number of ship types tested, that the IACS classification societies implement, for the same physical propeller, different calculation models, obtaining different results. This gives a very inconvenient situation for the propeller designer and the classification society technical specialist who approves the propeller documentation.

This situation will be proposed for consideration of IACS Machinery Panel. Hopefully, the members will recognize and support the possible need of introducing some more order into this topic, even by developing and introducing future IACS Unified Requirement for the marine propeller blade strength calculations. The same engineering component, operating in the same physical surrounding according to the same physical phenomenon, should not be subject to so different strength criteria in terms of its dimensions from one IACS classification society to another. The proposed unified approach, tidying up the present situation, will certainly contribute to the IACS basic goal of safer and cleaner shipping, as specified in [1]. The unified requirement implementation would help the technical specialists of IACS societies to avoid possible questions asked by propeller designers, or even by state attorney officers in case when failure if propeller blade jeopardizes human lives at sea.

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ABOUT SOME ASPECTS OF PROFESSIONAL RELIABILITY OF LOCOMOTIVE DRIVERS

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ABSTRACT

Increased requirements to certain professionally significant qualities (PSQ) are shown by a trade of the locomotive driver, and it means, what not every physically and mentally healthy person can successfully seize the given trade and provide further necessary level of professional reliability and safety on a railway transportation.
Professional reliability of locomotive driver – ability to preservation of demanded PSQ in extreme conditions of activity. The close interrelation and interdependence's degree of development PSQ and professional reliability allows considering process of their formation, perfection and development as the system which backbone factor is its purpose - formation of professional reliability, and a feedback mechanism - result - the level of the articulation PSQ.
The most effective way of development PSQ – special exercises prior to the beginning of activity, on separate actions of forthcoming activity.
Specific feature of labour activity of the locomotive driver of the main movement is work in the conditions of long influence of monotonous factors, as serves as the incentive reason causing a condition of monotony at which the mental activity directed on regulation and control over activity decreases.
Different in degree of monotony of working conditions cause also distinctions of characteristics of a condition of monotony, but the picture of this condition in the main will be same. Hence, stability formation to monotony and knowledge of ways and means of improvement of mechanisms of self-checking and self-control can raise efficiency of professional work not only locomotive drivers, but also other experts whose activity is realized in the conditions of monotonously operating factors.

Keywords: reliability, professionally significant qualities, self-checking, self-control

1 INTRODUCTION

The problem of professional reliability of locomotive drivers concerns complex problems. The organization of researches in this area is extremely difficult, but it is represented absolutely necessary as professional reliability in many respects is a guarantee of successful activity of locomotive drivers.

The individual and typological features refracting external influences of activity and promoting its best development, in the process of specialization are realized in PSQ [2].

Specificity of requirements to PSQ of the locomotive drivers depending on a kind of movement and working conditions is expressed both in criteria of professional suitability, and in updating of spent tests.

Allocation of high degree of readiness for emergency action in the conditions of monotonously operating factors (REA) as one of psychological correlations predicting success of activity in conditions of monotony [1], has allowed to receive not only the qualitative and quantitative characteristics of its PSQ at locomotive drivers, but also to develop techniques of its formation and correction [3-5].

Essential necessity of professional work of the locomotive driver is the requirement to long concentration of attention with simultaneous ability to its emergency switchings, and the exit over frameworks of optimum values can even interfere at achievement of high level of professional skill.

The raised indicators of emotional stability in extreme conditions of activity are observed at the most reliable locomotive drivers. It is possible to ascertain that this mental phenomenon becomes professionally significant quality of the locomotive drivers which is shown in extreme conditions of activity [1, 4].

The level of uneasiness raises and mental function of self-checking is overloaded because of insufficiently developed PSQ. On the one hand, it partially helps to compensate insufficiently developed PSQ, but on the other – the level of pressure raises up to intensity. It is expressed in infringements of logic structure of operating actions, and also in increase in time of their performance. It happens also because in normal conditions repeatedly and regularly fulfilled actions lead to formation of skills which are not enough in extreme conditions of activity. Developing any system of self-control, the locomotive drivers get qualities of actions, skills and the abilities similar professional that help to cope with adverse conditions with smaller expenses, keeping power resources [3].

On possibility of diagnostics, formation, perfection, correction professional reliability (as integrated professionally significant quality) the locomotive driver specified by following positions:

- PSQ is a cash level's possibility of display's function (mental and psychomotor processes), necessary for efficiency of professional work;
- PSQ – the merge of congenital and acquired;

- PSQ are a part of structure of the person and the general macrostructure of the person;
- Abilities in development and specialization in activity are realized in PSQ;
- Neurodynamic basis of PSQ are typological qualities of nervous system [4].

The work's purpose - formation of professional reliability of locomotive drivers

2 METHODS AND THE RESEARCH ORGANIZATION

For objecting view achievement theoretical and empirical methods were used: the theoretical and bibliographic analysis; comparison of independent characteristics that has allowed to receive the objective information on level of professional success of examinees; pedagogical supervision; pedagogical experiment; diagnostics; methods of mathematical statistics.

The estimation of the articulation of PSQ was defined by means of the techniques applied in engineering psychology for carrying out psychophysiological inspections on a railway transportation that has allowed to reveal reliability's interrelation of activity with a level of development of these qualities:

- Technique of an estimation of level of vigilance (Readiness for emergency action) in the conditions of monotonously operating factors (REA).
- Technique of speed's definition of switching attention (SA).
- Technique of definition of emotional stability (ES).
- Technique of an estimation of time sense (TS).
- Technique of an estimation of reaction to moving object (RMO).
- Technique of an estimation of time of simple visually - impellent reaction (SIR).
- Technique of an estimation difficult visually - impellent reaction (DIR).
- Technique of an estimation of volume of attention (Va).
- Technique of definition of individual psychomotor rate – tepping-test (TEPP).

As criterion of an estimation of level of the articulation professionally significant qualities indicators act:

- readiness for emergency action in the conditions of monotonously operating factors (REA):
  - difference between reactions to signals with the prevention and without the prevention (Prea),
  - number of admissions of signals (Nrea);
- speed of switching the attention (SA):
  - time of performance of the mixed search of black and red numbers (SAt),
  - time of switching attention (Tsa),
  - quantity of errors during performance of the mixed search of black and red numbers (SAer);
- emotional stability (ES):
  - time of performance of the mixed search of black and red numbers at active hindrances (ESt),
  - a difference in time of performance of the mixed search of black and red numbers with hindrances and without hindrances (Tes),
  - quantity of errors during performance of the mixed search of black and red numbers with active hindrances (ESer);
- difficult visually-impellent reaction (DIR):
  - time of performance of difficult impellent reaction (Tdir),
  - quantity of nervous pressing (Ndir);
- time of performance of simple impellent reaction (SIR);
- time sense (TS);
- time of reaction for moving object (RMO);
- attention volume (Va);
- the tepping-test (TEPP);
- an expert estimation (EE).

By the selected techniques 100 machinists have been surveyed. Marks of their professional reliability on a 9-ball scale are put down. As experts locomotive driver instructors have acted.

3 RESULTS OF RESEARCH AND THEIR DISCUSSION

The technology of formation of professional reliability of the locomotive drivers is understood as purposeful formation PSQ, individual receptions, ways and their sequence, the set parameters of activity providing preservation in difficult conditions. Following components are included in the structure of the developed technology of formation of the locomotive drivers' professional reliability: target, substantial, organizational, operational, diagnostic.

Ascertaining experiment was spent in vitro with use of the psychological diagnostic complex intended for diagnostics and control of functional conditions.

For revealing of interrelations of expert estimations and professional reliability with indicators PSQ the received results have been subjected to inter correlation analysis. The indicator of professional reliability of the locomotive drivers' activity (n=100) (by an expert estimation) significantly correlated with indicators of readiness for emergency action in the conditions of monotonously operating factors (REA – r = -0,287; -0,350); and emotional stability (ES – r = -0,196) which, in turn, are closely interconnected with indicators SA (r = 0,229-0,664), DIR (r = 0,196; 0,316), SIR (r = 0,560).

The presented results testify the importance of revealed PSQ for success of professional work of the locomotive drivers and possibility of their formation with the help of psychological and pedagogical training.

Various forms and methods of psychological and pedagogical training include as modeling, with working off necessary actions, and formation, training and perfection PSQ [3-5]. By working out of pedagogical technology both directions have given the chance diagnostics, formations, perfection, correction to professional reliability, as integrated professionally significant quality of the locomotive driver have been used.

Revealed statistically authentic communications of a professional assessment of locomotive drivers' work (n=25) with indicators REA, SA, ES, SIR, DIR (p<0,05-0,01) after forming pedagogical experiment testify that the selected indicators for locomotive drivers have appeared rather objective and informative (figure 1).

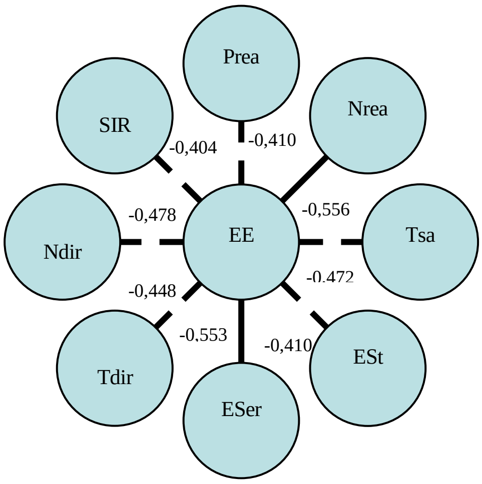

Figure 1: The Basis of a correlation galaxy round an indicator of an expert estimation of professional locomotive drivers' reliability

On the basis of results of the spent pedagogical experiment it is possible to take for granted that the technology of formation of locomotive drivers' professional reliability is effective enough. Positive changes after the end of pedagogical forming experiment at locomotive drivers of experimental group (n=25) are observed on indicators of performance of techniques: readiness for emergency action in the conditions of monotonously operating factors (REA), attention switching (SA), emotional stability (ES), simple impellent reaction (SIR), difficult impellent reaction (DIR), attention volume (Va) (p <0,05-0,01). In control group (n=25) the quantity of errors has significantly decreased (p <0,01) during performance of test DIR, on other indicators of significant distinctions is not revealed.

Application of the developed technology of formation of professional reliability has provided achievement diagnostic the purposes and a target component as a whole.

As well as acquisition of professional skill, PSQ locomotive drivers need special regular training.

4 CONCLUSIONS

Professional reliability of the locomotive drivers is provided with complex PSQ: readiness for emergency action in the conditions of monotonously operating factors, emotional stability, in the speed of switching attention, stability the intellectual functions, self-checking and the self-control, shown in the conditions of mental pressure, monotony and exhaustions.

Working out the technology of formation of the locomotive drivers' professional reliability is caused by necessity of minimization of failure of activity on the basis of revealed PSQ.

Purposeful development of PSQ promotes additional growth of professional reliability of the locomotive drivers.

4.1 Prospects of the further researches

Revealing of adverse factors complicating professional work, the emotional conditions arising under their influence, and PSQ, defining ability to resist to them and providing professional reliability has the big prospects for the further researches in transport sphere.

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LAND TRANSPORT DEVELOPMENT IN SLOVENIA

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ABSTRACT

Efficient and sustainable transport system is a globally present objective, and despite the availability of certain theoretical guidelines, countries worldwide tackle this issue in different ways. The path depends on the state of national transport system as well as on forecasted transport demand and financial capabilities. Transport system cannot develop into desired direction without the definition of many strategic documents. And the implementation of measures set in these documents is at least as important as their definition.

In this paper major strategic documents on development of Slovenian transport system since the beginning of 1990s are introduced and the focus is given to four interlinked transport system elements, namely transport infrastructure, traffic flows, traffic safety and public transport.

Keywords: Strategic transport documents, transport infrastructure, traffic flows, traffic safety, public transport

1 INTRODUCTION

The governments of all types consider transport as a vital factor in country's economic development (Rodrigue, Comtois, & Slack, 2006). Transport has an important role in economic development, but also in the evolution of society (Cowie, 2009). Transport provides many benefits to societies; it gives the individual freedom and independence to travel and facilitates trade (Haq, 1997). Simply said, the quality of life depends largely on the degree of development and operation of transport system. However, the uncontrolled growth of road transport has started to show first consequences; transport problems have become more severe than ever in both industrialized and developing countries alike (Ortuzar & Willumsen, 2011). Transport problems, such as congestion, pollution and accidents, are a causing political and public concern globally. There are nowadays a wide range of suggested solutions to these problems: from building new roads to banning cars, and from improving bus services to the use of telecommunications as an alternative to travel (May, 2006). This is pointing out that transport planning has undergone radical change in the last 40 years, and it is now barely recognizable from its origins in the highway building movement and its concerns over increasing the capacity of the system to meet the expected levels of demand (Banister, 2004). Nowadays transport planning is aiming to achieve sustainable transport system, that is an affordable, safe and environmentally friendly transport systems that allows the basic access and development needs to individuals, companies and society while it promotes equity within and between successive generations (ECMT, 2004). To do so strategic transport planning documents as well as other strategic documents, like for example spatial strategy or OP ROPI, must be coordinated and must provide systematically determined objectives, which in addition must be mutually harmonized, time-dependent, measurable and realistic (Perić, Radačić, & Šimulčik, 2000). Good decisions need clear objectives (MCA, 2009) and this is impossible without vast knowledge on current performance of transport system as well as good forecast on future transport demand and the national financial capabilities (Radačić, 1992). Transportation planning process thus includes a number of steps (DOT, 2007):

- Monitoring existing conditions;
- Forecasting future population and employment growth, including assessing projected land uses in the region and identifying major growth corridors;
- Identifying current and projected future transportation problems and needs and analyzing, through detailed planning studies, various transportation improvement strategies to address those needs;
- Developing long-range plans and short-range programs of alternative capital improvement and operational strategies for moving people and goods;
- Estimating the impact of recommended future improvements to the transportation system on environmental features, including air quality; and
- Developing a financial plan for securing sufficient revenues to cover the costs of implementing strategies.

The objective of this paper is to present major strategic transport development documents in Slovenia and to assess the performance of Slovenian transport system in four important interconnected aspects, namely transport infrastructure, traffic flows, traffic safety and public transport.

2 STRATEGIC TRANSPORT DOCUMENTS IN SLOVENIA

Slovenia gained its independence in the early 1990s. Its favorable geo-strategic position was early recognized by the European Economic Community (EEC, later European Union - EU), and in 1993 the Agreement between the EEC and the Republic of Slovenia (RS) in the field of transport was signed. After that, two pan-European corridors crossing Slovenian territory, namely corridor V and corridor X, were defined in 1994 and 1997 respectively.

