This book is a collection of research works in the cross-section of maritime studies, information and communication technologies (ICT), and operations research. It contains a "layer" of topics that are more technical, and a "layer" of topics that are more managerial and business oriented. The fields of research are related to the author's quite diverse interests in certain periods of time, and her success in applying for some research grants.

The manuscript can serve as valuable material for educational and research purposes. This is especially important if we keep in mind that digitalization in maritime sector lags behind other business and industry sectors.

Maritime Issues in Digital Age

Sanja I. Bauk

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CONTENT

Chapter 4: New media in seafarers' education and training

Chapter 5: Intelligent use of ICT in maritime business and some Cloud perspectives

Chapter 6: Neuro-fuzzy modeling and some ship route optimization problems

Preface

The book contains several original research ideas and their analysis, predominantly in the form of preliminary communications in several fields of maritime business and industry, and some overlaping areas. It analyzes the spectrum of topics in the cross-section of maritime affairs, information and communication technologies (ICT) and some operations research techniques. Some of the topics are more technical, while others are more in the domain of management. In other words, the book contains a "layer" of topics that are more technical, and a "layer" of topics that are more managerial and business related. It covers a fairly wide area of maritime issues, which typically requires inter-, multi- and/or trans-disciplinarity approaches.

From a technical point of view, the book firstly discusses the problems related to increasing the safety of port workers, and indirectly the protection of marine ecosystems by using wireless sensor networks and corresponding back-end info-communication systems. It also consideres the possibilities for modeling the degree of the ship hull corrosion deterioration during exploitation cycle. Finally, the group of technical problems discussed in the book includes the proposals and analysis of several decision support neuro-fuzzy models in sea navigation.

Regarding topics in the domain of management, in the broader sense, the book analyzes the possibilities of (re)positioning the seaports from the marketing aspect by using the methods of multi-criteria optimization. It also consideres the possibilities of adopting and implementing new media in the transfer of knowledge in maritime sector and in general, with a focus on the developing environments. Finally, the book presents the results of a pilot study on the intelligent use of the available info-communication systems in some selected maritime organizations, with the aim of creating a *fertile ground* for implementation and routinization of new, more advanced and more sophisticated systems of this kind in perspective.

This book does not have to be read from "cover to cover", even every single chapter does not have to be read from the beginning to the end. The reader can choose any work of his/her interest, and focuses on it. In a way, this book is a kind of *professional encyclopedia* of research studies in maritime industry, business, education, and even more. Each chapter begins with a concise description of the work it contains, the results obtained, and guidelines for further research, which can serve as a useful guide to the readers. Each study provides an exhaustive list of literature, which can be used as a *hyperlink* for further, more intensive analysis of related problems.

Thus, the book can serve as an inspiration and a starting point for further, more detailed research. It can also serve as an encouragement for comments by other researchers, in professional publications, which should be a constructive contribution to the development of critical thought and productive debate in maritime community. It will undoubtedly increase the visibility of included research works in the academic, administrative, commercial and/or industrial maritime communities.

Author

Introduction

This manuscript includes research works, which topics are related to vari-ous maritime issues and analyzed through the prism of information and communi-cation technologies and through the methods of operations research.

The book contains six chapters, and each begins with a short description of the issue discussed, the results obtained, and guidelines for further research. The topics are related to my research interests in certain time periods, based on the need for cooperation with some of my colleagues, and opportunities for my suc-cess in applying for some research grants.

Chapter 1: This chapter concerns the use of wireless sensor networks on worker's bodies, and on transport and transshipment machinery in seaports, with the aim to increase safety and wellbeing of port workers, pedestrians, and to pro-tect the port ecosystems. Thanks to this new technology, seaports should become recognizable as safety and green in the global maritime market.

Chapter 2: In the focus of this chapter is the (re)positioning of several ana-lyzed seaports in the Adriatic, Aegean and Black Sea basins on the basis of their qualitative and quantitative features, using some of the operations research meth-ods, such as: multi criteria decision making, analytical hierarchy process, matrix games, binary programming, and so on.

Chapter 3: This chapter examines the impact of corrosion degradation on the aging bulk carriers' stability. The simulation probabilistic models have been developed over the data on corrosion losses, collected during the operational cycle of the analyzed ships. These studies have had as an ultimate goal to provide rather modest contributions in terms of modeling procedures for maintaining and pre-serving the ship's hull structure, or to prevent the accidents caused by general cor-rosion.

Chapter 4: This chapter deals with the deployment of actual information-communication technologies in seafarer education and training, with a special emphasis on acquiring knowledge in maritime navigation. Distance learning mod-els have been analyzed, as well as the possibilities of using advanced tools for creation, postproduction, and distribution of e-instructional materials. Also, in this context, some basic info-communication functions of the nautical simulator were analyzed. Additionally, one paper in this chapter discusses the issue of current digital divide and real possibilities of moving education to the Cloud, with a spe-cial focus on developing regions.

Chapter 5: This chapter concerns the questions: to which extent are the available information and communication systems and tools intelligently used in some marine business organizations, and how the efficiency of their use could be increased. This chapter also discusses some issues related to tagging/chipping products (or, products digital charging) in the supply chains in developing countries, with recommendation of the methodological framework for adopting outsourcing in Cloud as one of the potential solutions.

Chapter 6: This chapter contains tree research studies related to neuro-fuzzy modeling as a tool for supporting the decision-making process in choosing an optimal navigation route, especially in a situation when the function of automatic route selection in the information system of the electronic charts requires the navigator intervention. Additionally, here are analyzed some possibilities of determining the optimal navigational route using the neural network itself, as well as a combination of neural network and fast insertion heuristics for the needs of prior data processing.

This book should serve to those who are interested in these topics, as a basis for acquiring certain knowledge, or as a starting point for further research in the cross-section of maritime studies, information and communication technologies, and some methods of operations research. Likewise, the book can be used as a reference material in teaching at maritime higher education under- and post-graduate studies.

Chapter 1:
Wireless networks models for increasing occupational safety at seaports

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1. Preface

This chapter considers several problems on the wireless networks modeling for the safety of port workers and pedestrians. Simulation experiments were performed in Opnet and Omnet++ environments over layout of the container and general cargo terminal at the Port of Bar (Montenegro). Firstly it was experimented with RFID technology, then with hybrid RFID/ZigBee systems, and finally with vehicular communication technology.

Primarily it was conducted a detailed research on what has been done so far in these areas. A considerable scarcity of the relevant literature has been noted. Somewhat similar experiments were performed in constructing-, mining, steel-, and oil-industry, but not in maritime one. Therefore, this is an innovative approach, worthy of attention. This chapter considers the protection of human lives and their wellbeing with zero accident tolerance, as well as the protection of port and marine ecosystems.

All simulation experiments have shown good results in terms of identifying and monitoring workers, also in checking whether workers wear personal protective equipment and, whether it is functional or not. However, the problem was adopting and routinizing of these new information-communication technologies in an invasive port environment. This problem is especially emphasized in the conditions of transitional economy, in which operates the Port of Bar, which was in the focus of the research. There are problems of infrastructure (dedicated access points, back-end systems, and servers), and the problems of administrative and organizational changes, which inevitably follow the implementation of such safety solutions based on sophisticated info-communication tools and back-end, so-called, system of systems.

In addition, all simulation experiments were performed in accordance with the real conditions of the Port of Bar, which include a relatively small operating surface, low workload and turnover, and a small number of workers per shift. This raises a new question: whether the proposed models would be equally effective in the case of a larger industrial (or harsh) system with a higher number of workers and a higher workload.

Here should be emphasized that we deliberately avoided using the Internet of Things concept, because such a solution would be too expensive for the Port of Bar as a port that has been developing for nearly three decades under conditions of an unstable transitional economy. In such circumstances, the functioning of the port can not be attributed to the validity of institutional isomorphism (i.e., coercion, mimesis, and norms), which additionally complicates the situation, increasing safety of employees and port ecosystems by using advanced info-communication capabilities.

In the preliminary research works which deal with the idea of using vehicular communication, as an emerging technology, in managing the port transport and the increase safety, there are numerous infra-structural, administrative and organizational impediments towards eventual achievement of innovative success.

Regardless of the perceived obstacles in the implementation of the proposed network models, we can view them as an inspirational basis for possible further research. Port managers and stakeholders can use them as an orientation towards the development of environmental management system, promoting the Port of Bar (or similar ports in developing countries) as safe and green, which would allow its (their) positive (re)positioning at the global maritime market.

1.1. Wireless networks in enhancing occupational safety

This research work proposes two Wireless Body Area Network Sensors (WBANSs) scenarios at the logical and simulation levels for improving occupational safety and health conditions at the developing seaport environment. The Port of Bar (Montenegro) is taken as an exemplar. The logical model is based on the actual position of the Port of Bar at the seaport market, its needs and capacities for the information systems innovation through technology transfer and diffusion. The simulation model analyses the channel between the body central unit (BCU) of the worker's on port wireless body sub-network and the port access point. The quality of the signal transmission at the physical layer has been tested through a source code generated in the Matlab. The code includes the BCU composite signal modulation, transmission, and demodulation, along with a noise and fading effects analysis. The results of the simulation experiments for the different transmission frequencies and distances between transmitter (worker's BCU) and receiver (port's access point) by using binary phase-shift keying (BPSK) and quadratic phase-shift keying (QPSK) modulation schemes are presented. Some directions for further investigations in this field are given, as well.

1. Introduction

With the advancement of Information and Communication Technology (ICT) which enables *smart* networking business models, cargo and passenger ports services are nowadays considered like high technological processes enriched by informational and electronic transactions components. However, it is not to be forgotten, transportation and traffic are still physical acts and all ports therefore need terminals including all corresponding capacities and features. The sea ports need primarily the adequate infra and suprastructural capacities, adequate organization, sustainability development planning and numerous other structural, financial, and environmental issues which form the foundation for the ICT superstructures [1,2]. This holds true for huge developed sea ports like Shanghai, Singapore, Hong-Kong, Busan, Rotterdam, Kaohsiung, Hamburg, Antwerp, Felixstowe, etc. On the other side, this is not the case for ports of developing countries in the South Adriatic region, e.g., Bar, Durres, Kotor, Ploce. Accordingly, in the focus of the paper shall be the last mentioned ones, primarily the Port of Bar.

Previous research in this field indicates that underdeveloped sea ports at the South Adriatic region suffer from the lack of the appropriate ICT solutions [1,3,4]. Some of the analyzed sea ports in this basin, e.g., Bar, Durres and Ploce, do not provide all, or some of the following *smart* operation processes: vessel monitoring, automatic containers control, scheduling and stacking containers, monitoring of cargo in stock, etc. These ports have mainly partial, fragmented ICT solutions for supporting some administrative and operational procedures, but they commonly do not have Enterprise Resource Planning (ERP), Customer Relationship Management (CRM) software solutions, Electronic Data Interchange (EDI) service, Vessel Traffic Management Information Systems (VTMIS), National Maritime Single Windows (NMSWs), Electronic Logistics Marketplace (ELM) access, etc. In addition, according to the previous research work [5-7], the passenger sea Port of Kotor is not digitally present at the appropriate scale on the web, in comparison to some developed EU ports of the same kind, what makes negative implications in terms of its position on the customers' perception maps.

The lack of ICT applications in some cargo and passenger ports within the South Adriatic region might be explained by a relatively small turn over of these ports. Consequently, they are lacking the justification for adopting the above mentioned rather costly ICT solutions which would provide greater automation and complete logistic integration of the ports' administrative and operational processes. From another side, insufficient digital presence of the Port of Kotor, e.g., in comparison to some recognized EU passen-

ger ports can be explained by the lack of some value-added and e-transactional services that this port should provide to the customers.

The question here is: Which kind of ICT solutions are urgently needed and at the same time feasible in developing seaports with focus on the South Adriatic and the Port of Bar in the first instance? – Regardless of the turn over of the ports in this region and the economical and political milieu in which they operate, providing the appropriate employees (primarily on port workers) safety and health management, must be placed in the forefront. Therefore, our idea is to propose two wireless network models convenient for improving working conditions and workers' occupational health and safety. The proposed models should be at the same time cost-effective and relatively easy to be implemented and run. The proposed models can be adapted to satisfy the individual needs and capacities, especially if we bare in mind certain organizational and human capacity limitations that are present in the considered Port of Bar, especially when it comes to installing new ICT solutions, along with their continuous maintenance, providing their flexibility and scalability in the future.

2. Port of Bar: In brief

The Port of Bar[1] has a favorable geographical position. With the railway line Belgrade-Bar and the road network in its hinterland, along with the intermodal transportation and traffic links with Italian ports Bari and Taranto, it could provide good connections within its rather wide gravitational area. Thanks to its advantageous geographical position it might be developed into the distribution center for the whole region. More about the Port of Bar can be found on its web site and in the documentation of numerous regional and EU projects in which realization the Port of Bar has been involved.

In the period from 2007 to 2013, the Port has participated in implementation of several EU projects which concerned [8]:

- strengthening intermodal transport;
- short-sea shipping possibilities;
- integrated logistics chains and attracting innovative investments;
- improving environmental impacts at ten South East European (SEE) ports (TEN ECOPORT);
- establishing a sustainable transport system at the Adriatic coast and in the hinterland;
- improving environmental protection (marine/river pollution);
- detecting dangerous materials under the sea water in the ports' area;
- developing sustainable integral sea-land transport/traffic network;
- concerning integration of maritime and river transport in the logistics chain;
- pollution prevention in the SEE ports (ECOPORT 8), etc.

Partners from the EU were at most of these projects leading ones, so that the Port of Bar was not mainly in a position to independently decide on the allocation of the available funds. During the projects implementation everything remains on the level of consideration of previous appropriate practices, data collection, analysis, modeling, but when it comes to the implementation of innovative solutions, it seems that the results are quite weak, almost minor. Attracting foreign investments is not realized in the planned volume

[1] URL: http://www.lukabar.me/eng/Port_of_Bar.htm, last access: September, 2016

due to the high administrative barriers, inconsistencies in law enforcement and economic uncertainty within the region. It seems that this geographical area, including Port of Bar as its strategically important sea-land transportation node, remains in the *vacuum of inadequate solutions* [8,9]. It is necessary to make a clear strategy including the competitive and agile administrative and personnel structures that will devotedly work on achieving development in the sphere of freight multimodal, intermodal, co-modal and/or synchromodal [10] transportation modes in the future.

2.1. Safety and health management in the Port of Bar

Within the projects TEN ECOPORT [11] and ECOPORT 8 [12], some recommendations for further actions towards improvement of working conditions and occupational safety in the Port of Bar are provided. The most harmful environmental and workers' health and safety impacts are identified. The working processes in the Port are also analyzed in detail and the points with the highest level of risk to the workers employed directly on port operations are specified. Most of the safety and health issues in the Port of Bar are described in detail in the Port safety management official acts and within the previously mentioned projects' documentation. On the basis of a previous detailed analysis in these fields, here will be given an envisaged approach to the problem, in terms of proposing two WBANSs scenarios which are in accordance with the Port of Bar needs and contemporary ICT based safety management recommendations in this domain.

For the purposes of the project TEN ECOPORT realization, several in-dept interviews with the managers in the Port of Bar were performed [13], and the highlights in terms of the most common risks to which the workers directly on port are exposed are identified. These risks are: working outdoors at various (unfavorable) weather conditions (extremely high or low temperatures, rain, wind, etc.), exposure to the dust during the transshipment of bulk cargos (grains, all types of ores and concentrates, alumina, etc.), maneuvering with obsolete transshipment equipment and transportation devices, manipulating with damaged cargo (bags, pallets, packages, containers, etc.), exposure to the risk of fire (especially during the summer months), etc. In addition, workers on port are realizing mostly monotonous and repetitive operations what results in fatigue which increases the risk of accidents.

Above listed risks correspond to those identified and in detail explained, e.g., by the UK Health and Safety Executive (HSE) and Irish Health and Safety Agency (HSA) in seaports, as credible institutions, including the advices for risks preventing and straightforward reacting in the cases when the accidents unfortunately occurred [14-16]. The HSE also gives the extensive list of references in terms of operational and law regulations in these fields, including the relevant statistics. It is worth to mention here that the UK Port Employment and Accident Rates (2009/2010) statistical report stands: "The estimated annual accident rate for all direct on-port employees was 1.1%, or 1,100 per 100,000 employees. …An employee of a direct on port company is more than fifty times more likely to have an accident (across all severities) in comparison to an employee based in office." These data support the hypothesis that working directly on a port is really dangerous occupation.

Since the Port of Bar has a low turnover, its workers are *spared* to the considerable extent of some risks to which are exposed the dock workers in the world's leading ports. Therefore the relatively low level of turnover in the Port of Bar, with the aspect of the risks, might be treated as an advantage. Regardless of this fact, in the following parts of

the paper two scenarios are proposed for improving safety and health conditions of workers on docks in the Port of Bar.

The first one is based on WBANSs being attached to the workers' personal protective equipment (hard helmets, protective jackets, or safety vests, and ptotective shoes) including a BCU (Body Central Unit), while the second one deals with wearable WBANSs for scanning and transmitting in regular time intervals vital body (electrophysiological) signals: skin temperature, heart activity, respiratory rate, acceleration, oxygen blood saturation, and level of glucose. Although the additional body signals relevant in assessing and improving overall human body (workers') health conditions today might be used trough: artificial cochlea, artificial retina, camera pill, carbon dioxide sensor, visual sensor, bio-impedance spectroscopy, chipped sweatbands, etc. [17-20], for the purpose of this study, the attention will be put to the firstly listed ones.

3. Scenario 1: WBANSs as parts of Personnel Protective Equipment (PEE)

The workers in the Port of Bar are working mainly at open space (docks, open stacking and warehousing areas, gangways, etc.) under various weather conditions with obsolete manipulative equipment and transportation devices, so they are exposed to the variety of non negligible risks. In order to reduce them, the workers should wear personal protective equipment which at least includes: hard helmet, jacket (safety vest) and protective shoes. Over each piece of these garments are to be attached Radio Frequency IDentification (RFID) tags/chips which provide at least an ID for each of the personal protective equipment parts and the data on its functionality. The RFID tags/chips play here the role of the WBANSs. Besides IDs and tags/chips functionality data, the RFID-sensor device attached to the workers' helmets should also provide the information about the temperature and light inside the helmet, while the RFID-sensor devices on the protective shoes should provide the data on workers' plantar pressure. By measuring temperature and light, it is possible to capture the information about working environment conditions, and by measuring plantar pressure distribution it is possible to get the information about the workers' performed actions (Figure 1).

These WBANSs are wirelessly connected through the access point to the advanced back-end info-communication system which sends warning to the worker in cases if a part of personal protective equipment is missing, or if it is not functional. In such case the worker has to come to the central and change that piece of the protective equipment. Also, the worker will be warned in cases when ambient temperature and light are not appropriate.

Similar scenario has been already employed at the Cagliari International Container Terminal, and analyzed in [21-23]. In these references Sole, et al., deal with radio networks for public safety; avoiding possible false alarms generated by the WBANSs; the system of video cameras for feature recognition; the specific absorption rate (SAR) level analysis, etc. We are focus here on simulating network segment on the physical layer between Body Central Unit (BCU), or handheld RFID-sensors' reader, and the access point or sink node of the port local area network by employing several wireless propagation schemes and two modulation (BPSK and QPSK) types.

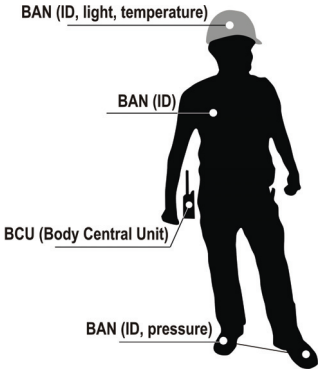

Fig. 1. The WBANSs on worker's personal protective equipment RFID-sensors and BCU (Adapted from [21])

The physical layer addresses the lower-level operations of the radio interface for a transmission and reception of packages in a harsh environment like the seaport one. These operations include the frequency selection, transmission power, modulation, signal coding and detection [24].

In the simulation section (Section 6), the communication between RFID tags/sensors and handheld reader is abstracted at this beginning phase of our research work. The content of that information is not clear at the moment and it may vary depending on the port's (i.e., workers, managers and stakeholders) real needs and preferences [25]. The attention is paid to the transmission of the composite signal, generated by previous fusion of personal protective equipment pieces IDs, temperature and light data according to the proposed scenario over the link BCU – the nearest port access point.

4. Scenario 2: WBANSs as scanners of workers' vital signs

The second proposed scenario is based on the concept of wearable sensors for measuring in real time workers' electrophysiological data. Since in Montenegro there is no reliable data on professional diseases, the choice of several types of common vital signal sensors which form worker's WBANSs is based mainly on our empirical assessments and intuition. The data published in [26] are incomplete, since they consider only the number of patients who have asked for the help in public health institutions in the recent period. But, there are a lot of people who consciously avoid asking for the health in the public health institutions in Montenegro, even if they have health problems, because the services provided there principally are unfortunately poor. Additionally, most of ill people do not have assets to ask for the help in growing number of specialized private health ambulates. This works for the on port workers, as well. Due to the best of our knowledge, the majority of ill people/workers do not "report" their illness and consequently the official statistics are trustless. Therefore the proposed model at the level of a black box, at the initial stage of our research work, might be of interest to the managers in the Port of Bar and for the health institutions in Montenegro in terms of starting with screening and collecting reliable real-time data on workers' health conditions in a harsh environment.

Figure 2 gives a schematic view of worker's on port WBANSs set, which is composed of several non-intrusive biomedical, vital data sensors for monitoring: (1) heart rate, electrocardiography (ECG), respiratory rate, skin temperature; (2) acceleration; (3)

oxygen blood saturation; and (4) glucose level, including optionally insulin pumps, only for those workers who still have some diabetes problems and who are willing to use these sensors-actuators (4).

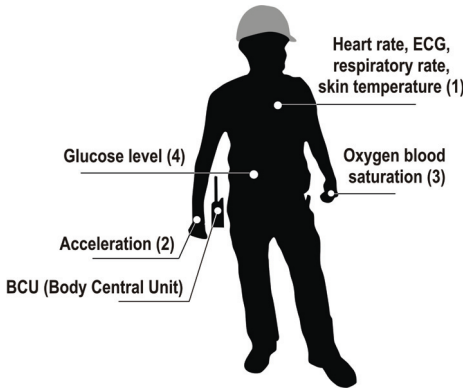

Fig. 2. WBANSs for scanning worker's vital signs sensors and BCU (Adapted from [25])

These wearable sensors (Figure 2) are briefly described as follows [25]:

Sensor module (1): It is a compact physiological monitoring module that enables capturing and transmission of comprehensive physiological data on the worker. It is proposed here for measuring: worker's heart rate, electrocardiography (ECG), respiratory rate and skin temperature.

Sensor (2): It is used for measuring the acceleration of a body in an inertial three-dimensional coordinate system, and it plays a key role in human energy expenditure detection and behavioral recognition. Since modern life style demands balanced physical work, the worker's on port physical activity in working-intensive and harsh seaport environment needs permanent recording on daily basis.

Sensor (3): It is commonly used for measuring oxygen blood saturation. It allows monitoring chronic diseases like obstructive pulmonary ones, congestive heart failures or asthma. Since on port workers are exposed to the dust and variety of air pollutants [11,12], we proposed this sensor as an element of the worker's WBANSs set.

Sensor module (4): This sensor module provides the information about the glucose level and it gives the insights into the body's glycemic profile. In addition, it may include the insulin pump therapy that implies the use of multiple daily injections or continuous subcutaneous insulin infusion therapy. It should provide an optional health care measure to the workers' on port who still have diabetes problems, strictly under the condition that they are willing to use this type of body sensor-actuator loop.

By all means, there is a plenty of options [27,28] in the considered case in terms which kind of sensors to use, who among the employees will use them or not, depending on their previous health assessment, on their personal will and on managers' decisions. The overlap in sensors' data collecting and processing is to be avoid, as well. It is important to mention that all these sensors should communicate, like in the previously proposed scenario, to the port access point via worker's handheld BCU device. The content of the information which BCU acquire from above proposed and briefly described sensors is still not clear and may vary depending on the port's needs and preferences, along with the workers readiness to become a part of such network. There-

fore, it is abstracted here as a payload that is to be transmitted between worker's BCU and the nearest access point at the port perimeter. Similarly to the first proposed scenario the WBANSs are connected through the access points to the appropriate advanced back-end info-communication system which sends warnings to the worker in cases if some of his/her biomedical parameters are outside the prescribed boundaries. In such cases the worker has to leave working place and ask for the medical advice and/or help.

3. Comparison of Scenarios 1 and 2

It is clear that both presented scenarios are purposeful and it is difficult to determine which one is more effective. We tried to analyze them through three qualitative parameters: medical independence (MI), technological independence (TI) and non-invasiveness (NI). The parameter *medical independence* means that sensors can realize its purpose without (continuous) medical supervision; *technological independence* means that sensors can operate independently of other technological systems (i.e., only in coordination with BCU), and *non-invasiveness* means that the sensors are wearable or non-invasive. The values of these parameters are given in Table 1. If (RFID)sensor is independent in medical and technological terms, and/or if it is non-invasive, mark "x" is used; if it is dependent than "o" mark is used, and if it is periodically dependent on the considered parameter(s), mark "x/o" is used. Numerical values assigned to the (x; x/o; o) are respectively (1.0; 0.5; 0.0). These parameters are heterogeneous, but with positive correlation, what means: it is favorable in all cases that sensors are medically and technologically independent and non-invasive. Therefore, by simple additive method, a rather rough approximation in terms which scenario is more desirable can be made.

Table 1. Qualitative-quantitative comparison

Scenario	Sensor	MI	TI	NI
Scenario 2	Heart rate, ECG, respiratory rate, skin temperature	x/o	x	x
	Acceleration	x/o	x	x
	Oxygen blood saturation	x/o	x	x
	Glucose level (insulin pump – optionally)	o	x	o
	Score:	1.5	4.0	3.0
Scenario 1	$RFID_{Helmet}$ (ID, light; temperature)	x/o	o	x
	$RFID_{Jacket}$ (ID)	x	o	x
	$RFID_{Shoe\ 1}$ (ID, pressure)	x/o	o	x
	$RFID_{Shoe\ 2}$ (ID, pressure)	x/o	o	x
	Score:	2.5	0.0	4.0

For instance the sensor for measuring worker's heart rate, ECG, respiratory rate and skin temperature functions independently, but after a certain time it needs to be read by the physician. Similar situation is with accelerometer and oxygen blood saturation meter; while glycol meter and insulin pump requires more frequent physician scrutiny. The RFID chips with light, temperature and pressure sensors require also periodically medical survey. When it comes to the technologically independent, then the sensors which belong to the scenario 2 can function independently.

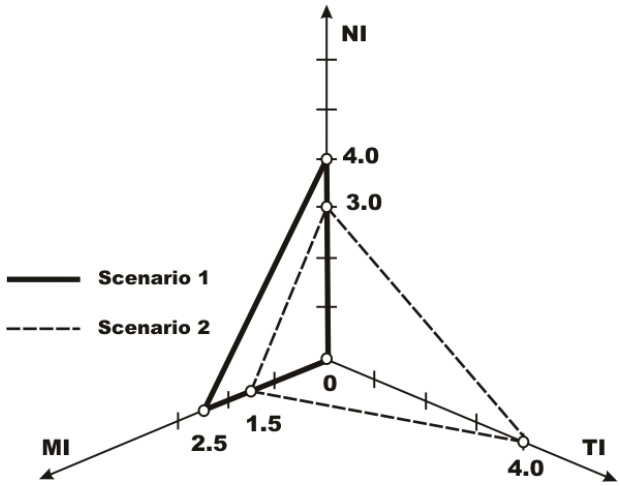

Fig. 3. Results of quantitative comparison

On the contrary, greater precision can be achieved if the sensors within the scenario 1 work in combination with system of video cameras and RFID readers fixed at strategically points in the port [22, 24, 25], besides those imbedded in workers' handheld sets (BCUs). Further, three of four sensors associate to the scenario 2 are non-invasive, except glucose pump, which can be use optionally; while all RFID-sensors in scenario 1 are non-invasive. These observations, expressed numerically, are shown in Figure 3.

The second scenario is obviously in a considerable advantage to the first one in accordance to the second parameter – *technologically independence* (TI). Meanwhile, if the port management decides to use the first proposed scenario without supplementing system of video cameras and fixed readers installed on port, it will be preferable, etc. At any rate, this comparative analysis is quite rough, and it can be used only for orientation, it terms how to perform later more detailed one. For this purpose it would be necessary to specify which of the commercial sensors will be used, in which intervals medical supervision will be carried out for each scenario, shall be used additional supporting systems in the case of scenario 1 or not, etc. However, these decisions are up to the port's managers and stakeholders, workers and ICT and medical experts who will be eventually engaged in designing and implementing such scenario(s).

4. Simulation model and some analysis

Since here are proposed two different conceptual models for monitoring occupational safety, in Figure 4 is given a wider network scheme that can envelop them. The worker's on port BCU performs RFID-sensors and biomedical sensors data access control and fusion, and transmits them through the access point to the outside world. This means data transmission via broadband modem (fixed, wireless, or mobile one), which provide high-speed connection via Internet, which is here symbolically presented as a cloud, to the advanced backend RFID-sensors' and biomedical sensors' central servers. The high-speed broadband connection can be established as: (i) Wireless Local Area Network (WLAN) by means of Bluetooth, Wi-Fi, ZigBee, UWB, or White-Fi; (ii) Wireless Metropolitan Area Network (WMAN) by means of WiMax USB modems and the towers;

and/or (iii) Wireless Wide Area Network (WWAN) by means of cellular or satellite communication systems [29,30], etc. (Figure 4).

If some among the screened on port workers need 24 hours long surveillance (Scenario 2), then they have to wear sensor(s) not only at work, but also at home. In such case, the corresponding connection to the network must exist from the home environment, i.e., the access points at worker's home place should be provided, as well.

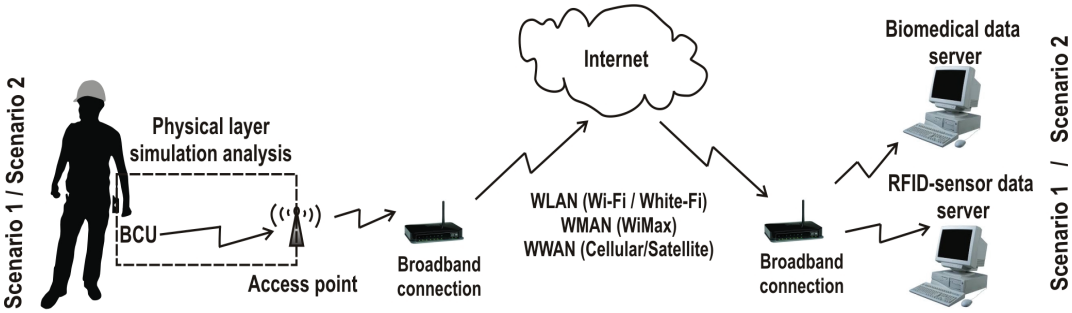

Fig. 4. A conceptual scheme of the worker's WBANSs connection to the backend servers

Whereas the proposed network structural model is a complex one, in this initial phase of our research work the simulations are limited to a small segment of the network, i.e., on the wireless link between the worker's BCU and the port's access point. Although this looks as a notably simplified simulation procedure, it is significant. Namely, this segment of the network requires at the same time low energy consumption, large scale of nodes mobility in a harsh working environment and high reliability in real-time. Hence, it is surely among the most vulnerable and challenging segments of the network in terms of further research endeavors.

The simulation model is realized in the Matlab (ver. 7.12.1), by an Inter(R) Core™ i5 processor on 2.4 GHz (4GB RAM). The key steps in creating simulation model of the channel between the worker's BCU and the port's access point are given in Table 2.