The Agreement with the EEC obliged Slovenia to extensive construction and modernization of rail and road transport infrastructure. In exchange EEC/EU would co-finance the projects. This led to definition of two separate national programs in mid 1990s that is, National Motorway Construction Programme in the Republic of Slovenia (NPIA) and National Programme of the Slovenian Railway Infrastructure Development (NPSRID).

The national programs set the priorities and dynamics of transport infrastructure construction, with the aim to achieve efficient transport system that would link Slovenia to other European countries and provide alternative route within the European space. In addition it would contribute to the improvement of traffic safety, economic growth and environmental performance of traffic. The programs were accompanied by yearly construction and maintenance plans and foreseen the realization of majority of strategic projects by 2004 (only some major railway projects were to be concluded only in 2015).

The first attempt to create transport policy in sovereign Slovenia was through separate development of individual transport modes. The easier, but outdated approach to tackle national transport system development resulted in an unbalanced and unsustainable development path. The first attempt to remedy the situation was with the proposal of first integral transport policy in 2004, but this transport policy was not approved. Finally, the resolution on national transport policy titled Intermodality: time for synergy was adopted in 2006. Within this resolution a SWOT analysis of Slovenian transport system was given. Its most important elements regarding the long distance land transport in Slovenia are presented in Table 1.

Table 1: Selected elements of SWOT analysis of Slovenian transport system

Strengths	**Weaknesses**
- Geographic position; - Integration into European land transport network; - Well-developed see port; - Relatively strong transport sector, especially road.	- Lack of integration among transport services and between different types of transport infrastructure; - Dispersed settlements; - Underdeveloped and segregated public transport; - Less competitive railway network and poor organization of the railway transport; - Unfinished motorway system; - Unfinished railway infrastructure system; - An unfinished toll charging system; - The absence of charging for infrastructure; - Poorly developed system of state roads.
Opportunities	**Threats**
- Unification and harmonization of transport systems; - Development of new transport technologies; - Further specialization of industrial production (increase in freight transport); - Relocation of production to East Asia, thereby northern Adriatic gaining importance; - Continued stabilization of Balkan countries and the inclusion of Turkey to the EU should cause increasing freight flows (mainly rail transit flows); - The development of modern high-speed rail lines on the corridors running through Slovenia.	- Redirection of transit transport flows to the parallel network; - Outflow of port's transit cargo to north European ports due to lack of connection of north Adriatic ports and inadequate railway hinterland connections; - Increasing traffic congestion and reduction of traffic safety due to slow modernization of the network and inadequate pricing of transport infrastructure; - Continued lack of connection between public transport services; - Deterioration of other state roads; - Failure to comply with the requirements of the Kyoto Protocol.

Source: (Official Gazette of the Republic of Slovenia No. 58/2006)

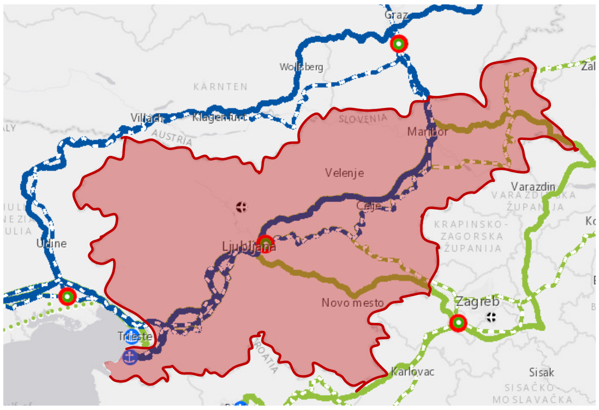
The Slovenian transport policy emphasized the importance of Slovenian geo-strategic position as well as the need to retain transit freight flows over Slovenian territory as they bring money; in fact, it was assessed that each transported ton over Slovenian territory procures 20 to 30 EUR to Slovenian budget (ReNRP, 2006). It was also stressed that these traffic flows should be accommodated by the railways.

This policy has many deficiencies in terms of its contents; for example very loose definition of goals and measures, no time horizons set to achieve the goals, no indicators which would allow measuring the progress etc. Transport policy from 2006 promised a lot of focused implementation plans and documents, but not many were later on actually developed. As a consequence many measures were taken *ad hoc* without broader consideration of their effects or the creation of cost benefit analysis thus resulting in rather unsystematic development of transport system.

Later in the same year the Resolution on national development projects (ReNRP) for the period 2007-2023 was adopted and it anticipated around EUR 11.7 billion of investments into transport infrastructure.

Sustainable and fully interconnected transport networks are a necessary condition for the realization of the well-functioning European single market and to increase European competitiveness. With the definition of Trans-European Transport Network (TEN-T) EU wants to achieve this, by improving cross-border connections, completing missing links and eliminating bottlenecks.

After the revision of TEN-T program in 2002, 30 priority projects were defined; two of these projects involve Slovenia, namely project no. 6 – Railway axis Lyon-Trieste-Divaca/Koper-Divaca-Ljubljana-Budapest-Ukrainian border and project no. 21 – Motorways of the sea. In addition, two corridors that cross the Slovenian territory were defined within the new TEN-T strategy in 2012. These corridors are Mediterranean and Baltic Adriatic corridor.



Source: Adapted from (EC, DG-MOVE, 2018)

Figure 1: TEN-T corridors over Slovenia

The largest percentage of investments into infrastucture must be assured from the national budgets (EC, 2018). However those national transport projects which are harmonized with EU investment plans can be co-financed by Connecting Europe facility (CEF), the European fund for strategic investment (EFSI) within The investment plan for Europe (Juncker fund), Horizon 2020, European structural and investment funds (ESIF) that includes the Cohesion fund (CF) and the European regional development fund (ERDF).

The Government of the Republic of Slovenia adopted the Transport Development Strategy of the Republic of Slovenia (Strategy) in 2015. Based upon this document the Resolution on the National Programme for the Development of Transport of the Republic of Slovenia until 2030 (National Programme) was adopted a year later. The Strategy is based upon detailed assessment of Slovenian transport system resulting in determination of 108 measures dealing with infrastructure, organisation, traffic management and traffic safety. Among these 29 measures are for rail transport, 37 measures for road transport and 22 measures for public passenger transport or sustainable mobility.

The Strategy is considered the first document to deal with the transport system in a comprehensive manner, thus enabling greater synergies in achieving the objectives of transport and spatial policies of the state and of other policies, and greater control of the impact of transport on the environment and the economy (Ministry of Infrastructure, 2017). Of course, only if the measures will actually be taken at the foreseen dynamics.

3 THE SLOVENIAN TRANSPORT SYSTEM

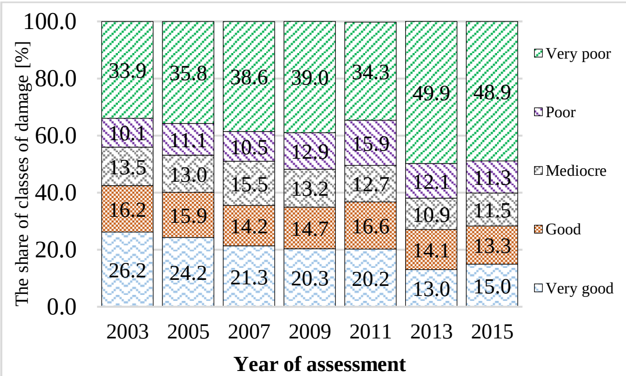
Slovenia covers only around 20,000 square kilometers of area and has a population of 2 million dispersed in around 6,000 settlements. These settlements are distributed in 212 municipalities; only 67 settlements have the status of a city and 86% of municipalities are considered residential municipalities (SURS, 2012). A diverse and very spread Slovenian industry is distributed in more than 500 locations. At the end of 2017 there were almost 437,500 inter-municipal working migrants, which is more than half of the working population in Slovenia (Brnot, 2018).

In addition, Slovenia is positioned on the junction of four large European geographic units, namely the Alps, Panonian basin, Dinarides and Mediterranean. The consequence is the variety of stone structures and diversity of terrains; Slovenia is a rather hilly and mountainous country with an average altitude of 577 meters. Only 10% of the territory of Slovenia is flat (Hrvatin, Kladnik, & Perko, 2011), which makes the establishment of an efficient transport system more difficult.

Nevertheless, we can state that today Slovenia has modern motorways network consisting of 534 kilometers, with only minor number of bottle necks on TEN-T corridors. But NPIA had foreseen the completion of the motorways system by 1999, with only a couple of sections being finished in 2000 and 2004. In reality the construction of motorways in the main directions has been concluded around 2010 and costed approximately EUR 6 billion, a lot more than predicted US$ 4.1 billion.

The major future project regarding motorways in Slovenia is the 3rd development axis, which is planned to pass through poorly accessible and underdeveloped Slovene regions and could bas well become an international corridor from Austria to Croatia. The start of its construction is planned for 2018 or 2019.

ReNRP anticipated the modernization of the railway network and the modernization of national road network on priority development axes; however, so far national roads other than motorways were rather neglected and their condition is quickly deteriorating as can be seen from Figure 2. In 2015 more than 60% out of 775 kilometers of main roads and 2,326 kilometers of regional roads were in poor or very poor condition (DI.GOV.SI, 2015).



Note: G1 and G2 main roads of first and second category, R1 and R2 are regional roads of first and second category

Source: (DI.GOV.SI, 2015)

Figure 2: The condition of national roads G1, G2, R1, R2 in Slovenia in the period 2003–2015

So far only around 25% of the NPSRID has been realized. The extent of the problem with railway infrastructure is also evident from the extent of the damage and number of malfunctions on tracks, the catenary, signaling and safety devices, and switches, and from low speeds. Žerak described the condition of the railways infrastructure in 2011. The same description was copied into the Transport development strategy from 2015 meaning that pretty much no improvement has been achieved since 2010, potentially even more deterioration could be evidenced. The following infrastructure elements require urgent measures (Žerak, 2011; Ministry of Infrastructure, 2017): 36 kilometers of tracks need to be replaced; 40% of catenary require full restoration, while 40% require major restoration works; around 39,000 sleepers should be replaced; 18 landslide sites and dangerous slopes with a total length of 8 kilometers along the tracks should be restored. In addition, in 30 locations with a total length of 60 kilometers lower speeds than anticipated in timetables are necessary due to the poor condition of tracks. Therefore, it is not surprising that the roads take up the vast majority of traffic flows, which are growing very quickly, especially after Slovenia joined the EU.

Annual average daily traffic (AADT) has increased by 18.6% from 2005 to 2016 on all state roads and by 36.7% on motorways alone. Together with AADT also traffic work increased. The calculation of annual average growth rate (AAGR) and compound annual growth rate (CAGR) indicate that the traffic work on state roads increased by 2% in the period from 2005 to 2016. If data on traffic work is normalized by the length on infrastructure, the annual growth is still significant; in both calculation it is 1.6%. The growth is even more considerable on the motorways; after the normalization of data, the growth of around 3% is recorded (AAGR yields 3%, CAGR 2.9%) when all vehicles are taken into the analysis. In 2005 the share of traffic work done on motorways was 31.4%, while in 2016 the share grew to 45.9%.

The growth of traffic work done by freight vehicles is even faster, leading to the heterogenization of traffic flows on the motorways which can affect traffic safety; the work done by heavy freight vehicles (freight vehicles with the mass of more than 3.5 tons) more than doubled in the 12-year period and the share reached 36.5% in 2016 (it was 30.4% in 2005). On almost one quarter of motorways the share of freight vehicles in terms of number surpasses 20%, and on some most critical parts this share is more than 30%.

According to research done by Zanne in March and April 2014, the following driving conditions were determined on Slovenian motorways:

- Higher density of vehicles on the fast lane than on regular lane (in 15.0% of measurements on motorways in total)
- Inadequate time heading (in 24.3% of cases when there is more traffic on fast lane than on regular lane the time heading is less than 2 seconds);
- High difference between the average speed on fast and regular lane (26 km/h when traffic density is higher on fast lane than on regular lane).

Traffic safety is deteriorating on Slovenian motorways in absolute numbers; there is an increasing trend in the number of accidents over the analyzed period. In fact, the basic statistics on traffic safety on Slovenian motorways indicate the general decrease of safety, as AAGR and CAGR of number of traffic accidents on Slovenian motorways are positive and high, 6.6% and 5.0% respectively. This is quite expected due to high increase of traffic work done. If traffic work is taken into account then it is possible to determine that the safety on the motorways improved almost threefold and that motorways are by far the safest roads in Slovenia.

The introduction of prepaid (vignette) toll system for the vehicles of up to 3.5 tons of maximum permissible mass. Although determined as not appropriate tolling system for Slovenia by the Slovenian transport policy, switched certain amount of long-distance traffic to motorways and thus contributed to the general increase of traffic safety in Slovenia.

Accidents are the outcome of mix of various factors; however, increasing traffic volumes are usually related to the increasing number of accidents. Based upon data on accidents provided by Slovenian police Zanne, Groznik, and Twrdy (2016) determined the following impact of traffic volume on the number of accidents on Slovenian motorways:

$$E(\lambda) = AADT^{0.7577} \tag{1}$$

where $E(\lambda)$ denotes the number of accident

In general, crashes involving trucks lead on average to higher casualty severities compared to other crashes (Sandin et al., 2014), due to the weight of the vehicle. A step forward in this model includes the share of trucks (%GV).

$$E(\lambda) = AADT^{0.8221} \times [\%FV]^{0.3110}\text{, for } [\%FV]>0 \tag{2}$$

where $[\%FV]$ denotes the share of freight vehicles within the traffic structure.

Also the Seasonal Autoregressive Integrated Moving Average (SARIMA) model applied to data on accidents on Slovenian motorways yields the increasing number of accidents in the forthcoming years (see Zanne & Groznik, 2018).

More rigorous legislation and higher fines for traffic offences have positive effect on traffic safety. Slovenian citizens are in favor of even more rigorous fines for the worst offences; 77% would increase the fine for alcohol or drug driving and around 50% would increase the fines for speeding (Zanne, 2013). Nevertheless, more than 92% of citizens support the statement the traffic control is more important than the fines in assuring high traffic safety level.

Different participants in traffic behave differently. Zanne (2013) determined that speeding is the reason of almost one third of accidents caused by young drivers aged less than 24 years. On the other hand, senior citizens aged 65 years or more, cause majority of accidents by wrong movements and neglecting of advantage rule. This indicates that tailored approaches towards education of transport participants should be taken.

Rail transport safety has steadily improved over the last decade, in terms of the number of extraordinary events and disturbances as well as of the amount of damage caused. Unfortunately, this does not apply to extraordinary events at the level crossings or walking along the line. On 1,207 km of rail lines there are still 756 level crossing, among which 434 are unsecured (Košir, 2017).

Due to disperse settlement structure in Slovenia it difficult to organize an efficient public transport system or a public transport system that would fit the needs of all citizens, so majority of passenger trips are done by personal cars. Nevertheless, some progress can be noted in the occupancy levels of personal cars. The research that Zanne carried out in 2013 shows average occupancy to be 2.2 with the lowest occupancy being identified for travels to work/school (1.7). Lipar and others (2002) determined the average occupancy of 1.8 and occupancy on trips to work being 14 at the beginning of new millennium.

The efficiency of interurban public road transport is low; regardless of the fact that the number of buses serving interurban connections almost halved since the 1990, the utilization of urban buses dropped from 73.6% in 1990 to 21.1 % in 2011 (Zanne, 2013). In recent years the use of interurban public road transport is reported to have an increasing trend, but the data which would to calculate utilization level is not collected any longer.

Utilization level of passenger trains is similarly low; according to the information obtained from the Slovenian railways, the average occupancy of passenger trains was 24.6% in 2015 (SŽ, 2015), which is around 4% less than in previous year.

The number of rail passengers is dropping and in 2016 only 14 million passengers used the rail transport services both in domestic (13.2 million) as well as in international transport; this represent a 4% decrease in regards to 2015 and a decline of 15% since 2013 (STAT.SI). Interestingly, the major decline is evident after the finalization of the project on integrated public passenger transport in Slovenia; in the same time intercity bus transport is in expansion (9% growth in 2016 and 20% growth since 2013). Moreover, Slovenian citizens are less satisfied with the provided services and are very favorable to the opening of rail passenger market to competition (summarized from EC, 2012).

Unsatisfied are also the users of road public transport. Only around 8% of all passengers' trips are done by public services (Ministry of Infrastructure, 2017). This affects the traffic flows and consequently traffic safety. As Zanne (2013) determined, the main reasons for not using more extensively the public transport are the schedule and the frequency, followed by the trip duration. The results do not differ significantly in regards to the type of settlement (big city, small city, suburb, rural) from respondent comes; only in big city trip duration is more important than schedule and frequency.

Zanne (2013) also determined that citizens are (expectedly) hesitant to measures that would increase the operating costs of passenger cars in order to achieve more sustainable distribution of passengers' flows (e.g. more expensive fuel, more expensive tolling, higher tax on motor vehicles, less parking places, more expensive parking places etc.). Instead, the opinion of majority is that the improvements in public passenger transport would contribute more to achieving this goal (e.g. better service (higher frequency, better reliability, etc.), adjusted schedule, single ticket etc.). This is in line with studies showing that the public perception of non-coercive or "pull" measures is that they are fairer, more effective and correspondingly more acceptable in comparison with "push" measures such as pricing (Pridmore & Miola, 2011).

4 DISCUSSION AND CONCLUSIONS

The main objectives of transport development is to provide safe and unconstrained daily travel for citizens and to provide the basis for the development of economy while meeting TEN-T standards.

Slovenia has been marked by the above-average growth of road transport and by declined volume of freight rail and public passenger transport in last decades. This decline can be mainly attributed to poor facilities and non-competitive services. This leads to an unsustainable development of land transport in Slovenia, which is why it is necessary to take actions as soon as possible.

So far, Slovenian strategic transport development documents are partially successful; the modal split is rather unsustainable as nor the policy or the national programs have managed to transfer transit cargo flows to rails (mainly because the infrastructure is deficient) as well as to organize and promote more intensive use of public transport. But there have been some positive initiatives mainly shown in the improved traffic safety (eg. lump sum tolling system for light vehicles, redirection of heavy vehicles to motorways, stricter driving license process). However, if road traffic flows continue to increase, the safety will deteriorate. Also if tolling systems for light vehicles changes and becomes more expensive for majority of users, severe safety problems might be faced as traffic flows would probably switch to non-payable lower category roads, many of which are already in poor condition.

The heterogenization of traffic flows is evidenced on Slovenian roads. The delayed modernization of the rail transport network and constantly increasing road transport, demand the construction of new infrastructure. The investments are forecasted to EUR 2.1 billion into five major railway projects that are planned for the period from 2015 to 2020 (MZI, 2015). It is also necessary to bear in mind, that the Regulation (EU) No 1315/2013 of the European Parliament and of the Council on Union guidelines for the development of the TEN-T foresees that the Commission carries out a review of the implementation of the core network by 31 December 2023. If major delays occur, corridors currently passing over Slovenian territory might be rerouted to neighboring countries.

Besides obviously much needed modernization (eg. elimination of "black" spots on roads and rail-roads level crossings) and construction of transport infrastructure, performance of transport system can be improved by optimizing the use of the assets that are currently available. For example, intelligent transport systems which could provide better traffic fluidity, uniform ticketing for public transport, tact train schedule and harmonized timetables as well as easier transfer between means of transport could increase the use of public transport services. These are only a couple of measures listed in the latest Strategy on transport development in Slovenia. These measures could improve the performance of Slovenian transport system, but if they actually will, remains an open question. Measures must be implemented not only defined.

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"GREEN SHIPS" – PERSPECTIVE AND DEVELOPMENT

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ABSTRACT

There is a wide field of technologies like low-sulphur fuels, internal engine modifications (such as water injection and exhaust gas recirculation), humid air motors, selective catalytic reduction, duel-fuel engines that are contributing to air pollution reduction caused by ships. With growing concern for environmental air pollution, there is also a growing interest for the application of renewable energy technologies on ships. These technologies are not new to the world, but when considering the ship as the place of the installation this raises the question regarding the ship overall design and the impact on fuel consumption and air pollution. In this paper the concepts of wind and solar energy production on ships are presented. The overview of the experimental ships that are harvesting the renewable energy is given in the text. Also, the new concept of wind and solar combined in the form of rigid sail is presented. The concept of medium voltage direct current distribution system application is presented in the paper. Traditional electrical distribution system on ships is low voltage AC system. This concept is very different from renewable energy technology but also provides fuel saving thus providing less air pollutants.

Keywords: Renewable energy, Green ships, Air pollution, New concepts, MVDC system

1 INTRODUCTION

Every undesirable change in physical, chemical and biological properties of the air, land and water which has a negative effect on the environment that has organisms in it, represents environment pollution. Traffic in general (land/roads and railways/, marine/ sea, river and canal/ and air), as well as the industry have a huge influence on the environment [1]. In this paper the focus is on air pollution of sea transport.

Exhaust gases from marine diesel engines are the primary source of emissions from ships and significantly contribute to environmental pollution due to the characteristics of the combustion process, typical for large marine two-stroke low speed engines and the use of heavy fuels. Oceangoing ships are the major contributors to global emissions of several hazardous air pollutants, such as nitrogen oxides (NOx), sulphur oxide (SOx), fine particulate matter (PM), hydrocarbons (HCs), carbon monoxide (CO) and greenhouse gas carbon dioxide (CO2) [2].

The most important legal document that regulates the issue of prevention and control of pollution from ships is the International Convention for the Prevention of Pollution from Ships - MARPOL. Annex VI of the MARPOL Convention is considering the issue of air pollution from ships, and in it are defined limit values of exhaust emissions [3].

There is wide field of research dedicated to reducing air pollutions caused by ships. One approach to pollution reduction is through mechanical and chemical enhancement (internal engine modifications like water addition or intake valves closing time, low-sulphur fuels, ultra-low sulphur fuels, emulsified fuels). Other approach is through renewable energy application. In this paper the innovative solutions for wind and solar energy utilization on ships are presented. To exploit the renewable energy in the most efficient way some interesting ship designs appeared. These designs are presented in the paper.

Parallel to renewable energy technology there is a new concept that is being developed. Medium voltage direct current (MVDC) system shows promises regarding prime mover efficiency improvement and reduction of specific fuel oil consumption (SFOC). The basic concept of MVDC system is presented in the text.

2 NEW" FUELS AND INTERNAL ENGINE MODIFICATIONS OVERVIEW

The decision to implement a global sulphur limit of 0.50% m/m (mass/mass) in 2020 was taken by the International Maritime Organization (IMO), the regulatory authority for international shipping. This decision represents a significant cut from the 3.5% m/m global limit currently in place [4]. Fuels that could achieve the 2020 sulphur limit are biofuels, LNG.

There are various types of biofuels: straight vegetable oils (SVO), biodiesel (Fatty Acid Methyl Ester - FAME), renewable diesel (Hydrotreated Vegetable Oil – HVO), ethanol, butanol, methanol, dimethyl ether (DME) etc. Methanol, ethanol, methane and butanol can be used in spark ignition engines, while DME is a good fuel for diesel engines. It is expected that most biofuels can be utilized in ship engines. Use of such fuels would require major changes to the engines and the on-board storage and require a secure bunkering logistic for such fuels at ports. Such logistic is expected to be first introduced for local (port) traffic or two-point traffic by e.g. ferries. Biofuels contain little or no sulfur and could be used in emission control areas (ECA). However, utilizing biofuels is not yet common practice. Main barriers to the deployment of marine biofuels include: higher price of biofuels as compared to other marine fuels, insufficient logistic support at ports for fuels not compatible with diesel type fuels, lack of long-term fuel test data to guarantee the safety and continued reliability of the selected fuel, reduced cargo space when using less energy dense fuels such as methanol and gaseous fuels [5], the effective greenhouse gas emissions of all types of biofuels, including fuels derived from biomass, is currently an area of active research. It is possible that the available global resource of biomass and biofuels may be inadequate to supply shipping [6].

Using LNG to supply vessel engines is an attractive commercial solution for both, new building LNG-fuelled vessels and existing vessels. There are three main drivers that make LNG a feasible alternative. First and foremost, LNG as ship fuel removes completely SOx emissions and PM, reduces NOx emissions up to 90% and also minimise CO2 emissions around 20%. Second, in the shipping industry there is an important number of vessels using LNG as fuel, since LNG carriers have been using it for several years. Finally, LNG as marine fuel is commercially attractive because of its worldwide availability, since LNG reserves will be able to fulfil LNG demand from the maritime industry in the coming years, and its low price compared to the main marine fuel oils used on board vessels [7]. Drawbacks of using LNG are: lack of bunkering supply system, higher cost for engines and fuel system and tanks, mostly unfounded fear of LNG, potential loss of cargo space on some ship types, possibility of no cargo operations during bunkering [8].

Internal engine modifications (IEM) are considered to be combustion adjustment methods because they attempt to reduce the formation of NOx in the combustion process. Several different techniques have been applied in this field, such as reduced scavenging air temperature, the Miller process, delayed fuel injection, compression ratio modification and injector-nozzle design. Only the slide-valve technique, which is a change in the injector-nozzle design, is considered to be a basic IEM. This technique uses improved fuel spray to delay fuel injection and subsequently reduces NOx formation while maintaining fuel efficiency. The other technologies are advanced IEMs and are under further development by their manufacturers. Hence, their individual NOx reduction potential may not yet be fully demonstrated, although a total overall NOx reduction performance of 30 % may be assumed for all advanced IEM measures [9].

3 RENEWABLE ENERGY ON SHIPS

One way of harvesting the wind energy is through kite installation (Figure 1). The effect of the kite is towing of the ship. This reduces the load on the ship engine and thus lowers the fuel consumption. The propulsive force generated by the kite is calculated as the projection of the tether tension vector onto ship direction. The magnitude of the tether tension vector is [10]:

$$|\vec{T}| = \frac{1}{2}\frac{C_L \rho_{air} A_k V_a^2}{\cos(\varepsilon)} \quad (1)$$

where: C_L is kite lift coefficient, ρ_{air} is air density, A_k is kite surface, V_a is apparent wind velocity and ε is the kite lift to drag angle.

Source: https://www.goodnewsnetwork.org/skysails/

Figure 1: Wind energy harvesting through kite application

The case study for the ship *British Bombardier* presented in [10] states that with kite technology fuel savings could reach more than 50 %. This percentage is estimated for the kite area of 320 m^2 and wind velocity of 15.68 m/s (Beaufort 7). *British Bombardier* characteristics are presented in Table 1.

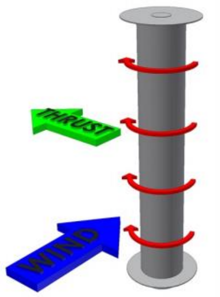
Table 1: British Bombardier technical characteristics

Length water line	225.86 m
Length over all	231.34 m
Beam	29.57 m
Draught	12.5 m
Displacement	65,089 m^3
Block coefficient	0.797
Wetted area	10 105 m^2
Total resistance coefficient	0.002414
Ship service speed	7.97 m/s
Brake power of the engine (design)	12,000 kW
Number of propellers	1
Propeller diameter	6.706 m
Thrust deduction factor	0.187
Wake factor	0.324
Relative rotative efficiency	0.99
Transmission efficiency	0.97
Initial metacentric height	5.675 m

Source: [10]

Utilization of wind energy through physics of Magnus effect is not a new concept. Anton Flettner, a German engineer, patented the concept of rotating cylinder in 1922 under the patent name "Flettner Rotor Ship Concept". Figure 2 show the concept of Magnus effect. To produce thrust the rotor must be in the wind field and the Flettner rotor itself must rotated. According to [12] the net output power of the Flettner rotor system is:

$$P_{net} = (P_s - P_{con})\eta_s \quad (2)$$



Source: [11]

Figure 2: Magnus effect on Flettner rotor

where: P_s is power from the Flettner system in the ship direction, P_{con} is power consumed by the Flettner system and η_s is ship propulsion efficiency.

To get a more physical insight of the Flettner system it is shown how P_s and P_{con} are calculated:

$$P_s = F_x V_s \tag{3}$$

$$F_x = \frac{1}{2}\rho_A V_a^2 A C_L sin\,(\beta)\; - \frac{1}{2}\rho_A V_a^2 A C_D cos\,(\beta) \tag{4}$$

$$P_{con} = F_f U_{rot} = (\frac{1}{2} c_f \rho_A U_{rot}^2 A_r) U_{rot} \tag{5}$$

where: F_x is effective force in the direction of the ship, V_s is ship speed, ρ_A is density of air, V_a apparent wind speed, A is maximum projected area of the Flettner system, C_L three-dimensional lift coefficient, β is the angle between ship direction and apparent wind speed vector, C_D is the three-dimensional drag coefficient, c_f is skin friction coefficient, U_{rot} is rotational speed of the rotor and A_r is surface area of the rotor.