Table 2. Simulation steps in modeling the channel between BCU and access point at the physical layer

Step 1:	Definition of the simulation parameters: carrier frequency, distance between transmitter and receiver, a sequence of input bits, number of iterations, and Signal-to-Noise-Ration (SNR) range
Step 2:	Calculating Free Space Path Loss (FSPL) by (Eq.1): $\mathrm{FSPL} = \left(\frac{4\pi \mathrm{df}}{\mathrm{c}}\right)^2$ (Eq.1), where d – is the distance between the transmitter and the receiver [m]; f – is the frequency of the carrier [Hz]; and c – is the speed of light in vacuum, i.e. $\approx 3 \cdot 10^8$ [m/s]
Step 3:	Applying binary phase-shift keying (BPSK) and quadratic phase-shift keying (QPSK) modulation schemes on real and complex signal components respectively
Step 4:	Generating Gaussian noise and computing the standard deviation for each SNR value by (Eq.2): $\mathrm{P_{noise}} = \sqrt{\frac{\mathrm{P_{signal}}}{\mathrm{SNR} \cdot \mathrm{FSPL}}}$ (Eq.2), where

	P_{noise} - is the power of noise [W]; P_{signal} - is the power of transmitting signal [W]; and SNR – is the signal-noise-ratio
Step 5:	Simulating Additive White Gaussian Noise (AWGN)
Step 6:	Generating recovering (source) signal by Wiener filter which minimizes the mean square error between the estimated random process and the desired one
Step 7:	Compute the number of Bit Error Rate (BER) after the slicer, i.e., part of the code that compares the original signal with the recovered one, point by point, specifying if it is well recovered or not
Step 8:	Plotting graphics: BER vs. SNR

6.1. Simulation analysis

On the basis of the Matlab code briefly described above and summarized in Table 2, the relations between the transmitted signal, between worker's BCU and port's access point, BER and SNR are presented. In the first case the considered relation is examined for characteristic carrier frequencies in different wireless technologies [24], e.g., 915 [MHz], 2.4 [GHz] and 3.1 [GHz]. The simulation results are presented in Figure 5, and it is obvious that in all cases the BER decreases as SNR increases. The simulations are run through several thousand loops. It is clear that higher frequency causes higher BER and inversely.

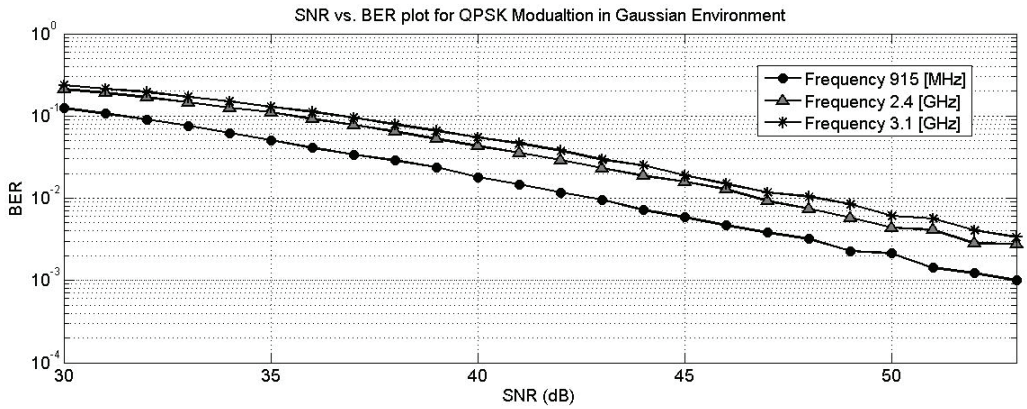

Fig. 5. SNR vs. BER for three characteristic wireless networks frequencies

Similar simulations are realized for different distances between the transmitter (worker's BCU) and the receiver (port's access point). The characteristic distances between end nodes of the simulated network segment of 10, 20, and 30 [m] are considered (Figure 6). It is clear that the BER decreases by rising SNR in all considered cases, in a manner that greater distance corresponds to a higher BER and conversely. The simulations are run like in the previous case trough several thousand loops.

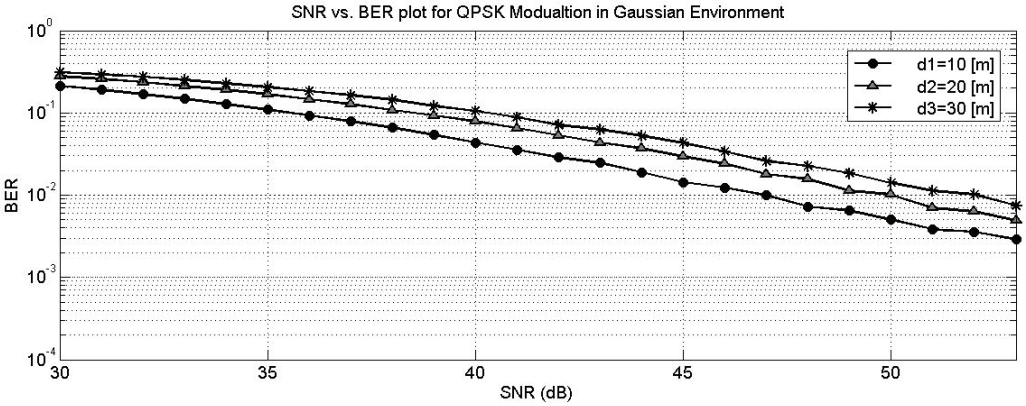

Fig. 6. SNR vs. BER for various distances between end-nodes (BCU and access point)

In addition to the simulations for typical wireless frequencies and covered distances, some simulations for White-Fi are performed. It is to be pointed out that by using White-Fi signal absorption can be avoid easily, while some additional, otherwise unused TV frequencies, might be used. In order to achieve this, the new technologies and rules are developing, like cognitive radio, geographic sensing, etc. [31]. Hereto, due to the best of our knowledge, there are no obstacles for implementing White-Fi in the considered port environment.

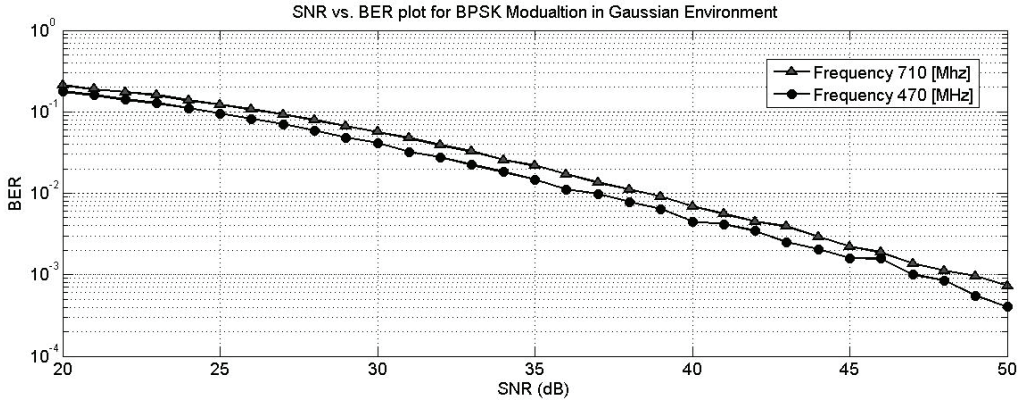

Fig. 7. SNR vs. BER for two characteristic White-Fi frequencies

In Figure 7 are shown the transmission simulation results for two typical White-Fi frequencies: 470 [MHz] and 710 [MHz]. The simulations are realized by using the BPSK modulation scheme, and it is obvious that the BER decreases to E-03 as SNR reaches about 50 [dB]. The obtained simulation results in all considered cases (see Figure 5, 6 and 7) speak in favor of the applied modulation scheme, path loss and noise models, so they can be employed as a sound basis for further, more extensive, analysis in this domain. The trade-off between BPSK and QPSK modulation schemes is simulated, as well, and it is observed that the BER is slightly lower in the case of BPSK, but it is negligible in terms of the transmitted data amount which is doubled by using QPSK [24, 32-35].

With the aim to add a dynamic dimension to the simulation analysis, we have analyzed the scenario with, e.g., four workers and four access points at 2.4 [GHz] over the port area of 1000 [m^2]. The change interval is 1 [sec] with 0.1 [sec] of standard

deviation. This means that over 1 [sec] each node will make a move at a specified speed. The speed was set to emulate the movement of a worker, approximately 3 [m/sec]. The transmission power was set to [-30 dB]. Figure 8 shows the relation of the reception power of the fixed access points and the delay. The distance and delay are linked by the speed of transmission of the signal. It is easy to notice that the received power is less as the distance and the delay decreases.

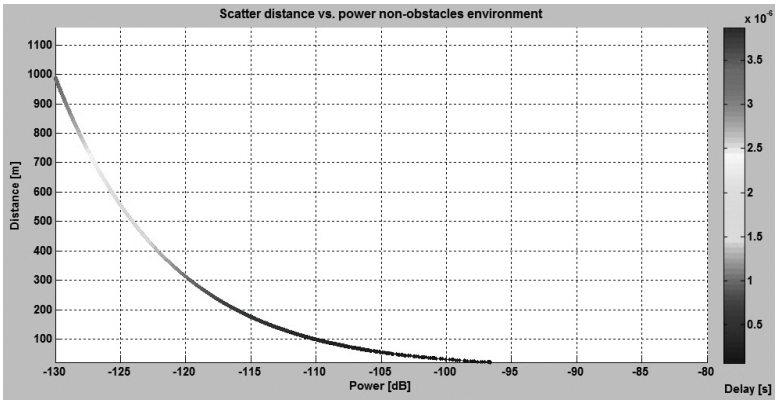

Fig. 8. The distance/delay vs. received power for a non-obstacle scenario over the port layout

If we introduce the obstacles, the scatter function will be changed (Figure 9). As the simulation experiment has been done over the layout of the Port of Bar container and general cargo terminal, the obstacles were imaginary containers blocks. Therefore, the obstacles' approximate measures were 200x100x4 [m]. The containers (obstacles) have a specific relative permittivity and permeability, which also affects the channel. When the distance and the delay were biger, the received power became lower and vice versa.

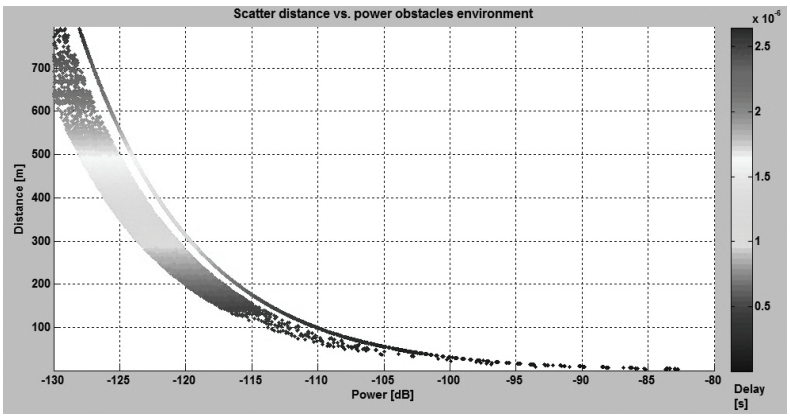

Fig. 9. The distance/delay vs. received power for a scenario with obstacle over the port layout

The scatter diagram in the scenario with obstacles has two significant shapes. The thin one represents the line of the sight signal, while the thicker one represents the reflections or the signals that pass through the obstacle. The difference between the received power of the line of a sight signal and the received power of a reflected one, or those that passes through the obstacle is approximately 1-5 [dB]. Consequently, the scenario with

obstacles needs a higher value of SNR in order to achieve the same level of BER like in the case of non-obstacle environment.

7. Conclusions

In the paper are proposed conceptually two WBANSs scenarios for monitoring workers' occupational safety and health conditions at the developing seaport environment. The Port of Bar (Montenegro) is taken as an example. A short overview of its current position at the seaport market is given. Also, some projects recently realized in the Port in the environmental and occupational safety domains are briefly presented and used as a base for the proposed occupational safety models.

The first proposed scenario has direct impact on improving workers' safety through strengthening their awareness about the necessity of the protective equipment proper use. By employing this scenario, managers can locate workers, get insight in their behavior and undertake the appropriate safety measures. On the other side, scanning and collecting data on workers' health conditions, within the context of the second scenario, might be useful in protecting workers' health and for collecting the data that can be used later for establishing cross-correlations between workers' health and their eventual (occupational) diseases.

One of the most vulnerable and at the same time challenging segments of the proposed scenarios, i.e., those between moving worker's BCU and fixed port's access point, is analyzed through the simulation experiments, and the following is drawn out:

- By analysing different characteristic frequencies for wireless communications and distances between the transmitter (BCU) and receiver (access point), a satisfying level of BER is achieved by using both binary phase-shift keying (BPSK) and quadratic phase-shift keying (QPSK) modulation schemes;
- In addition to standard frequencies for wireless communications (915 [MHz], 2.4 [GHz], and 3.1 [GHz]) between the transceivers, two characteristic frequencies from White-Fi spectra (470 [MHz], and 710 [MHz]) have been examined, while the satisfying level of BER has been achieved, too;
- The scatter functions, in the simulation environment without and with obstacles, both contain the line of sight signals, and their values are the same in both cases;
- In the scenario which includes the obstacles, the attenuation of the signal of 1-5 [dB] has been noticed (shadowed area below line of sight signal in Figure 9), etc.

The managers in the Port of Bar can use the proposed WBANSs scenarios, along with the simulations results, as the landmarks in the course of adopting these or similar models and in the negotiation processes with the ICT experts responsible for the (eventual) implementation in the future. It should be noted that both concepts simultaneous adaptation can make a burden for workers and port management.

Our work is not without shortages and below are noted some of them. Albeit the considered topic is a *hotspot* of contemporary research in several scientific disciplines, numerous and complex problems still remain. There are a lot of challenges when it comes to the on- and in-body sensors' technology, data fusion and network communication technology. The networks of such kind also need evolving standards for co-existence and data transfer with other networks and Internet. In this paper, simulations are realized rather at the level of black box over one small and simplified segment of the network. Therefore, the further experiments should be oriented toward considering larger network

segment, or the entire network, in terms of data processing algorithms, communication protocols, power consumption, network flexibility and robustness. Bearing these in mind, our further investigations will be focused on the simulations of the network with larger number of moving BCUs and fixed port's access points. These simulations will be done by means of Matlab, LabView, Opnet and/or Omnet++ tools.

In addition to the above mentioned limitations in the technological realm, there are several organizational and ethical issues which deserve to be examined. The level of the Port's mangers and stakeholders readiness for providing funds and employing such safety and health solutions should be evaluated. The possibilities of engaging medical institutions and experts, besides ICT ones, are to be examined, as well. And finally, the willingness of the on port workers to become constituents of the proposed network(s) is to be assessed. The achieved results of these planned examinations might cause considerable modifications of the proposed WBANSs models.

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1.2. An RFID model for improving on port workers' safety

This research study proposes an RFID (Radio Frequency IDentification) model for enhancing port workers' safety with reference to the Port of Bar (Montenegro) as a developing seaport operating in a transitional environment. It also highlights the lack of appropriate ICT (Information and Communication Technology) solutions in some developing seaports, including safety-related ones. It emphasizes the importance of safety measures through the prism of reducing the number of accidents, and gives a review of some RFID safety solutions in the harsh environments. The main part of the study deals with the RFID worker's safety model proposed according to the Port of Bar's individual needs. The model has been presented at a logic level, while some of the physical and link layers performances between the set of an active and several passive RFID devices embedded into the port workers' PPE (Personal Protective Equipment) and the UHF (Ultra High Frequency) RFID readers located at the port perimeter, are simulated in Matlab and OMNeT++. The obtained results followed by discussions can be used as landmarks to the ports' management in adopting this or a similar model for enhancing safety measures in the port and its promoting as a safety one at the maritime market.

1. Introduction

Seaports are logistic and industrial centres of maritime nature that play an active role in the global transport system. They are characterized by spatial and functional clustering of activities that are directly and indirectly involved in seamless transportation and info-communication processes in production chains (Notteboom, 2001). Harbours combine the major operations of large-scale shipment, storage, and transportation. The fact that about 90% of the world trade (by volume) and 60% (by value) is performed by the sea, whereas the sea transportation is still the most cost-effective way to move row materials and goods *en masse* around the world (IMO, 2015; UNEP 2012), speaks in favour of the seaports as critical nodes of the global economy.

On the other side, ICT functions support contemporary multimodal, intermodal, co-modal, and/or synchromodal transportation chains and bring multiple benefits to all involved parties, inevitably including seaports, by providing real-time visibility, efficient data exchange, and better flexibility in the context of unexpected changes during a shipment (Harris, et al., 2015; Moxa Inc., 2008). There has been a debate about ICT being the major technological facilitator of economic globalization by creating a *death of distance* (Cairncross, 1997) or a *flat world* (Fredman, 2005). However, it is not possible to exclude the role of innovation in transport, most notably in containerization (Levinson, 2006). It is the combination of both - containerization and ICT that has allowed the reduction of shipping costs and the rise in importance of logistics and supply chain management (Jacobs, 2011). Both sea ports and ICT play important roles in the world trade. Nevertheless, they are still insufficiently present among research trends of some transitional economies.

In an extensive survey of papers on ICT-related topics within transitional economies (including countries of former Eastern-Soviet Block, former Yugoslavia, and Albania) published between 1993 and 2012 (Roztocki and Weistroffer, 2014) there are several papers which are explicitly concerned with ICT in the domain of transportation. These papers are the results of projects' work, or they deal only with organizational, either national level. The lack of research outcomes and especially ICT applications in developing countries is a result of their unstable economies and still rigid administrations, which additionally increases digital divide and put them at risk of being further marginalized (Parliamentary Office of Science and Technology, 2006).

We would like to mention several papers published in the context of transitional economies, though from their titles it might not be obvious that they are considerably

concerned with ICT. In addition, some of these papers have been published after 2012. For instance, the presence of contemporary ICT solutions at eight seaports of developing countries (Bar, Durrës, Constanza, Koper, Piraeus, Ploče, Rijeka, and Thessaloniki) was explored in (Bauk et al., 2013). The results, unfortunately, were not encouraging. All the ports, except one (Durrës), had EDI (Electronic Data Interchange) service, while five ports, except Bar, Durrës, and Ploče, had VTS (Vessel Traffic Service) system. However, neither of the considered ports had (at the time of the survey) contemporary ICT solutions such as: ERP (Enterprise Resource Planning), CRM (Customer Relationship Management), VTMIS (Vessel Traffic Management Information System), PCS (Port Community System), nor access to ELM (Electronic Logistics Marketplace). Also, they did not use cloud computing services, neither Internet of Things (*Internet of everything*) concept (Cisco, 2015), etc. Furthermore, Vitic and Bauk (2014) concluded that the Port of Kotor, as an emerging cruising destination of the South Adriatic Sea, suffers the lack of transactional and added-value e-services, which are on the contrary, notably present at the official web sites of some recognized EU cruising ports (e.g., Southampton, Venice, Dover, Genoa, Civitavecchia, Helsingborg, etc.). Ivanovic and Bauk (2014) offered a novel model of logistics (based on real data collected *in loco* over several years), developed for the coastal tourist destinations in Montenegro (Bar, Budva, Kotor, Tivat, and Herceg Novi). This model, of course, includes the ICT dimension. In addition to these research works, which are more or less concerned with seaports, sea-land transportation, passenger traffic, and corresponding ICT solutions, research works in the domain of PCS and ICT integration in the Croatian seaports (Tijan 2012; Tijan et al., 2012; Bezic et al., 2012) are also worth mentioning. It might be of interest to point out, that Tijan et al. (2012), among other points, concluded: "Croatian seaports are currently in the phase of transition from isolated seaports to communicated seaports". It is also important to mention, that Beskovnik and Twrdy (2014) gave an original seven-pillar regional model of ports' development within a single port system of the Balkans. The uniform IT (Information Technology) platform at the port and logistics level was proposed as one of the pillars. The authors suggested a regional approach to develop standardized IT tools and platforms. They also pointed out: "Anyhow, the main issue remains on how to motivate all transport and logistics entities to accede to this important project. Certainly, a top down model is needed, where governments and transport ministries should achieve wider agreements for the region."

2. ICT in improving safety at seaports

Seaports can be dangerous places for port workers and pedestrians in terms of operational risks connected to (un)loading operations, port traffic management and transportation, handling manipulative equipment, warehousing, etc. Additionally, seaports usually operate 24 hours a day, in all conditions, with a variety of employees and contractors performing different activities (Roberts and Gray, 2013). It is the employer's duty to preserve the health and safety of workers and to improve occupational safe systems. Unfortunately, accidents in seaports are not rare (Darbra and Casal, 2004). The reason for the growing number of accidents is the increase in the seaports' turnover over the past decade. On the other side, the relatively low turnover at developing seaports should be in favour of the workers' safety, even though, as to our knowledge, there is no official statistical data concerning this issue in the aforementioned transitional countries. Regardless, improving safety measures is a must.

The world-class seaports use the latest technology based on advanced ICT solutions to help reducing the risk of accidents. These technologies include end-to-end flexible seaport surveillance solutions (Milestone, 2014), i.e., sophisticated camera systems based on CCTV (Closed Circuit Television) comprising a cutting-edge graphical interface and video analytics features, then radar systems connected with port transportation devices and vehicles, variety of infrared/laser, ultrasonic and/or RFID sensors for safety purposes (Russell, 2015) monitoring of cargo handling operations and allied activities (Vizag Seaport Pvt. Ltd., 2010), different pathway anti-collision systems (Roberts and Gray, 2013; SICK, 2014), etc.

The simple transfer and diffusion of these and similar systems sometimes might not be fully effective for the developing countries (Avgerou, 2011). In other words, setting up over-ambitious goals for employing ICT in a developing environment could end up with little hope of being effectively put into practice. Bearing this in mind, we are here looking for a feasible and cost-effective RFID system for monitoring port workers' safety at the developing Port of Bar (Montenegro).

3. The needs of the Port of Bar

The Port of Bar has a favourable geographical position. With the railway line Belgrade-Bar and the road network in its hinterland, along with the intermodal transportation and traffic links with Italian ports Bari and Taranto, it could provide good connections within its rather wide gravitational area. Thanks to its advantageous geographical position, it can be developed into the distribution centre of the area. More about the Port of Bar can be found on its official web site[2] and in the documentation of numerous regional and EU projects. In the period from 2007 to 2013, the port participated in the implementation of several projects (Bauk, 2015) concerned with:

- strengthening of intermodal transport;
- short-sea shipping possibilities;
- integrated logistics chains and attracting innovative investments;
- improving environmental impacts at ten South East European (SEE) ports (TenEcoport);
- establishment of a sustainable transport system at the Adriatic coast and in the hinterland;
- enhancing environmental protection (marine/river pollution);
- detection of dangerous materials under the sea water in the ports' area;
- development of a sustainable integral sea-land transport/traffic network;
- integration of maritime and river transport in the logistics chain;
- prevention of pollution in the SEE ports (Ecoport 8), etc.

The projects TenEcoport (TenEcoport, 2014) and Ecoport 8 (Ecoport 8, 2013) are of particular importance in the context of environment protection and enhancing workers' safety. During their implementation and in the final reports, some recommendations for further actions towards improving environmental and safety management were provided. The working processes in the port were analysed in detail and the points with the highest level of risk to the workers directly employed in port operations were specified. Several in-depth interviews with the managers in the Port of Bar were performed (Bauk, 2014), and the highlights in terms of the most common risks to which the dock workers were

[2] Port of Bar, URL: http://www.lukabar.me/eng/Port_of_Bar.htm, last access: May, 2015

exposed were identified. These risks are: working outdoors in various (unfavourable) weather conditions (extremely high or low temperatures, rain, wind, etc.), exposure to dust during the transhipment of bulk cargos (grains, all types of ores and concentrates, alumina, etc.), manoeuvring with obsolete transhipment equipment and transportation devices, handling damaged cargo (bags, pallets, packages, containers, etc.), exposure to the risk of fire (especially during the summer months), etc.

In addition, port workers perform monotonous and repetitive operations, which results in fatigue increasing the risk of accidents. It is not easy to overcome all these risks, but it is feasible to upraise the safety by identifying and (periodically) locating personnel and their safety equipment.

In the next section we are giving an overview of RFID-based solutions for enhancing working safety in harsh environments, since it could be useful in conceiving a satisfying, individually tailored solution in the case of the Port of Bar.

4. On some RFID working safety solutions

There is a significant number of academic survey papers in the field of RFID technology and its applications (Ngai et al., 2008; Ferrer, Dew and Apte, 2010). Far fewer papers deal with the implementation of RFID technology in the field of seaports' safety management, particularly in the sub-field of identifying and locating workers and their PPE (Personal Protective Equipment). Therefore, we shall firstly mention some seaports RFID safety applications in general, and then in the next sub-section (4.1), we shall give a review of three applications in the domain of PPE.

The paper on RFID model for intelligent seaports (Siror et al., 2011) is, e.g., an envisaged approach to the intelligent safety measures in the seaport made at the exemplar of Mombasa Port (Kenya). On the basis of the performed simulations, the model is promising and it might be used as a framework for planning future safety solutions for seaports. It is also important to mention the RFID application of the *smartPORT* traffic light, implemented for the first time in the Port of Hamburg (Kathrein Corp., 2015). Seaport workers, pedestrians and vehicles are equipped with RFID chips which communicate among themselves and with the smart traffic light via Wi-Fi network. A rather theoretical approach to similar solution, based on drafting the algorithm for establishing efficient communication between traffic density, vehicle priority, RFID controllers, and traffic lights is given in (Sigh et al., 2012). Also we have to mention several papers which consider the adaptation of RFID safety solutions in the port of Cagliari (Italy). They deal with several aspects of the complex centralized control system of the seaport audio communications, video surveillance, and Web GIS (Geographical Information System) applications combined with workers' wearable RFID sensor networks (Sole, 2014; Musu, 2015).

In the following parts of the paper, we are focusing on the Port of Bar individual needs and challenges of working safety monitoring, concerning in the fist instance identifying and examining functionality of port workers' PPE pieces equipped with RFID devices. Our aim is giving support to the Port's managers to become able to select the right RFID workers' safety system and provide the correct justification to the senior management and stakeholders to secure its buy-in (Ferrer, Dew and Apte, 2010).

Table 1. Supply/supporting/research RFID industry: some providers

No.	Name	Web
1.	**Avonwood Development Ltd.**	http://www.avonwood.co.uk/ (last access: 22nd July, 2015)
2.	**ChainLink Research**	http://www.chainlinkresearch.com/rfid/index.cfm (last access: 13th July, 2015)
3.	**CiscoSystems**	http://www.cisco.com/web/strategy/docs/trans/Seaport_Overview.pdf (last access: 28th July, 2015)
4.	**DominateRFID**	http://www.dominaterfid.com/ (last access: 9th November, 2015)
5.	**Identec Solutions**	http://www.identecsolutions.com/ (last access: 13th July, 2015)
6.	**IdentyTag**	http://www.identytag.de/rfid-labels-tags/smart tag/?gclid=CIuai_nTg8kCFda4Gwod-uABBQ (last access: 9th November, 2015)
7.	**Kathrein**	https://www.kathrein.com/de/ (last access: 22nd July, 2015)
8.	**Nedap**	http://www.nedapidentification.com/ (last access: 28th July, 2015)
9.	**Pema**	http://www.pema.org/ (last access: 13th July, 2015)
10.	**Phase IV Engineering Inc.**	http://www.phaseivengr.com/product/pressure-temperature-rfid-uhf-wireless-sensor/ (last access: 9th November, 2015)
11.	**Savi**	http://www.savi.com/ (last access: 13th July, 2015)
12.	**Skyetek**	http://www.skyetek.com/solutions/rfid/personnel-tracking (last access: 2nd November, 2015)
13.	**Synometrix**	http://www.synometrix.com/all-products/rfid/ (last access: 28th July, 2015)
14.	**Syrma Technology**	http://www.syrmatech.de/index.php?content=unternehmen (last access: 9th November, 2015)
15.	**WhereNet**	https://www.zebra.com/us/en/products/location-solutions/wherenet.html (last access: 13th July, 2015)

In this regard, firstly, below is given the list of some providers of RFID solutions, equipment and/or services (Table 1) that can be consulted by the Port of Bar managers in a case that they decide to upgrade safety measures.

It is important to mention that there are several key factors to consider when selecting an RFID solution, like: cost, reliability, security, compliancy, read/write range, read/write speed, multi-tag capacities, environment, etc. The cost is often one of the most important, and one the most difficult to evaluate at the same time (Sattlegger and Denk, 2014). At this initial stage of our research, it is really hard to give reliable costs evaluation. Therefore, we will be focusing on the conceptual solution and some simulation analysis.

4.1. Considering some RFID and PPE solutions

We proposed an RFID port workers' safety model on the basis of the secondary literature resources and three previously developed systems for monitoring working safety in harsh environments. They identify, localize, and/or check operability of RFID devices embedded into the workers' PPE.

The first system has been commercialized and applied in the construction industry (Kelm et al., 2013) but there are no obstacles for its implementation in seaports. The second one is applied in seaports (Sole, 2013a, 2013b, 2014). However, these two scenarios do not provide permanent real-time monitoring of the workers' PPE (safety helmets, reflective safety vests, and steel-toed safety shoes) at working place. The third one is devel-

oped at the level of prototype and it has not yet been commercialized. It is designed with the intention to provide a permanent PPE traceability, i.e., its real-time monitoring. The main shortcomings of the last mentioned system are: (a) it is not utterly unobtrusive, and (b) it is not easy to establish a proper communication between RFID tags and readers over the end points, here workers' BANS (Body Area Network Sensors), in terms of determining the position of PPE items, what was one of the main goals of this experimental project (Barro-Torres et al., 2012). Let us consider now the three models in some more detail.

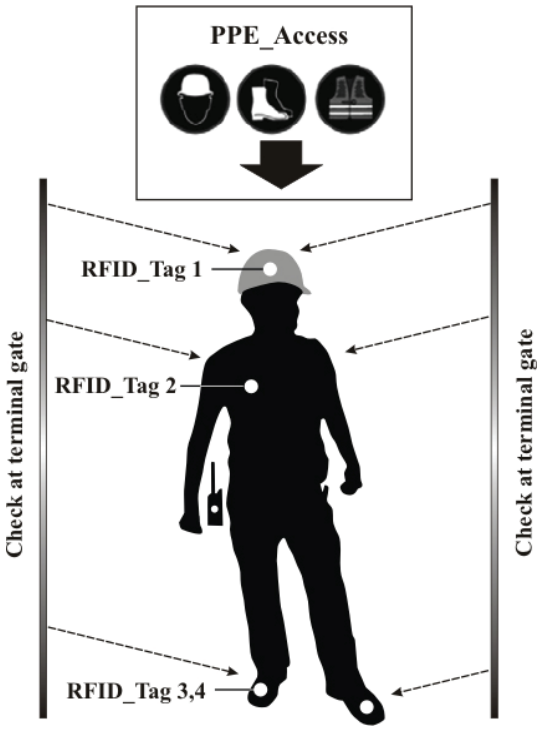

Fig. 1. Inspection of worker's PPE at entrance gate
[Adapted from (Kelm et al., 2013)]

Case 1*:* In this case, before entering the working place, a worker has to pass through the control gate. He/she should not pass through too quickly, since the standard UHF signal update is 1 [Hz]. The worker and his/her PPE must be uniquely identifiable. The intelligent system and user interface provides real-time feedback to the worker. The system is able to recognize multiple tags simultaneously, thus the worker is immediately notified if the ID is not proper and/or which PPE component(s) is(are) missing. Once the worker has been properly identified and proved to be wearing the required equipment, the turnstile at the terminal entrance opens, otherwise entry will be denied. The scheme of this scenario is given in Figure 1. The main shortcoming of this solution is the impossibility of locating and monitoring workers and their PPE pieces after passing through the gate, unless the whole working area is covered by the sufficient number of the long range RFID readers.