Two ships that are in service and use Flettner technology are M/V Estraden and E-Ship 1. Estraden is Ro-Ro cargo ship built in 1999. Overall length is 162.7 m, deadweight is 9700 t, service speed is 19 knots [13]. In 2015 two rotors of the manufacturer Norsepower were installed on the ship (Figure 3). Rotors height is 19 m.

Source: http://www.sciencemag.org/news/2017/09/spinning-metal-sails-could-slash-fuel-consumption-emissions-cargo-ships

Figure 3: M/V Estraden with two Flettner rotors manufactured by Norsepower company

According to [13] average net savings with two rotors are 6.1 % (400 t fuel and 1200 t CO2/year).

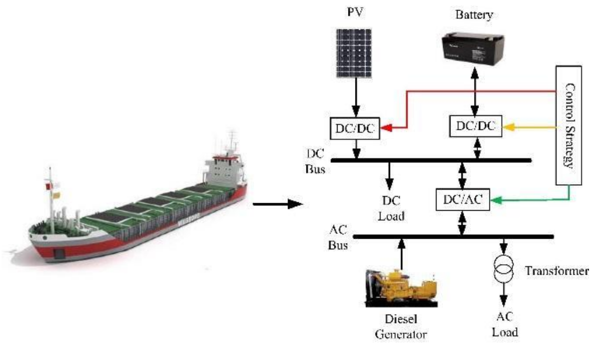
E-Ship 1 is a cargo ship built in 2008 and whose overall length is 130.42 m, deadweight 10020 t and max. speed 17.5 knots [14]. It has 4 rotors whose height is 27 m (Figure 4). According to [15] fuel savings up to 15 % can be achieved.

Source: http://www.dailymail.co.uk/sciencetech/article-4342856/The-ROTOR-ships-set-comeback.html

Figure 4: E-Ship 1 of the manufacturer Enercon

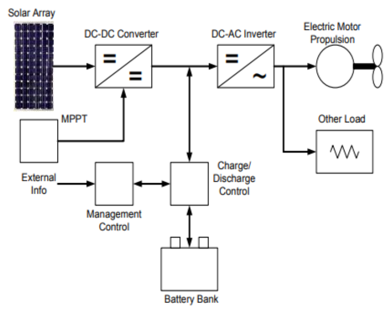
Regarding close future Norsepower company has announced a retrofitting of LNG fueled cruise ferry MS Viking Grace [16].

Solar energy utilization on ships is more complex problem then utilization of solar energy on land. Due to ship motion, changes in course the conditions like temperature, humidity and sun irradiation are more dynamical than on land. The exploitation of solar energy is technically very different from kite towing and Flettner rotors. The effect on ships due to usage of the kite or the rotors is mechanical. Solar energy is converted through photovoltaic (PV) panels into electric energy. That electric energy must be adapted for existing ship power system. This is achieved through power electronics (DC-DC converters, maximum power point tracking, battery management system). There are two approaches regarding PV system on ship. One is hybrid power system or PV-diesel system and the other is PV-only system. Figure 5 shows the hybrid system and Figure 6 shows the PV-only system.



Source: [17]

Figure 5: PV- diesel power system



Source: [18]

Figure 6: PV-only system

Insight to environment condition influences are presented through following equations [17]:

$$P_{PV(s,t)} = \eta_{pv} A_{pv} G_{(s,t)} \tag{6}$$

$$\eta_{pv} = \eta_{pv\_ref} \eta_{MPPT} [1 - \beta (T_c - T_{c\_ref})] \tag{7}$$

$$T_c = T_a + [(NCOT - 20)/800] G_{(s,t)} \tag{8}$$

$$G_{(s,t)} = G_{b(s,t)} + G_{d(s,t)} + G_{r(s,t)} \tag{9}$$

where: $P_{PV(s,t)}$ is output power of PV system at time t in season s, η_{pv} is the instantaneous PV generator efficiency, A_{pv} is the area od modules used in PV system, $G_{(s,t)}$ is the hourly total solar radiance, η_{pv_ref} is the PV generator reference efficiency, η_{MPPT} is the efficiency of power tracking equipment, T_c is the temperature of PV cell, T_{c_ref} is the PV cell reference temperature, β is the temperature coefficient of efficiency, T_a is the ambient temperature, NCOT is normal operating cell temperature, $G_{b(s,t)}$ is the hourly direct radiation, $G_{d(s,t)}$ is the sky diffuse radiation, $G_{r(s,t)}$ is hourly ground reflected radiation.

To propel large cargo ship the large PV panel area would be needed. So, for large ships only the PV-diesel system is practical. Nevertheless, this system contributes to fuel consumption reduction. And by doing so it reduces air pollution. The PV-only system is still reserved for concept ships.

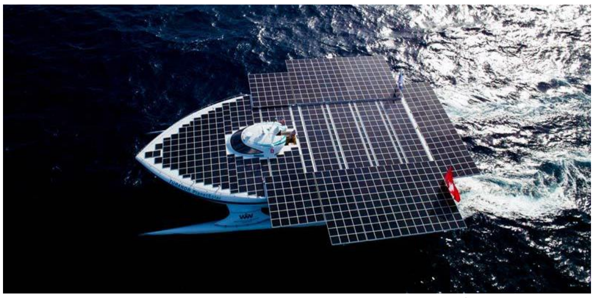
DRIVE GREEN HIGHWAY (Figure 7) is vehicle carrier ship built in 2016 whose over-all length is 200 m, deadweight is 20034 t and has max. speed of 18 knots [19].

Source: http://www.sankei.com/premium/photos/160227/prm1602270010-p4.html and https://blog.goo.ne.jp/atis128/m/201602

Figure 7: DRIVE GREEN HIGHWAY – side and top view

On its top deck more then 900 high efficiency solar panels were installed. Their peak power is 150 kW and they are used to power all LED lighting on board [20].

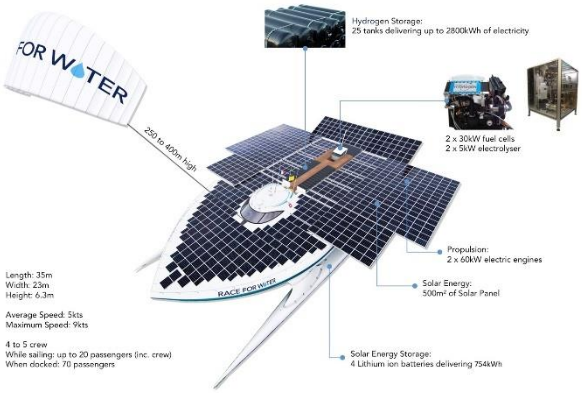
The most famous and the biggest ship that has PV-only system is MS Turanor PlanetSolar (Figure 8). The ship was launched in 2010. Its over-all length is 31 m, deadweight 85 t and the max. speed is 14 knots. It can accommodate four crew members and up to 60 personnel. The number of installed PV panels is 127 and they are covering the area of 537 m2. The solar plant can produce peak power of 93.5 kW. Advanced lithium-ion batteries can store up to 1.3MW of solar energy under deck. The four high-efficiency electrical permanent magnet synchronous motors driving five-bladed carbon fiber propellers through two drive shafts make the ships propulsion system [21].



Source: http://7minutesolar.com/solar-sunday-photo-of-the-day-march-11-2018/

Figure 8: MS Turanor SolarPower

The MS Turanor SolarPower was given as a gift to Race for Water Foundation in 2015. It was renamed to Race for Water. In 2017 it set off to five-year voyage with a purpose to explore impact of microplastic on marine ecosystem and to promote innovations that could help to reduce air pollution [22]. Race for Water ship is upgraded version of SolarPower. Now it is using solar energy, kite towing and hydrogen. Figure 9 shows the Race for Water ship with all its energy sources.



Source: http://www.raceforwater.com/r4w_odyssey_2017_2021/a_pioneering-100-energy-self-sufficient-vessel

Figure 9: Race for Water energy sources

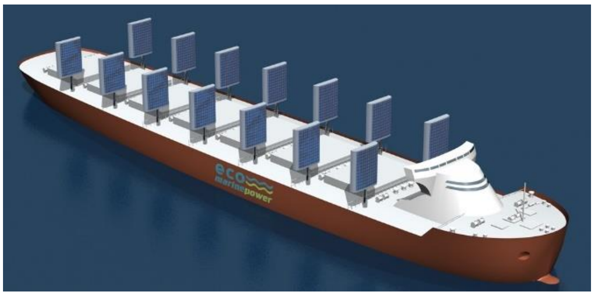
The Race for Water is a good example of combined renewable energy systems. The answer to large air pollution reduction for large ships may very much be in combined/hybrid energy systems. In the following text few concepts, prototypes and ideas are displayed.

Company Solar Sailor Holdings Ltd launched in 2000 vessel Sydney SolarSailor. It was operated commercially over 10 years as ferry in Sydney Harbour (Figure 10). It uses solar and wind energy through PV panels and solar wings. Solar wing is the concept introduced by SolarSailor. This concept combines the function of the sail and PV panel. SolarSailor has 8 movable solar wings.

Source: http://www.talkgreen.ca/the-greenest-boat-on-planet-earth/

Figure 10: Sydney SolarSailor vessel

The company Eco Marine Power (EMP) has introduced the Aquarius Eco Ship concept that is under development. It is an ongoing comprehensive study project focused on optimizing the design of a large ocean going ship such as a bulk carrier, oil tanker, RoRo vessel or cruise ship, to harness the power of the wind & sun using Aquarius Marine Renewable energy (MRE) system. Aquarius MRE is a system that incorporates a variety of elements including solar panels, energy storage modules, a computer control systems and an advanced rigid sail design [23]. The concept of ship with rigid sails is shown on Figure 11.



Source: http://www.ecomarinepower.com/en/research/58

Figure 11: Aquarius Eco Ship concept

Figure 12 shows the concept of the "solar sail" from the EMP company for large ships along with the concept of SolarSailor company for the ship like catamaran.

a) b)

Source: http://www.ecomarinepower.com/en/company-news-archive/120-production-of-first-energysail-begins-at-factory and http://www.yachtforums.com/threads/solar-wind-assisted-vessels-including-cargo-vessels.17011/

Figure 12: a) Eco Marine Power EnergySail b) SolarSailor catamaran ferry with SolarSails

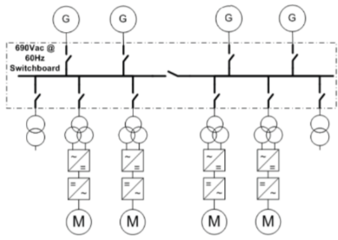
Energy Observer is an experimental catamaran that uses only renewable energy (Figure 13). The accent for this ship in on hydrogen which is produces by the electrolysis of the seawater. Energy Observer consists of the following systems: PV panels, two vertical-axis wind turbines, desalination system, routing optimization system, real-time tracking of the performances, two-story H_2O compressor, smart traction kite sail, electrolyzer, hydrogen storage, fuel cells, 400 V batteries, two 97 % efficient electric motors that work as hydrogenerators when kite sailing is used [24].

Source: http://en.meretmarine.com/energy-observer-named-paris/171965

Figure 13: Energy Observer

4 MEDIUM VOLTAGE DIRECT CURRENT SYSTEM

The traditional power electric distribution system on ships is alternating current (AC) system (Figure 14). This system has fixed frequency (50/60 Hz) which means that the speed of diesel engine shaft must be also fixed.



Source: http://www.elkraft.ntnu.no/eno/News/MiniProjects-fall-2012/gruppe%20O.pdf

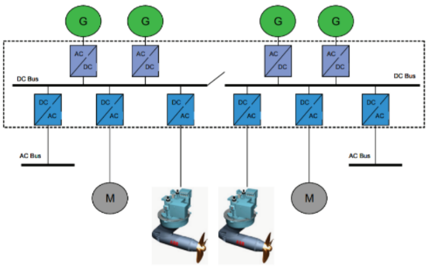
Figure 14: AC power distribution topology

DC onboard system does not depend on the shaft speed of the diesel engines. So, the speed can be adjusted for various loads. This means that fuel consumption can be optimized. This kind of system is in development stage and for now there is one ship with medium voltage direct current (MVDC) system. The platform supply vessel named Dina Star was designed by Norwegian company Marin Teknikk (Figure 15).

Source: https://www.offshoreenergytoday.com/reach-subsea-receives-contract-for-dina-star/

Figure 15: Platform supply vessel Dina Star

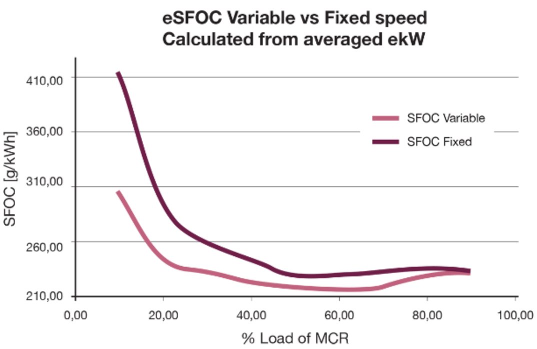
The DC system for the ship was delivered by ABB company. The concept of DC distribution topology is shown in Figure 16.



Source: http://www04.abb.com/global/seitp/seitp202.nsf/0/292d42e87306453dc12579ad0050a457/$file/12_10_OnboardDCGrid_Technical-Information.pdf

Figure 16: DC distribution topology concept

Specific fuel oil consumption (SFOC) of the DC system relative to AC system is shown on the example of Dina Star. ABB conducted the operational fuel measurement test in dynamics positioning mode. For the test the engine was run at variable speed for 45 min and then for 45 min at constant speed. The PEMS (Power and Energy Management System) data were used to compare time, fuel, power and RPM data. The power was integrated over the time period for the variable speed test and the produced energy in kWh and fuel consumption was calculated. For the constant speed test, the power was also integrated and the fuel consumption noted at the time when the produced energy was the same as the energy produced during the variable speed test. This made the results directly and academically comparable [25]. The results are shown on Figure 17.



Source: http://new.abb.com/marine/generations/technology/onboard-dc-grid---one-year-in-operation

Figure 17: Results of the DP operational fuel measurement test conducted on platform supply vessel Dina Star

From Figure 17 it can be seen that for wide range of load (10% - 90%) the SFOC is lower for variable speed case. As the load decreases the difference between variable and fixed speed SFOC increases.

Benefits from MVDC ongrid system could be: up to 27 % spesific fuel saving if taking full advantage of all features including energy storage and variable speed engines, reduced maintenance of engines, improved dynamic response by use of energy storage, which may give a better DP performance with lower fuel consumption or more accurate positioning, increased space for payload through lower footprint of electrical plant and more flexible placement of electrical components, more functional vessel layout through more flexible placement of electrical components, considerable noise reduction (up to 30%) [26].

The challenges for this system are: lack of high power DC-DC converters, lack of MVDC protection devices, no commercial rectifiers for MVDC, two different protective schemes for LVAC and MVDC [27].

5 EEDI

All mentioned technologies in this paper: renewable energy, new fuels, engine modifications, DC onboard grids have an impact on emissions. The measure of this impact for specific technology can be calculated with energy efficiency design index (EEDI).

EEDI sets the minimum energy efficiency requirements for new ships built after 2013. It is a measure of design efficiency that provides the estimate of CO2 emission per capacity mile. The target requires stepped efficiency improvements of between 10 to 30% until the year 2025. Simple formula for EEDI is:

$$EEDI = \frac{P \cdot SFC \cdot \alpha}{CAPACITY \cdot SPEED}\left[\frac{CO2(grams)}{TEU \cdot MILE}\right] \qquad (10)$$

where: P is power installed (kW), SFC is specific fuel consumption (g/kWh), α is carbon conversion factor for specific vessel type, Capacity equals TEU (twenty equivalent unit – ISO container 20'), speed is measured in knots (nautical mile per hour) [28].

From the equation 10 it can be concluded that for lower EEDI ship is more energy efficient and it has lower negative impact on the environment.

6 CONCLUSION

Thanks to legislatives and convections (IMO, MARPOL) the problem of air pollution caused by ships is "legalized". This certainly opened the doors to technical improvements and new solutions. Improvements can be found in the field of fuel chemistry and diesel engine modifications. Renewable energy technology application on ships is advancing rapidly. Sails that combine solar and wind energy are innovative solutions and concepts that could greatly contribute to large ships efficiency. The solution for effective air pollution reduction of large vessels is certainly in combined technologies like wind, solar, hydrogen, fuel cells, battery storage system. Other perspective for fuel consumption reduction is changing the traditional AC distribution system with medium voltage DC system. This system despite the fact that it has its technical challenges promises specific fuel oil consumption reduction up to 30%. To express the impact of the technological advancement on ship through numbers the energy efficiency design index is introduced. The index consideration become mandatory for new ships built after 2013.

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AUTONOMOUS SAILING BOATS – APPARENT BLIND SPOT OF RESEARCH COMMUNITY

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ABSTRACT

Practically every transport mode has awaited its version of autonomy. During the construction phase of the university's sailing model, the paper extracts the reasons for authors' initial thoughts, that autonomous sailing vessels activities are very weak. Engine vessels' autonomy concentrates around an intelligent integrated bridge as a key awareness element of each ship, propelled by modern engine. According to public sources, classical sailing program, sharing a small market, is not completely excluded from the autonomy oriented progress, but it is in the initial phase due to the high safety levels and navigation prediction demands. The unmanned sailing model challenges drive the enthusiastic attempts into various research activities, which are kept out of mass-public appearance. The unmanned sailing model's (USM) autonomy attempts are briefly described. In the dawn of e-navigation, an envisaged artificial intelligence based advanced assistance for the sailing crew is outlined. An understanding of the reasons for status of unmanned sailing attempts is given.

Keywords: Unmanned Sailing, Robotic Sailing, Marine Robotics, Autonomous Boats

1 INTRODUCTION

For the in-house self-construction of sailing model with survival affinities, authors are facing its autonomy reality through in-depth study of public accessible knowledge bases. The team utilizes sailing experiences of members for the design optimization, and an interest of students involved, which gradually raise by their adaptation to the limitations of today's status of ships' autonomy. From the perspective of the lecturers of navigational aids to the future officers on watch and the control engineering to the future marine engineers, the ship's autonomy is a great step forward towards avoiding shortages of human's nature and also awareness deficiencies. From these aspects, some key technical and economic reasons or questions on sailing vessels autonomy drawbacks are introducing the following chapters.

Historically, sailing is an activity, which has transformed in several thousands of years from a way of moving from one place to another towards the modern hi-tech sport, losing its economic character on its way. Since the decline of clippers, the sailing stepped-out of the transportation chains, the economic reasons for its existence changed severely. Controlling the vessel while driven by a weather dependent source of energy and solving the task of ever changing interactions between the wind flow, the conditions at the sea surface, and of the currents beneath it, all together demand a very skilled person to overview the whole situation and decides appropriately. Evolution of relevant sailing equipment itself has brought many original strategic solutions, involving mechanical and electronic self-steering systems for controlling rudder and sails, nowadays even for changing the form of the hull, aided by an artificial intelligence (AI).

A legislation is on the way to be put in place to ensure that autonomous motor vessels are safe and fully meet the guidelines for the vessel encounter at sea named Collision Regulations (COLREGs) [1], set out by the International Maritime Organization (IMO). Compliance with good seamanship practice and other relevant requirements are also required. It is then up to researchers' community whenever treat the unmanned sailing either as a fundamental or applied robotic technology, to cooperate with technologists in the process of transforming new ideas into reliable solutions. Which research domains should further contribute to such transformation or optimize it?

By modern pleasure and sport sailing a human gets self-esteem through the struggle with the pure natural elements and by counting on own perception and powers. Mainly enthusiasm, however sportive professional, and the substantial financial support, keeps such type of sailing alive. What are the reasons for and against the introduction of unmanned sailing vessels (USV) in the modern sailing communities?

During sailing, human is forced to respond, to interact with the nature. With introduction of USV, enhancing the self-esteem seems shifted from direct interaction of sail men, to the indirect interaction of researchers, which splits the sailing community and triggers profound questions. Consequently, by the unmanned approach humans do not struggle anymore with their physical body abilities by presence, the interaction with the nature occurs in advance, with merely mind abilities, and through the use of autonomous robots.

Sailboat crew may feel that the unmanned control of sailing boat is outside their interest. Imperatives of classic sailing itself hold back the complete relaxingly leaving the command to a machine, or to somebody else, if AI was not a machine. The community of sailing sportsmen, even the disabled, including pleasure seekers, due the rules of the sport accepts at most the myriad of sensors to extend their human awareness, but without involving much actuators. Small companies for USVs' tailored autopilots do not survive on the market, due to the poor capacity of such market. By keeping sail men decisions for on-board actions to the present human, they dictate the sailing industry not to invest into programmes, which may lead to over-populated marinas. Such communities with possible exceptions who for some reasons get involved into USV, are reluctant towards the closed-loop control and involvement of artificial intelligence. Public appearance of massive auto-helm AI based leisure and sport are not often, and technical information on USV solutions are not widespread, as sentient AI being is not a machine in the sense we are used to. It is not software or hardware, we need to develop AI-psychology, AI-ethics and also safety assurance, which face us all with a new reality. Researchers, together with boat architects, after modelling all predictive situations and implementation of the control theory including decision making, still stand before the question: Is their artificially intelligent sailing robot able to interact with the non-perfectly predictive differing air-water circumstances better than humans do?

The ongoing digitalization-of-everything supports in-lining of the sailing activities with other transport services which strive for unmanned approach. Driven by wind, stand-alone autonomous sailing vessel improves performance based on intelligent pilot with a decision support system [2] and become able to adapt its planned route on weather data with an appropriate tacking and jibing. Human element, comprised of the roles of helmsman, watchman, navigator and skipper [2] merely remains on decision upon a person which inserts the desired destination. Whose economic interest may attract such ultimate decision making which involves passengers as an intelligent ballast [3]?

But who may be interested in USVs if not the operators of sailing boats? From the sailing sector candidates are for example sailing yacht charter offerers, who attract fresh investments into their business processes. With an appearance of reliable USVs, renting such vessels may, inherently constrained with COLREGs, rely on vessel's friendliness to not self-esteem, but more adrenaline seeking travellers on a sort of roller coaster in the nature. So there may exist an economic reason in nowadays sailing community for the USV introduction, however not very solid, nor advertised. For the wandering, specially equipped and non-populated unmanned sailing models (USMs), an interest exists for the persistent ocean state monitoring including sea-air interactions studies, hydrologic research, and even navigational safety and security related surveillance [4], [5]. In oceanography there exist strong research motivations for the research of deep-sea exploration by unmanned subsea surface glider models, which tend to eliminate the factors of hard predictable wind and sudden weather change to accomplish demining operations [6], but generally endure the effects of ocean eddies [7].

Authors are not alone with perceiving the unmanned sailing boats cross-discipline research's state-of-the-art as still in its infancy period [8]. The distinction in the text is made between the attempts by USMs from those with man-populated USVs. Obvious physical reasons (e.g. the size, LOA[1] LWL[2] and the weight) drive modern USM research away from the activities oriented on populated i.e. persons carrying USV. The USMs dimensions are kept very limited regarding to those of the USVs, planned to be inhabited with pleasure seekers without sailing skills or perhaps with disabled persons. Physical differences between USMs and USVs open a gap between their abilities and goal achieving or survival chances. Such a gap also makes them differently attractive for the investments.

USM research arose from the needs of professional sport teams, whose sailing boats were equipped with AI based recommender solutions (i.e. King-fisher, [2]) and which in-line them with advanced assistance vessels. But USM based research now continues as abundance of activities of enthusiasts, seeking for the self-esteem reward, not strictly the financial one.

In the following text, Chapter 2 continues with motivations for the paper on USMs, while Chapter 3 brings main topics of the USM research. From the perspective of strategy, two critical issues are outlined. Leaving the prediction questions behind, authors decide to further focus on research of collision avoidance. An important parts of Collision Regulations for USMs, as extracted from plans for unmanned motor vessels, are presented in a separate Chapter 4, the missing activities are finally listed in Chapter 5, together with suggestions of relevant activities for the university's undertaking.

2 UNMANNED MODELS' RESEARCH CHALLENGE

In spite of inspiration by large sailing boats abilities, authors focus on challenges of the USMs research for three reasons: because its findings are better publically disseminated than of larger USVs, the use of USMs is more open research oriented, and nevertheless, since the University of Ljubljana group builds an own sailing boat model, with autonomy affinities.

3 AN OPEN COMPETITION

Similarly, to the epic challenges, the attractiveness of the premier winning of the ocean, tempts the engineers and designers to construct the USM to cross the Atlantic in the challenge called Microtransat (www.microtransat.org). The challenge origins back to 2005, while the first model has started its own race in 2010. The race rules for the USM restrict the LOA to 2.4 m, LWL to 2.4 m, clarifies the passive safety means, and exclusive details on USM's status reporting. For the tracking purposes, at least once every 6 hours USM must report its position to remain in the classification. Along with the robotic use of wind sails, entering criteria for USM permit also the wind turbine as the power source. The model's performance depends only on its embedded algorithms; in order to pass the 25 km long start line on one side and pass the finish line on the other

[1] hull length overall

[2] Load Water Line

side of Atlantic, while no remote access is allowed. After eight annual races with altogether 21 USMs transatlantic attempts, so far no USM has succeeded. The credits to the misbehaviour mainly go to hardly predictable weather of the Atlantic, tidal effects, and nevertheless also to carelessness or curiosity of fishermen, whose actions inevitably lead to disqualification of the USM.

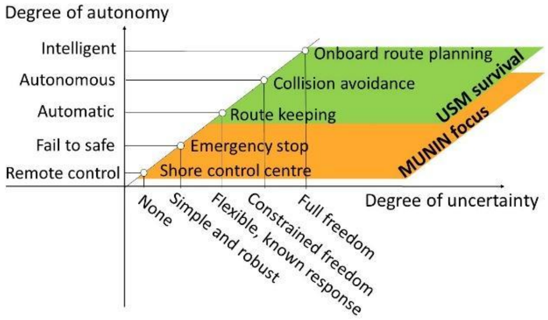

Figure 1: Extracted expectations for the USMs, based on MUNIN project outcomes [9]

Quite often, also a technical error leads to the resignation or disqualification of the vessel. USMs often lose their navigation ability because their GNSS receiver can't establish its position, however GNSS technology becomes highly reliable and robust. Electric circuits are vulnerable to electromagnetic noise peaks, originated from frequent atmospheric storms, whose strikes may lead to sensitive circuits' overvoltage. Failures of the steering mechanism itself are not seldom. The boat can compensate and hold the course with the sails, but if the rudder stumbles in one of the extreme directions, it is almost impossible to keep the vessel's course only with sails and the boat ends rotating in circles.

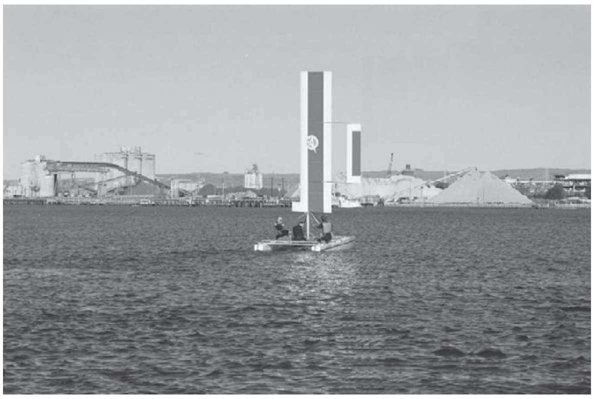

Figure 2 Catamaran Atlantis's use a self-trimming wing-sail demonstrated a high navigation and control [3].

A higher degree of autonomy and uncertainty are expected for the USMs not only to survive but with good prospections for successful crossing the finish line, as suggested by Figure 1.

The World Robotic Sailing Championship (WRSC) as a spin-off of Microtransat, has been established in 2008. Annually held competition of USMs aims to gather teams to compete in two categories and four daily contests, to decide upon a winner in each category. Following the WRSC rules on tracking data, each USM must provide its position at least once per second.

4 FOCUS ON OPEN RESEARCH

The critical research areas cannot be spotted only by comparing the results from the aforementioned races with abilities of the contested models and their performances. If the blind spot of autonomous sailing research exists, it seems better recognizable through checking the public accompanying activities of the WRSC. The International Robotic Sailing Conference (IRSC) gathers the researchers to discuss the scientific topics related with autonomous i.e. robotic sailing. Checking the IRSC archives [8], [10], [11], one may observe the evolution of newly elaborated crucial disciplines and the persistence of the others. Even more, the mushrooming of new autonomous sailing research centres e.g. [12], [13], diminishes the initial perception of authors, that the autonomous sailing is a real blind spot.