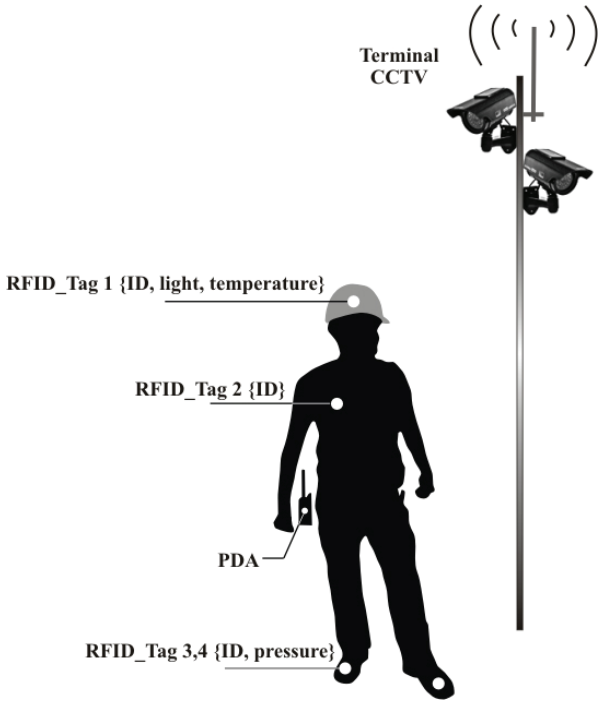

Fig. 2. Checking the proper usage of the worker's PPE at the terminal by means of CCTV [Adapted from (Sole, 2013a)]

Case 2*:* In this case, assuming that the worker has passed the identification and PPE control at the entrance gate, the CCTV system installed at the terminal provides continuous monitoring with the intention to discover if the worker properly wears the PPE at the working place. In the case of non-use, or improper use of PPE, the technician responsible for the video surveillance will warn the worker by sound or text message alarm via the port wireless network (Wi-Fi) and PDA (Personal Digital Assistant) device attached to the worker's belt (Sole, 2014). Wearable sensor network in this case consists of passive RFID and WISP (Wireless Identification and Sensing Platform) devices which provide the ID and ambient light and temperature (helmet), and worker's plantar pressure (shoes) data. Figure 2 gives a scheme of this scenario. It is presented as an example of a possible port workplace safety solution, but it hasn't been recommended for application in the case of the Port of Bar. The centralized monitoring system of the CCTV connecting with the port Web GIS maps, RFID/WISP sensors and readers, might be too complicated for implementation at the present stage of the Port of Bar development. This model has been recently re-engineered towards the Internet of Things concept (Musu et al., 2014; Musu, 2015). In this regard, among other things, it excludes workers' PDA devices and provides direct communication between worker's clothing with embedded RFID tags and readers placed at the strategic port's locations. A smart software system is used for locating workers, their PPE functionality, and helmet position, thanks to the accelerometer installed in it. The segment of this safety solution that provides direct (periodical) communication between tags and readers through the intelligent software back-end system might be partially implemented in the Port of Bar, in the manner presented in the next section.

***Case 3**:* This system can be treated as a novel one in comparison to the previous two systems. It is composed of BAN (Body Area Network) that collects information from the RFID tags by the readers located throughout the workers' clothing. The CUM (Central Unit Microcontroller) processes the data and transmits them by radio module to the external mesh network composed of the set of end nodes (workers' BANs), routers, and the coordinator. The coordinator collects and stores the data coming from the end nodes, configures nodes and performs synchronization. End nodes are the critical part of the system. They are composed of central unit microcontroller, radio module and RFID readers. The readers are located at strategic points in the clothing, since the technology used allows them to be read at close range. The detection rate clearly increases when the antennas of the reader and the tag are in parallel, while it decreases dramatically when the antennas are oriented orthogonally. To avoid the null spots, different alternatives have to be weighted up in order to modify the antenna radiation pattern. The scheme of this scenario is given in Figure 3. We do not recommend this model to be implemented at the Port of Bar, since it is complex, intrusive, and the central microcontroller is currently at the level of a prototype.

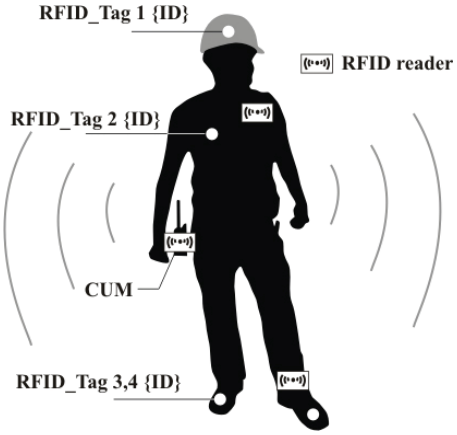

Fig. 3. Self-checking system of the worker's PPE proper usage
[Adapted from (Barro-Torres et al., 2012)]

By merging *Case 1* and *Case 2* scenarios and some modifications, an acceptable model for the Port of Bar can be conceived. Instead of scanning and alerting workers at the port gate, we proposed collecting data from an active and several passive RFID tags attached to/embedded into the workers PPE pieces by UHF RFID readers (Musu, 2015) located at strategic points within the port perimeter. These readers can be connected by Wi-Fi or Ethernet to the port backend info-communication system through which the status of the tags and the information returned can be read and stored in the database.

5. Proposed model and some simulation analysis

Although the range of negative working and environmental impacts in the Port of Bar is quite large, prospective application of PPE equipped with RFID tags will strengthen port workers' safety and increase the level of their corporate safety culture. Previously described systems *Case 1* and *Case 2* can be adapted by the Port of Bar with some conceptual and technological modifications. Namely, an active UHF RFID-enabled worker's badge can transmit the ID number at preset intervals to the port's fixed readers. These ID

badge can be worn around the neck, attached to clothing or placed in the pocket and it can be read up to 500 [m] (Swedberg, 2011). It allows the smart software system and RFID hardware to track the number-identities of the port worker at any time, as well as, in some cases, pinpointing the worker's location. The system memorizes the "last seen location data" for each worker. On the other side, each time the worker is in the range of the reader(s), approximately in the range of 10 [m], the control system will have the information on the status of passive RFID tags attached to the PPE, i.e., if they: work correctly, don't work correctly, or don't work at all. Figure 4 shows an example of the worker who does not have a helmet on site, and whose shoe is damaged. In such a situation, the worker must be alerted to go to the central for wearing/changing PPE.

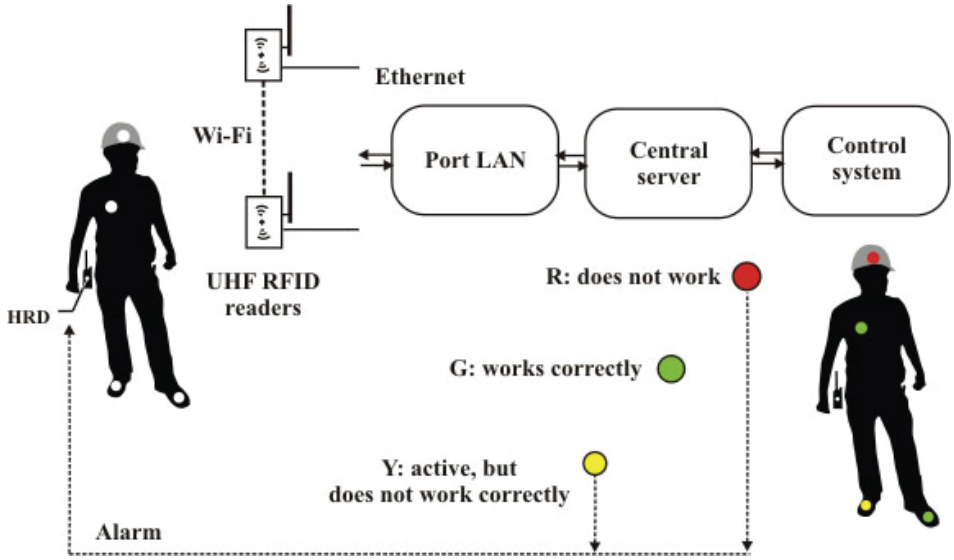

Fig. 4. An RFID model for port workers' safety monitoring
[Adapted from (Musu, 2015)]

Hence, a worker's PPE is composed of a helmet, safety vest and shoes with passive UHF RFID tags attached/embedded. These tags must unambiguously identify a particular safety garment and communicate via reader(s) to the port's safety control centre which provides alarm to the worker's HRD (Handheld Radio Device) in a case a certain tag(s) does(do) not work (at all/properly). It is important to mention that the RFID inlay provides data on radio frequency functionality of any tag (RFIDinsider, 2015). The tagged PPE should be designed, produced, and tested in accordance with the port's needs by specialized companies such as: Extronics, Identytag, Omni-ID, ScanLink, Syrmatech, etc. All readers are connected via Wi-Fi or through the port's Ethernet through which the status and the information returned can be read and stored in the beck-end server connected to the central control system. If a worker is not wearing the mandatory and functional PPE clothes, or if he/she is in an extremely dangerous zone, a signal alarm alerts of a dangerous situation.

The system should be used as an emergency preparedness one, as well (Vermesan et al., 2010). In the event of an emergency, the workers should be alarmed to leave the zone of potential danger and come immediately to the appointed place. At the appointed place, the workers' current position can be determined and all PPE tags identified and checked.

In the following sub-sections we shall analyse the channel between workers' wearable sensor sub-network composed of an active UHF RFID ID badge and four passive UHF RFID tags (attached to the helmet, vest, and shoes), and the UHF readers located at the port perimeter. The readers should work at EU standardized carrier frequency range of 865-869 [MHz] and offer a flexible platform to evaluate the identification and status of the RFID transponders by supporting EPC (Class 1) Gen2 standard.

The layout of the Port of Bar container terminal is used as a base for some simulation analysis of the proposed workers' wireless safety model (Figure 5).

Since our goal is not to offer the *final* solution, but to provide an insight to the managers in the Port of Bar into the existing solutions of the kind and a framework for an individually-tailored solution, we considered it important to analyse some of the key parameters of wireless networks. Regardless of the model which will be adapted, wireless networks will be in any case essential segments of the whole project: whether it is a BAN that connects PPE RFID active and passive devices, or WLAN (Wireless Local Area Network) that connects UHF RFID readers with PCs, routers and other components of the port network infrastructure. Therefore, in the first set of simulations, we gave some analysis of the channel between the transmitter and receiver at the physical and the link layers. This might be helpful for the managers in understanding the principles of wireless networks and later on making the decision on adapting certain workplace safety systems. The simulation experiments have been done in Matlab. In the second set of simulation experiments, the channel between the moving nodes (the sub-networks of port workers' RFID devices) and several fixed nodes (RFID readers) located over the Port of Bar container terminal operational area, was analysed. These simulation experiments were realized in an OMNeT++ environment. The obtained results are discussed in the following sub-sections.

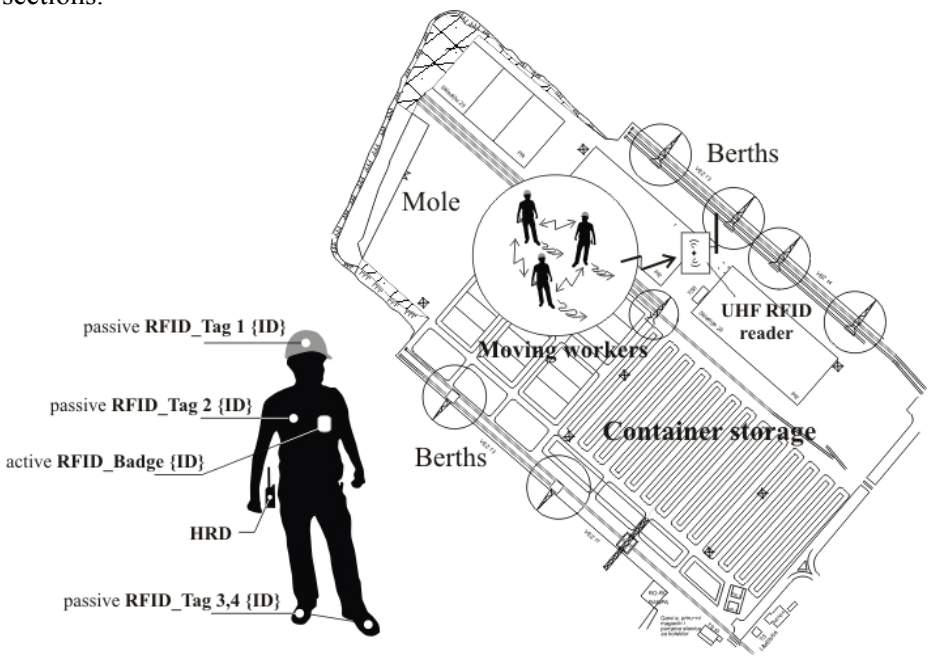

Fig. 5. An RFID occupational safety model on the layout of the Port of Bar container terminal

5.1. Simulation model 1: Wireless networks' performances

The first set of simulation experiments was performed in Matlab (ver. 7.12.1), by an Intel(R) Core™ i5 processor on 2.4 GHz (4GB RAM). The key steps within these Matlab simulations are as follows:

(a) Definition of the simulation parameters: carrier frequency, distance between transmitter and receiver, a sequence of input bits, number of iterations, and SNR (Signal-to-Noise-Ratio) range;
(b) Calculation of FSPL (Free Space Path Loss):

$$FSPL = \left(\frac{4\pi df}{c}\right)^2 \qquad (1)$$

Where:
d – is the distance between the transmitter and the receiver [m];
f – is the frequency of the carrier [Hz]; and,
c – is the speed of light in vacuum;
(c) Application of the binary phase-shift keying (BPSK) and quadratic phase-shift keying (QPSK) modulation schemes on real and complex signal components respectively;
(d) Generation of the Gaussian noise and computation of the standard deviation for each SNR value:

$$P_{noise} = \sqrt{\frac{P_{signal}}{SNR \cdot FSPL}} \qquad (2)$$

Where:
P_{noise} - is the power of noise [W];
P_{signal} - is the power of transmitting signal [W]; and
SNR – is the signal-noise-ratio;
(e) Simulation of AWGN (Additive White Gaussian Noise);
(f) Generation of the recovering (source) signal by the Wiener filter which minimizes the mean square error between the estimated random process and the desired one;
(g) Computation of the number of BER (Bit Error Rate) after the slicer, i.e., part of the code that compares the original signal with the recovered one, point by point, specifying if it is well recovered or not; and,
(h) Plotting graphics: BER vs. SNR (see Figures 5 and 6).

On the basis of the source code in Matlab, the relation between the transmitted signal BER and SNR have been analysed. In the first case, the considered relation has been examined for characteristic carrier frequencies in different wireless technologies (Mahalik, 2007): 915 [MHz] (ZigBee), 2.4 [GHz] (Bluetooth), and 3.1 [GHz] (Ultra Wide Band). In addition to the simulation experiments for these typical WLAN carriers' frequencies, the simulations for White-Fi have been performed, as well. Two characteristic frequencies in the White-Fi domain have been analysed: 470 [MHz] and 710 [MHz]. By using the White-Fi signal, the absorption can be easily avoided and otherwise unused TV frequencies might be exploited. In order to achieve this, the new technologies and rules are currently developing (IEEE, 2015), such as cognitive radio,

geographic sensing, etc. It is clear that in all cases the BER decreases with the increase of SNR (Figure 6). In addition, it is clear that the higher frequency causes higher BER and inversely. The simulations have been made for the distance between the transmitter and receiver of 10 [m], and they have been performed through several thousand runs in order to achieve smoother curves.

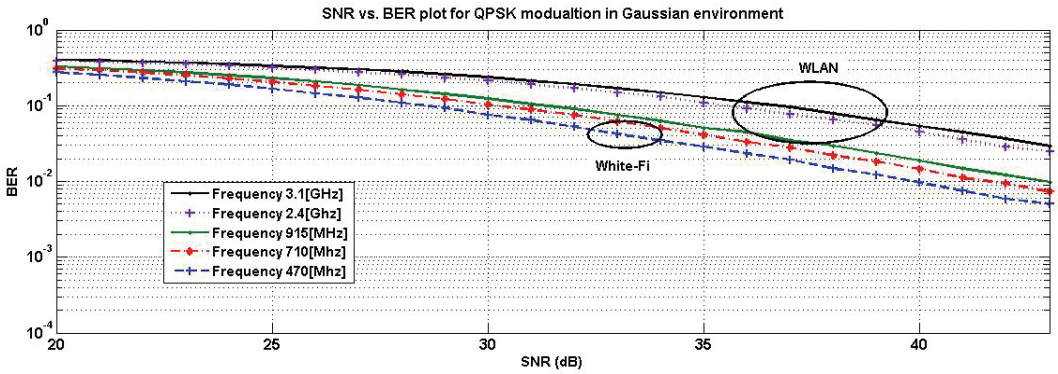

Fig. 6. BER vs. SNR for three characteristic WLANs and two White-Fi carriers' frequencies

Similar simulations have been done for different distances between the transmitter and receiver (Figure 7), i.e., for 10, 20, and 30 [m]. The BER decreases with rising SNR in all the considered cases, in a manner that a greater distance corresponds to a higher BER and conversely. The simulations have been run like in the previous cases trough several thousand trials. They have been realized by using the BPSK modulation scheme, and it is clear that the BER decreases to E-02 as SNR reaches ca. 45 [dB].

The obtained simulation results in the considered cases (Figures 6 and 7) speak in favour of the applied modulation schemes, path loss and noise models. The trade-off between BPSK and QPSK modulation schemes has been simulated, too, and it shows that the BER is slightly lower in the case of BPSK, but it is negligible in terms of the transmitted data amount which is doubled by using QPSK.

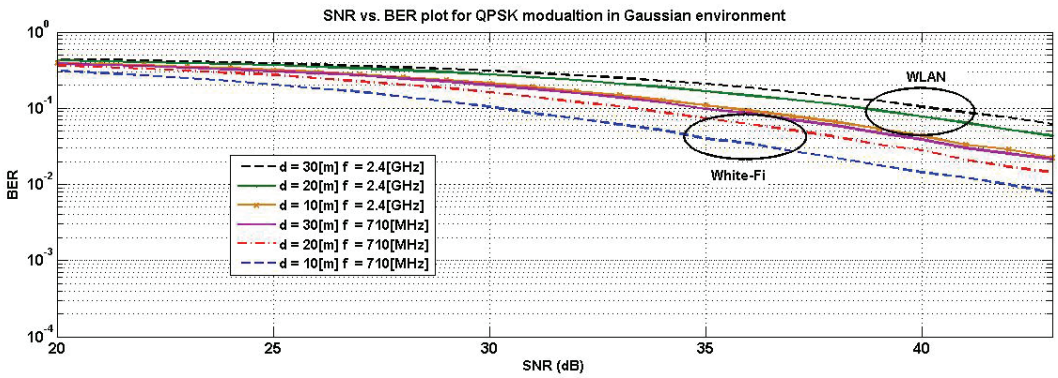

Fig. 7. BER vs. SNR for three different distances at two characteristic WLAN and White-Fi carriers' frequencies

5.2. Simulation model 2: Moving-fix nodes channel analysis

The second set of simulation experiments has been performed in OMNeT++ (ver. 4.6) environment, by an Intel(R) Core™ i5 processor on 2.4 GHz (4GB RAM). The average time per simulation was approximately 15 [min]. OMNET++ is a relatively new simulation tool. It is a modular, extensible, component-based C++ simulation library and framework. The main use of this tool is to simulate, model, and build all kinds of networks: wired and wireless, on-chip, queuing ones, etc. This tool provides component architecture for models. Components are programmed in C++ and then assembled into larger schemes using a high-level network description language (OMNeT++ Community, 2015).

The 2D simulation area is limited within 1000 [m] in both directions. It includes four randomly moving port workers' sub-networks and four fixed port's nodes (readers). The change interval is 1 [sec] with 0.1 [sec] of standard deviation. This means that over 1 [sec] each node will make a move at a specified speed. The speed was settled to emulate the movement of a human person, i.e., 3 [m/sec]. The type of selected channel was the Rician fading channel. The transmission power was set to 1 [mW] or [-30 dB]. Figure 8 shows the relation of the reception power of the fixed nodes and the delay. The distance and delay are linked by the speed of transmission of the signal. It is easy to notice that the received power is less as the distance (or the delay) decreases.

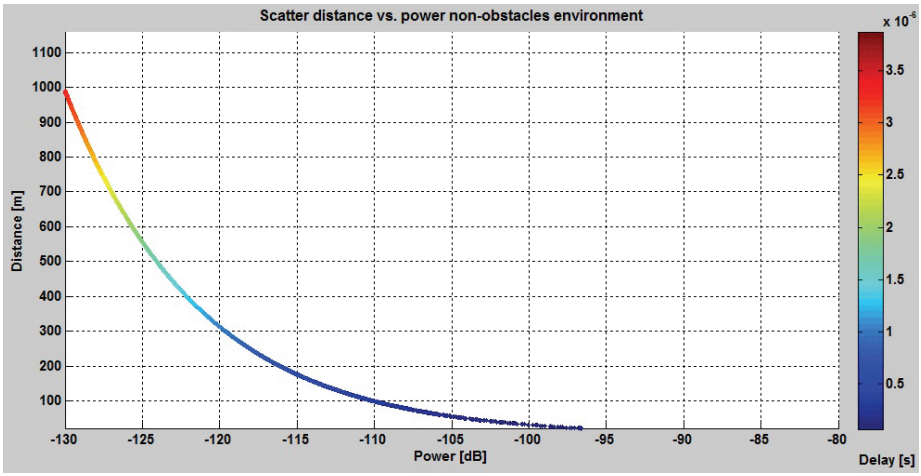

Fig. 8. Scatter function of the distance vs. received power for a non-obstacle scenario

If we introduce the obstacles, the scatter function will be changed (Figure 9). As the simulation experiment has been done over the layout of the Port of Bar container terminal, the obstacles were imaginary containers blocks (12 of them). The obstacles' approximate measures were 200x100x4 [m]. They were metallic with a specific relative permittivity and permeability, which also affects the channel. When the distance/delay was big, the received power was very low and vice versa. The scatter diagram in the scenario with obstacles has two significant shapes. The thin one represents the line of the sight signal, while the thicker one represents the reflection or the signals that pass through the obstacle. The difference between the received power of the line of a sight signal and the received power of a reflected or a signal that pass through an obstacle is approxi-

mately 1-5 [dB]. This is completely meaningful as long as the signal through an obstacle or a reflected signal is received with less power.

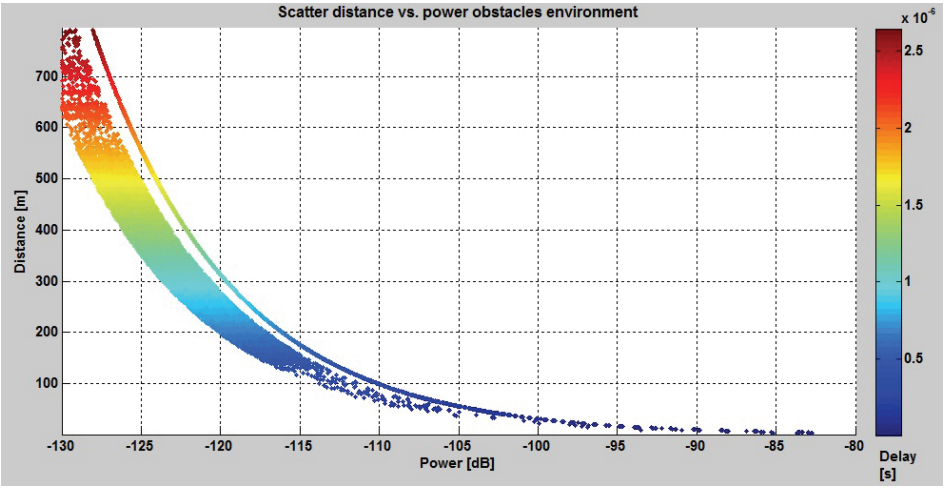

Fig. 9. Scatter function of the distance vs. received power for a scenario with obstacle

Over the simulation scenario with the obstacles, different modulation types: BPSK, QPSK, 16QAM, 64QAM, were used. It is easy to notice that BER decreases if SNR increases in for each modulation scheme (Figure 10). The curves are not smooth, resulting from the random nature of the simulation environment, and the presence of the obstacles. Depending on the modulation type, BER is different. Namely, BPSK modulation works with only one bit per symbol, and it is therefore the simplest one. On the other hand, if the simulation used QPSK, the number of bits per symbol was two, if it used 16QAM, the number of bits per symbol was four, and finally, for 64QAM modulation type, the number of bits per symbol was six. This causes the proportional trade-off between BER and the number of bits transmitted.

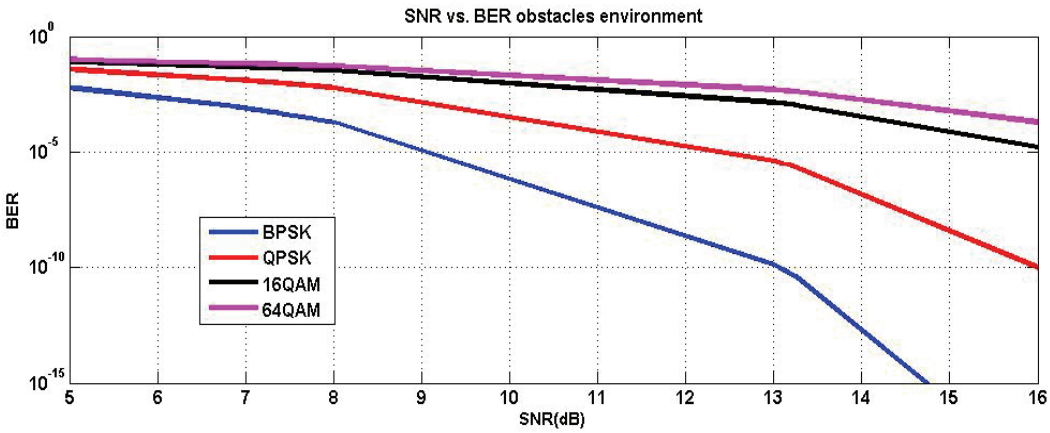

Fig. 10. Scenario with obstacles: SNR vs. BER for BPSK, QPSK, 16QAM, 64QAM

The simulations outcomes can be summarized as follows: (i) Both scatter functions (for the scenario without and with obstacles) contain the lines of sight signal components

and their values are the same. (ii) The attenuation of the signal caused by the block of containers' obstacle cannot be neglected (it's approximately 1-5 [dB]); and (iii) The scenario with obstacles needs a higher value of SNR in order to achieve the same level of BER as in the case of non-obstacle environment.

6. Conclusions

The paper describes the current situation in the developing seaports regarding the implementation of innovative ICT solutions, with emphasize on the Port of Bar (Montenegro). It has been observed that some seaports in transitional economies do not have contemporary info-communication business and safety solutions. Our intention was to identify where the implementation of new ICT tools is necessary, but also feasible. Consequently, we came up with the idea that enhancing port workers' safety by introducing RFID technology might be useful and cost-effective solution in the initial phase of adapting modern ICT safety models.

Throughout the simulation experiments in Matlab and OMNeT++, the performances of the channel between the transmitters and receivers placed at appropriate locations within the seaport perimeter have been tested over the Port of Bar's layout. The simulations in Matlab have been performed for the simplified one-to-one (transmitter-receiver) communication channel, while the simulations in OMNeT++ have been realized for the case of several constantly moving workers' wearable sub-networks and several fixed port's nodes. The obtained results are presented in the sub-sections 5.1 and 5.2, while the following can be summarized:

- For different carrier frequencies and distances between the transmitter and receiver, a satisfying level of BER is achieved by using binary phase-shift keying (BPSK) and quadratic phase-shift keying (QPSK) modulation schemes above real and complex signal components, respectively, while Wiener filter was successfully used for recovering source signal in the Gaussian environment;
- In addition to standard frequencies for wireless communications (915 [MHz], 2.4 [GHz], and 3.1 [GHz]) between the transceivers, two characteristic frequencies from White-Fi spectra (470 [MHz], and 710 [MHz]) have been examined, while the satisfying level of BER has been achieved, as well;
- In the seaport environment without and with the obstacles (container blocks) in OMNeT++ environment: the scatter functions of the distances vs. received powers have been generated, and SNR vs. BER for BPSK, QPSK, 16QAM, and 64QAM modulations schemes compared;
- It has been concluded that both scatter functions, in the simulation environment with and without obstacles, contain the line of sight signals, and that their values are the same in both cases;
- In the scenario in OMNeT++ that includes the obstacle, the attenuation of the signal of 1-5 [dB] was noticed; and,
- By comparing plots for SNR vs. BER in the cases of different modulation schemes: BPSK, QPSK, 16QAM, and 64QAM, it is clear that the scenario with obstacles needs a higher SNR value in order to achieve the same BER value characteristic for the same environment without the obstacles.

The presented findings might be of importance to the managers in the considered developing seaport, since they can be used as *landmarks* in negotiations with senior manag-

ers and stakeholders in the port in order to provide funds, as well as in negotiations with ICT companies being in charge of implementing the proposed workers' safety model.

Active RFID workers' badges and passive RFID tags for identification and periodical locating, together with the PPE pieces (helmets, vests, and shoes) should have both direct and indirect positive effects. The PPE protects the workers from injuries, and this is direct positive effect of the proposed safety solution. Indirectly, by regular usage of the PPE garments equipped with RFID devices, including alarm capabilities, raises the port workers' and supervisors' awareness of the occupational risks, as well as the level of the corporate culture.

However, the proposed model for enhancing port workers' safety has certain shortcomings. They are primarily related to the RFID technology and backend network infrastructure limitations. The proposed technology has several significant beneficial aspects, such as: batch readability, resistance to some harsh environment conditions, large information storage and processing capability, etc. On the other hand, it has also several substantial disadvantages (Kapoor et al., 2009), such as: reading error, privacy/security concerns, computing bottleneck, cost-benefit issues (vagueness of investments returns and difficulties in estimating opportunity costs), risk of obsolescence, inter-operability (global) standards issues, etc. In addition to these rather general shortcomings of the RFID technology, there is one more, specifically related to the issue in matter, i.e., inability of monitoring workers in real time and checking whether the workers wear their PPE correctly. Barro-Torres et al. (2012) have done the efforts for resolving this problem, but the proposed solution has some limitations and it has not yet been commercialized. Therefore, the real-time locating and tracking of port workers and their PPE garments by employing Internet of Things concept, might be considered as next step in developing this model, although it is more expensive.

There is an additional problem which is not technical in its nature, but it should not be ignored, either. Namely, there are several organizational and ethical issues which deserve to be examined in this context. The level of the seaport's both senior managers' and stakeholders' readiness for providing funds and employing the proposed occupational safety solution should be assessed. Also the willingness of the workers to become the active constituents of the proposed network is to be assessed. The achieved results of planned *soft* examinations might cause some modifications in the proposed RFID port workers' safety scenario.

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1.3. A ZigBee/RFID seaport safety system

This research work examines three potential safety solutions for the protection of port workers, which are based on a junction of Radio Frequency IDentification (RFID), as an automatic identification, data collecting and positioning system from one side, and ZigBee, as a low energy consumption communication technology from another. The considered solutions are placed in the context of the individual needs and capacities of the developing Port of Bar in Montenegro (South East Europe), which has been operating in the transitional environment for almost three decades. The transitional circumstances prevent the port from adopting advanced occupational and environmental safety systems. Therefore the models for improving the workers' safety that are at the same time cost-effective, reliable and flexible are proposed. More precisely, the on port workers' body area sub networks formed by RFID active/passive devices are treated in the work as end nodes of the ZigBee network. On the other hand, the forklifts' RFID warning systems are treated as the moving routers of the ZigBee network. Some simulation experiments with such RFID/ZigBee hybrid system in an OPNET environment have been implemented over the Port of Bar container and general cargo terminal layout, while corresponding conclusions have been derived, along with some directions for further research work in the field.