Figure 3 Sailboat model with bending rudder [14]

5 GETTING OWN EXPERIENCES

At the Faculty of Maritime Studies and Transport a small test sailboat model (LOA 2.0m) with fabric sails, and improved rudder has been set-up and tested. The steering system mounted on a sailboat model allows the rudder to bend 35° in each direction [14] (see Figure 3). The self-designed larger model (LOA 2.4m), planned to be equipped with hard i.e. wing-sails (see Figure 2), is in the assembly phase. The steering and hydraulic sail actuating elements are the care of the Faculty of Mechanical Engineering, while the software is developed by the Faculty of Electrical Engineering, both University of Ljubljana.

6 REVIEW OF RESEARCH ACTIVITIES

The autonomous ships oriented research activities, initiated by economic reasons, favour the engine vessels research, which is three-fold: 1) *monitoring ships' abilities* to continuously check their own working performance, 2) *monitoring situation in the area* that also has *to be communicated* and 3) *decision making* on the observed. Development of merchant ships' automation reduces owner's expenses, and with autonomy it is envisioned to keep a smaller crew aboard. A variety of advanced driver assistant functionalities can be noticed in almost all sectors of transport. The rise of fuel costs created potential interest for alternative sources of energy, including self-sustainable

USMs. Developed algorithms and technical solutions of USMs are getting research interest from other areas of maritime navigation, which relate to the safety of navigation of all types of vessels.

7 ENGINE VESSELS AUTONOMY TRIALS

The commercial shipping interest for reliability reasons, at the moment opts for remotely controlled vessels. The research methods and technologies mitigate disadvantages against those of the traditional manned vessels. Maersk and Rolls Royce for example, indicate that some form of autonomous ships may routinely perform their duties in the 2030-35 timeframe, which coincides with the end of the useful life of their recent new builds [15]. ReVolt is a wide known project and at the moment is within testing phase with a model of container ship, capable also of dynamic positioning [16]. In a joint attempt of classification society De Norske Veritas Germanischer Lloyd, the Norwegian University of Science and Technology and Kongsberg Maritime, they test data fusion of various sensors for monitoring the vessel's surroundings and development of technology, planned to work for days and weeks without any type of maintenance despite of the harsh sea and bad weather conditions. System fuses data captured by sound, thermal and optical sensors, together with ship's classical S and X band navigation radars together with LIDAR. Additionally, Ka and W-band radars are applied to detect close objects, while ECDIS is used for the route planning. At sea and in harbour areas, system uses both terrain and nautical charts like on manned vessels, but for dynamically observed obstacles and conditions, it receives data from situation awareness system. It collects and fuses data from all aforementioned sensors also the AIS data for detection of others AIS equipped vessels and floating navigational aids, and data from the navigational, meteorological and safety equipment on board. Gathered information mainframe console use to build a map of potentials dangers for navigation. Collision avoidance modules purpose (see Chapter 4) is to assure the safe navigation. Ships dynamic positioning systems are to maintain ship's high integrity position and heading with the use of data from multiple GNSS receivers, wind sensors, together with propulsion systems status [16].

A key monitoring element of ship's status and the navigation element of autonomous system is thus an advanced sensor module, which is a main part of integrated bridge system on engine propelled ships. Intelligent integrated bridge will gradually replace the perceptions of the duty officer on the bridge. The envisioned capability of unmanned bridge has two options. After the first, the maintenance engineer is kept on board, after the other the bridge is completely empty. But, if the human is not present, the equipment redundancy factor must be increased. From the second option, more supervisory computers are needed, more radars, etc. Forcing the personnel off the ship will lead to certain savings, because supportive systems, such as air-conditioning, are no longer required. Costs for larger redundancy factor would increase. It is expected that humans will remain on board of autonomous vessels but overlooking the cargo or performing maintenance tasks or - as passengers, only the bridge will be unmanned.

The engine vessels use Deep-Sea Navigation System and the Remote Manoeuvring Support combined with Engine monitoring and control system, ensure, that big merchant ship follows its planned route. If needed, authorized persons alter the course due to unexpected circumstances. The technology is already developed, but still make improvement on high latency and low-bandwidth communication data in remote areas. The technology like Autonomous Navigation System (ANS) accumulates a complete AAWA autonomous architecture and the use of dynamic positioning system linked with an ANS, including situational awareness, collision avoidance, route planning, and Ship State Definition [17].

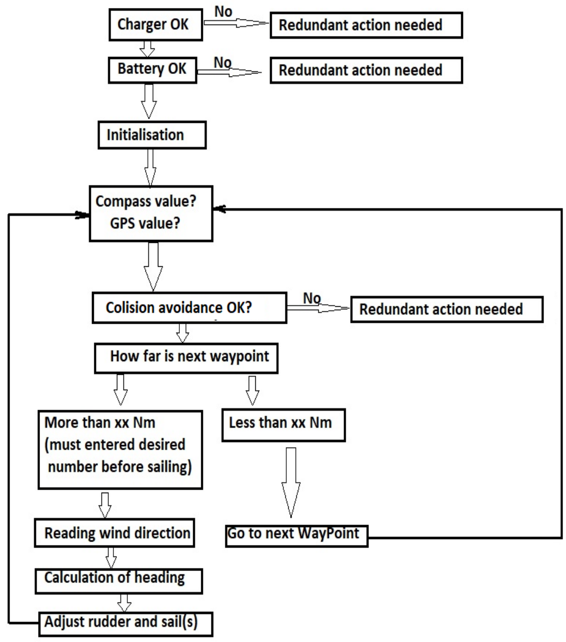

Figure 4: An example of a simple navigation algorithm [11]

Combining different skills as a challenge to the AI system, generates additional multidisciplinary activities. A replacement for the human with AI, as first brings the sensory-motoric part to understand 'human feeling', model it, and involve it into an algorithm. In a complex and dynamical sailing environment, an algorithm itself becomes complex as well and performance outcomes may become highly unpredictable. But the use of intelligent techniques in a combination with conventional controllers obtains good results also in the case of complex system [18]. To train AI, system needs to pass several attempts to gather enough information to learn AI how to sail efficiently. Adding a common knowledge to the system significantly increases the rate of convergence, and after increasing the knowledge and learning attempts, the task of sailing can be significantly upheld.

Following the reasons listed in Chapter 1, the scope of the paper is narrowed to USM research, where autonomy doesn't bring the cost savings, nor the questions on human presence aboard. The multi-disciplinary IRSC gathered science reveals, the findings on USM equipment improvements and decision strategies, realized by the selected hardware and software components.

8 USM'S HEALTH AND AWARENESS

Emerging new technologies and advanced applications for ocean observations shifted an interest of multidisciplinary research from motor driven to sailing models.

From the perspective of researchers, topics discussed at IRCS show the tendency from the early general robotic issues (localization, route planning) towards survival at sea oriented (mission planning, boat to boat communications, legal issues, naval architecture) [9], [10], [11], [19]. From the perspective of designers, relevant standards are emerging in the form of IEEE projects, such as *7009 Standard for Fail-Safe Design of Autonomous and Semi-Autonomous Systems*, under the auspices of IEEE Reliability Society or discussions are opened within a project *7003 Algorithmic Bias Considerations* in the framework of IEEE Computer Society. Due to USM price accessibility, a wider network of stakeholders is involved in research area, more participants work on similar problems, more likely and sooner the efficient solution and algorithms meeting special demands appears.

Some relevant USM research activities are listed and briefly described.

Construction Hull and rudder shapes of the contested USMs at IRSC vary. Hollow constructed wing-sails [3], [13], are the major choice of the contested models' makers, due to their significant lift-to-drag ratio, they have more predictive response in difficult environmental circumstances than the classic fabric sails. Difficult design in order to be reefed reliably is wing-sails drawback. A solution named Sail and tail substitutes the rudder for the bearing control [20].

Energy consumption All systems on USM platform are tested for energy efficiency, energy sources status is monitored, safety regulations are followed to avoid possible hazards in the event of sensor failure or malfunction. Conditions of data processing aboard USM complies with the regulations, inherently the how much energy is available from the solar panels or wind generators, either directly or stored in batteries of limited capacity.

Data collection and conditioning Reliable and robust sensors with peripherals' interfaces are available on the market. A replacement of human senses for observing hull position and spatial orientation generates navigation demands (heading, speed), pressure transducers seem promising for the continuous vessel's stability checks. Vessel's geo-referencing is applied by the geomagnetic field sensors fused by GNSS receivers. Sensor data fusion is applied for drift corrections and other known intrinsic irregularities of thoroughly tested inertial sensors [21]. Electric field sensors detect the side USM electrical fields fluctuations to get an additional warning on the possibility of electric strike and the need for lower the computer's activity. For the required continuous and proper look-out by sight and hearing additional sensors are applied [9]. On USMs a set of world detection sensors is limited. A short range, course directed wide angle limited FMCW radars can be combined with look-out sensors, tied also with the class B Automatic Identification System (AIS) receiver's perception to detect the obstacles and to further confirm the detection of AIS carrying transponders platforms such as vessels or aids to navigation, especially in the coastal areas. To sustain the awareness within rough seas conditions, and even during vessel rolling a processing of sensors outputs is coupled with inertial sensors' outputs.

Modelling A comparison with more developed car cruising for modelling long-distance sailing can be made – as either the boat's heading or the wind direction changes, the sails and rudder can adjust themselves automatically. For minimizing the dependency on operator's intervention a set of stable models, describing the behaviour of USM elements and their interactions with surrounding marine system are required. By thorough knowledge on dynamics and of the properties of sensors an intelligent model should decide which sensors outcomes are reliable in certain conditions. Recalling blind spots, infamous fails may occur from modelled errors. With machine learning approach, trained system checks possibilities with modelled based simulations. In extreme weather conditions at sea, which could not be predicted, lack of appropriate models may cause a new source of error. At every situation the conflict comes up between the expectations based on modelled experiences, and the probability of outcomes. Such conflict with the new situation makes the expected outcome more uncertain, i.e. the uncertainty raises. With training of AI models, the uncertainty of sailing performance decrease. High expectations from such models in USMs towards managing presentation of reality and reliably coping with highly complex situations at the time being seems pushed far into the future.

Datalink and communication is one of the main part of autonomous navigation system and must be cyber proof, especially if the unmanned vessel is remotely controlled. When the voyage planning is completed, a level of autonomy of the vessel can be selected. At the moment, USMs with full autonomy is still avoided. In the coastal areas a high speed connections are used, while at open sea areas only the satellite connections are feasible. Existing satellite system for unmanned ships is Inmarsat Global Xpress. The system has a worldwide coverage, and wide bandwidths [12]. Important issue especially for users without sponsors is also satellite airtime price, which vary from 150 usd per month for regular customer to 5k usd for companies with special contract. This aspect slowing down faster and wider growth especially among researchers who seeking cheaper and independent maritime solutions.

9 USM'S DECISION MAKING

In order to efficiently sail in the changing conditions of the wind, currents and sea-state towards a distant destination or just to survive in a certain ocean area, the models of sailing vessels need to overcome vessel navigation challenges to make the best navigational decisions, mainly as route planning and collision avoidance, which both demand not only for the high autonomy of the USM and also increase of uncertainty (see Figure 1). On-board computer is capable of recognizing the wind conditions, understanding its own location, and control the sail and rudder primarily to compensate the heading, the speed at the open sea is of secondary importance. After sailing basics, for downwind there is a need to increase the resistance of the front sail, and to decrease the rear sail, when configuration is opposite, it leads the boat turning into the wind. In each moment a desired angle is calculated based on the estimated trajectory and the dynamic model of the autonomous vessel. From the control perspective, a real problem is a strong non-linearity of the sailing vessel system and the uncertainties, also from environmental changing conditions [18]. A modelling example, bringing human experiences into decision system shows, that from the logged apparent wind angle and speed (boundaries, moving averages and trends) a steering windward angle can be efficiently estimated [2].

Algorithms and software Software based data fusion is crucial for the data integrity checks, followed by risk assessment and the situational awareness check (see an example on Figure 4). Path planning heuristic algorithms are required to generate a route from the initial to the last waypoint. The crucial element of algorithms with autonomous tendencies is the anticipation of events, the weather and navigation i.e. traffic conditions related [19]. The autonomous navigational software involves the strategic route planning, which for the safety reasons follows the collision avoidance strategies algorithms (see Chapter 4), which can nowadays base on the systematic big data processing [9]. A dilemma exists about the delay and in which conditions the algorithm should immediately send the demand, e.g. to change the heading. In this case, algorithms calculate the probability of predicting the event, which again is based on the integrity checking of the data obtained from the inertial and GNSS sensors.

Research activities are focused on automatic steering devices. **Electronic autopilot systems** use various inputs, such as compass heading which is not ideal under sailing conditions, anemometer data, speed over water, GPS data, etc., and PID control algorithms to control the heading [19]. The electric automatic winches are connected to control system from where system operate with sails according weather conditions. Machine learning approach usually employs either adaptive fuzzy logic and neural network [20] for the rudder control, while for the sails control another fuzzy controller is used. Again, for reliable operations on sailing boat enough electrical energy must be assured. On USVs, the changing circumstances require several readjustments inside submenu settings. Various systems operate via a dedicated industrial screen from where electrical winches raise and furl the sails. Load sensors detect jams and ease halyards. There is also a manual mode, which allows the operator to tune and trim, or open up the automated functions. At the learning phase, operator trims the sails properly, as the computer learns. After few turns system learns and know how to releases one winch and trims the new working one to the same trim angle as on the previous tack. Electronic self-steering, based on gyrocompass makes much of the work of the helmsman, especially with the position and course controllers attached. During the temporary absence of electric energy when battery is drained, a self-steering systems can be applied, to use a wind force to move rudder blade. But the absence of sufficient wind, a self-steered USM is left to ocean currents, making it non-autonomous.

A collision avoidance USV's sub-system is a very disseminated activity [22], [23], [24] which concerns the critical maritime regulations. Although one may think that the owner of such a small vessel should not care about his liability for the possible damage on a huge merchant ship, IMO is strict on these questions, as presented in Chapter 4.

10 COLLISION AVOIDANCE

IMO has accepted the term 'autonomous ship' as either remotely or fully autonomously controlled vessel. According to the Convention on the Prevention of Marine Pollution (1972), vessels and aircraft implies waterborne or airborne craft of any type whatsoever. The definition includes air cushioned craft and floating craft, whether self-propelled or not, and also the Advanced Autonomous Waterborne Applications (AAWA) prototypes, which suits for the USMs [10] [19].