1. Introduction

Seaports (hereafter ports) are traditionally viewed as an economic springboard for the country development, since their services and manufacturing activities create economic benefits and socio-economic wealth via labor income, business earnings, taxes, etc. (Park and Seo, 2016). Ports also have catalytic economic and social impacts on their corresponding hinterlands. Over the past years, advances in Information and Communication Technologies (ICT) have played a key role in transforming the way they function. The successful transfer and implementation of the actual ICT applications is a prerequisite for their greater business achievements. However, port innovations cannot be restricted to the adoption of new technologies, which have been mostly ICT driven in the recent years. The so-called soft innovation is currently used to refer to non-technological dimensions such as: people and organization, markets and relationships, knowledge and integration, meanings and experiences (Martino et al., 2013), etc. It seems that both technological and soft innovations can ensure a sustainable advantage to a port. The afore remarked holds true for highly developed leading class ports, but unfortunately not for the developing ones, e.g., the Port of Bar in Montenegro. It has been operating for decades in a transitional environment and it combats with the lack of investments and rigid administration structures, which permanently reproduce crises and prevent its economic development. Through several projects and research papers we have tried to at least enlighten and merely alleviate these problems (Bauk, 2014; Bauk, 2015; Bauk et al., 2015; Bauk at al., 2016). We have been focused on conceiving and developing ICT models for enhancing on port workers' safety and uprising the level of their occupational culture. This paper provides a continuation in this regard, and it is organized in the following manner: (i) it gives a short overview in terms of how working on port can be dangerous; (ii) it considers three available RFID solutions for reducing the workers' safety risks; (iii) it presents some channel analysis in an OPNET environment, while workers' body central units (BCUs) and active RFID identification (ID) badges are treated as moving end nodes of the ZigBee network; (iv) it also analyses the channel between the workers' and/or pedestrians' RFID active ID badges (tags) as end nodes, and forklift trucks' (hereafter forklifts) RFID warning systems as moving routers of the ZigBee network. Finally, the paper gives some concluding remarks based on the simulation experiments' results, as well as directions for further examinations in this domain.

2. On port working risks

Work at ports takes place throughout the day and night in all weather conditions (HSE, 2011; HSE, 2013). It involves a number of different employers and contractors carrying out various activities: harbor authorities, stevedoring firms, haulers, ship's masters, crews, etc. This requires a synchronized co-operation and communication between all the involved parties. There are frequent pressures to load or unload ship's cargo quickly to catch a tide or to free up a wharf for another ship; or, for example, visiting drivers want to pick up or drop off their cargo as quickly as possible and get back on the road.

Ports also tend to be associated with emerging environmental problems (Darbra and Casal, 2004): water and air pollution, soil contamination, problems related to dust and noise, generation of waste, dredging operations, warehouse storage of hazardous substances, etc. Therefore, they can be dangerous places especially for on port workers and/or pedestrians in terms of operational risks connected to un-loading operations, managing on port traffic and transportation, handling manipulative equipment, warehousing dangerous cargoes (Roberts and Gray, 2013), etc. All these make the port work challenging, but also highly risky.

Under the regulations, both employers and employees in ports must ensure the health and safety of themselves and others. In developed ports, employers have specific obligations concerning the provision and use of the Personal Protective Equipment (PPE) by the employees who are exposed to risks. This is still not the case in the Port of Bar, but it should become obligatory. In this regard, within the following section we shall refer to several PPE intelligent solutions proposed and/or employed in highly developed harsh working environments. PPE can include items such as safety helmets, gloves, eye protection, highly visible clothing, safety footwear, safety harnesses, etc., but it is commonly limited to the 3 Point PPE, i.e., helmet, safety vest and protective shoes. Garments equipped with passive or active RFID devices can help in identifying each protective piece, examining its functionality and proper use. By a corresponding alarm system, workers are alerted if some PPE garment is missing or is not properly worn, or if some of the RFID tags embedded-attached to the PPE do not function properly. Furthermore, using active RFID ID badges allows smart back-end software system monitoring the workers' presence at the port, their access to dangerous zones, and, in the case of emergency, the workers can be alerted to come to the appointment place which is well covered by the anchor readers. Thanks to the numerous interrogators installed at strategic points of the appointment zone, the workers can be automatically identified, located, and the inspection of using and correctness of their PPE garments can be carried out. Additionally, the RFID locating system can be used for both the workers equipped with ID cards (i.e., active RFID tags) and forklifts equipped with RFID light/audio alerting system for warning the workers and/or pedestrians and providing them with enough time to get themselves to safety. These safety solutions will be described in some more detail within the next section.

3. Concerning some PPE-RFID safety solutions

For the purpose of giving support to the managers of the developing Port of Bar in providing justification to their senior management and stakeholders regarding a secure buy-in and implementation of smart safety solution(s) for preventing and reducing occupational risks, we described within this section some of the previously mentioned smart

PPE-RFID systems. The first one is described at large in Barro-Torres et al. (2012). However, it is still at the level of a prototype, with the intention to be implemented at construction sites. The second system, which is presented here, is implemented in the North Sea oil and gas industry (Vermesan, 2010), and the third one can be implemented at a port or at any other industrial and transportation environment of high density. In any case, there are no severe restrictions for implementing these solutions at any rough and commercially intensive port environment whatsoever. Introducing the ZigBee network for establishing communication between workers', pedestrians', and forklifts' RFID enabled devices and warning systems at the port perimeter, including port's backend info-communication system, might be considered as a novelty of this paper in comparison with the previous research works in this domain (Musu, 2014; Musu, 2015; Sole, 2014; Sole and Musu, 2013a; Sole and Musu, 2013b; Bauk et al., 2016).

3.1. The RFID equipped PPE functionality and correct wearing inspection

This system is composed of a body area network (BAN) that collects information from the readers located throughout the workers' clothing (Barro-Torres et al., 2012). The short range RFID readers are located at strategic points within the clothing, for checking the correctness of wearing 3 Point PPE. The detection rate clearly increases when the antennas of the reader and the tag attached to each 3 Point PPE garment are in parallel, while it decreases dramatically when the antennas are oriented orthogonally. To avoid the null spots, different alternatives have to be weighted up in order to modify the antenna radiation pattern. The central unit microcontroller (CUM) processes data from the readers and transmits them by a radio module to the ZigBee mesh network composed of the set of end nodes (workers' BANs), routers, and the coordinator. CUM contains the XBee module for ZigBee communications. This module has a transmitting power of 2 [mW] and works at 2.4 [GHz], while its range varies significantly depending on the environment (temperature, humidity, size, and material of obstacles). The coordinator collects and stores the data coming from the end nodes, configures the nodes and performs synchronization. The end nodes are the critical part of the system. The scheme of this scenario is given in Figure 1. We do not recommend it to be implemented in the Port of Bar at the present moment, since it is complex, intrusive, and the central microcontroller is currently in the developing phase. In any case, we believe it is worth presenting to the management of the Port of Bar as a potential environmental safety solution, which might be adopted in the future.

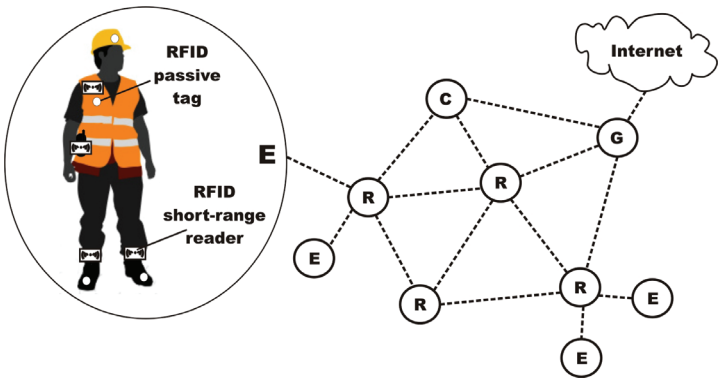

Fig. 1. ZigBee/RFID scenario 1: Worker's BAN as an end node
(Legend: E-end node; R-router; C-coordinator; G-gateway/coordinator)

3.2. The PPE and active RFID tags in reducing risks

A cost effective RFID technology solution for locating and tracking personnel in case of emergency situation was deployed at oil and gas rigs in the North Sea in the first decade of 2000's.This system is conceived as an offshore emergency preparedness system, rather than a personnel surveillance one. Its two key components are RFID readers and tags. In the event of an emergency, the system determines the current and past locations, and the identities of all the personnel wearing an active RFID tag (ID badge, or card) for the purpose of tracking. Naturally, in addition to this emergency safety system, using PPE at oil and gas rigs is obligatory. The extended version of the personnel tracking system may also include the use of environmental sensors, e.g., for temperature, humidity, gas detection, etc. In some cases, the active ultra high frequency (UHF) Gen2 tags are installed onto the hard helmet of each worker. By installing RFID readers at each entry gate of the floating ship or another enclosed space, the system can track the number of persons on board. This way the fire and security officials are provided with real-time information on head count and are able to decide on the necessary escape routes (Hild, 2007).

Platforms operating in an offshore environment typically employ hundreds of people. Some of them are connected via bridges creating a center that can hold up to thousands of persons. Each person on the rig has an RFID active ID badge which can be worn around the neck, attached to the clothing or placed in the pocket. The badge has a battery powered UHF tag working at 868 [MHz] (EU standard) and transmitting the ID number at preset intervals. The tags can be read from the distance of up to 500 [m]. Back-end software stores each worker's name, shift, job, education, etc., which is linked to the unique ID number on the badge. When the reader captures the tag's ID number, it forwards that information via a wireless connection to a computer, which can then pass on that data, either to the company's back-end server or to a server on-site via Wi-Fi or the Internet connection (Swedberg, 2011).

We propose here the employment of the ZigBee mesh network as a connector to the smart back-end control system, while the end nodes would be the workers' active RFID tags. Simplified, the worker has an RFID active tag, while the router reads the tag and sends the information to the ZigBee network. At the end, the data arrive to the coordinator which is connected to a geographic information system (GIS) map (Grupo Autolog, 2010). The basic scheme of this workers' RFID safety scenario is given in Figure 2. If there are several readers on the site, the system can determine each employee's location, while the accuracy of the position depends on the number of readers used. The system typically tracks the zone of the employee's presence, rather than the worker's specific location. The system also provides an alerting function, in case certain personnel are not allowed to enter one or more specific zones. Using active ultra-wideband RFID tags, which operate at 3.1-10.6 [GHz], should allow for the determination of the worker's position with the precision of a few inches (Roberti, 2013). However, such tags can be fairly expensive, especially if we bear in mind the specific economic and administrative working conditions of the Port of Bar. Therefore we suggest using UHF active RFID ID badges for the workers' identification and their locating within a certain zone or read field within the range of about 5-10 [m].

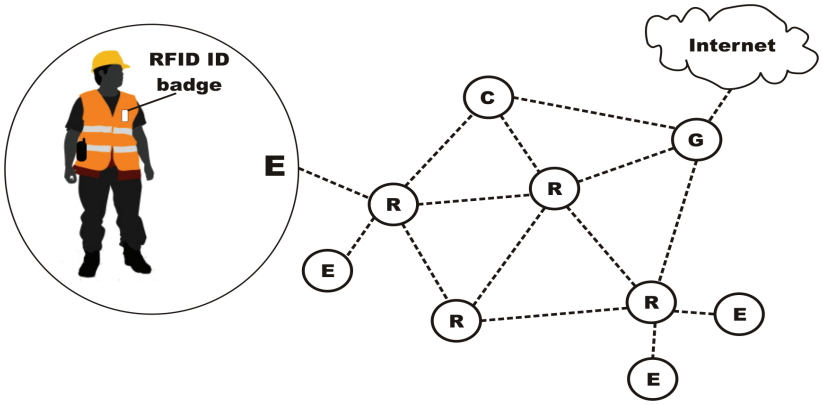

Fig. 2. ZigBee/RFID scenario 2: Worker's RFID active ID badge as an end node (Legend: E-end node; R-router; C-coordinator; G-gateway/coordinator)

3.3. The RFID supported forklift warning system

Workplace accidents involving moving vehicles (e.g., forklifts) cost ports huge amounts of money in terms of expensive downtime, investigations and increased insurance premiums (Orbitcoms, 2016). Above all are fatal injuries and loss of human lives. In 2014, e.g., the number of casualties in the transportation sector in the USA was 734, according to the Bureau of Labor Statistics (Grayson, 2015). Fortunately, the fatal accidents have not been recently recorded in the Port of Bar, but this should not be excluded as a potential danger and should be prevented anyway.

There are several ready made, commercial solutions for reducing the risk of collision between moving vehicles and workers/pedestrians at the workplace, such as: Forklift Safety RFID Solutions (SPT, 2016), BodyGuard (Orbit, 2016), Pedestrian Alert System (IcnitaSafety, 2016), EGOpro Safety Move Proximity Warning Systems (AME, 2016), etc. They all improve safety through a proximity alert system for forklifts and workers/pedestrians. The main operating features of these systems are: the detection of workers/pedestrians in frontal (0.5-6.5 [m]), back (0.5-6.5 [m]), and side area (up to 4 [m]) of the forklift in operation to warn the forklift's driver (while maximum detection range can be adjusted to smaller). They also alert the worker/pedestrian by visual and/or audible alarms and automatically reduce the speed or stop the forklift, while its maximum speed is limited to 10 [km/h] (IcnitaSafety, 2016).

The systems help in overcoming the typical risks caused by factors such as driver inattention, poor visibility (e.g., blind entry/exit, warehouse aisles, etc.), worker's non-compliance with exclusion areas around vehicles, collision between a worker and moving vehicle at a common working area, etc.

Through the simulation experiments (Section 5) we are considering the case when a forklift contains an RFID long-range reader and an alerting system and is treated as a moving router of the ZigBee network at the port area (Figure 3).

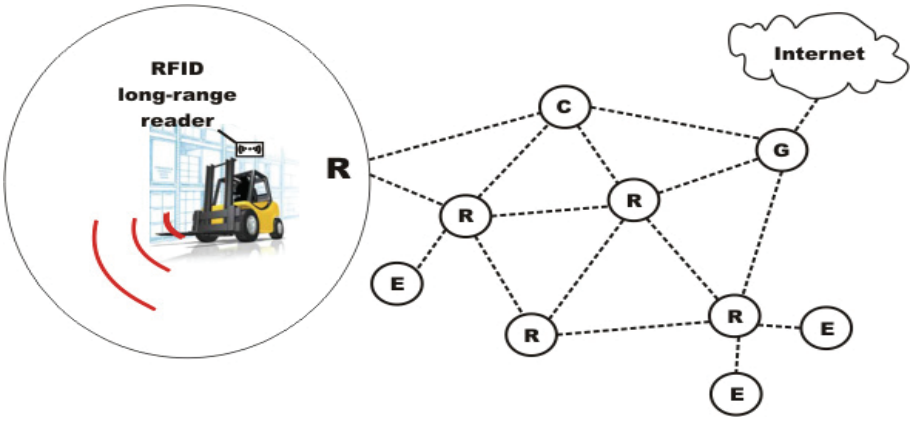

Fig. 3. ZigBee/RFID scenario 3: Forklift's RFID reader as a moving router (Legend: E-end node; R-router; C-coordinator; G-gateway/coordinator)

All three previously shortly presented occupational safety scenarios include the combination of RFID and ZigBee technologies, which can be applied at the port working environment. Therefore, ZigBee/RFID hybrid technology will be described in the next section. Also, some simulation experiments over ZigBee communication channels at the OPNET environment shall be performed.

4. Blending ZigBee and RFID technologies

The ZigBee networks can collaborate with RFID devices to enhance the reduction of battery power consumption, robustness, extension of ranges, communication with applications and other network devices, etc. In other words, an integrated ZigBee/RFID system architecture has the performances of multiple applications and of more capability than stand-alone RFID products. It can deliver an extended range through multi hops and considerable savings in power consumption when all the network components are well coordinated. In the ZigBee/RFID system, a ZigBee end device like a worker's BAN, an active on port worker's ID badge and a forklift RFID warning system have the ability of returning a unique identifier to a nearby scanning reader. The ZigBee transceivers automatically form a mesh network with any ZigBee transceiver in the range of the same network ID and frequency range (Abdula and Widad, 2011; Rubio, 2010). The XBee product (Digi, 2016) is a radio frequency transmission module programmed to be used as a ZigBee end device with a transparent operation as an active RFID tag and receiving and transmitting capabilities in a wireless transmission physical layer. In the following simulation experiments we assumed that the workers' BANs composed of active/passive RFID devices (Figure 1 and Figure 2) are end nodes of the ZigBee network the features of which we analyzed. Also, we considered the forklifts' RFID sub network composed of a reader, warning devices, and driver's ID badge as a moving router of the analyzed ZigBee mesh network on the port parameter (Figure 3). Some of the results of the performed experiments in OPNET (Hammoodi et al., 2015; Saha, 2013; Sahraei, 2009; Kaur, 2014) are presented and discussed in the following section. In addition to improving the on port workers' and pedestrians' safety, the ZigBee/RFID systems can also be used for enhancing the building security (Infanta, 2013), traffic flow management (Chao and Chen, 2014), intelligent traffic control and patient monitoring for efficient ambulance services (Suneesh, 2015), etc.

5. Simulation results

The simulation experiments with the ZigBee network with end nodes being the workers' RFID sub networks, and moving routers being the forklifts' RFID warning systems sub network, are performed in OPNET Modeler (Riverbed Modeler v.17.5.A) on PC (Intel-Core™ i7, 2.50 GHz, 8GB RAM) over the layout of the Port of Bar container and general cargo terminal which covers the area of 650 x 350 [m2] (Figure 4).

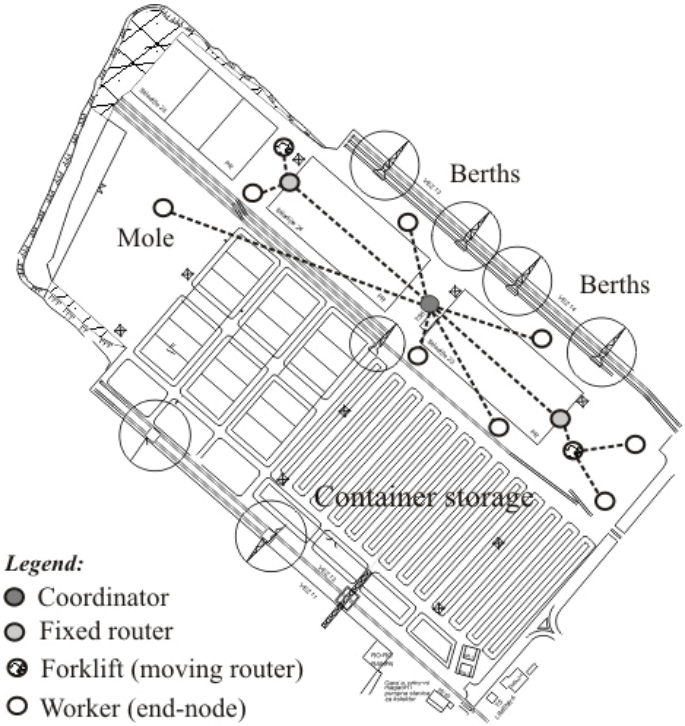

Fig. 4. Layout of the Port of Bar container terminal over which some ZibBee/RFID network performances are analyzed

For the needs of the simulation experiments, the fixed routers and the coordinator of the ZigBee network are set on the top of the main warehouse buildings at the terminal, which are approximately 10 [m] high, in order to be higher than the container blocks at the container yard. We used a mesh topology since it generally has superior performances in comparison with star and tree topologies (Vancin and Erdem, 2015; Mihajlov and Bogdanovski, 20011; Vats et al., 2012). Workers and forklifts are moving over the operational area between wharfs and storage (warehousing) area. We suppose that a worker's speed is 2 [km/h], and the forklift's speed is 10 [km/h]. The paths of the workers and forklifts are chosen randomly. Since the Port of Bar has about 100 on port workers who are allocated at seven terminals depending on the workload: (1) container and general cargo terminal; (2) wood terminal; (3) terminal for grains; (4) bulk cargo terminal; (5) container and general cargo terminal; (6) liquid cargo terminal, and (7) passenger terminal, we supposed (according to the usual turnover) that mostly 18 workers might be engaged daily at the container and general cargo terminal. Also, according to some previ-

ously made consultations with port managers, we assumed that 2 forklifts are usually in operation on the terminal daily. In order to get a better insight into the simulation experiments' results, we tested the network for various combinations of the workers and forklifts, e.g., for: (a) 4 workers and 1 forklift; (b) 9 workers and 1 forklift; (c) 13 workers and 2 forklifts, and (d) 18 workers and 2 forklifts. The main settings for the network end nodes are as follows:

- Packet Interval Time: constant (1);
- Packet Size: constant (32);
- Start time: constant (30);
- Stop time: infinite; and,
- Transmition power: 5 [mW].

The forklifts, treated as moving routers, have the same application traffic parameters, but the transmission power is greater, i.e., it is 50 [mW]. The routers do not generate application traffic. The coordinator is responsible for the configuration of the network parameters. It sets the network topology (tree, star, or mesh; here the mesh one), the number of children that each node can have, the number of routers, the depth on the network tree, it defines PAN, etc. The coordinator does not generate any application traffic either, but will be the final destination for all the application traffic generated in the end nodes.

Figure 5 presents the traffic received by the coordinator in the cases (c) and (d) at the frequencies 868 [MHz] and 2.45 [GHz], respectively. It is obvious that the received traffic is about 12-18 packages per second for 2.45 [GHz], and that it is considerably lower, i.e., it is between 6-9 packages per second for 868 [MHz]. This is due to the increased performances that we have in the 2.45 [GHz] band, compared to 868 [MHz], such as the data rate, the number of channels, or the use of more efficient modulation protocols. We may also remark that each end node sends the traffic each second, therefore some packet losses are acceptable, as long as not all the data from one worker is completely lost.

Figures 6 and 7 present end-to-end delays for (a), (b), (c), and (d) scenarious, for 868 [MHz] and 2.45 [GHz] carrier frequencies. It is clear that the delay is consideralby lower for 2.45 [GHz] than for 868 [MHz]. More precisely, in the better case (at 2.45 [GHz]) it is about 0.07-0.16 seconds, while in the worse one (at 868 [MHz]) it is about 0.12-0.44 seconds. This happens because the data rate increases at 2.45 [GHz], and because of the more efficient QPSK modulation scheme used (in comparison with BPSK one).

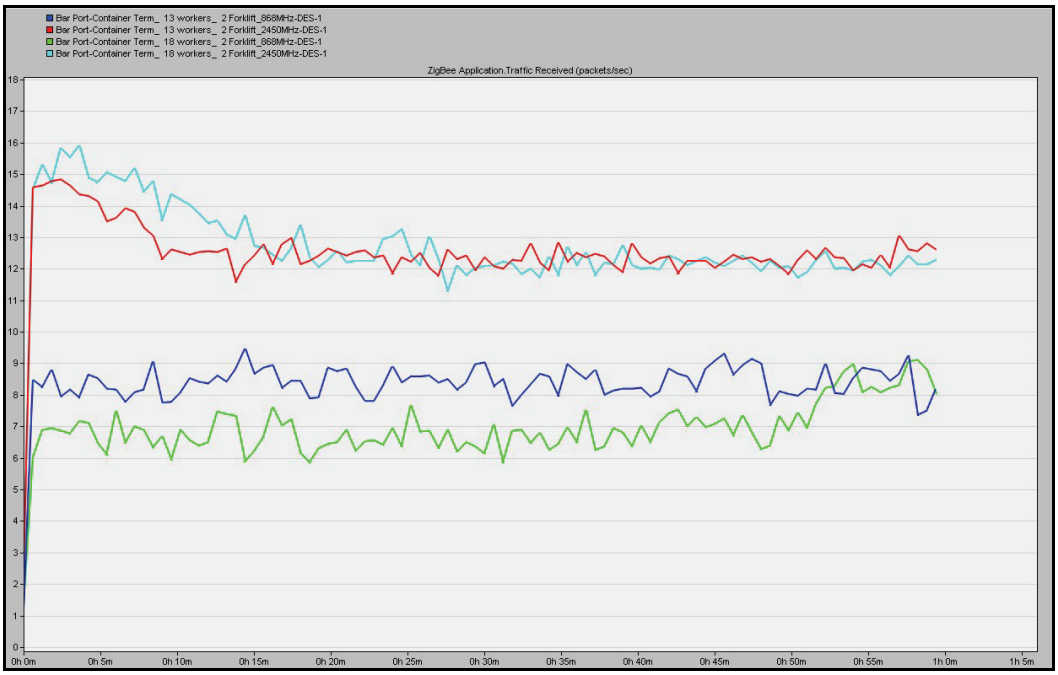

Fig. 5. Traffic received by coordinator for different on port scenarios

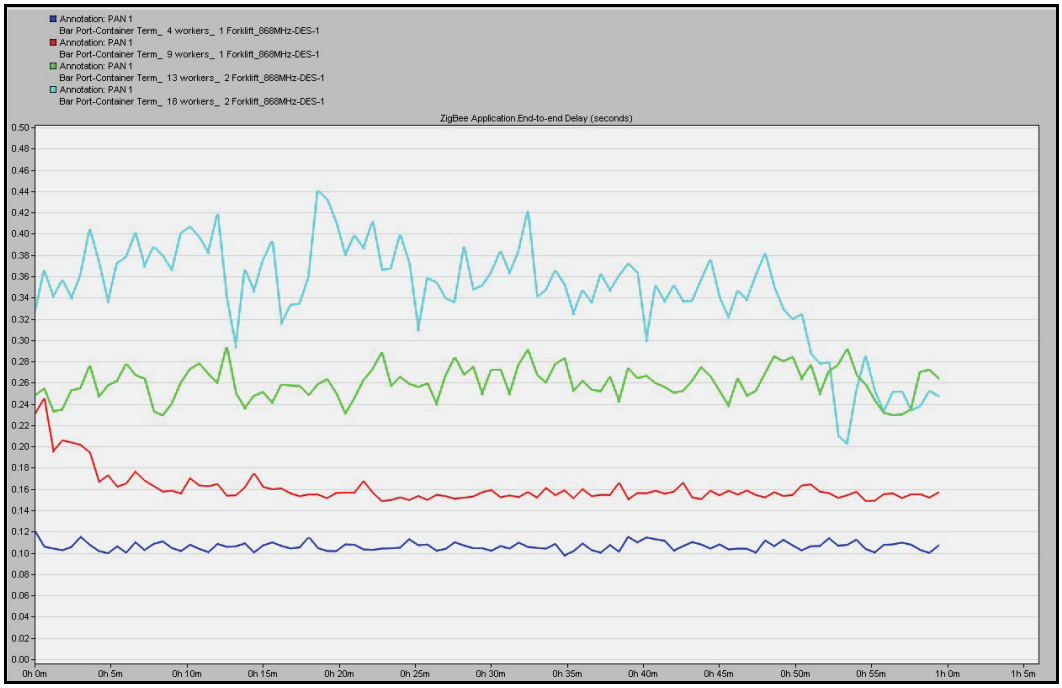

Fig. 6. End-to-end delay for 868 [MHz] carrier's frequency

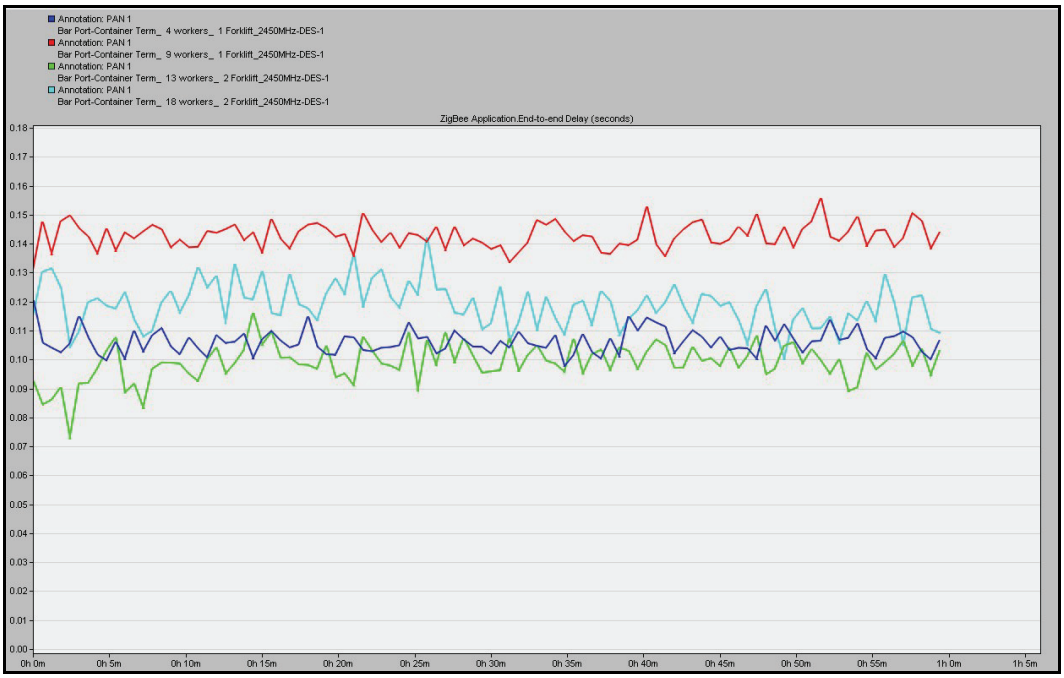

Fig. 7. End-to-end delay for 2.45 [GHz] carrier's frequency

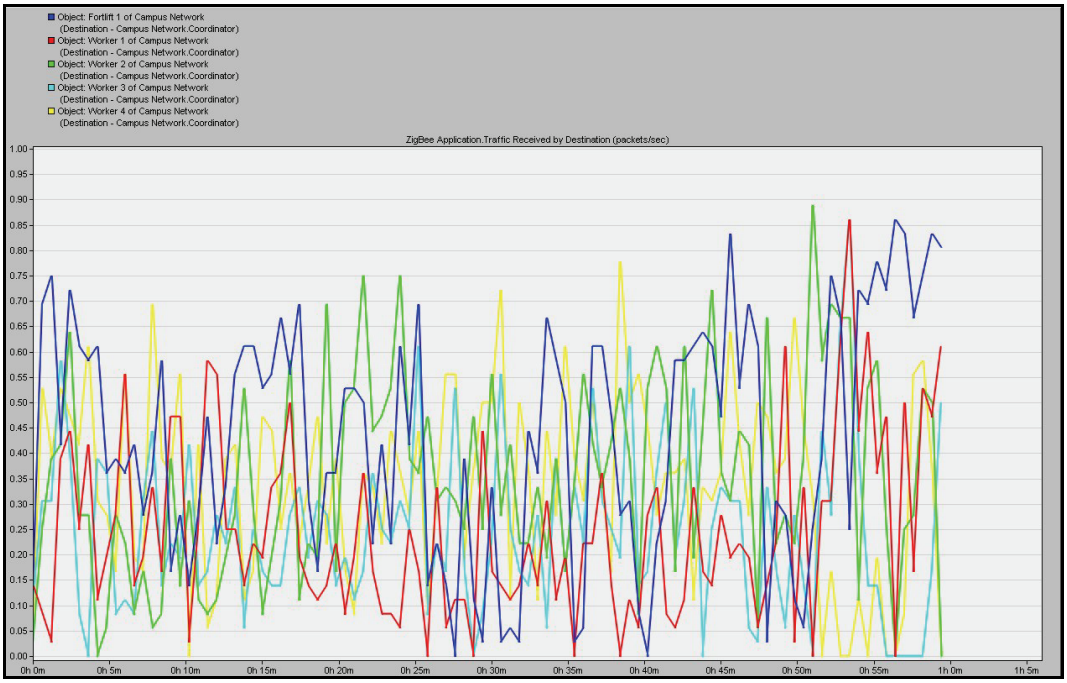

Fig. 8. Traffic received by destination from different routers and end nodes at 868 [MHz]

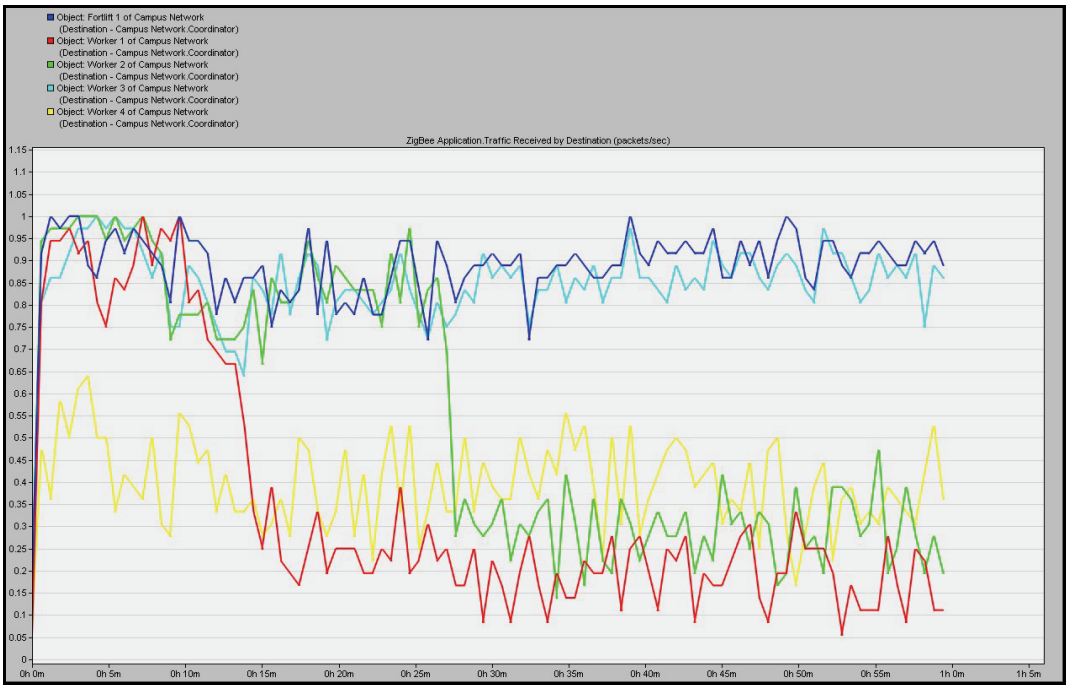

Fig. 9. Traffic received by destination from different routers and end nodes at 2.45 [GHz]

It is also interesting to consider the traffic received by destination, i.e., network coordinator from certain end nodes (workers) or moving routers (forklifts) as it is shown in Figures 8 and 9. The traffic received by destination reaches 1 package per second for 2.45 [GHz] and 0.75 package per second for 868 [MHz]. Although the received traffic has oscillations which mostly depend on the distance between the end nodes and/or moving routers from the destination within the time interval covered by the simulation period, there is no permanent interruption in receiving. This is of particular importance.

The simulations were performed for the actual number of workers and forklifts usually employed per shift based on the workload on the container and general cargo terminal in the Port of Bar. In the forthcoming analysis, a larger number of workers and mobile mechanization units should be involved in order to confirm the experimental ZigBee technology functionality for a greater number of network nodes, i.e., its reliability and scalability. Furthermore, the impacts of different obstacles and environmental parameters should also be analyzed. The on port workers' readiness to become constitutive parts of the proposed smart safety solutions is to be examined, as well. All these should assist the managers in making the port safer and greener at the global market of un-loading, manipulation, transportation, and various added-value services.

6. Conclusions

The paper presents a continuation of the previous authors' research work (Bauk et al., 2015; Bauk et al., 2016) and attempts towards repositioning the Port of Bar at the market of safety ports. It considers the RFID based occupational safety solutions in ports and other similar harsh environments and proposes the RFID system co-work with ZigBee technology in a satisfactory and efficient way for the purpose of enhancing the on port

workers/pedestrians safety. The ZigBee was analyzed as a communication technology because it provides low energy consumption, a larger range, and it works properly with quite a large number of end devices. An XBee module was proposed as a link between the workers' and forklifts' RFID sub networks and ZigBee communication channel. The simulations are focused on the ZigBee performances over the Port of Bar container and general cargo terminal. They were realized in OPNET (Riverbed Modeler v.17.5.A) environment, while the following have been obtained:

- As the number of end-nodes increases (from 15 to 20), the traffic received by the coordinator decreases (from about 12 to 7 packages per second), but there are no interruptions such as the coordinator not receiving any traffic at all;
- The experiments show that the performances of the ZigBee network are in general significantly better at 2.45 [GHz] than in the case of 868 [MHz] carrying frequency. This is due to the greater data rate at 2.45 [GHz], greater number of available channels, more efficient modulation schemes, etc.;
- Better performances at 2.45 [GHz] than at 868 [MHz] are noticed when it comes to the number of packages received by the coordinator per second, and when it comes to the end-to-end delay of the received signal;
- The number of packages received by the destination (coordinator) from different routers and end nodes varies depending on the current location of these devices. It is greater in the case of using 2.45 [GHz] than 868 [MHz]; and,
- Concerning the received power, it is in all the cases higher than the power reception sensibility threshold, which is the minimum reception power needed by the receiver. In all our scenarios, it was set to -85 [dBm] to all the devices.

The experiments were done for the real number of workers and forklifts being commonly in operation at the Port of Bar container and general cargo terminal. They show a completely satisfying level of the ZigBee network performances. In our simulation experiments we assumed that the ZigBee end nodes and moving routers are RFID sub networks joint to the ZigBee via XBee modules. In the forthcoming research, a larger number of end nodes and routers should be involved. Additionally, some more detailed explanations of connecting possibilities for RFID and ZigBee technologies are to be considered.

Our goal here was to familiarize the managers and stakeholders of the developing Port of Bar, operating in a transitional economy, with contemporary ICT solutions which might be adapted for improving the safety of human lives and environmental management system. Since the industrial safety systems use a whole panoply of technologies, our intention was not to offer the best solution, but just to open a discussion about cost and energy effective and, at the same time, reliable occupational safety measures. It is upon the port's management to develop strategies for their implementation in the future, with the ultimate goal of protecting the on port workers'/pedestrians' lives and maritime ecosystem. These should promote the Port of Bar in the future as safe and green at the maritime market and upgrade its current position at the customers' perception maps.

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1.4. Some ZibBee/RFID safety system performances

This research work considers some possibilities of developing and adopting a ZigBee/RFID occupational safety smart system for protecting workers', pedestrians', and marine environment at the seaport perimeter with reference to the Port of Bar (Montenegro). The key features of RFID, ZigBee, and ZigBee/RFID systems are briefly considered. In addition, some simulation experiments in OPNET environment over ZigBee/RFID network at the physical layer are performed, while the corresponding conclusions are derived. Finally, some directions towards further research in the field are proposed.

1. Introduction

Seaport are dangerous places especially for on port workers, pedestrians and marine environment in terms of operational risks connected to un-loading operations, managing on port traffic and transportation, including hard manipulative mechanization, warehousing dangerous cargoes [1], etc. Work at ports takes place through the day and night, in two or three shifts, in all weather conditions [2,3]. It involves a number of different employers and contractors carrying out different activities. This requires highly synchronized co-operation and communication between all involved parties. Seaports also tend to be associated with emerging environmental problems [4]: water and air pollution, soil contamination, problems related to dust and noise, generation of waste, dredging operations, warehouse storage of hazardous substances, etc.

All these make work at port challenging, but also high risk one. Therefore we did an effort to mitigate these potential risks by proposing a ZigBee/RFID safety network for protecting on port workers and/or pedestrians, as well as the seaport environment.

The paper is organized in a manner that its 2, 3 and 4 sections describe briefly RFID, ZigBee and their junction through ZigBee/RFID hybrid system, respectively. Section 5 proposes ZigBee/RFID smart occupational safety system for the individual needs of the developing Port of Bar which functions for decades in transitional economy. Section 6 presents and discusses some simulation experiments' results obtained by OPNET modeler over the Port of Bar container and general cargo terminal layout. The last section contains some conclusion remarks, along with few suggestions for the following research work in this field.

2. On RFID in brief

RFID is acronym for radio frequency identification. This technology is a member in the family of automatic identification and data capture technologies. It is suitable for low-power wireless tracking of people and objects [5]. RFID applications include ID (identification) badges and access control, car tracking and rental lots, airport security checks (passports and baggage), tracking livestock and pets, timing for sports, inventory control, product tracking through manufacturing and assembly, supply chain management, toll payment, libraries, etc.

There is a significant number of academic survey papers in the field of RFID technology and its applications [6,7]. Far fewer papers deal with the implementation of RFID technology in the field of seaports' safety management, particularly in the sub-field of identifying and locating workers and their PPE (Personal Protective Equipment) [8,9,10].

In this paper we shall consider on port workers' and pedestrians' active RFID ID badges as moving end nodes of the ZigBee communication network. Also, we shall consider RFID readers build-in forklifts which operate at the port as moving routers of the

ZigBee platform supported by XBee module for establishing co-work with RFID technology [11].

3. On ZigBee in brief

ZigBee is a wireless communication technology provided by ZigBee Alliance which uses IEEE 802.15.4 global standard. It is used in almost every appliance. Its key features are following ones [5, p.134]:

- Easy to install and maintenance (mesh, self-organizing);
- Reliable (self-healing);
- Ability to scale to thousands of devices (nodes; theoretically it can manage up to 65.535 nodes [12, p.164]);
- Long battery life (e.g., AA batteries can operate for several years);
- Low cost (open standard, multi-vendor availability), etc.

ZigBee technology is embedded in a wide range of products and applications across customer, commercial, industrial and government markets worldwide. Predominantly it is used for monitoring and control applications. ZigBee operates in the industrial, scientific and medical (ISM) radio bande: 868 MHz in Europe, 915 MHz in USA and Australia, and 2.4 GHz in most jurisdictions worldwide. This technology is simpler and less expensive than other WPANs (Wireless Personal Area Networks) like Bluetooth, e.g.

4. On ZigBee/RFID hybrid system shortly

ZigBee networks can collaborate with RFID devices to enhance lower battery power consumption, robustness, extension of ranges through multi hops, communications with applications and other network devices, etc. An integrated ZigBee/RFID system architecture performs the needs of multiple applications with more capability than stand-alone RFID products. It can deliver extended range through multi hopes and considerable savings in power consumption when all network components are well coordinated. An XBee Digi product is radio frequency transmission module programmed for use as a ZigBee end device with transparent operation as an active RFID tag and receiving and transmitting capabilities in a wireless transmission physical layer [13].

In the ZigBee/RFID system, ZigBee end device like worker's BAN (Body Area Network), an active on port worker's ID badge, or forklift RFID warning system have capabilities of returning a unique identifier to a nearby scanning reader, while ZigBee transceivers automatically form a mesh network with any transceiver in range [14].

5. A ZigBee/RFID smart safety system at the seaport

Seaports' accidents which involve moving vehicles (e.g., forklifts) and workers/pedestrians are costing ports huge amount of money in terms of expensive downtime, investigations and increased insurance premises [15]. There are several ready made, commercial solutions for reducing the risk of collision between moving vehicles and pedestrians/workers in the workplace, like: Forklift Safety RFID Solutions, BodyGuard, Pedestrian Alert System, EGOpro Safety Move Proximity Warning Systems, etc. They all improve safety through a proximity alert system for forklifts and pedestrians/workers. Some of the operating characteristics of these systems are: detection of pedestrians/workers in frontal, back, and side area of operation of forklift and warning forklift's driver (while maximum detection range can be adjusted smaller); alerting at the same time pedestrian/worker by

visual and/or audible alarm; and, automatic reducing speed or stopping forklift (max. speed is of 10 [km/h]). The system helps to overcome typical risk caused by factors such as driver inattention, poor visibility (e.g., blind entry/exit, warehouse aisles, etc.), worker non-compliance with exclusion areas around vehicles, collision between worker and moving vehicle at the common working area.

In the paper we assumed that on port workers' and pedestrians' BANs composed of active RFID ID badges are end nodes of the ZigBee network which features at the level of communication channel are analyzed in the next section. Also we considered forklifts' RFID reader as a moving router of the ZigBee mesh network within the port parameter (Figure 1).

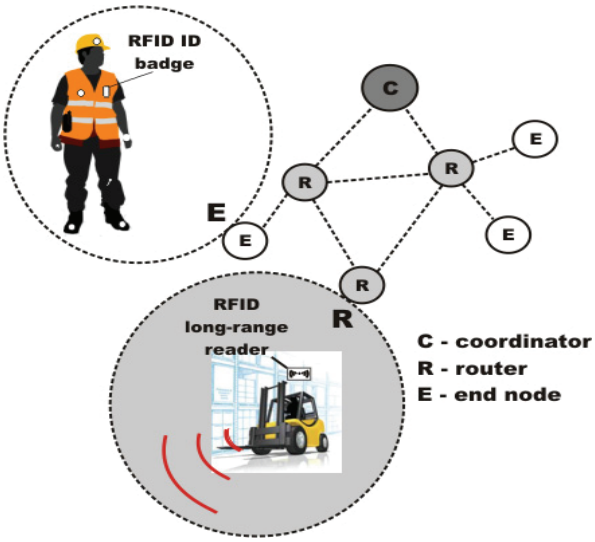

Fig. 1. Model of a hybrid ZigBee/RFID seaport safety system

6. A ZigBee/RFID simulation analysis

Simulations of the ZigBee network which end nodes are workers' RFID sub networks, and moving routers are forklifts' RFID reader and warning systems sub network are realized in OPNET Modeler (Riverbed Modeler v.17.5.A) on PC (Intel-Core™ i7, 2.50 GHz, 8GB RAM) over the layout of the Port of Bar container and general cargo terminal which covers the area of about 650 x 350 [m2].

The Port of Bar has 100 on port workers who are scheduled at five terminals depending on the workload: (i) container and general cargo terminal; (ii) wood terminal; (iii) terminal for grains; (iv) bulk cargo terminal; (v) general cargo terminal; (vi) liquid cargo terminal, and (vii) passenger terminal. We supposed that mostly 18 workers might be engaged daily at the container terminal. Besides that, according to some consultations with port managers, we assumed that 2 forklifts are usually in operation daily on the terminal. In order to get better insight into the simulation experiments' results, we tested the network for various combinations of workers and forklifts, e.g., for: 4 workers and 1 forklift (Scenario 1); 9 workers and 1 forklift (Scenario 2); 13 workers and 2 forklifts (Scenario 3), and 18 workers and 2 forklifts (Scenario 4), see Table 1.

A segment of the considered OPNET Modeler network is shown in Figure 2. The settings of the network for the end nodes are as follows: - Packet Interval Time: constant; - Packet Size: constant (32); - Start time: constant (30); - Stop time: infinity; - Transmition power: 5 [mW]. Routers do not generate application traffic, while the coordinator is responsible for configuration of the network parameters. It sets the topology of the network (tree, star, or mesh; here mesh), the number of children that each node can have, the number of routers, the depth on the network tree, defines the PAN, etc.

Table 1. Supply/supporting/research RFID industry: some providers

Scenario	**Scenario's features**		
	Frequency	***No. of workers***	***No. of forklifts***
Scenario 1	868 [MHz] & 2.45 [GHz]	4	1
Scenario 2		9	1
Scenario 3		13	2
Scenario 4		18	2

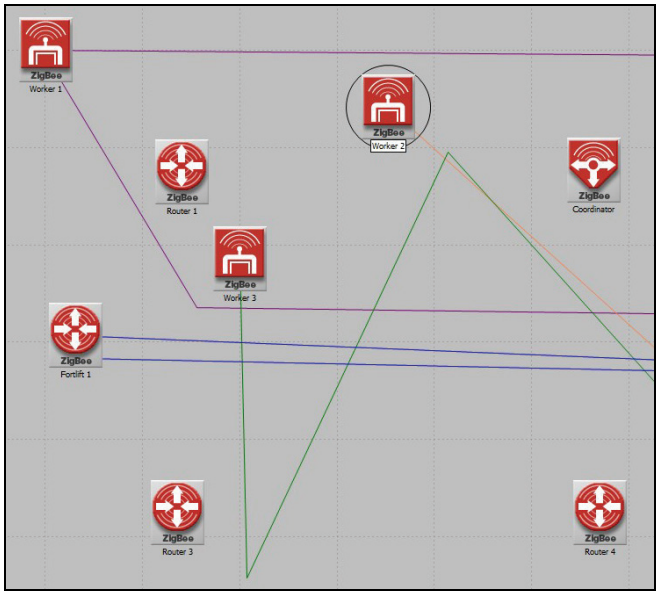

Fig. 2. A segment of the analyzed network in OPNET environment

In Figure 3 is presented the traffic received by coordinator for Scenarios 1-4 (Table 2) at 2.45 [GHz]. In the case of the first scenario the traffic is mostly constant, while it less or more varies for the scenarios with higher number of end nodes, i.e., workers and fork-lifts.

It Figure 4 is shown end-to-end delay at the coordinator for Scenarios 1-4 at 2.45 [GHz]. It varies between 0.07 and 0.15 seconds, depending on number and arrangement of end nodes and moving routers in accordance to the fix position of the coordinator (at the roof of the main storage building at the port perimeter).

In Figure 5 is presented the traffic received by coordinator for all four considered Scenarios (Table 2) at the frequencies 868 [MHz] and 2.45 [GHz]. It is obvious that the received traffic is about 12-18 packages per second for 2.45 [GHz] frequency, and that is considerably lower, i.e., it is between about 6-9 packages per second for 868 [MHz] frequency. This is due to the increased performances of the 2.45 [GHz] band, compared to the 868 [MHz] one. The 2.45 [GHz] band has advantages like greater data rate, greater number of channels, it uses more efficient modulation protocols, etc. We may remark also, that each end node sends application traffic each second, but for our application we can assume some packets losses, as long as all the data traffic from one worker is not completelly lost.

Fig. 3. Traffic received by coordinator for different scenarios

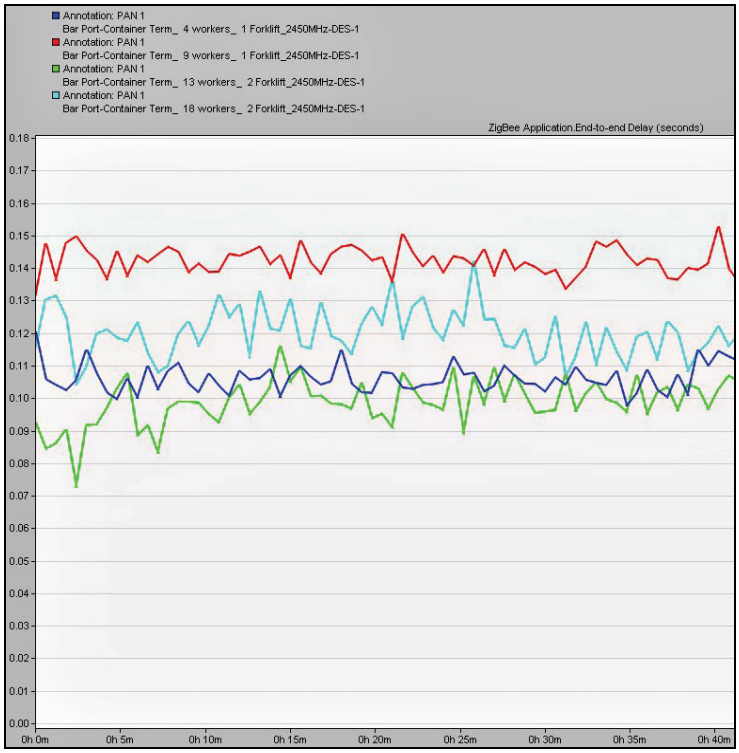

Fig. 4. End-to-end delay for different scenarios

Some further OPNET simulations showed that the delay is consideralby lower for 2.45 [GHz] that for 868 [MHz]. More precisely, in better case (i.e., at 2.45 [GHz]) it is about 0.07-0.16 seconds, while in worse one (i.e., at 868 [MHz]), it is about 0.12-0.44 seconds. This happens since the data rate increases at 2.45 [GHz], and because more efficient modulation scheme QPSK (in comparison to BPSK one) is used, as it is noted previously.

It is also interesting to consider traffic received by destination, i.e., network coordinator from certaing end nodes (workers) or moving routers (forklifts). The traffic received by destination reaches 1 package per second for 2.45 [GHz] and 0.75 package per second for 868 [MHz]. Although the received traffic have oscilations which mostly depent on the distance between end nodes and/or moving routers from the deastination at the certain time interval covered by the simulation period, there is no permanent interuption of receiving [11].

The simulations are realized for the real number of workers and forklifts employed ordinary in the shifts, according to the workload on the container and general cargo terminal at the Port of Bar. In the further analysis, larger number of workers and mobile manipulative and transportation devices should be taken into consideration in order to confirm experimentally ZigBee technology functionality for greater number of network nodes, i.e., its reliability and scalability. The impacts of different obstacles and environmental parameters should be analyzed, as well.

Fig. 5. Traffic received by coordinator at 868 [MHz] and 2.45 [GHz] for two different scenarios (15 & 20 end nodes)

7. Conclusions

In the paper are briefly described the basic features of the RFID, ZigBee and ZigBee/RFID technologies. It is clear that junction of ZigBee and an RFID has better performances than these technologies employed separately. Two models for enhancing on port workers and pedestrian safety by using active RFID ID tags (for tracking and access control to the dangerous zones) and RFID readers mounted at the forklifts with aim to detect approaching worker/pedestrian and to activate audio/fleshing alarm and slowing down the vehicle are considered. These two RFID sub networks are treated as end nodes and moving routers (respectively) of the ZigBee communication protocol adjusted by an XBee module to the RFID technology needs. Some simulation analysis in OPNET environment of these two working safety models are performed over the container and general cargo terminal of the developing Port of Bar in Montenegro. Besides examining ZibBee/RFID features at the level of communication channel, the idea of this paper was to open discussion about improving safety at the port and its developing towards safe and green one. Future simulation experiments should include considerably larger number of end nodes and routers, including possibilities of energy harvesting when it comes to securing battery free active devices.

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1.5. Vehicular communication for safety purposes

This study presents a model and some simulations of vehicle-to-pedestrian/infrastructure (V2P/I) communication channel performances at the seaport, whereas vehicles are taken as front-lifts and pedestrians as on port workers. More precisely, the aim of this work is to examin the important radio channel features between end nodes in order to optimize the network deployment and, at the same time, to display the communication limitations under realistic conditions. An ultimate goal is providing the contribution towards increasing works' and environmental safety at the invasive seaport industrial and commercial areas. Consequently, the corresponding radio channel simulation analyses are realized over the layout of the container and general cargo terminal at the Mediterranean Port of Bar (Montenegro).

1. Introduction

The vehicle-to-pedestrian/infrastructure (V2P/I) commu-nication has to improve traffic management in order to prevent traffic accidents (collisions), which are causing deaths, injuries, waste of productive hours, additional insurance costs, environmental impacts, etc. Intelligent Transportation Systems (ITS) which constitutive part, among others, is V2P/I communication have to provide safety, efficiency and comfort applications [1]. The cellular or broadband wireless interfaces provide the vehicles (here front-lifts) with connectivity to pedestrians (here on port workers) and infrastructural base stations, while dedicated short-range communication (DSRC) allows data transfers. Let us note that there is an IEEE 802.11p standard for vehicular communication in the 5.9 GHz (75 MHz RF) band as DSRC to enable vehicular communication for different safety and infotainment applications. This standard allows vehicle (front-lift) to transmit up to 1,000 m with 32 dBm power [1,2]. A vehicle (front-lift) is a source node and whenever it detects some danger, e.g., obstacle, reduced visibility, malfunctioning of braking system, road merging, potential collision situation, etc., it generates a warning message. This warning message should be broadcasted to all nodes (other front-lifts and workers) in the seaport area of relevance as quickly as possible [3].

Within this context, it is important to note that pedestrians (i.e., on port workers) safety at the invasive seaport environment is not an issue to be overlooked. For instance, front-lifts account for thousands of serious injuries and dozens of deaths each year in American workplaces. According to the National Institute for Occupational Safety and Health statistics reported to government inspectors by employers [4]:

- 20% of all front-lift accidents involve a pedestrian being struck by a front-lift, translating to almost of 19,000 people per year;
- 100 workers are killed in front-lift accidents every year;
- 20,000 workers are seriously injured in front-lift related accidents every year;
- 34,000 injuries are treated in emergency rooms every year due to the front-lift accidents.

While the above given statistics are not negligible, many pedestrians/workers and employers are still unaware of the dangers associated with operating/employing front-lifts. What is even more unfortunate is that many of these injuries could have been prevented by the simple installation of safeguards in the workplace, e.g., V2P/I devices.

When it comes to avoiding putting oneself at risk of being struck by front-lift, here are some of the common situations to watch for [5]:

- pedestrian/worker did not see the front-lift;
- pedestrian/worker did not hear the truck;
- pedestrian/worker came into too close proximity of the front-lift, etc.

The frequency of pedestrian/worker involvement in front-lift truck accidents can be controlled through better traffic management, in conjunction with safety equipment and awareness training. The traffic management can involve the demarcation of pedestrians'/workers' routes to keep mobile equipment and pedestrians/workers separate. The safety equipment on the part of pedestrians (workers) starts with wearing a high visibility vests. Additionally, front-lifts are required to have horns, and can be fitted with warning lights or other warning indicators. Curved mirrors can also be used to improve safety. As more sophisticated safety measure, an appropriate V2P/I system might be employed.

Unfortunately, there is no official statistics on above mentioned accidents in the under developed and developing countries (including Montenegro) due to the best of our knowledge. These numbers of incidents are not, most probably, so high because of the considerably lower workload in industrial and commercial areas of these countries, but anyway, stakeholders, employers and workers should be aware of the potential dangers, while the possibilities of introducing and adopting the appropriate V2P/I safety-warning systems should be taken into consideration in addition to other previously mentioned safety mechanisms. The V2P/I collision avoidance system uses energy-efficient and non-dedicated technologies [6]. This system employs existing infrastructure (if it is available) and devices like smart phones (widespread among drivers and pedestrians), cellular network and cloud. The safety mobile apps can be set to driver or pedestrian mode. These apps frequently send vehicle and pedestrian geo-location data to cloud servers. In cloud are performed threat analysis and alerts are sent to the users in risky situations.

On the basis of previously noted, the rest of the paper is organized as follows: Section 2 gives short research background with focus on the considered seaport environment; Section 3 contains the problem definition along with the description of the simulation environment; Section 4 discusses simulation results, and Section 5 gives some conclusion remarks, including potential directions for further research endeavors in the field.

2. Research background

Within several previous research works, we have tried to show how occupational safety can be increased at the developing seaport harsh environment at the example of the Port of Bar. Accordingly, we have firstly considered a deployment of safety-warning solutions based on RFID technology. Some safety measures were proposed at logical level and tested in Opnet and Omnet++ simulation environments [7]. Then, we considered some possibilities of adopting ZigBee/RFID hybrid solutions for enhancing on port workers' safety [8]. And finally, we compared the application of ZigBee and MANET communication technologies [9]. All proposed solutions are cost-effective and energy-sparing, and they can be taken into consideration as affordable ones from the perspective of a developing seaport which is permanently facing the lack of available funds for environmental safety system improvements.

The obtained results, through the above referred research studies, should be used by the port top management team, stakeholders, and ICT experts as a kind of landmarks for increasing occupational and environmental safety, and also for repositioning (of course, in positive direction) the considered port at the global market of safe and green ports.

3. Problem definition and simulation environment

The aim of this paper is to study the important radio channel characteristics of a V2P/I system (received power, delay and angular domain) in order to optimize the network deployment and, at the same time, display the communication limitations. In this context, the paper shows a realistic simulation using a semi-stochastic radio channel model, i.e., a combination of a ray-tracer algorithm and stochastic parameters [10]. The base stations (BS) are deployed covering the maximum area possible. The workers and their walking paths are randomly selected covering almost the entire seaport area (blue lines), while the front-lifts are simulated covering longer routes from side to side of the port working area (red lines), Figure 1.

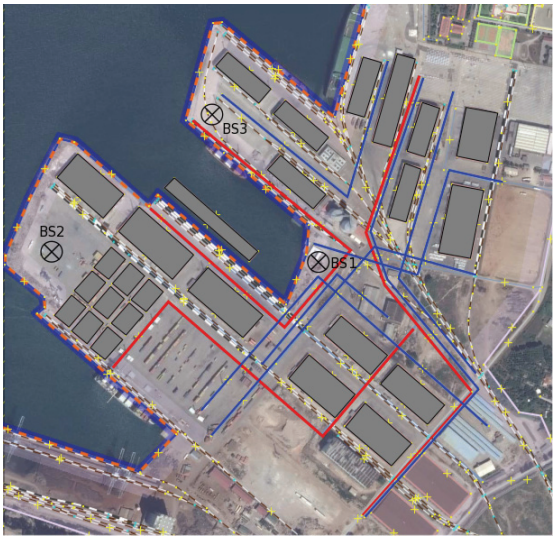

Fig.1. Layout of the container and general cargo terminal at the Port of Bar with front-lifts (red) and workers (blue) routes

The container terminal is located at the Pier I of the Port of Bar and it covers the area of 60,000 m2. Wharf length is 330 m and the depth of the sea is 11 m. The surface of the terminal is marked by zones, and the connections for refrigerated containers are provided. The terminal has an area for disposal of 2,635 TEU in the range of the container crane. It has also 13 modular fields with capacity of 2,320 TEU per field. Additionally, the terminal has 6 modular fields for transportation and manipulation operations with 6,320 TEU per field. The containers handling is realized in direct manipulation with railway wagons or other means of transportation.

The general cargo terminal is located at the Piers I and II of the Port of Bar, and it is equipped with necessary devices for un/loading and manipulation cargo (including front-lifts). The length of the operational waterside line is 1,370 m. The average sea depth is 10 m. The terminal is equipped with 15 portal cranes with capacity of 15 t per crane. The number of workers at the port depends on the workload and daily operational plans, and it varies from several workers to 20-25 per terminal/shift. The workers paths are simulated with a speed in the range of 1.4 m/s to 2.5 m/s (blue lines in Figure 1), while the front-lifts move at a maximum speed of 6 m/s (red lines in Figure 1). The simulation has been conducted deploying three base stations and 10 mobile users, i.e., workers and front-lifts in total. The simulations are performed in a PIROPA environment, i.e., by using a deter-

ministic ray-tracer algorithm [11], at a vehicular communication frequency of the 5.9 [GHz], which is envisaged for short distances 10-1,000 [m] using 2.6 GHz Intel Core i5 with 16 Gb of RAM, while the obtained results are presented within the next section.

4. Simulation Results and Discussion

Regarding the V2P/I communication network using the ray-tracer algorithm output and adding stochastic properties, the following network features are considered:

- the Empirical Cumulative Distribution Function (ECDF) of the received power for the different workers and different speed, as well as for the front-lifts;
- the angular spread and delay spread for workers and front-lifts; and,
- the Doppler spread for all the workers (focus on max/min) and the front-lifts.

The first analyzed parameter is the received power at each position using the Empirical Cumulative Distributed Function (ECDF), which shows the distribution function associated to the empirical measure of the received power. As shown in Fig. 2, the received power for the workers and front-lifts is within the range of -140 dBm to -65 dBm, and around 40% of the receiver positions are above the -100 dBm threshold, which fits in the range of our previous study [12]. The simulated curves for Base Station 2 and Base Station 3, show the same behavior where the received power by the front-lifts is slightly higher due to the higher elevation, i.e., the front-lift has the receiver located at 10 m. Using Figure 2, it is possible to plan the required number of base stations in order to fulfill certain power requirements for all users with different communication systems.