The legislative authorities try to avoid situations where human mariners have to learn new techniques for safe navigation when dealing with autonomous vessels, and also USM researchers anticipate that the manned vessels strictly apply COLREGs [1]. Accordingly, an appropriate legislation will be put in place to ensure that autonomous vessels were safe, not least acting to every situation in a way that fully meets the COLREGs and other relevant requirements, already mentioned in Chapter 1. Following the pre-planned route should be made safely and effectively. Course change by the vessel must be large enough to be observed by other vessels.

Collision avoidance in a maritime environment can be also divided into obstacle detection and after obstacle avoidance. Simple algorithm is able to involve very simple commands and request data from a sensor. It is an appropriate way for a start with robotics without the expert knowledge in electronics and programming. Autonomous systems adopt an algorithm to control the set of sensors and actuators. Simple network provides a set of commands which allow uniform communication to a wide range of devices. The protocol is based on standardized serial communication or even universal serial bus, to utilize even Arduino microcontroller. For the proximity sensing an infrared or ultrasonic sensors are used. The concept for the USMs is in the early prototyping phase when devices frequently change, which makes a prototype easy to set up, and to adapt.

Then, the power module drives electric winches connected to sails which are used for propulsion, and also rudder for steering. Aim of the algorithm is to avoid obstacles, and maintain the sailing course. Reactive aspect of handling the rudder is the tactical notion of navigation. Without autopilot, these tasks are handled by a complete crew; in single handed sailing, however, everything on board has to be done by only one skipper. When there are so many different tasks to be carried out, so the actual steering or let say correction of the course can be only 10% to 20% of the voyage. Therefore, the benefits of the use of an intelligent autopilot are obvious [23]. Research to improve autopilot systems are of utmost importance for sailing's professional teams. Self-tacking jib is a sail on forward position that does not require operation of the jib sheet when tacking, as it automatically changes from one side to the other [19].

Maritime Unmanned Navigation through Intelligence in Networks project [9] aims to develop technology for an unmanned autonomous vessel. Work is focussed on the technical, legal and business aspects of the project. Next generation modular control systems and communications technology enable monitoring and control ships parameters locally on board or remote from land. This also include advanced decision support systems to operate ships under semi or fully autonomous control. COLREGs requirements evolved by the MAXCMAS project implementations for autonomous motor vessels guidance and control [24], produce the similar expectations also for the USMs, propelled by natural sources [22]. MAXCMAS special software module instantly estimates collision risks with the surrounding obstacles and provides collision avoidance decisions and actions that can be executed by the autonomous vessel [24].

Collision avoidance system for sailing boat becomes complex for the consumption restrictions and navigation abilities, since the driving source is only the wind. Basic sailing skills are projected to unmanned vessel's computer systems, but the relevance of safety strategies, and particularly collision avoidance is difficult. There are few robotics approaches how to avoid obstacles, mainly the deliberative and reactive method.

When operating with deliberative approach, a model of the environment is created together with all relevant and available information. A sailing route is calculated and predicted for this very environment model. The change of environment parameters dictates to change the route. The parameters, the wind, weather data or adapted obstacle information, all influence the environment model. In a highly dynamic environment requiring a complex model, the computation power can be a serious limitation. Collected sea conditions data and properly conditioned weather prediction data should feed the prediction deliberative model that fits to the system's processing abilities and perform the weather dependent routing [19].

The reactive method depends on local environmental sensors and according to the received data, system reacts in real time, with no planning.

Deliberative approaches have their advantages especially at long distance navigation where available data like weather forecasts and topological data are relatively stable. In contrast, reactive methods reacting fast and this is important when dangerous obstacle is in proximity. Optimal solution is a combination of deliberative and reactive methods and use advantages of both, deciding promptly which to apply according to a predefined scheme [24].

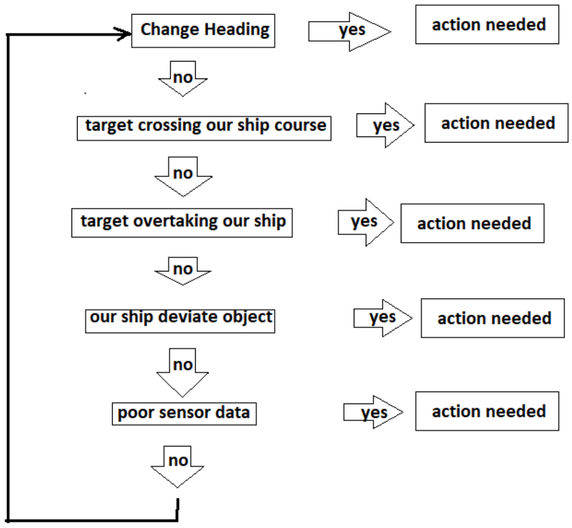

Figure 6: Part of the algorithm for collision avoidance system [24]

11 CONCLUSION

A research team fail on the public scene may lead to the bad image of any of its members and events with no winners distract major public attention. However, Microtransat competitors failed until now for the reasons far out of the reach of researchers and designers, but mainly for rough Atlantic weather conditions and perhaps carelessness of fishermen.

USMs due to their legal status of 'AAWA prototype' must follow COLREGs, however they do not pose an important threat to the safety of maritime traffic. Its decision system, similarly to of any other unmanned vessel, should behave like a well-trained and experienced ship master, who fully exploits his limited capabilities.

Comparing to engine unmanned vessels, certain USM activities involving AI are missing, that make training trials not sufficient and causes USMs' fail. Since investments in USM's endurance are not attractive, at the time their price-performance ratio opts for the exploration applications where some of the vessels can be missed, but the data from the remaining would still continue with their mission.

Usually USMs fail on challenges where e-navigation concept, based on avoidance of areas or situations for which system was not trained well. The limitations of processing power and the constrains of energy on-board challenges programmers to optimize the coding and algorithms.

Interaction between the unmanned vessel and the human, which comply with COLREGs and reliably solve the unpredicted harsh situations, can be applied on an USM logic. Gradual transition from human controlled engine vessels to fully autonomous vessels, will need longer time.

Solving the navigation task by the USM seems like wandering along the unknown labyrinth space when the desired room may suddenly appear. From the prototyped

UL USM should be expected to collect and regularly send interesting geo- and time-referenced oceanographic data, while wandering around or at least to survive for more than the last years US Naval Academy's Trawler Bait, which endured Atlantic for 39 days 3h 11min.

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ANALYSIS OF STEAM TURBINES FOR FEED WATER PUMPS ON LNG SHIPS

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ABSTRACT

Steam propulsion plants for LNG ships have main feed water pumps that are driven with steam turbines. Those steam driven feed water pumps are one of the most important components in the plant. Their function is to dose the feed water for main steam boilers timely and exactly in order to maintain normal functioning of the steam propulsion plant. In this paper the mostly used steam driven feed water pumps are presented. Their construction details, steam temperatures, pressures, velocities, efficiencies and losses over the steam turbine stages and wide range of steam turbine operating loads are analyzed.

Keywords: Steam turbine, feed water pump, working parameters, efficiency

1 INTRODUCTION

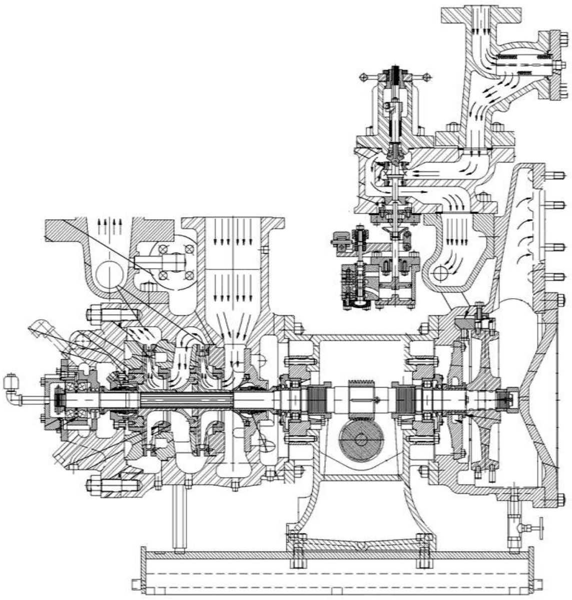
This paper presents two types, Coffin and Shinko, feed water pumps that are driven with steam turbines and used to deliver the feed water to main steam boilers of LNG ships. Coffin main feed water pump is constructed as a two staged centrifugal pump [1] and Shinko main feed water pump is of three stages centrifugal type pump [2]. Both feed water pumps are driven by the short and light weight Curtis wheel steam turbine [1, 2].

Feed water pumps take water suction from the highest point in the engine room, from the deaerator which acts as a header tank, and deliver the feed water with high pressure, over 60 bar, into the main steam boilers. Before it enters the main steam boilers the feed water temperature is usually raised passing through the high pressure feed water heater and economizer in order to reduce the fuel oil consumption in the boilers and to increase the overall efficiency of the steam plant.

The main steam boilers level control and thus the capacity control of main feed water pump is often a three term control. This control measures water level, steam and water flow and controls the output to the boiler feed water control valves. The steam flow to the steam turbine and the running speed of feed water pump is controlled by the differential discharge pressure control. This control compares the feed water discharge pressure with boiler steam drum pressure and adjusts the feed water pump speed by regulating the steam flow across the steam turbine in order to maintain the constant difference across the feed water regulator [3].

Coffin feed water pump, shown in Figure 1, consists of four sections: turbine assembly, bearing housing assembly, governor gear and oil pump assembly and pump assembly. At the one end, the driving steam enters the single stage, impulse, two bucket row, velocity compounded, axial flow turbine and expands through the turbine wheel and then exhausts in an axial direction directly above the turbine end cover. A single shaft, used for driving the two stage centrifugal pump at the other end, passes through the turbine housing, bearing housing, and pump housing. This shaft is supported by two roller bearings located in the bearing casing and the thrust bearing located on the outboard end of the pump housing. The bearing casing additionally serves as an oil reservoir and for providing the power to the horizontal governor drive shaft through a worm and a worm gear. Feed water pump control is accomplished by the pump discharge pressure via constant pressure regulator, through centrifugal speed governor when rated speed has been exceeded and through excess exhaust back pressure trip and low lube oil pressure trip protection [1].

Outer design of one Shinko pump is shown in Figure 2. It consists of feed water pump assembly and steam turbine assembly interconnected by the gear coupling. Feed water pump is also multi stage centrifugal pump (in this case three stages) where the first stage impeller is of the double suction type and the rest are of the single suction type. It has horizontally split casing in order to have easier maintenance. Rotor is supported by plain forced lubricated bearings and tilting pad type thrust bearing. Feed water pump is directly connected to the driving steam turbine but in this case through a forced lubricated gear coupling. Steam turbine is of the horizontal single stage speed compound impulse type. The turbine casing is also horizontally split into two parts. Bearing housings are at the both ends of the turbine shaft. The governor end bearing housing is provided with radial bearing and thrust bearing. The bearing housing near the feed water pump has radial bearing only. For the control of the steam turbine operation the Woodward governor is used. Its speed setting mechanism and the pressure controller unit are interconnected to effect constant discharge pressure control [2].



Source: http://coffinpump.com/wp-content/uploads/2013/07/Turbine-Driven-Boiler-Feed-Pump-Page-2.jpg [4]

Figure 1: Construction details of Coffin feed water pump

Source: http://sftspb.com/content/21-shinko [5]

Figure 2: Shinko feed water pump

2 STEAM TURBINE FOR FEED WATER PUMPS

Before steam enters in the steam turbine, the pressure is reduced from boiler pressure to the steam chest pressure. This is due to steam passing over the turbine governing valve. There, the steam pressure and temperature is reduced but the steam specific enthalpy remains constant. After passing the governing valve, steam enters the steam chest from where it flows to the first stage nozzles of the steam turbine and expands to exhaust pressure (Figure 3).

Curtis wheel steam turbine, mostly used for feed water pumps drive, comprises of first row of stationary or stator nozzles, two rows of moving or rotor (bucket) blades and one stator row of guide blades situated between two rotor stages. In the first row of stator nozzles the steam expands from inlet pressure to the exhaust pressure and a kinetic energy of the steam is increased. This expansion should be adiabatic as it gives the greatest possible heat drop but due to friction losses it is polytropic (Figure 3). After the first stator nozzles the steam enters the first row of moving or rotor blades where the kinetic energy and thus the absolute velocity of the steam is reduced. This reduction of kinetic energy and velocity produces a force which acts on the turbine rotor blades and turns the rotor of the steam turbine. From there, steam flows through second stage of stator blades or guide blades where steam is proceeded to the second row of moving or rotor blades. There the kinetic energy and thus the absolute velocity of the steam is again reduced in order to produce a rotational force. Figure 4 shows the behavior of the steam pressure and absolute velocity over the stages in one Curtis wheel steam turbine.

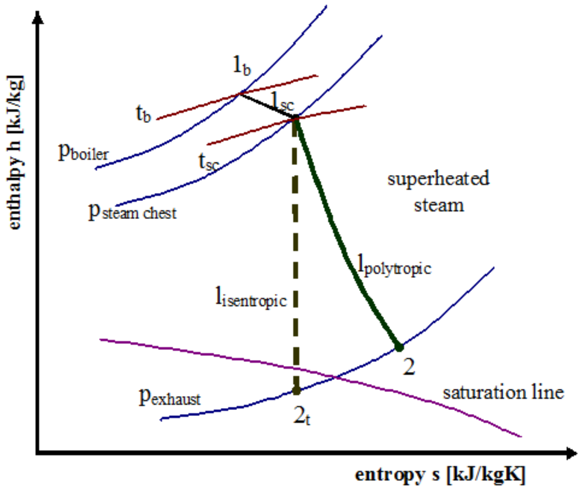


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Figure 3: Main feed water steam turbine isentropic and polytropic expansion

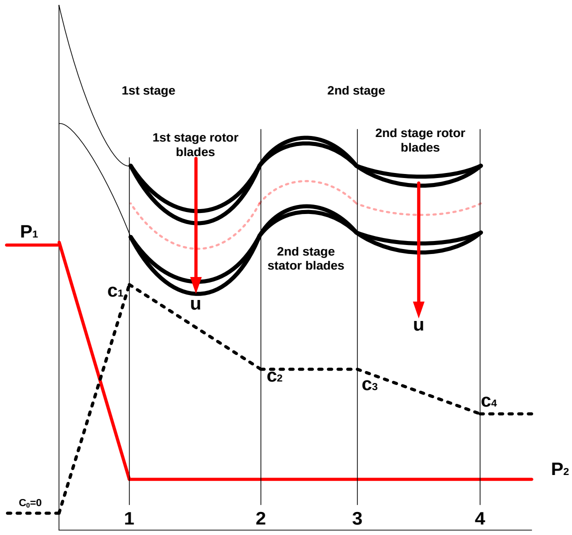

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Figure 4: Steam pressure and absolute velocity diagram in Curtis wheel steam turbine

Because of the steam turbine rotor rotation the absolute steam velocity has to be divided into relative steam velocity *w* and rotational velocity *u*. Figure 5 shows diagram of absolute steam velocities *c*, relative steam velocities *w*, rotor rotational velocity *u*, axial forces F_x, and thrust forces F_y over the stages in one Curtis wheel steam turbine.