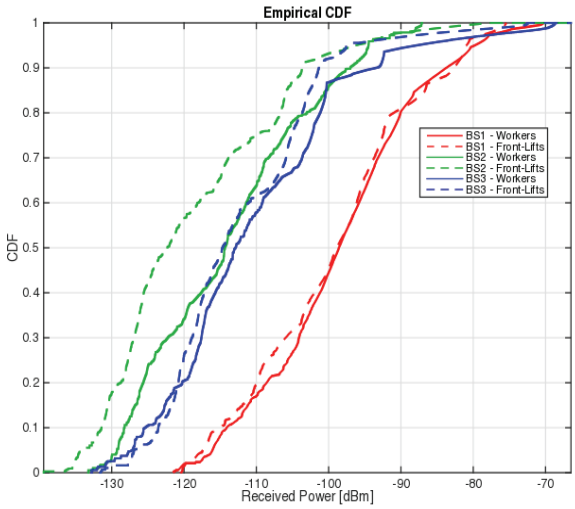

Fig. 2. ECDF vs. received power [dBm]

In Figure 3, the angular directions for all the users are displayed. The optimal antenna pattern has to be designed depending on the communication requirements and it also required fulfilling the technical limitations, i.e., antenna design. The last studied parameters are at the receiver side, Doppler shift and delay, which are useful in order to design the receiver devices for workers and front-lifts. Table 1 shows the maximum Doppler shift for the communication between the workers and front-lifts, i.e., for both sides of the

communication channel, which are movable. Due to low speeds in the port area, the Doppler shift can be neglected in the base station-worker scheme and easily reduced in the case of worker to worker communication.

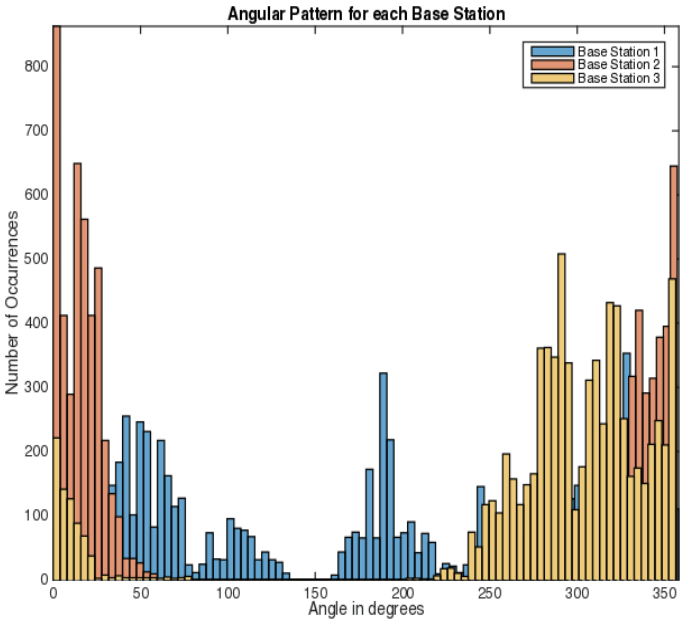

Fig. 3. Angular patterns for deployed base stations

Regarding the delay values, the results show a higher delay in the base station-worker communication, which is to be taken into consideration in the safety measurements design. However, in the worker to worker communication scheme, the delay is in the range of a few microseconds which does not impact the communication scheme at the receiver side.

Table 1. Supply/supporting/research RFID industry: some providers

Features vs. Interplays	MAX DS	MIN DS	MAX DELAY	MIN DILAY
BS/FL-W	negligible	negligible	13.941 μs	0.202 μs
W/FL-W/FL	3.969 Hz	-3.455 Hz	1.652 μs	35.967 μs

Legend: DS – Doppler Shift; BS – Base Station; W – Worker; FL – Front-lift

From the view point of the developing Port of Bar, which is here used as example, it is very important to consider expected costs of deploying such safety system. On the basis of secondary literature resources in the field, the figure of 50,000 $ can be used as a total potential average costs per site [13,14]. This cost should be affordable for the Port of Bar, despite the fact that it functions during almost three decades in transitional economy,

which causes permanent reproduction of crises and prevents its economic development and growth.

5. Conclusions

The paper presents an idea of adopting V2P/I comm-unication pattern for enhancing occupational safety over the seaport operational area. An appropriate communication channel model is conceived for the needs of the developing Port of Bar, while some corresponding simulation experiments are realized using a semi-stochastic channel model in a PIROPA environment. Accordingly, it has been shown that:

- three arbitrary placed base stations can cover the entire container and general cargo terminals at the considered seaport perimeter and provide smooth communications between a certain number of moving on port workers and front-lifts in order to improve pedestrian (worker) detection and on port road safety by avoiding collisions;
- for the proposed arrangement and azimuth angles of the base stations antennas, the received power is at the satisfying level in the range of each base station; and,
- the Doppler shifts and delays at the receiver's side are negligible for different workers and front-lift interplays in relation to the fixed base stations.

Since the idea of deploying V2P/I communications in the developing seaport environment is proposed, it is necessary to mention the costs of deployment under such conditions. Due to the data given in Section 4, it becomes obvious that such safety system might be affordable in the considered case. However, it is up to the port's top managers and stakeholders to provide funds for such safety-warning system, and also to engage ICT experts in its implementation.

Further experiments in the field should be realized over the whole Port of Bar, i.e., over its all seven available cargo and passenger terminals and for greater number of pedestrians (workers), front-lifts and/or other transportation devices. Also, more extensive simulation experiments should be realized for different numbers and arrangements of base stations including different obstacles that might appear at the seaport terminal(s) and cause communication channel disruptions.

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1.6. Safety management and vehicular communication

This research work proposes vehicular communication principles in order to increase workers and pedestrians cross-roads safety at the seaport. A hybrid environment-based approach for modeling the vehicular communication channel is used. It is based on a combination of a deterministic ray-launching algorithm (PIROPA) to model large-scale parameters, and a stochastic model to obtain small-scale ones. Simulation analysis of some power-delay profiles for different workers or pedestrians and front forklifts seaport cross-roads interplays are done over the selected container and general cargo terminal area of the Port of Bar (Montenegro). The results provide good understanding of the communication requirements in order to obtain a feasible on-post safety system.

1. Introduction

Increasing safety at seaports (afterwards ports) is among the main tasks of the environmental management system, while safety of on-port workers and pedestrians is at the forefront. Among the most dangerous places are cross-roads at the port operational area and quay side, where unexpected collisions of workers and/or pedestrians and transportation/manipulation vehicles are to be avoided. Therefore, the appropriate safety-warning systems are to be conceived, designed, adapted and implemented at the cross-roads.

In the previous research attempts in the field, different types of communication channels between workers/pedestrians and transportation/manipulation heavy mechanization structures are analyzed, like: RFID [1], ZigBee/RFID and MANET [2]. Keeping in mind that Port of Bar operates since decades in transitional environment, an intention to propose affordable, reliable and flexible smart safety solutions was present. Therefore our main intention through the previous research experiments was to introduce the research community, but also the managers and stakeholders in the port with contemporary safety systems, which might be used at the port and promote it as safety and green one.

This paper presents a pioneer attempt to involve vehicular communication propagation principles into a real on-port scenario over the layout of the Port of Bar container and general cargo terminal, which has the greatest turnover at the port, and consequently the highest potential risks. This approach is reasonable since the on-port safety is the main goal and vehicular communications focus on this aspect. Moreover, the workers/pedestrians and the transportation vehicles form an ad-hoc network in order to share their location in the same way as vehicles use beacon messages [3].

2. On radio channel modelling

The term channel is generally used to describe the models, theory, and experimental data, which include one's knowledge of a wireless channel in a specific type of environment. Typically, it is a function of bandwidth and center frequency. The channel can be described as the complete set of parameters for all paths that transmitted electromagnetic waves in the frequency band of interest take from transmitter to receiver over the spatial region of interest [4]. The vehicular communication propagation channel has strong impact on the coverage, reliability, and real-time capabilities of the networks. Wrong assumptions about fading, e.g., can lead to wrong conclusions on the dependability of pedestrians'/vehicles' warning systems at the cross-roads. On the contrary, sound and reliable knowledge of the propagation channel and its realistic corresponding model can be used as a core one for flexible and practical design and testing of vehicular communication systems [5].

In this research work, a combination of ray-launching algorithm (PIROPA - Parallel Implemented Ray Optical Propagation Algorithm) to model large scale parameters (path-loss, delay, angle of arrival/departure and number of rays per cluster) and stochastic model to obtain small scale parameters (Doppler shift, inter-cluster phases and fast-fading) [6] has been used.

2.1. Large scale parameters

The impulse response obtained by applying PIROPA is based on the double-direction radio channel [7] described by (Eq. 1):

$$h(t,\tau,\theta,\varphi) = \sum_{n=1}^{N} A_n \delta[(\tau-\tau_n)(\theta-\theta_n)(\varphi-\varphi_n)] \tag{1}$$

Where, A_n is the complex amplitude of the received ray, τ is the delay of each signal path, θ is the angle of arrival, φ is the angle of departure, and δ is Dirac delta function. By Eq.1 the received power can be calculated as (Eq. 2):

$$P(t,\tau,\theta,\varphi) = \int_0^{\infty} |h(t,\tau,\theta,\varphi)|^2 dt \tag{2}$$

Where, h is the channel impulse response calculated using the long-scale parameters. These parameters involved in the calculation of the received power are deterministic and they are calculated by ray-launching algorithm. This is acceptable due to the fact that θ, φ, and A_n of each cluster are not changing rapidly. On the other side, the phase of the inter-cluster rays fluctuates fast and needs to be determined stochastically, along with Doppler shift and fast-fading phenomenon.

2.2. Small scale parameters

Small-scale stochastic parameters are used for final adjustment of the channel model to its random nature. Parameters too fine grained for modeling in the previously shortly described deterministic approach, e.g., workers and/or pedestrians, and transportation and/or manipulation vehicles signs at the analyzed on-port scenario, are considered by adding stochastic components, as: Doppler shift, inter-cluster phases and fast-fading.

Doppler shift is influenced by relative motion of the communication network end nodes and its behavior can be summarized as follows: the bigger the relative speed between both end nodes of the channel and the higher the mobility of the environment elements, the higher the Doppler shift will be. It is worth to mention that speeds of moving end nodes and environment objects in concrete port scenario are relatively low, and consequently Doppler shift is small.

Inter-cluster phases is caused by the movements of the surrounding network elements (e.g., ship, container cranes and railway wagons at the port scenario), which produce a change in the indirect phase of the ray. It is calculated as a function of the inter-cluster phases obtained by PIROPA, scaled by coefficient $K \in (-1,1)$ and uniformly distributed values in the range $(0,2\pi)$ [6].

Fast-fading is the fluctuation suffered by the transmitted signal due to the multipath components. It is modeled as Racing fading and the scaling factor of the distribution biased by the environment [8]. In a Line of Sight (LoS) situation, fast-fading have smaller impact on the channel than in a Non-Line of Sight (NLoS) case, where the multipath propagation has a bigger impact. Both situations are present in the considered port area.

3. The port environment scenario

The Port of Bar suffers the lack of contemporary infra- and supra-structural capacities, including advanced info-communication solutions which could optimize working processes and reduce occupational and environmental risks. Relatively low turnover of the port protects workers of some occupational risks, but this fact should not be recommended as a model of the port's desirable operational and business state. Working conditions should be improved through effective and progressive adoption of new transportation and manipulative technologies, along with corresponding info-communication systems.

Therefore, through the previous research works in the field [1,2], several models for enhancing on-port workers safety have been proposed at logical and simulation levels. As a follow-up of these pioneer research endeavors, this paper considers theoretically, with rather high level of abstraction, the possibility of deploying vehicular communication propagation patterns over the port container and general cargo terminal. In focus are cross-roads between the quay and storage area, and between container blocks at the storage area itself.

End nodes of the communication network are on-port workers/pedestrians and front forklifts which are hypothetically equipped with sensing and vehicular communication platforms, which include warning system in the case when workers/pedestrians and front forklifts are in the vicinity of the cross-road. Front forklifts are chosen as manipulative and transportation devices which suffer of both NLoS and LoS visibility problems, black spots, death angels, etc., since the container is always in front of the driver. There is no records on accidents at the cross-roads at the Port of Bar, mostly because of its relatively low turnover, but in the future this situation can be changed and here proposed safety communication model might be useful.

4. Simulation experiments and results

The container and general cargo terminal at the Port of Bar has a quadrilateral form, which can be approximated by a rectangle with dimensions 650 x 350 [m] (Figure 1).

Workers/pedestrians can move with high level of freedom over the terminal, while their movements are restricted by the physical structures present on the surface, which are in this case industrial warehouses, moving vehicles, moving railway wagons, vertical and horizontal mechanization structures, and several container blocks.

Workers'/pedestrians' moving speed is approximately 2-3 [km/h]. Front forklifts are moving along the roads and free spaces at the terminal. They are moving by the speed of about 15-20 [km/h]. Our idea is to simulate the communicational channel between these moving end nodes in order to trigger warning system when workers/pedestrians and front forklifts are in the vicinity of their paths cross.

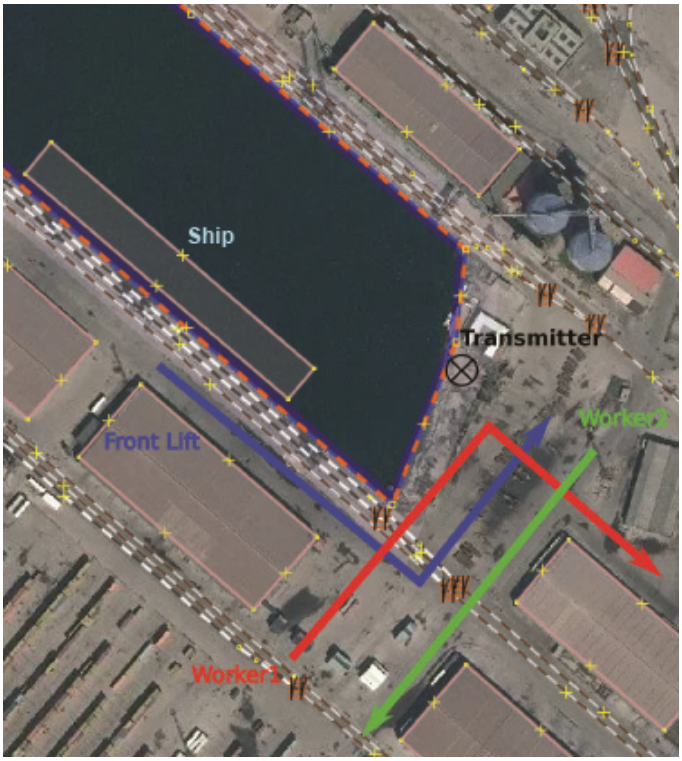

Fig. 1. Layout of the container and general cargo terminal at the Port of Bar

The berth is about 330 [m] long and it can allow sailing in of a container ship which depth gauge is maximally 11.5 [m] and which carries 800-1200 [TEU]. Ship's speed while sailing into the port is only a few knocks. There is a container crane and railway line along the coast which length is approximately 500 [m] and there are 24 railway wagons which operates during ship's (un)loading operations. The speed of these railway wagons is 5-10 [km/h]. These are the main elements of the dynamic port environment [9,10] in which vehicular communication channel is simulated by the combination of previously described deterministic and stochastic approaches over OpenStreetMaps background.

Simulation experiments are realized over several different scenarios which consider interplays between two workers (Worker 1 in red, and Worker 2 in green) and one front forklift (Front Lift in blue), while transmitter (in black) is placed at the strategic location at the terminal perimeter (Figure 1). The lower and upper bounds of the received power by end nodes are given in Table 1, and they are all in-between the thresholds. Delays are also negligible.

The shapes of power-delay curves vary depending on the mutual positions of the network end nodes within the dynamic port environment. In Figure 2, power-delay profile for Front Lift – Worker 2 interplay is shown. Blue-green dots represents direct signal, while yellow-green dots represent its multipath components. Direct signal is obviously more compact than multipath rays which show large scattering trend.

Table 1. Power-delay boundary values for different on-port dynamic scenarios

	Power [dBm]		**Delay** [10^{-6} s]	
Scenario	min	max	min	max
1. Front Forklift-Worker 2	-75	-33	0.2	2.8
2. Transmitter-Front Forklift	-105	-72	2.2	10
3. Transmitter-Worker 1	-108	-75	0.2	1.2
4. Transmitter-Worker 2	-103	-84	4.2	9.4
5. Worker 1-Worker2	-110	-30	0.01	0.12

(*Source*: Own)

Figure 3 shows the power-delay profile in the case of Transmitter-Front Lift interplay in the considered dynamic environment, which has "W" shape, following the moving pattern of the Front Lift. It has a sense if one takes into account relative movement of these end nodes. Multipath components are not so emphasized in this case, due to the higher altitude of the Front Lift which provides a predominance of LoS situations.

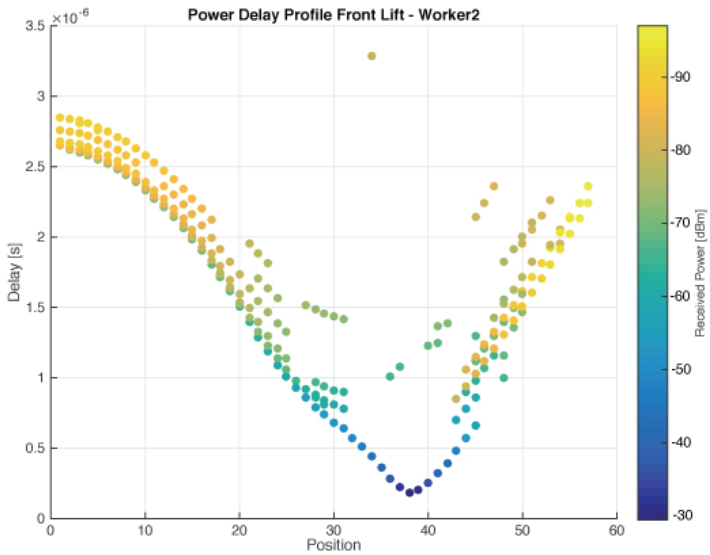

Fig. 2. Front forklift-Worker 2 power-delay profile

Figure 4 presents rather parabolic power-delay curve in the case of Worker 1 - Worker 2 communicational channel. Received power is closed to the threshold, but one must have in mind the distance between them, which should be considerably reduced, e.g., in the need of triggering alarm at the cross-road. There are also some multipath components which are arranged as extensions of direct signal.

Simulations are done in PIROPA environment, at the vehicular communication frequency 5.9 [GHz], which is envisaged for short distances 10-1000 [m] using 2.6 GHz Intel Core i5 with 16 Gb of RAM. The simulation time is almost negligible due to the reduced number of receiver points. Since the density of moving objects is not so high, as well as their speeds in comparison to general vehicular communication environments [11,12], stochastic components are not predominant like in the cases of high density of end nodes and surrounding objects movements. In addition, the Port of Bar has modest

infra- and supra-structure objects and it can not be treated as a real "urban canyon" scenario. However, it was worth to analyze its dynamics from the perspective of actual vehicle communication channel modeling principles. This can stimulate further research endeavors in this domain.

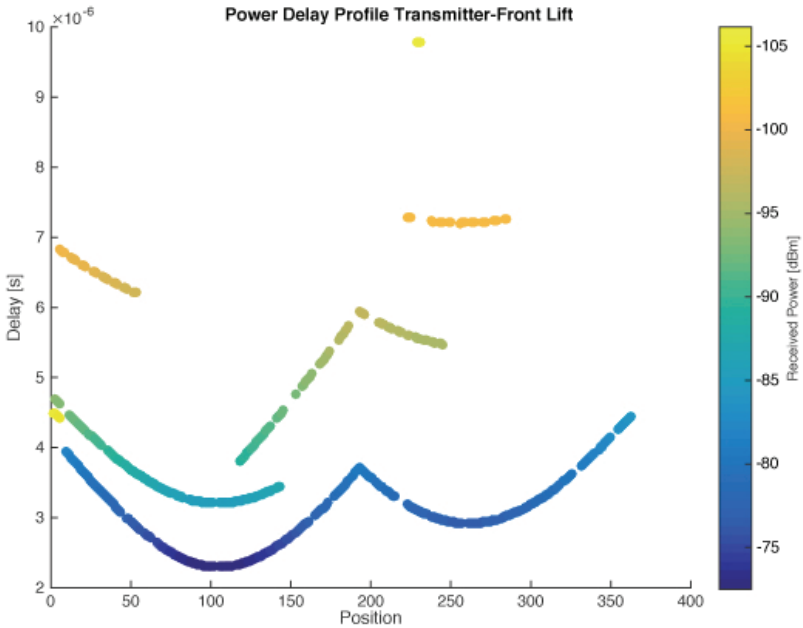

Fig. 3. Transmitter-Front forklift power-delay profile

Fig. 4. Worker 1-Worker 2 power-delay profile

5. Conclusions

Vehicular communications are increasingly gaining importance in research and industry as a viable communication technology, which makes cost-efficient, reliable and flexible deployment strategies [13]. In this paper, a port industrial environment-based strategy is used in simulation analysis of the communication channel power-delay profiles for different transmitter, workers and front forklift interplay scenarios. Our main motive was increasing on-port workers/pedestrians safety at the cross-roads at the port perimeter. It is shown that the strengths of the received signals is in all considered cases are within the boundaries of upper and down received power thresholds, while delays are negligible. There is no connectivity interruption when it comes to the direct signal. This works for each considered on-port scenario. The main drawback of the considered port environment-based model is low density and speed of end nodes (two workers and one front forklift), as well as, low density and speed of surrounding objects (container ship, quay crane, railway wagons, and two straddle-carriers, which also operate at the terminal). Further research should be oriented towards exploring vehicle communication channel performances in larger ports, which have higher level of commercial and industrial activities. Exploring such environments will require more detail analysis of both deterministic and stochastic features of the channel. In addition, end nodes sensor-communication platforms and corresponding warning system features are to be considered, since it is an important segment of proposing affordable, reliable and scalable safety solutions. Also, the in-situ experiments might be planed and realized in the future, with an aim to make comparison with here presented simulation results.

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Chapter 2:
On (re)positioning the seaports in the maritime market

2. Preface

This section provides three studies on the positioning of seaports in the port services market. It analyzes eight container ports in the Black, Aegean and Adriatic Sea basins, as well as eleven passenger (cruise) ports in the Mediterranean. Its aim was to define the methodological framework for mutual comparison of ports with emphasis on their marketing dimension. Also, a certain attempt has been made to give guidelines to managers and stakeholders how to reposition, in a positive direction, the developing ports: the Port of Bar and the Port of Kotor. The Port of Bar was treated as a container port, and the Port of Kotor as a passenger port and a growing cruise destination.

The container ports were mutually positioned in the port services market according to their quantitative and qualitative features. The quantitative features include all those determinations that are directly physically measurable, and qualitative features are all those determinations which the port simply possesses or not. The second group of properties has been encoded in a binary set of zero and one, which is used in the procedure for determining the ports' rank. Researches were based on intensive data collection through questionnaires and in-depth interviews with top managers in analyzed ports. For the ports ranking were used the PROMETHEE method as a multi-criteria optimization tool, regarding quantitative criteria, and analytic hierarchy process, regarding qualitative criteria. The guidelines for (re)positioning of the respective ports, primarily on customers' perception maps have been based on the established rank by using both sets of criteria.

The analyzed cruise ports in the Mediterranean were ranked on the basis of e-services provided to users. The ranking was preceded by a detailed analysis of port web sites, through which e-services were categorized into basic, added values, informational, transactional, and informational-transactional e-services. Each of these categories was weighted based on the scale obtained by interviewing experts in tourism, with many years of professional experience, and high level of logical reasoning. After the categorization and weighting of certain e-services, a binary approach was applied: if the port provides an e-service, its value is assigned as one, based on that service, and otherwise, it is assigned as zero. In sum, the best ranking was logically associated with the port that provided the highest e-service score. Similar to the previously analyzed group of container ports, some guidelines were given to managers and stakeholders regarding the positive repositioning of the passenger ports in the growing market of cruise services, including the development and promotion of related tourist destinations.

These studies could be upgraded by including more ports from different geographic regions and/or by expanding a set of analyzed properties. There is also a possibility of using different methodological approaches, and comparing the obtained results.

2.1. A quantitative-qualitative approach to the seaports' (re)positioning

The ports' management is facing the challenge of sustainable port development, considering several aspects: economic, technological, logistical, environmental, and community involvement. Although the numerous scientific concepts have been developed for explaining the trends of ports' involvement into the logistics chains, this research work presents an attempt to draw the attention to the marketing aspect of the port mission, being focused primarily on the customers' needs, whose preferences are the key factor in selecting specific port in competitive environment. Therefore, the Adriatic, Aegean, and Black Sea ports, sharing the unique marketing features and target market, have been analyzed with the aim to be mutually positioned. The considered ports have similar goals: to achieve the greater degree of competitiveness as well as to acquire the larger number of customers being attracted on the basis of superior port choice criteria. These circumstances have been explored through some distinctive quantitative and qualitative criteria by employing the appropriate, well known and structured PROMETHEE and AHP methods. The obtained results are presented by perception maps, and described on the basis of gained quantitative indicators and the qualitative explanations given by the authors, primarily, in the marketing manner.

1. Introduction

Expanding the spatial and functional scope of their activities, modern ports represent significant logistical and industrial centers, but they are dominantly related to maritime transport (Noteboom and Yap 2012). Also, ports are the elements of value - driven chain systems (Robinson 2002), i.e. seaports are the link without which, the two modules of transport - maritime and land could not be effectively connected. In a competitive environment, marketing as a concept and port business practice offers a wide range of solutions for achieving and maintaining competitive advantage, which could be expressed as financial (profit) and/or nonfinancial (port image, etc) parameters. The variety of methods have been applied, many ideas and activities carried out in order to achieve the ultimate goal - to be more competitive in the port services market and to be chosen by users (shippers, forwarders, shipping companies, terminal operators, port authorities, government agencies, and other clients).

For the purpose of developing an efficient marketing (re)positioning strategy for ports, we emphasize here the two basic themes attracting the attention of the scientific and professional community: a) seaport competition and competitiveness, and b) the port choice criteria. Many methods have been used in order to define the factors of seaport competitive performance, but benchmarking is standing out as a method of the marketing positioning of the ports based solely on the comparison and the research aiming to determine, which port is the leader in the market. Rugman and Verbeke (1993) applied the Porter's Diamond in the case of seaports, concluding that a seaport position in the market is based on six key "diamond" factors. Pando *et al.* (2005) showed that the benchmarking practice was appropriate and applicable in the case of seaports. Pardali and Michalopoulos (2008) applied the benchmarking method in the case of Mediterranean container ports. Evaluating the competitiveness of container ports in Korea and China, Yeo, Roe, Dinwoodie (2008) made the comprehensive literature review of the port competitiveness components, concluding that port competitiveness is determined by the port service, hinterland condition, availability, convenience, logistics cost, regional centre and connectivity. Efficiency, shipping frequency, adequate infrastructure, location, port charges, quick response to port users' needs, reputation regarding cargo damage, intermodal and value – added services, information system availability are some of the port selection criteria (Tongzon 1995, 2005, 2009; Murphy, Daley, Dalenberg 1992; Malchow and Kanafani 2004; Magala and Simmons 2008; Vickery, Jayaram, Dröge and Calantone 2003).

There are many quantitative methods that are used to measure the degree of port competitiveness. One of them is linear programming, where a considerable number of authors agree about the most important factors such as: domestic (captive) traffic, good hinterland connections, adequate feeder networks, good infrastructure and competitive port pricing, which determine the port position as the hub one (Aversa, Botter, Haralambides and Yoshizaki 2005). The use of MCDM (Multi Criteria Decision Making) has also been promoted in the analysis of container port competitiveness. Song and Yeo (2004) carried out the competitive analysis of Chinese container ports using AHP (Analytic Hierarchy Process), while Guy and Urli (2006) used multi-criteria analysis to examine port selection in case of Montreal - New York ports. The AHP method has found an application in transshipment port selection from a global perspective (Lirn *et al.* 2004). The quantitative simulation modeling of some intelligent port transport systems' functional characteristics have been done by Jolić *et al.* (2003, 2004). Also, some quantitative analyses of the relevant indicators of the traffic flows (including some ports' flows), as well as their structure and dynamics have been presented in the work of Poletan-Jugović *et al.* (2009). Data envelopment analysis (DEA) is the method usually applied (Tongzon 2001; Barros 2003; Barros and Athanasiou 2004; Cullinane *et al.* 2006), though some authors (Panayides *et al*. 2009) critically reviewed its application in seaport economic efficiency measurement. Container port competition has also been considered in the context of applying hierarchical fuzzy processes (Huang *et al.* 2003; Yeo and Song 2006). All variables that are taken into consideration in these works are mostly related to infrastructure and superstructure, financial and development parameters, productivity and efficiency. They are also measurable and comparable, and discussions based on these variables are essentially objective.

In the case of ports investigated in this article which are characterized by the unique attribute of pretending to share the same target market, in the most general sense, their marketing positioning is the activity of designing a port offer and its image in terms of taking a distinctively (recognizable) place in the mind of the target market (customers), aiming to increase potential benefits for the ports (Kotler and Keller 2006). Previous researches have rarely, and mostly in the widest economic context and less in the marketing one, discussed the question of the seaport positioning strategy development. Not earlier than in the 90's of the previous century, the strategic positioning of seaports started to be discussed from the point of seaport economy, i.e. port position in terms of growth, market participation and diversification, at the same time including the aspects of added value (Haezendonck and Noteboom 2002). Although the subject of seaport positioning hasn't been sufficiently researched in terms of customers' preferences, some elements featuring the marketing differentiation strategy had already been determined by the 80's of the previous century (Slack 1985). These researches aimed to find factors that would make the seaport services different and recognizable, e.g. based on efficiency, quality, reliability, etc. There are, of course, many contemporary research works that descriptively present current trends in container ports and shipping business. Notteboom and Rodrigue (2005) introduce the term of the port regionalization. Slack (2007) describes the terminalization of seaports. Particularly relevant topics are shipping networks and port development (Comtois and Slack 2007; Heaver, Meersman, Moglia and Van de Voorde 2000). A very attractive area of research is the domain of maritime supply chains and the role of ports in them (Notteboom and Winkelmans 2001; Carbone and De Martino 2003; Bichou and

Gray 2004; Carbone and Gouvernal 2007; Wang and Cullinane 2006; Panayides and Dong-Wook Song 2009).

All the mentioned methodologies confirm the extent and complexity of topics related to the container ports positioning strategy. What is the most important in this paper and what makes it original in a way, is that the particular attention has been paid to the marketing dimension of the issue. This means that all factors that are considered here, both quantitative and qualitative, are to be chosen by their importance regarding users' satisfaction, which is essential for ports marketing positioning.

2. Methodology

The applied methodology can be divided into two categories: a) firstly, the quantitative method that includes PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) multi-criteria decision making method and b) secondly, the multi-criteria procedure of the analytic hierarchy process (AHP). In order to account different criteria, we developed four survey campaigns aimed at the following groups: the port community members, port development and marketing managers, port customers and academic researchers. Additionally, in order to position the considered eight seaports: P1-Bar; P2-Durres; P3-Constantza; P4-Koper; P5-Piraeus; P6-Ploce; P7-Rijeka; P8-Thessaloniki, the two sets of criteria have been identified and analyzed: quantitative (A), and qualitative (B). These criteria are divided into the appropriate sub-criteria sets as it is given in Tables 1 and 6. Regarding the first set of the quantitative criteria exact numerical values (A), the PROMETHEE multi-criteria decision making method was employed and the appropriate ranks were obtained for each sub-criteria set. In the second set of the qualitative criteria (B), each criterion was qualified by the linguistic value (YES/NO), and subsequently translated into the appropriate binary value (0/1): one-YES, and zero-NO. Then, these (0/1) values were summed separately per each sub-criteria set previously identified within complete B set of criteria. These sums were finally pondered by the average weight coefficients being estimated on the basis of AHP method, and the total score was found as the average value of all previously calculated and pondered sums per each sub-criterion set in B.

3. Quantitative criteria analysis and obtained results

The PROMETHEE is one of the most efficient multi-criteria methods, based on the numerous research works, among which are those of Brans *et al.* (1984, 1985, 1986, 1989), Petrović *et al.* (1988), etc. Namely, the preference function and the weights given to each variable have to be chosen before it might be applied to any problem. This method has been applied in many research articles in the field of seaport management, because it is reliable, the outcomes are easy for interpreting economically, and in marketing manner (Castillo-Manzano *et al.* 2009). In this article, PROMETHEE is applied to the problem of ranking (positioning) a finite number of alternative ports. Since the relative importance of the considered criteria is usually not the same, it is necessary to estimate their importance by giving them weight coefficients. In order to reduce the subjectivity factor in estimating these coefficients and setting preference function types, we have conducted a survey among the focus group experts.

Table 1. Quantitative criteria

A. Quantitative criteria (fixed)	A1. Container terminal infrastructure features	C_A1.1	Number of container terminals (no.)
		C_A1.2	Number of berths (no.)
		C_A1.3	Total length of berths (m)
		C_A1.4	Maximum water depth (m)
		C_A1.5	Terminal storage capacity (TEU)
		C_A1.6	Number of reefer plugs (no.)
	A2. Cargo handling: vertical and horizontal mechanization	C_A2.1	Gantry crane (no.)
		C_A2.2	Transfer crane (no.)
		C_A2.3	Straddle carrier (no.)
		C_A2.4	Forklift (no.)
		C_A2.5	Reach stacker (no.)
		C_A2.6	Container trailer (no.)
	A3. Cargo handling and human capacities	C_A3.1	Total cargo handling turnover (tons)
		C_A3.2	Annual operations (days)
		C_A3.3	Daily operations (hours)
		C_A3.4	Number of employees (no.)

The quantitative set of criteria (A) is composed of the following sub-criteria sets: A1-container terminal infrastructure features, A2-cargo handling vertical and horizontal mechanization, and A3-cargo handling turnover and human capacities, along with the corresponding units given in Table 1. Each of the used criteria represents one of the aspects of the investigated seaports' competitiveness. When deciding about these criteria and sub-criteria choices, we used the studies criteria by Rugman and Verbeke (1993), Pardali and Michalopoulos (2008), Tongzon and Heng (2005), Yeo, Roe, and Dinwoodie (2008). After setting the general scheme of the quantitative criteria given in Table 1, the exact numerical data values were acquired by the authors' survey of the respective ports in cooperation with the ports managers. These numerical data are given in Table 2.

Table 2. Quantitative criteria (A): sub-criteria sets A1, A2, and A3

Criteria / Port	P1	P2	P3	P4	P5	P6	P7	P8
C_A1.1	1	1	3	1	2	1	1	1
C_A1.2	2	11	9	25	9	1	2	2
C_A1.3	330	2200	1968	3200	2774	280	450	550
C_A1.4	14	11.5	16.5	18	18	13.8	12	12
C_A1.5	1760	2000	35472	24400	30500	1400	6500	7390
C_A1.6	174	105	987	340	288	32	150	276
C_A2.1	1	1	8	8	7	1	3	4
C_A2.2	0	2	15	14	1	0	0	0
C_A2.3	0	0	0	0	10	0	1	17
C_A2.4	2	2	7	0	3	1	0	6
C_A2.5	0	4	4	45	1	3	9	5
C_A2.6	2	5	60	30	2	5	14	1
C_A3.1	2407.4	968.3	36975.6	15372.0	11706.2	4532.8	4611.7	2281.4
C_A3.2	361	365	364	365	362	365	365	365
C_A3.3	24	24	24	24	24	24	24	24
C_A3.4	65	92	546	130	1250	15	83	150

Upon the numerical data (Table 2), PROMETHEE multi - criteria decision making method has been employed and the obtained results for positive (Phi+) and negative (Phi-) flows, along with the net preference flow (Phi), are given in Tables 3-5. This has been done for each sub-criteria sets (A1, A2, and A3) composing quantitative criteria (A). The weight coefficients, as well as preference function type (linear), and the corresponding coefficients (here, q and p) were estimated through the consultations of the focus group experts (the port managers and experienced academic researchers).

Table 3. PROMETHE II complete rank of the ports for A1 sub-criteria set

Criteria	C_A1.1	C_A1.2	C_A1.3	C_A1.4	C_A1.5	C_A1.6	Phi^+	Phi^-	Phi	Rank
max/min	max	max	max	max	max	max				
Port/weight	0.15	0.10	0.15	0.15	0.35	0.10				
P1	1	2	330	14	1760	174	0.037	0.402	-0.365	7
P2	1	11	2200	11.5	2000	105	0.740	0.382	-0.300	6
P3	3	9	1968	16.5	35472	987	0.628	0.027	0.601	1
P4	1	25	3200	18	24400	340	0.689	0.117	0.472	2
P5	2	9	2774	18	30500	288	0.531	0.059	0.471	3
P6	1	1	280	13	1400	32	0.016	0.454	-0.439	8
P7	1	2	450	12	6500	150	0.102	0.368	-0.266	5
P8	1	2	550	12	7390	276	0.162	0.330	-0.168	4
Preference	linear	linear	linear	linear	linear	linear				
q	1	1	300	1	1500	30				
p	3	24	3000	5	7000	150				

Thus, the obtained results are as follows: a) The complete rank of the considered ports, obtained by the PROMETHEE II method (PROMCALC software), for the first sub-criteria set (A.1) is: 1. Constantza; 2. Koper; 3. Piraeus; 4. Thessaloniki; 5. Rijeka; 6. Durres; 7. Bar; and, 8. Ploce (Table 3); b) The complete rank of the considered ports, obtained by PROMETHEE II method (PROMCALC software) for the second sub-criteria set (A.2) is: 1. Constantza; 2. Koper; 3. Piraeus; 4. Thessaloniki; 5. Rijeka; 6. Durres; 7. Ploce; and, 8. Bar (Table 4), and, c) The complete rank of the considered ports, obtained by PROMETHEE II method (PROMCALC software), for the first sub-criteria set (A.3) is: 1. Constantza; 2. Koper; 3. Piraeus; 4. Rijeka; 5. Ploce; 6. Bar; 7. Thessaloniki; and, 8. Durres (Table 5). The numerical results of sea ports positioning by the PROMETHEE MCDA method for three different sub-criteria sets (A1, A2, and A3) regarding the quantitative criteria overall set A are graphically shown below in Figures 1-3, as well.

Table 4. PROMETHE II complete rank of the ports for A2 sub-criteria set

Criteria	C_A2.1	C_A2.2	C_A2.3	C_A2.4	C_A2.5	C_A2.6	Phi^+	Phi^-	Phi	Rank
max/min	max	max	max	max	max	max				
Port/weight	0.40	0.20	0.10	0.10	0.10	0.10				
P1	1	0	0	2	0	2	0.007	0.438	-0.431	8
P2	1	2	0	2	4	5	0.045	0.385	-0.340	6
P3	8	15	0	7	4	60	0.643	0.052	0.591	1
P4	8	14	0	0	45	30	0.629	0.081	0.548	2
P5	7	1	10	3	1	2	0.315	0.182	0.139	3
P6	1	0	0	1	3	5	0.018	0.399	-0.381	7
P7	3	0	1	0	9	14	0.176	0.326	-0.150	5
P8	4	0	17	6	5	1	0.278	0.247	0.031	4
Preference	linear	linear	linear	linear	linear	linear				
q	1	1	1	1	1	1				
p	5	10	15	5	5	15				

Table 5. PROMETHE II complete rank of the ports for A3 sub-criteria set

Criteria	C_A3.1	C_A3.2	C_A3.3	C_A3.4	Phi^+	Phi^-	Phi	Rank
max/min	max	max	max	min				
Port/weight	0.50	0.20	0.20	0.10				
P1	2407.4	361	24	65	0.024	0.220	-0.196	6
P2	968.3	365	24	92	0.020	0.257	-0.238	8
P3	36975.6	364	24	546	0.510	0.034	-0.476	1
P4	15372.0	365	24	130	0.393	0.072	0.322	2
P5	11706.2	362	24	1250	0.277	0.186	0.091	3
P6	4532.8	365	24	15	0.059	0.186	-0.127	5
P7	4611.7	365	24	83	0.59	0.185	-0.126	4
P8	2281.4	365	24	150	0.022	0.223	-0.201	7
Preference	linear	linear	linear	linear				
q	900	360	16	100				
p	11000	365	24	1000				

According to the group of A1 sub-criteria (container terminal infrastructure features), Constantza is the leading port, which is realistic, due to the fact that this port has the largest number of container terminals, terminal storage capacity, and number of reefer plugs. Also, the remaining three of the A1 sub-criteria are very competitive to other ports' sub-criteria. Koper port occupies the second position, which can also be confirmed, since this port has the largest number of berths and consequently the greatest length of berths, which can be an extremely important parameter for shipping companies choosing this port, if it is compared to the rest of the competing ports.

Also, this port has the highest value of the maximum water depth that could be a crucial port choice criterion for modern mega-carriers. Piraeus port is in the third position that is particularly determined by a significant number of reefer plugs and very competitive surface of storage capacity. This port also has a significant potential in terms of the number of container terminals. Thessaloniki port occupies a position which is very close to an *imaginary* average port (see Fig. 1). The remaining ports, in terms of A1 sub-criteria set, show a smaller degree of competitiveness compared to the four above mentioned well positioned ports.

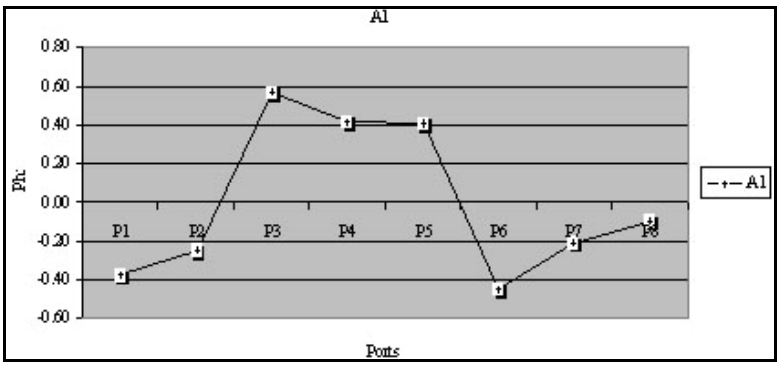

Fig. 1. The ports positions corresponding to the PROMETHEE net flows determined according to the A1 set sub-criteria values

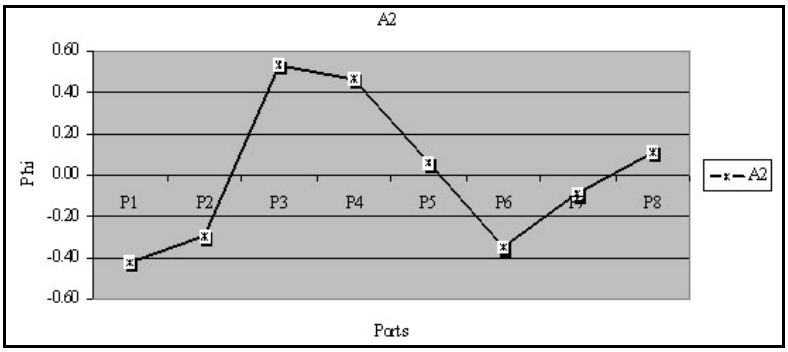

Fig. 2. The ports positions corresponding to the PROMETHEE net flows determined according to the A2 set sub-criteria values

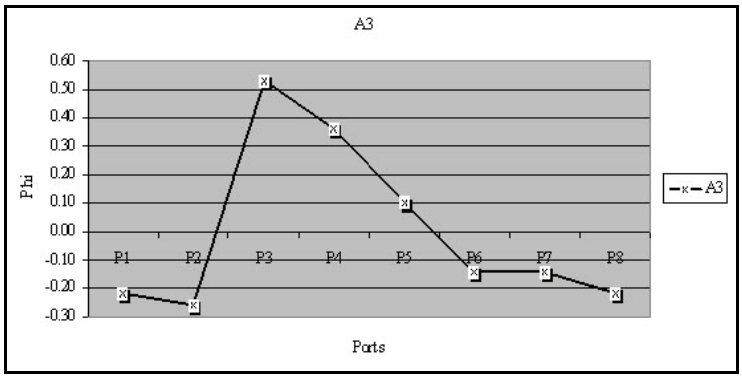

Fig. 3. The ports' positions corresponding to the PROMETHEE net flows determined according to the A3 set sub-criteria values

According to the group of A2 sub-criteria set (cargo handling: vertical and horizontal mechanization), Constantza port occupies the leadership position as in the previous case. This time, Koper port is very close to Constantza, while they share the same number of gantry cranes. Also, these two ports have small differences related to horizontal mechanization, however, slight advantage belongs to Constantza port. The remaining ports are of nearly similar ranking as they are ranked in the case of A1 sub-criteria set. Special emphasis is given to the Thessaloniki port, which now occupies the fourth place, and its position is very close to the third positioned Pireaus port. Bar port is in this case in the last position, which can be a very significant signal to this port's technical and development department to improve and modernize this segment of its operation.

According to the group A3 sub-criteria (cargo handling and human capacities), Constantza is highly advanced in comparison with all remaining ports, which confirms the highest total cargo throughput. This port has almost twice higher cargo handling turnover than the second ranked Koper port, and almost three times higher than the third positioned Piraeus port. According to this criterion, Durres port indicates smaller degree of competitiveness, which means that the marketing and development department of this port must intensify efforts in increasing the volume of traffic in this port, particularly container traffic. Concerning human capacity, Piraeus port has the largest number of employees, while each of the analyzed ports operate 24 hours a day, though this criterion in fact

has no impact of the ports' positions. Concerning different values of the weight coefficients, different types of preference functions and their characteristic coefficients – ports' positions should be slightly, or even considerably different. Thus, in the next subsections, additional method based on both qualitative and quantitative estimations have been used in determining the ports' mutual positions as an additional aid for the ports' (eventual) (re)positioning.

4. Qualitative criteria analysis and obtained results

The container ports are likely to be more competitive if they are superior in terms of: proximity to key centers of production and consumption, and major trade lanes; maritime excellence and hinterland access; levels of productivity; efficiency of the capacity management; the ability to adapt to the new logistics business environment; potential to attract private capital at the level of terminal operations; possibility to become the key drivers of the local economies, and being supported by the stakeholders in the port area and the wider community (Noteboom and Yap 2012). Accordingly, the second qualitative set of criteria (B) is composed of the following sub-criteria sets: B1-infra and superstructure features, B2-connections with hinterland, B3-marketing features, B4-port management models, B5-vessels' and cargos' services, and B6-ICT applications. These criteria are listed in Table 6, along with the corresponding sub-criteria sets. Since the values of the qualitative criteria are expressed in terms of zero-one numerical values, these values are summarized per each sub-criteria sets in B, and then pondered by the average weight coefficients previously estimated by the AHP method, explained in more detail in the following sub-sections of the paper.

4.1. Ranking qualitative sub-criteria sets

The idea of qualitative sub-criteria sets' ranking is associated with AHP (Saaty 1977, 1980, 1990, 1994, 2003) approach applied to sub-criteria sets of B qualitative complete criteria set, with respect to the estimates of the respondents. Namely, ranking is a procedure, where the most significant sub-criteria set is given the highest rank, the last significant sub-criteria set is given the lowest rank, while the other sub-criteria sets are somewhere in between these two upper and down rank boundary values. Here, the respondents, i.e. three competitive persons (managers and/or administrative staff members), per each of the considered ports, are asked to compare each pair of the criteria sets (B1-B6) according to the Saaty scale by using grades: 1-same importance; 3-weakly more importance, 5-moderately more importance, 7-strongly more importance, and 9-absolutely more importance of the first than the second considered criterion; or, by the corresponding reciprocity values depending on the mutual importance of the compared elements composing the certain pair(s). Although 24 competent persons were asked to create the Saaty matrixes, only ten Saaty matrixes have been taken into further consideration. Namely, the application of AHP requires highly developed logical thinking, though the estimate of only one highly qualified expert may be more important than the estimates made by a number of inexperienced persons (Sivilevičius and Maskeliunaite 2010). By the normalized eigenvector values calculus (Shikin and Chhartishvili 2000), the ranks of the considered criteria B1-B6 have been calculated (Table 7), along with the values of the largest eigenvalue λ_{max}, and the consistency index CI, while the random index RI is equal to 1.24 in all cases, since the number of criteria is constant and equal to six. It is

obvious that all λ_{max} values, for each considered matrix, are less than 0.01, which is to be fulfilled in order to provide a satisfying degree of the Saaty matrix consistency (Table 8).

Table 6. Qualitative criteria

B. Qualitative criteria (fixed)	B1. Infra and superstructure features	C_B1.1	Container terminal (Y/N)
		C_B1.2	General cargo terminal (Y/N)
		C_B1.3	Bulk cargo terminal (Y/N)
		C_B1.4	Liquid cargo terminal (Y/N)
		C_B1.5	Ro-Ro terminal (Y/N)
		C_B1.6	Passenger terminal (Y/N)
	B2. Connections with hinterland	C_B2.1	Railway connections (Y/N)
		C_B2.2	Road connections (Y/N)
		C_B2.3	Pipelines connections (Y/N)
		C_B2.4	Barge service (Y/N)
		C_B2.5	Shuttle service (Y/N)
		C_B2.6	Bottleneck (Y/N)
	B3. Marketing features	C_B3.1	Free zone (Y/N)
		C_B3.2	Value-added logistics services (Y/N)
		C_B3.3	Distribution centers (Y/N)
		C_B3.4	Quality Management System (Y/N)
		C_B3.5	Integrated marketing communications (Y/N)
	B4. Port management models	C_B4.1	Service port model (Y/N)
		C_B4.2	Tool port model (Y/N)
		C_B4.3	Landlord port model (Y/N)
		C_B4.4	Private port model (Y/N)
	B5. Vessels' and cargos' services	C_B5.1	Vessel monitoring (Y/N)
		C_B5.2	Vessel repair (Y/N)
		C_B5.3	Vessel servicing (Y/N)
		C_B5.4	Container control (Y/N)
		C_B5.5	Non-containerized cargo control (Y/N)
		C_B5.6	Automatic scheduling and stacking of containers (Y/N)
		C_B5.7	Automatic monitoring of cargo in stock (Y/N)
		C_B5.8	Container leasing (Y/N)
	B6. ICT applications	C_B6.1	The classic IT system (Y/N)
		C_B6.2	ERP (Enterprise Resource Planning) (Y/N)
		C_B6.3	EDI service (Y/N)
		C_B6.4	MIS (Management Information System) (Y/N)
		C_B6.5	VTS service (Y/N)

Though, the results of the sub-criteria sets weights ($w_i, i = \overline{1,6}$) in B, and corresponding ranks, per each of the ten considered Saaty's matrixes obtained by the algorithm presen-ted in details in the article of Sivilevičius and Maskeliunaite (2010) are given in Table 7.

Table 7. The ranks of the sub-criteria sets in B assigned by ten competitive respondents

		Criteria											
		B1		B2		B3		B4		B5		B6	
		w_1	Rank	w_2	Rank	w_3	Rank	w_4	Rank	w_5	Rank	w_6	Rank
Respondents	R_1	0.3660	1	0.2650	2	0.0282	6	0.0704	5	0.1688	3	0.1016	4
	R_2	0.4493	1	0.2125	2	0.0615	5	0.0966	4	0.0283	6	0.1517	3
	R_3	0.3903	1	0.2559	2	0.0398	6	0.1496	3	0.1037	4	0.0607	5
	R_4	0.4076	1	0.2711	2	0.0280	6	0.1499	3	0.0875	4	0.0558	5
	R_5	0.2522	2	0.1677	3	0.0322	6	0.3910	1	0.0927	4	0.0643	5
	R_6	0.2565	2	0.1682	3	0.0346	6	0.3498	1	0.1166	4	0.0743	5
	R_7	0.3853	1	0.2790	2	0.0288	6	0.1542	3	0.0902	4	0.0625	5
	R_8	0.3831	1	0.2656	2	0.0339	6	0.1469	3	0.1109	4	0.0596	5
	R_9	0.4228	1	0.2371	2	0.0316	6	0.1428	3	0.1078	4	0.0579	5
	R_{10}	0.3584	1	0.2946	2	0.0280	6	0.1562	3	0.0995	4	0.0633	5

The values of the largest eigenvalue λ_{max}, and the consistency index CI are given in Table 8 per each respondent, as it is previously noted above. Used *Mathematica* codes are given in Table 9.

Table 8. The largest eigenvalue and consistency index per each AHP matrix given by the respondents

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
λ_{max}	6.5620	6.5274	6.4419	6.4441	6.5202	6.5758	6.5439	6.4711	6.5972	6.5278
CR	0.0906	0.0851	0.0713	0.0888	0.0839	0.0929	0.0877	0.0760	0.0963	0.0851

Table 9. Code 1: Calculating weight coefficients and testing Saaty's matrix consistency

```
Code 1: Off[General::spell1]
(*n=Input["Number of criteria is (n):"];*)
(*A=Table[0,{n},{n}]; For [i=1,i≤n,i++, For [j=1,j≤n,j++, A[[i,j]]=Input["Input Saaty matrix A ["<>ToString[i]<>
","<>ToString[i]<> "]:"]; If [A=[[i,j]]= =$ Canceled ∨ A[[i,j]]= =Null, Abort[]]]];*)
n=6; A={{1,5,9,3,5,5},{1/5,1,7,3,3,3},{1/9,1/7,1,1/5,1/5,1/3},
{1/3,1/3,5,1,3,3},{1/5,1/3,5,1/3,1,3},{1/5,1/3,3,1/3,1/3,1}};
wn=Table[0,{n}]; wp=Table[0,{n}]; For[i=1;ws=0,
i≤n,i++,wn[[i]]= ∏_{j=1}^{n} A[[i,j]];wp[[i]]=wn[[i]]^(1/n);ws=ws+wp[[i]]]; w=Table[0,{n},{1}];
For[i=1;i≤n,i++,wn[[i,1]]=wp[[i]]/ws]
V=A·w; l=V/w; λ= (1/n) ∑_{i=1}^{n} l[[i,1]]; CI=( λ-n)/(n-1); RI={0,0,0.58,0.9,1.12,1.24,1.32,1.41,1.45}; CR=CI/RI[[n]];
Print ["Eigen value: λ= ",N[λ]]; Print ["Index of Saaty's scale consistency is: CI= ", N[CI]]; Print ["Random index of
consistency is: RI= ", N[RI]]; Print ["Ratio of consistency indexes is: CR= ", N[CR]]; If CR≤0.1, Print ["Saaty's matrix
is consistant"], Print ["Saaty's matrix is not consistant"]
```

The values obtained by this code are: $\lambda = 6.527$, CI=0.105, RI=1.24, CR=0.085. Since, $CR \leq 0.1$ it means that the considered Saaty's matrix is a consistent one. On the basis of the ranks of B1-B6 sub-criteria sets in B, the average weights per each sub-criteria set have been calculated and used for pondering the sums of 0/1 values corresponding to each criteria in B1-B6 sub-criteria sets. The values 0/1 for all analyzed criteria B had been previously collected at the considered ports. The total score per each analyzed port was calculated by the formulae:

$$B_{SCR_i} = \sum_{j=1}^{6} v(i,j)\cdot \overline{w}_{1n} + \sum_{k=1}^{6} v(i,k)\cdot \overline{w}_{2n} + \sum_{l=1}^{5} v(i,l)\cdot \overline{w}_{3n} + \sum_{m=1}^{4} v(i,m)\cdot \overline{w}_{4n} + \sum_{n=1}^{8} v(i,n)\cdot \overline{w}_{5n} + \sum_{p=1}^{5} v(i,p)\cdot \overline{w}_{6n}, \; i=\overline{1,8}$$

Where,

- B_{SCR_i} - is total score for the i-th considered port, while $i=\overline{1,8}$ and corresponds to the analyzed ports;
- $v(i,j)$, $v(i,k)$, $v(i,l)$, $v(i,m)$, $v(i,n)$, $v(i,p)$ - are the variables' binary values 0, or 1 for i-th port, while $j=\overline{1,6}$, $k=\overline{1,6}$, $l=\overline{1,5}$, $m=\overline{1,4}$, $n=\overline{1,8}$, $p=\overline{1,5}$ are indexes of the criteria within each sub-criteria sets in B set; and,
- $\overline{w}_{1n,2n,3n,4n,5n,6n}$ - are the normalized average values of the weight coefficients for each B1-B6 subsets of criteria in B. The positions of the analyzed ports obtained by the calculations (1) are shown in Figure 4.

However, the method by which the normalized average weight coefficients per each sub-criterion set in B has been determined, needs to be explained, as well. The idea of evaluating these weight coefficients is associated with the sum of ranks of each criterion c_q, with respect to the estimates of respondents:

$$c_q = \sum_{r=1}^{10} c_{qr}, \; q=\overline{1,6} \tag{2}$$

Where,

- c_q - is the sum of ranks of each criterion set (B1-B6), while q is the number of sub-criterion sets in B (here 6), and r is number of experts, or respondents (here 10); and,
- c_{qr} - is rank of the q-th criterion estimated by the r-th respondent. Now, the average weight coefficient for each sub-criterion set in B can be calculated by the following formulae:

$$\overline{w}_q = \left[c_q / \sum_{q=1}^{6} c_q \right]^{-1}. \tag{3}$$

Finally, the normalized average weight coefficients are to be calculated and used in (1) for pondering the sums of zero, or one values for each criterion, and per each of the considered ports ($n=\overline{1,8}$):

$$\overline{w}_{qn} = \overline{w}_q / \sum_{q=1}^{6} \overline{w}_{qn} \tag{4}$$

The ranking of B set subsets of criteria (B1-B6) according to their significance, carried out by ten respondents is demonstrated in Table 10.

Also, the normalized average weight coefficients per each B criteria subsets (B1-B6) are given in the last column ($\overline{w}_{qn}$, $q=\overline{1,6}$). These weight coefficients have been calculated by the formulae (4), and on the basis of the previously realized calculus (2) and (3).

Table 10. Ranking of the B criteria sub-sets (B1-B6) in the respondent questionnaires

	Respondent No.										Sum of ranks	$\overline{w}_{qn}$, $q=\overline{1,6}$
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
B1	1	1	1	1	2	2	1	1	1	1	12	0.3689
B2	2	2	2	2	3	3	2	2	2	2	22	0.2012
B3	6	5	6	6	6	6	6	6	6	6	59	0.0750
B4	5	4	3	3	1	1	3	3	3	3	29	0.1527

B5	3	6	4	4	4	4	4	4	4	4	41	0.1079
B6	4	3	5	5	5	5	5	5	5	5	47	0.0942
Total	21	21	21	21	21	21	21	21	21	21	210	1.0000

Since the consistency of the respondents ranking is important in making conclusions regarding the ports final mutual positions, in following subsection of the article the concordance coefficient value has been calculated as the measure of reconciliation of the respondents' attitudes towards the considered issue.

4.2. The respondents' estimates consistency

In order to examine the level of consistency of the respondents' estimates (see Table 7), the concordance coefficient W is to be calculated as:

$$W = 12S / r^2 q\left(q^2 - 1\right) \tag{5}$$

Where,

- $S = \sum_{q=1}^{6}\left(c_q - \sum_{q=1}^{6} c_q\right)^2$ - is analogue to the variance of the ranks;
- r – is the number of the respondents; and,
- q – is the number of the sub-criteria sets in B (B1-B6).

Now, the smallest value of W, i.e. W_{min} is to be calculated by the formulae:

$$W_{min} = \chi^2_{\alpha,v} / r(q-1) \tag{6}$$

Where, $\chi^2_{\alpha,v}$ - is critical chi-square statistics, found in the table (Montgomery 2008) by assuming the degree of freedom $v = 6-1$, and the significant level $\alpha = 0.010$. Here, it is $\chi^2_{\alpha,v} = 15.09$. By taking into account the previous assumptions $W_{min} = 0.3018$, while $W = 0.8514$. Since the condition $W_{min} \le W$ has been satisfied, it implies that the estimates of the respondents are consistent. The pseudo-code in *Mathematica* program used in the realization of the previously explained calculus is given below, in Table 11.

Table 11. Code 2: Estimating the level of consistency of respondents' estimates

Code 2: Off[General::spell1]
n=Input["Number of criteria is(n):"]; m=Input["Number of respondents is (m):"]; Cm=Table[0,{n},{m}];
For [i=1,i≤n,i++, For [j=1,j≤n,j++, Cm[[i,j]]=Input["Input rank for the criterion "<>ToString[i]<> "and respondent"<>ToString[i]<>"]:"]; If [Cm=[[i,j]]= =$Canceled ∨ Cm[[i,j]]= =Null,Abort[]]]];*)
c=Table[0,{n}]; For[i=1;cs=0, i≤n,i++,c[[i]]= $\sum_{j=1}^{m} Cm[[i,j]]$;cs=cs+c[[i]]]/n; $S = \sum_{i=1}^{n}\left(c[[i]] - cs\right)^2$; $W = \frac{12S}{m^2 n\left(n^2-1\right)}$;
$\chi^2 = Wm(n-1)$; $\chi^2_{\alpha,v}$ =Input["Input the critical chi-square, from the statistical table: "]; $W_{\min} = \frac{\chi^2_{\alpha,v}}{m(n-1)}$;
Print["Variance of the ranks is: S= ",S]; Print["The concordance coefficient is: W= ",W]; Print["Random value χ^2 is: χ^2 = ", χ^2]; Print["The smallest value of W, W_{min} is: W_{min} = ", W_{min}]; If[W_{min} ≤W, Print["The estimates of the respondents are consistent."], Print["The estimates of the respondents are not consistent"]

4.3. The results presented by the ports perception map

On the basis of the previous calculus given in (4.1) and (4.2), the final positions of the considered ports, according to the qualitative B criterion set are obtained, and presented in Figure 4. The leading position in the case of the qualitative criteria analysis belongs to Constantza port. As opposed to the case when the quantitative criteria were considered, Rijeka port has significantly enhanced its position. Specifically, it is now ranked as the second port. The reasons for this *progress* lie in the fact that in the case of Rijeka

port all B1 sub-criteria are present (i.e. each of them has value 1). Also, this port has appropriate connections with the hinterland. It is competitive in terms of ship and cargo services, while the lower degree of competitiveness exists related to the ICT applications.

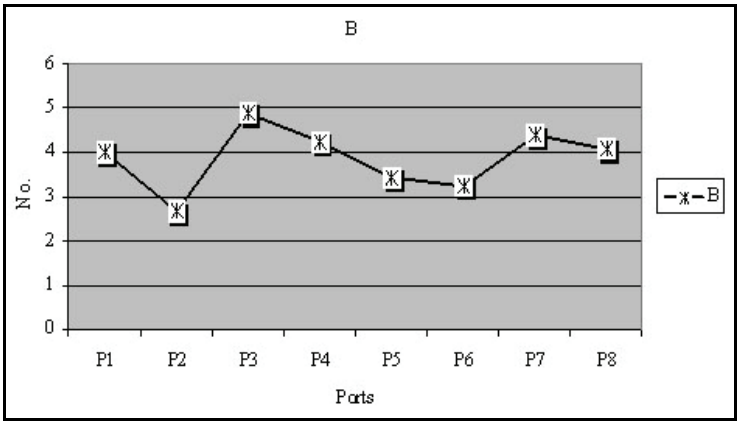

Fig. 4. Ports positions according to the qualitative criteria obtained by AHP approach

Koper is slightly lower positioned than Rijeka, however, it could be concluded that they share the second position. Koper differs from Rijeka in terms of PMM (Port Management Models) criteria. It is weaker in terms of ship and cargo services, but better than Rijeka in terms of ICT solutions. Thessaloniki and Bar are sharing the fourth position. Port users perceived them as strong competitors in terms of B criteria. Users found that each of them has bottleneck regarding connections with the hinterland. Also, both ports share similar marketing, but different organizational models. Piraeus port takes lower position now, in comparison with the position previously established by the PROMETHEE method. Possible reasons are the absence of liquid cargo terminal, railway connections, and VAL (value-added logistics) services. Ploce and Durres are characterized by weaker positions in relation to other six ports. Compared with Durres, Ploce port has an advantage concerning marketing variables. Therefore, the Durres port management should intensify their efforts towards the affirmation of the free zone concept and other marketing issues, but also towards the strengthening of the links with the hinterland. Ploce and Durres are different in terms of organizational models, but competitiveness factors of these two ports are largely overlapping. The results obtained here were tested among the focus group experts in this field, who agreed that the positions of the investigated ports, determined using these quantitative methods, correspond to the real situation.