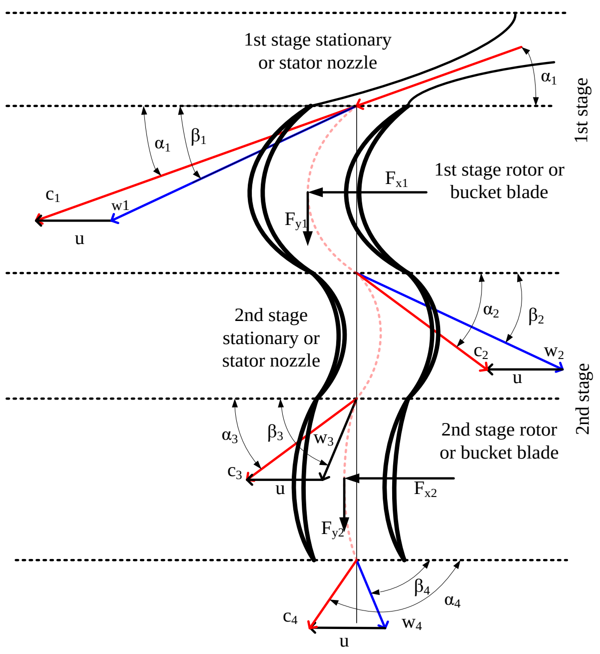

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Figure 5: Absolute and relative steam velocity diagram at Curtis wheel steam turbine

Each value can be calculated using following equations [6]:

$$c_1 = \varphi \cdot \sqrt{2(h_1 - h_2)} \quad \left[\frac{m}{s}\right] \tag{1}$$

$$u = D \cdot \pi \cdot n \quad \left[\frac{m}{s}\right] \tag{2}$$

$$w_1 = \sqrt{u^2 + {c_1}^2 - 2 \cdot u \cdot c_1 \cdot \cos\alpha_1} \quad \left[\frac{m}{s}\right] \tag{3}$$

$$w_2 = \psi \cdot w_1 \quad \left[\frac{m}{s}\right] \tag{4}$$

$$c_2 = \sqrt{u^2 + {w_2}^2 - 2 \cdot u \cdot w_2 \cdot \cos\beta_2} \quad \left[\frac{m}{s}\right] \tag{5}$$

$$c_3 = \varphi \cdot c_2 \quad \left[\frac{m}{s}\right] \tag{6}$$

$$w_3 = \sqrt{u^2 + {c_3}^2 - 2 \cdot u \cdot c_3 \cdot \cos\alpha_3} \quad \left[\frac{m}{s}\right] \tag{7}$$

$$w_4 = \psi \cdot w_3 \quad \left[\frac{m}{s}\right] \tag{8}$$

$$c_4 = \sqrt{u^2 + {w_4}^2 - 2 \cdot u \cdot w_4 \cdot \cos\beta_4} \quad \left[\frac{m}{s}\right] \tag{9}$$

$$F_x = F_{x1} + F_{x2} \quad [N] \tag{10}$$

$$F_{x1} = m \cdot (w_1 \cdot \cos\beta_1 + w_2 \cdot \cos\beta_2) \quad [N] \tag{11}$$

$$F_{x2} = m \cdot (w_3 \cdot \cos\beta_3 + w_4 \cdot \cos\beta_4) \quad [N] \tag{12}$$

$$F_y = F_{y1} + F_{y2} \quad [N] \tag{13}$$

$$F_{y1} = m \cdot (w_2 \cdot \sin\beta_2 - w_1 \cdot \sin\beta_1) \quad [N] \tag{14}$$

$$F_{y2} = m \cdot (w_4 \cdot \sin\beta_4 - w_3 \cdot \sin\beta_3) \quad [N] \tag{15}$$

$$P = F_x \cdot u \quad [W] \tag{16}$$

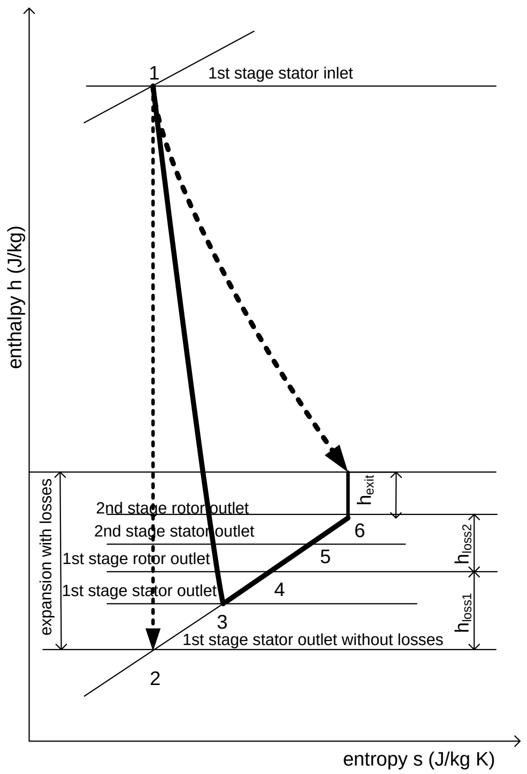
$$\eta_T = \frac{P}{(h_1 - h_2) \cdot m} \tag{17}$$

Where φ is friction loss in stator nozzle, h_1 and h_2 are steam specific enthalpies, *D* is rotor diameter, *n* is number of turbine revolutions, ψ is friction loss in rotor blades, *m* is steam mass flow in kg/h, *P* is steam turbine power and η_T is steam turbine efficiency.

Angles α and β can be calculated using laws of cosine or sines. In an impulse steam turbine, which Curtis wheel is, the $\beta_1=\beta_2$ and $\beta_3=\beta_4$ because of the same inlet and outlet geometry of the rotor blades [6].

Manufacturing defects, carry-over deposits, corrosion and erosion in stator and rotor blades increase the friction and reduce steam velocity. Some of the kinetic energy converts back into heat energy, re-heating the steam and representing losses in the turbine [7].

Those steam velocity losses are presented as a velocity losses in stator nozzles φ and are from 0.90-0.98 and velocity losses in rotor blades ψ (from 0.70-0.90) [6]. Also, Curtis wheel has high exhaust velocity (which is like a available heat drop) and this represents a considerable loss of energy that is not used in other stages [7].



Source: Authors

Figure 6: Losses in the stator and rotor blades of Curtis wheel steam turbine

Because of the all mentioned losses, steam turbine efficiency decreases. Figure 6 shows how steam velocity reduction and high exhaust velocity influence the reduction of heat drop and thus on steam turbine efficiency.

This velocity losses and consequently heat drop losses can be calculated using following equations [6]:

$$h_{loss1} = \frac{c_{1t}^2}{2} - \frac{c_1^2}{2} + \frac{c_2^2}{2} - \frac{c_3^2}{2} \quad \left[\frac{kJ}{kg}\right] \tag{18}$$

$$c_{1t} = \sqrt{2(h_1 - h_2)} \quad \left[\frac{m}{s}\right] \tag{19}$$

$$h_{loss2} = \frac{w_1^2}{2} - \frac{w_2^2}{2} + \frac{w_3^2}{2} - \frac{w_4^2}{2} \quad \left[\frac{kJ}{kg}\right] \tag{20}$$

$$h_{exh} = \frac{c_4^2}{2} \quad \left[\frac{kJ}{kg}\right]. \tag{21}$$

Other losses in steam turbine like windage, gland and blade tip leakage can be neglected because of its small influence on overall efficiency and in this paper it will not be taken into consideration.

3 STEAM TURBINE ANALYSIS

In this paper the steam turbine for feed water pump is analyzed using the data from the performance test on one LNG ship. During the test, steam flow to the turbine was changed by opening and closing the governing valve. This change affects the turbine revolution, steam chest pressure and exhaust temperature. Available steam turbine data from the performance test is presented in Table 1. Steam specific enthalpies and entropies necessary for the calculation were taken from steam tables [8].

Table 1: Data from the performance test of steam turbine for Shinko feed water pump

Steam inlet pressure bar	Steam inlet temperature °C	Steam chest pressure bar	Exhaust pressure bar °C	Exhaust temperature °C	Steam flow kg/h	Revolution min^{-1}
59.8	372	29	2.8	200	2591	5420
59.8	376	35	2.8	193	2994	5491
59.8	379	43	2.8	189	3510	5583
59.8	382	46	2.8	185	4031	5762
59.8	384	46	2.8	185	4668	5981
59.8	384	49	2.8	185	4893	6115
59.8	383	46	2.8	197	4620	5977

Source: Shinko Ind. Ltd. (2006): Final drawing for Main Feed Pump & Turbine, internal ship documentation. Hiroshima, Japan.

Steam turbine parameters for calculating all other data presented in Table 2 are as follows:

- Rotor diameter D=800 mm,
- Steam inlet angle α_1=18°,
- Stator losses φ=0.94,
- Rotor losses ψ= 0.7-0.79.

Rotor diameter and steam inlet angle used in this analysis are values taken just for the calculation and in reality depend on steam turbine production model or type. Stator and rotor losses, as already mentioned, depend on various factors. In this example value for stator losses was assumed to be 0.94 in order to simplify the calculation. Values for rotor losses were modified from 0.7-0.79 depending on the initial steam and temperature situation in order to obtain certain steam turbine power. In reality, steam turbine power depends on various combinations of stator and rotor losses, rotor diameter and steam inlet angle. Major influence on this analysis have steam inlet and exhaust pressures and temperatures. Rotor diameter and steam inlet angle are fixed for any analyzed turbine and losses depend on the actual status of the steam turbine and will not change end parameters a lot.

Table 2: Calculated data for steam turbine used for driving the Shinko feed water pump

t_1 °C	372	376	379	382	384	384	383
p_{sc} bar	29	35	43	46	46	49	46
t_2 °C	200	193	189	185	185	185	197
m kg/h	2591	2994	3510	4031	4668	4893	4620
min^{-1}	5420	5491	5583	5762	5981	6115	5977
φ	0.94	0.94	0.94	0.94	0.94	0.94	0.94
ψ	0.79	0.77	0.73	0.74	0.75	0.73	0.70
c_1	955	985	1014	1024	1026	1033	1025
u	227	230	234	241	250	256	250
w_1	743	770	795	799	792	794	791
α_1 °	18	18	18	18	18	18	18
β_1 °	23.4	23.3	23.2	23.4	23.6	23.7	23.6
w_2	587	593	579	588	593	579	554
c_2	389	392	375	379	377	360	340
α_2 °	36.8	36.7	37.4	38.0	39.0	40.4	41.0
β_2 °	23.4	23.3	23.2	23.4	23.6	23.7	23.6
c_3	366	369	353	356	355	338	319
w_3	229	230	219	223	225	219	209
α_3 °	36.8	36.7	37.4	38.0	39.0	40.4	41.0
β_3 °	73.2	73.4	77.7	79.8	83.6	89.6	92.2
w_4	181	177	160	164	168	160	146
c_4	246	247	254	267	286	301	295
α_4 °	135	137	142	143	144	148	150
β_4 °	73.2	73.4	77.7	79.8	83.6	89.6	92.2
F_x	964	1138	1310	1502	1703	1713	1564
F_y	78	100	140	158	176	198	202
h_{l1}	69	73	76	78	78	78	76
h_{l2}	114	131	160	158	149	159	171
h_{exh}	30	30	32	36	41	45	43
η_T %	58.8	57.2	53.9	54.4	55.2	53.3	51.2
P kW	219	262	306	362	426	439	391

Source: Authors

As it can be seen from the analysis, steam turbine efficiency depends on many parameters and varies from 51.2 to 58.8%. Enthalpy of the inlet and outlet steam, steam losses in stator and rotor blades, value of exhaust velocity and steam mass flow are one of the crucial parameters that affect the steam turbine efficiency. Steam velocities across the turbine depend on the operational and manufacturing parameters and that affects φ and ψ parameters and stator and rotor enthalpy losses. Steam turbine power varies from 219 up to 439 kW. It depends on steam mass flow, revolution and converted kinetic energy in rotor blades into the axial force for turning the rotor. The higher the value of these parameters is, the higher will be the value of steam turbine power.

Analysis performed in this paper shows an example of how steam turbine can be modeled and presented in a way that end users can easily understand all processes in the turbine and through available data/parameters in the engine room calculate all other specific parameters of the steam turbine.

Every engineer should follow instruction manual recommendation for operation and maintenance of the steam turbine in order to timely recognize any fault or failure of the feed water pump. Additional information through parameter analysis can help in better understanding the processes and recognizing any problem during normal operation of the steam turbine.

4 CONCLUSION

This paper presents types of feed water pumps and driving steam turbine used for delivering the feed water into the main boilers of the LNG ships. Coffin and Shinko feed water pumps are mostly used types. They are centrifugal pumps with two or three stages. Both feed water pumps are driven with Curtis wheel steam turbine which comprises of first row of stationary or stator nozzles, two rows of moving or rotor blades and one stator row of guide blades situated between two rotor stages.

The expansion in the steam turbine stator nozzles is polytropic where increased steam kinetic energy in the stator is converted into force which acts on the turbine rotor blades and turns the rotor of the steam turbine. Steam velocities and losses in the stator and rotor blades directly influence the steam turbine efficiency. Analysis performed using the performance test data provides the end user all necessary data and enables him a better understanding of the processes and to recognize the problem if any exists.

Steam turbine efficiency in analyzed example depends on many parameters and varies from 51.2 to 58.8%. Some of the crucial parameters that affect the steam turbine efficiency are: enthalpy of the inlet and outlet steam, steam losses in stator and rotor blades, value of exhaust velocity and steam mass flow. Steam velocities across the turbine depend on manufacturing defects, carry-over deposits, corrosion and erosion in stator and rotor blades. Other losses that can affect the steam turbine efficiency are windage, gland and blade tip leakage. Steam turbine power in analyzed example varies from 219 up to 439 kW. It depends on steam mass flow, revolution and converted kinetic energy in rotor blades into the axial force for turning the rotor.

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