5. Conclusions

In this paper, the set of Adriatic, Aegean and Black Sea ports has been analyzed in order to gain an objective view of their business systems situations, having in mind that these ports have been facing great challenges of reorganization and integration into the global flows of international economics, foreign trade, maritime and inland transportation reforms, etc. With reference to both quantitative and qualitative criteria analysis, the following general observations can be given, which, to a certain extent, present the directions for marketing repositioning and development of the ports:

(I) According to the **quantitative** (sub)criteria (A)

- Constantza port is the leading port according to all three analyzed sub-sets of quantitative criteria (A1, A2, and A3), which is not surprising, considering that one of the leading terminal operators has overtaken the initiative over this port's container terminal; - Koper port is on the second position and its specific advantage is related to A2 group of criteria, thus this port should work on the enhancement of it's infrastructure; - Piraeus port is on the third position in the cases of A1 and A3 criteria sub-sets, while in the case of A2, it is in a worse position than in the previous two cases. The reasons can be found in the lack of horizontal mechanisation structures, which can be one of prospective directions for the enhancement of this port's capacity; - The positions of the other considered ports (Tessaloniki, Rijeka, Bar, Durres, and Ploce) are lower in comparison to the above mentioned ones, and they vary more or less, depending on the numerical values and nature (max/min) of the considered quantitative criteria. These ports must be headed towards the modernization of infrastructure, and especially horizontal and vertical mechanization assets, i.e. they need to improve the efficiency of the capacity management system, having in mind that it becomes an economically non-elastic feature in the short term. First of all, it would be especially favourable to turn towards developing a marketing concept related to the management of relationships with loyal customers in order to maintain or enhance their actual market share.

(II) According to the **qualitative** (sub)criteria (B)

- The positions of most of the ports are uniform, which confirms that they are very competitive-oriented toward each other; - The ports of Constantza, Koper and Rijeka are nearly the leaders and their development direction would be based on management and marketing variables, considering that the customers' selection greatly depends on these disciplines; - Solun and Bar share the fourth position and they will be highly competitive, especially for the target market of South East Europe, meaning that these ports' management must consider the modernization of their hinterland connections; - Piraeus port takes lower position in this case. The possible reasons are: absence of liquid cargo terminal, railway connections, and value-added and logistics services; - The other two ports (Ploce and Durres) are found at lower positions than the previously ranked ones, and they need to be managed in a way that would intensify their container transhipment, considering that they have a highly competitive geo-strategic position.

Ultimately, the aim of this research work was to, using the marketing logic, as well as applying quantitative tools, clearly define the positions of these ports in terms of their competitiveness, taking into account the perceptions of users about the quantitative and qualitative criteria of their business systems. Also, the goal was to *create a space* for acting in the direction of defining the port development strategy. In this sense, the paper could be dedicated primarily to the management of these ports, potential investors, port authorities, as well as the wider scientific and professional community. In this context, the PROMETHEE multi-criteria quantitative optimization method allowed us to set the positions of the analyzed ports as objectively and precisely as possible. The PROMETHEE method *reduces* large differences in numerical values of certain criteria in order to achieve more precise positioning of the considered ports at the market, although here they are all positively correlated to the objective function. While the PROMETHEE method included a set of purely quantitative (sub) criteria, in the paper applied AHP method *covered* a set of qualitative (sub) criteria of the observed ports operations. Using the AHP approach, the focus of the investigation has been expanded from the internal (established

within each port, and unchangeable within a rather longer time interval) to the set that includes the external criteria, more visible to the users and more flexible in terms of adapting to their current preferences. Also, this method, in a sorely qualitative manner, provides the validation of the results obtained by the PROMETHEE method, since there are no crucial differences in the ports positions, especially the leading one.

The direction of future research work in this domain has a tendency to employ (or combine) additional quantitative, as well as qualitative methods, in order to verify the validity of the results presented by the ports perceptional maps in the paper. Also, there is a possibility to include some novel, additional, market-generated criteria for the purpose of more efficient (re) positioning of the analyzed ports.

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2.2. Combining benchmarking and matrix game in the seaports' (re)positioning

This research study considers the effects of two approaches in developing seaports positioning strategy. The first one is based on comparing the most important quantitative and qualitative seaports choice criteria by benchmarking method. Benchmarking has been used in creating the appropriate model for efficient marketing positioning of the Aegean, Adriatic and Black Sea seaports. The criteria that describe the degree of the seaports competitiveness are chosen upon the investigation of ports customers' preferences. The second employed approach based on matrix game concept has been used for the purpose of optimal repositioning of the ports. Though, nine selected ports' functions are treated in a way that they are divided into two sets: one composed of the functions which are to be developed, and the other consisted of the functions for which it is expected to be suppressed in the future. According to the numerically obtained results the ports are (re)positioned, and corresponding explanations are given in the marketing manner. The mixture of these two concepts should contribute to the review of the state of these business systems and their images at the market, as well as to open prospective toward finding out the ways of creating and maintaining their competitive advantages.

1. Introduction

During the past few decades, there has been an evident necessity for adopting marketing principles in maritime industry, especially in port business, considering the importance of their role in logistics supply chains. Globally, ports' business policies are basically created in accordance with modern principles of market business, as well as innovations imposed by modern technologies of maritime transport. Nevertheless, only small number of ports worldwide has a developed marketing, as a concept, function and practice.

The port management of today faces numerous marketing challenges, primarily regarding market research management. This process includes the collecting of information on the existing and potential customers, economic, technological, social and political development changes in trade and logistics, legislation and its implication on port business, development of competitive ports and other stakeholders, etc. All mentioned issues aim at resolving the dilemma: why certain port is preferred to the alternative ones?

Modern marketing business aspects of port operations anticipate the finding of efficient ways for strengthening their position in the market, development of market participation maintenance and increase strategy, market segmentation and selection of target markets (segments), differentiation of the offer and positioning. In addition, marketing as a concept of seaport business, but practice, as well, offers solutions for measuring the beneficiary satisfaction, especially for strategic attraction and keeping of profitable and loyal clients. In addition, it is necessary to more intensively apply a variety of all marketing strategies in the domain of port business, but also to have a wider comprehension of the importance of port service offer instruments (7P-service product, tariffs, distribution channels, integrated marketing communication, service processes, service ambient, people). Marketing approach to port management is based on the awareness of customers' needs, while moving the focus from internal performances of port business (such as the capacity) toward the market ones, such as beneficiary preferences.

In the widest context, the positioning of ports analyzed in this paper should enable a clear positioning in the mind of customers, and determine them so that customers can see the offer of a certain port compared to the competitive one [13]. The position developed is actually the place that organizations want to occupy in the mental map of the customers [14]. The strategic positioning of seaports started to be discussed from the wider economic aspects. Namely, the analysis of determining the competitive position of the port has included: analysis of port service portfolios, shift-share analysis and analysis of diver-

sification [17]. Although the subject of seaport positioning hasn't been sufficiently researched in terms of marketing, some researches were aimed to find factors that would make the seaport services different and recognizable, e.g. based on efficiency, quality, reliability, etc [31].

In literature two basic themes are related to marketing positioning of seaports: a) seaport competition and competitiveness, and b) the port choice criteria. Many methods have been used in order to define the factors of seaport competitive performance, but primarily benchmarking is standing out in the marketing positioning of the ports, as a method that is based solely on the comparison of variables, processes, and results of seaport functioning, etc. Pardali and Michalopoulos [28] applied the benchmarking method in ranking of 14 Mediterranean container ports, with special emphasis on determination of the position of average, leading and Piraeus port. Yeo, Roe, Dinwoodie [41] made comprehensive literature review of components of port competitiveness, concluding that port competitiveness is determined by port service, hinterland condition, availability, convenience, logistics cost, regional center and connectivity. Efficiency, shipping frequency, adequate infrastructure, location, port charges, quick response to port users' needs, reputation for cargo damage, intermodal and value – added services, and information system availability are some of the port selection criteria [20, 21, 22, 34, 35, 36, 37, 38].

The quantitative method like AHP (Analytic Hierarchy Process) is very appropriate for setting the bases of seaport positioning (or, their ranking), while port charge, tax, rent and cost, port operation efficiency, load/discharge efficiency, size and efficiency of container yard, hinterland economy and depth of berth are found as the most important contemporary port choice criteria [8]. In the domain of quantitative analyses, the theory of games has been also applied regarding marketing in the domain of: a) negotiations between buyers and sellers in the sale process, b) determining the strategy of competitive behavior in the market, c) innovations, d) determining prices and competition between marketing subjects, e) development of marketing strategies, f) advertising and promotions, g) marketing channel, h) product marketing, i) company reputation in the market, etc [19]. In this paper, certain port functions shall be an example of resolving matrix games, based on Von-Neuman min/max principle, presenting the constant sum game [4].

Descriptive studies are also important in terms of explaining current moments in global port business. These are the topics related to port regionalization [24], terminalization of seaports [32], shipping networks and port development [9, 18] maritime supply chains and the role of ports within them [5, 6, 7, 23, 26, 39] etc.

All the mentioned methodologies confirm the extent and complexity of related topic. The paper discusses many aspects of seaport positioning, but what makes it innovative is that the particular attention is paid to the marketing dimension of the issue.

2. Methodology

In the paper, two sets of criteria have been analyzed: quantitative (7) and qualitative ones (26), which are listed in Table 1 and Table 2. These two sets of criteria are divided into several subsets of criteria [3, 28, 33]. Upon the sets of the considered container ports (P1 - Bar; P2 - Durres; P3 - Constantza; P4 - Koper; P5 - Piraeus; P6 - Ploce; P7 - Rijeka; P8 - Thessaloniki), the following methodology is applied in order to make their proper positioning:

- The quantitative and qualitative sets of criteria have been identified;

- Two focus groups have been formed. The experts and researchers formed the first one, while the customers formed the second one. The respondents were asked (in the form of an interview) to estimate the importance of each criteria, from their own point of view, at the scale from 1 to 10;
- The focus group members' i.e. responders' grades are collected and the average values per each of the predefined criteria have been calculated for each of the analyzed ports;
- These average values of grades are used later as weight coefficients or ponders by which the values representing considered criteria are multiplied;
- The scores obtained by the previous calculus are summed per each of eight considered ports; and,
- The obtained scores for quantitative and qualitative criteria, as well as the total score, have been used for positioning the examined ports, what is shown by the perceptual maps. The mathematical formulation that follows the previous linguistic statements is given below.

Table 1. Quantitative criteria (A)

A. Quantitative criteria	A1. Container terminal infrastructure features	C_A1.1	Number of berths (no.)
		C_A1.2	Total length of berths (m)
		C_A1.3	Maximum water depth (m)
		C_A1.4	Terminal storage capacity (TEU)
		C_A1.5	Gantry crane (no.)
	A2. Cargo handling and human capacities	C_A2.1	Total cargo handling turnover (tons)
		C_A2.2	Daily operations (hours)

Firstly, it is to be noted that each of the analyzed criteria has been assigned by the appropriate variable: v_{Ai} - for quantitative criteria ($i = \overline{1,7}$), and v_{Bj} - for qualitative criteria ($j = \overline{1,26}$). Values of v_{Ai} are in fact exact numerical values corresponding to each quantitative criterion per each of the considered ports (Appendix, Table A.1). Values of v_{Bj} are binary ones (Appendix, Table A.2). Namely, if the considered port has the qualitative criteria (feature) v_{Bj} has value one (1), and vice versa if it has not posses certain criteria the variable has value zero (0), [28].

Table 2. Qualitative criteria (B)

B. Qualitative criteria	B1. Infra and superstructure features	C_B1.1	General cargo terminal (Y/N)
		C_B1.2	Bulk cargo terminal (Y/N)
		C_B1.3	Liquid cargo terminal (Y/N)
		C_B1.4	Ro-Ro terminal (Y/N)
		C_B1.5	Passenger terminal (Y/N)
	B2. Connections with hinterland	C_B2.1	Railway connections (Y/N)
		C_B2.2	Road connections (Y/N)
		C_B2.3	Pipelines connections (Y/N)
		C_B2.4	Barge service (Y/N)

		C_B2.5	Shuttle service (Y/N)
	B3. Marketing features	C_B3.1	Free zone (Y/N)
		C_B3.2	Value-added logistics services (Y/N)
		C_B3.3	Distribution centers (Y/N)
		C_B3.4	Quality Management System (Y/N)
		C_B3.5	Integrated marketing communications (Y/N)
	B4. Port management models	C_B4.1	Service port model (Y/N)
		C_B4.2	Tool port model (Y/N)
		C_B4.3	Landlord port model (Y/N)
		C_B4.4	Private port model (Y/N)
	B5. Vessels' and cargos' services	C_B5.1	Vessel monitoring (Y/N)
		C_B5.2	Vessel repair (Y/N)
		C_B5.3	Vessel servicing (Y/N)
		C_B5.4	Container control (Y/N)
		C_B5.5	Container leasing (Y/N)
	B6. ICT applications	C_B6.1	EDI service (Y/N)
		C_B6.2	VTS service (Y/N)

The values of the quantitative criteria are divided with the maximum value among them, per each of the considered ports, in order to neglect the differences in numerical values. Though, the variables v_{Ai} ($i = \overline{1,7}$), are now replaced with $\overline{v_{A_i}} = v_{A_i} / MAX\left(\left\{v_{A_i}, i = \overline{1,7}\right\}\right)$. Intention is to reduce all numerical values of the quantitative criteria to the interval between 0 and 1 ($0 \le \overline{v_{A_i}} \le 1$). Further on, the respondents from the focus groups, formed of the experts (5), researchers (5), and customers (10), estimated each criteria importance due to their own opinions (at the scale from 1 to 10). Their marks then are averaged. The average values per each criterion are used as weight coefficients w_{Ai} - per quantitative criteria ($i = \overline{1,7}$), and w_{B_j} - per qualitative criteria ($j = \overline{1,26}$). This method of estimating weight coefficients through the interview, requires highly developed logical thinking, so the estimate of only one highly qualified expert (or, 20 experienced persons, like in this paper) may be more important than the estimates made by a considerably larger number of inexperienced persons [30].

Though, the total benchmarking score for quantitative and qualitative criteria, per each of the considered ports can be calculated by the following formulas:

$$BA_k = \sum_{i=1}^{7} w_{A_i} \cdot \overline{v_{A_i}}, k = \overline{1,8} \quad (1)$$

$$BB_k = \sum_{j=1}^{26} w_{B_j} \cdot v_{B_j}, k = \overline{1,8} \quad (2)$$

Where,

BA_k - is a total benchmarking score for the quantitative criteria for k - th port;

BB_k - is a total benchmarking score for qualitative criteria for k - th port;

w_{Ai} - is weight coefficient per i - th quantitative criterion from A, while i - is number of quantitative criteria;

$\overline{v_{Ai}}$ - is value of the i - th criterion in A divided by the maximum numerical value of that criterion per each ports;

w_{Bj} - is weight coefficient per j - th qualitative criterion from B, while j - is number of qualitative criteria;

v_{Bj} - is binary value of j - th qualitative criterion; k - is number of ports, here $k = 8$.

Since the Excel sheets are employed in realization of the calculus two SUMPRODUCT (array_1; $array_2) imbedded functions are actually used: one for quantitative (A) sub-set of the criteria, and the other for qualitative (B) sub-set of the criteria. In both cases array_1 corresponds to the values of the variables representing criteria, while the values of the $array_2 are fixed and represent the values of corresponding weight coefficients. More precisely, on the basis of formulas (1) and (2), it is enabled to create separate perceptual maps for both quantitative and qualitative criteria analysis per each of the ports which are to be mutually positioned at the market.

2.1. Positioning based on the quantitative criteria analysis

In the previous section defined formula (1) is general one, and it is to be modified depending on the needs for different calculus. Namely, in the case of estimating imaginary leading port the total benchmarking score is reduced to the formula: $BLP_A = \sum_{i=1}^{7} w_{A_i}$, since $\overline{v_{A_i}} = 1$, while in the case of calculating the imaginary average port total benchmarking score, the following formula can be applied: $BAP_A = \sum_{i=1}^{7} w_{A_i} \cdot AVG(v_{A_i}) / MAX(v_{A_i})$. The obtained values of benchmarking total scores for each port ($BA_k, k = \overline{1,8}$), the imaginary leading port (BLP_A), and the imaginary average port (BAP_A), are shown in Figure 1.

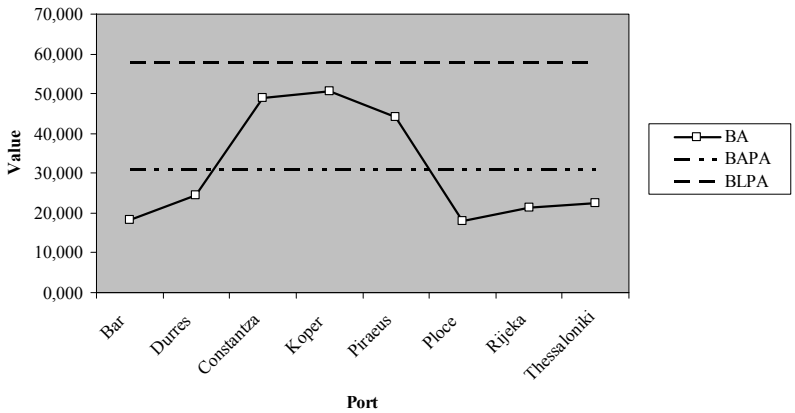

Fig. 1. Positioning of investigated seaports based on the quantitative criteria analysis

According to the scores for imaginary leading and average ports it is possible to calculate the following differences: D_LP_A - the differences between values of the benchmarking total scores for imaginary leading and each considered port; and, D_AP_A - the differences between values of the benchmarking total scores for imaginary average and each considered port. The obtained numerical results are given in Table 3.

Table 3. The variations among leading, average, and each considered port in A

Port	D_LP_A	Rank 1	D_AP_A	Rank 2
P1 – Bar	39.638	7	12.727	7
P2 – Durres	33.476	4	6.565	4
P3 – Constantza	8.906	2	-18.004	2
P4 – Koper	7.451	1	-19.460	1
P5 – Piraeus	13.894	3	-13.017	3
P6 – Ploce	39.804	8	12.894	8
P7 – Rijeka	36.560	6	9.650	6
P8 – Thessaloniki	35.555	5	8.645	5

Based on the numerical results given in Table 3, the Koper port, in terms of quantitative criteria, generally viewed, is positioned in the market as the leading port. In case we consider the criteria individually, this port has the best competitive performance in regard with: the number of berths; total length of berths; and maximum water depth. The port of Constantza achieves the highest total cargo handling turnover, while sharing the same number of gantry cranes with the leading port. Furthermore, the port of Constantza has the highest terminal storage capacity, while the third positioned port of Piraeus, based on this quantitative criterion, is superior compared to the leading port of Koper. It is important to emphasize that in terms of daily operations, all ports are well positioned, since they provide services during 24 hours a day.

In creating this kind of port positions, in addition to the values of fixed quantitative parameters, the values of related weight coefficients were also included. Namely, the respondents approximately gave the highest values to the terminal storage capacity parameter, followed by the maximum water depth, noting that the differences in valuing the two parameters were minor. The port service customers treated the total length of berths and number of gantry cranes fairly equally, awarding them very high weigh values. Daily operations are given the priority compared to the number of berths, but also the total cargo handling turnover, which, to some extent, influenced the better position of the Koper port compared to the biggest Black Sear port of Constantza.

2.2. Positioning based on the qualitative criteria analysis

The situation with qualitative criteria is simpler comaring to the previously described one. For the purpose of estimating imaginary leading port the total benchmarking score BB_k ($k = \overline{1,8}$) is reduced to the formula: $BLP_B = \sum_{j=1}^{26} w_{B_j}$, since $v_{B_j} = 1$. In the case of calculating the imaginary average port total benchmarking score, the following formula can be applied: $BAP_B = \sum_{j=1}^{26} w_{B_j} \cdot AVG\left(v_{B_j}\right)$. The obtained values of bench-

marking total scores for each port ($BB_k, k = \overline{1,8}$), the imaginary leading port (BLP_B), and the imaginary average port (BAP_B), are shown in Figure 2.

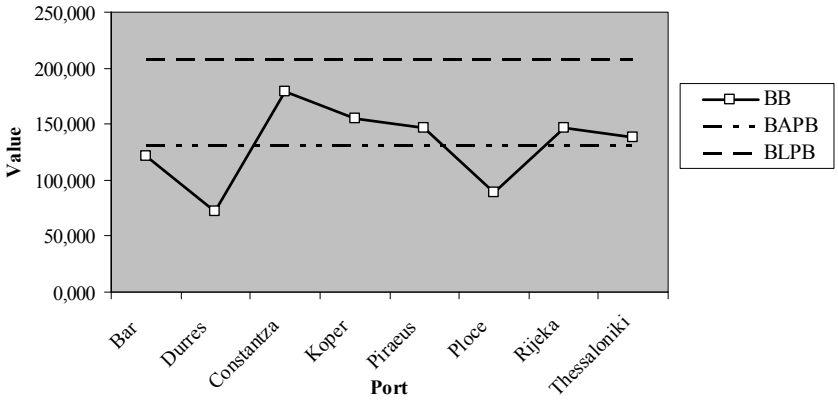

Fig.2. Positioning of investigated seaports based on the qualitative criteria analysis

Based on the scores for imaginary leading and average ports it is possible to calculate the following differences: D_LP_B - the differences between values of the benchmarking total scores for imaginary leading and each considered port; and, D_AP_B - the differences between values of the benchmarking total scores for imaginary average and each considered port. The obtained numerical results are given in Table 4.

In analyzing qualitative parameters, the port of Constantza reaches the best position in conditions in which the eight examined ports share the same target market. The port of Koper has features significantly different compared to the leading one, but here it is perceived by the customers as the second-ranked. The ports of Piraeus and Rijeka are expressively competitive with each other, while the port of Thessaolinki is positioned slightly above the average. Among weakly positioned, there are the ports of Ploce and Durres, while the Port of Bar, with appropriate management efforts, could be lead to the level of an average port. When considering ponder values, we can conclude that, generally, hinterland connections criteria are highly ranked, than ICT applications and marketing variables, while we find slightly lower ponder values accompanying port management models and infrastructural features.

Table 4. The variations among leading, average, and each considered port in B

Port	D_LP_B	Rank 1	D_AP_B	Rank 2
P1 – Bar	85.907	6	9.188	6
P2 – Durres	135.779	8	59.059	8
P3 – Constantza	28.607	1	-48.113	1
P4 – Koper	53.093	2	-23.627	2
P5 – Piraeus	61.071	3	-15.648	3
P6 – Ploce	118.607	7	41.888	7
P7 – Rijeka	61.150	4	-15.569	4
P8 – Thessaloniki	69.543	5	-7.177	5

3. Matrix game in the repositioning of the seaports

In general, the theory of games is considered the examination of decision making issues in situations when several *players* – decision makers, participate [12]. In addition to this, the theory of games is considered a way of anticipating the results of *the game*, representing commercial situations in which two or more players participate, being mutually related and inter-dependent [42]. The *Player* in maritime market can be any port, ship operator, shipper, agent or other that must take into consideration the actions of the other before establishing their own business strategy and during the period of its implementation. Therefore, the maritime industry has applied two game categories: non-cooperative and cooperative games [10]. According to the given classification, the cooperative approach can be applied to alliances of liner sea transport and alliance of port transport (hub-and-spoke system). Thus, Guo and Min discuss the situation in which the shipper chooses the strategy of maximizing net profit, liner shippers the strategy of minimizing total logistics cost resulting from the total cargo transport, and port authorities appear as the player in charge of management and marketing policies in order to maximize port tariffs and taxes, but also tending to maximize their own contribution to the national economy. As the result of the numerical calculation gained from the three-party game, we get the optimal position (location) of the hub port, but also the accompanying ports in the related hub-and-spoke system. The authors emphasize that the same model of cooperative games can be applied to the optimization of transport routes at the national, regional and world level. Furthermore, the strategy of coalition games on the example of port has been examined within the port co-opetition concept [11].

In this part of the paper, the example of the well known two-player zero-sum matrix game is being discussed, which needs to give an answer to the question: How will the considered ports be (re)positioned on the basis of the analysis of their development features? - Consequently, the players, i.e. two groups of confronted functions are given in Table 5 [43].

Table 5. Development criteria (C)

C. Development criteria	C1. Port functions preferred to be empowered	C_C1.1	Container cargo handling
		C_C1.2	Automation of processes
		C_C1.3	ICT applications
		C_C1.4	Range of port services
		C_C1.5	ISPS and accident prevention
		C_C1.6	Environmental protection and port sustainability
	C2. Port functions preferred to be suppressed	C_C2.1	General cargo handling
		C_C2.2	Number of employees
		C_C2.3	Role of the government in port managing

3.1. Determining the reward matrix

The top managers in the considered ports matched the analyzed development functions, in accordance to the matrix game concept, and estimated their importance at the scale from 1 to 5, due to their experience or intuitively (Table 6).

Table 6. The importance of the ports' development functions

Port/ Criteria	P1	P2	P3	P4	P5	P6	P7	P8	Avg.
C_C1.1	5	4	5	5	4	3	4	5	4.375
C_C1.2	4	3	5	4	4	4	4	3	3.875
C_C1.3	4	3	5	4	4	4	4	4	4.000
C_C1.4	3	3	4	2	2	4	5	5	3.500
C_C1.5	3	4	5	4	4	4	3	3	3.750
C_C1.6	4	4	5	4	4	4	3	5	4.125
C_C2.1	3	2	3	3	4	4	2	2	2.875
C_C2.2	4	3	5	1	4	4	2	5	3.500
C_C2.3	4	4	4	2	4	4	4	3	3.625

Then, the top managers are asked to define the reward matrix for the confronted functions for their own ports. However, the profound question which here is: what logic should be used in estimating reward matrixes? The possible explanation in which way this might be done, is given through the following example (Table 7).

Table7. An example of reward matrix for two confronted sets of development port's functions

Confronted functions	C_C2.1	C_C2.2	C_C2.3
C_C1.1	3	3	4
C_C1.2	1	4	4
C_C1.3	-2	2	3
C_C1.4	4	-3	4
C_C1.5	1	-2	-5
C_C1.6	2	-3	-5

The pairs of corresponding strategies may be explained as follows [1,2]:

- (C_C1.1, C_C2.1): (+3) – Along with the aim of achieving effective integrated transport, there was a need for an unified manipulative transport unit - container, as a result of developments in cargo handling and packaging technologies. It is clear that nearly all ports around the world are trying to increase their own level of containerization, which consequently impacts on reducing the rate of conventional general cargo handling. Though, this coefficient in the reward matrix is positive and estimated as +3;
- (C_C1.1, C_C2.2): (+3) – Growth of the volume of container loading significantly affects the reduction of the number of employees in the port. For example, the unloading/loading sacks, pallets, bales, etc., need to engage more stevedores on the ship, operating queue, and warehouses. Contrary to the above, for the container transshipment is not necessary to engage stevedore on board, and the port operating queue, as logistics supporters of loading/unloading processes. The reason is that modern container crane has a capacity which can compensate the work of at least five workers, or more. But of course, although it has a tendency to development, container transport

can not be based only on mechanization and automation, it still requires live work, and therefore this coefficient is positive, but limited on (+3);

- (C_C1.1, C_C2.3): (+4) - Due to the appearance of a large number of operators in container terminals, and their investments in port superstructure and equipment, the ownership structure of the ports is commonly changing in favor of private capital, though the role of the Government in this field of port management becomes weaker. The container business is attractive, trying to find and attract private operators, and thus the role of the government is becoming less entrepreneurial and more regulatory. The assigned coefficient to this pair of strategies in the game has a quite high ratio of (+4), which means intensifying the growth of container transshipment at the expense of reduction of the role of the government in managing the port.

Since previously explained coefficients in the reward matrix have "+" prefix, let's explain some with "–" sign:

- (C_C1.3, C_C2.1): (-2) - Increased use of information and communication technologies (ICT) in ports enable better relationships with both internal and external port's stakeholders, which certainly should not reduce the scope of the conventional general cargo transshipment. Rather, this phenomenon may intensify container transport, but not sure that will limit the transfer of conventional general cargo. This is the reason that this coefficient has a negative sign in the reward matrix of the game, i.e. (-2);
- (C_C1.6, C_C2.2): (-3) - High quality implementation of environmental standards, environmental compliance procedures and sustainable development of ports is not possible without adequate staff in the quantitative and qualitative terms of its meaning, which implies that the port development in this direction will provide certain benefits to the working force, i.e. employees in the port. This is expressed in terms of (-3) coefficients in the reward matrix;
- (C_C1.6, C_C2.3): (-5) - The legislative and regulatory role of the government in the domain of the port sustainable development is irreplaceable. So, in this game the role of the government is *winning* one, and it is logically evaluated as negative coefficient, subjectively assigned by (-5), etc.

3.2. Resolving the marix game

Following in the previous subsection described logic, the top managers in each of the examined ports (P1 - Bar; P2 - Durres; P3 - Constantza; P4 - Koper; P5 - Piraeus; P6 - Ploce; P7 - Rijeka; and, P8 - Thessaloniki) have offered their estimations of the reward matrices (Table 8).

Table 8. Reward matrices for the considered ports and the LP solutions

Port 1	S/E	S1	S2	S3
	E1	4	4.5	4.5
	E2	3.5	4	4
	E3	3.5	4	4
	E4	3	3.5	3.5
	E5	3	3.5	3.5
	E6	3.5	4	4

→ d+ = 0

S/E	S1	S2	S3
E1	4	4.5	4.5
E2	3.5	4	4
E3	3.5	4	4
E4	3	3.5	3.5
E5	3	3.5	3.5
E6	3.5	4	4

Solution:

V = 4
P = (1,0,0,0,0,0)
Q = (1,0,0)

Port 2	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	-3	3.5	4	d+ = 3	E1	0	6.5	7
	E2	-2.5	3	3.5		E2	0.5	6	6.5
	E3	-2.5	3	3.5		E3	0.5	6	6.5
	E4	-2.5	3	4		E4	0.5	6	6.5
	E5	-3	3.5	4		E5	0	6.5	7
	E6	-3	3.5	4		E6	0	6.5	7
					Solution:	V = 0.5 P = (0,0,1,0,0,0) Q = (1,0,0)			

Port 3	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	4	5	4.5	d+ = 0	E1	4	5	4.5
	E2	4	5	4.5		E2	4	5	4.5
	E3	4	5	4.5		E3	4	5	4.5
	E4	3.5	4.5	4		E4	3.5	4.5	4
	E5	4	5	4.5		E5	4	5	4.5
	E6	4	5	4.5		E6	4	5	4.5
					Solution:	V = 4 P = (0,0,1,0,0,0) Q = (1,0,0)			

Port 4	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	4	-3	-3.5	d+ = 3.5	E1	7.5	0.5	0
	E2	3.5	-2.5	-3		E2	7	1	0.5
	E3	3.5	-2.5	-3		E3	7	1	0.5
	E4	-2.5	-1.5	-2		E4	1	1.5	1.5
	E5	3.5	-2.5	-3		E5	7	1	0.5
	E6	3.5	-2.5	-3		E6	7	1	0.5
					Solution:	V = 1.43 P = (0,0.071,0,0.929,0,0) Q = (0.143,0,0.857)			

Port 5	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	4	4	4	d+ = 3	E1	7	7	7
	E2	4	4	4		E2	7	7	7
	E3	4	4	4		E3	7	7	7
	E4	-3	-3	-3		E4	0	0	0
	E5	4	4	4		E5	7	7	7
	E6	4	4	4		E6	7	7	7
					Solution:	V = 7 P = (0,0,1,0,0,0) Q = (0,0,1)			

Port 6	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	3.5	3.5	3.5	d+ = 0	E1	3.5	3.5	3.5
	E2	4	4	4		E2	4	4	4
	E3	4	4	4		E3	4	4	4
	E4	4	4	4		E4	4	4	4
	E5	4	4	4		E5	4	4	4
	E6	4	4	4		E6	4	4	4
					Solution:	V = 4 P = (0,1,0,0,0,0) Q = (0,0,1)			

Port 7	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	-3	-3	4	d+ = 3.5	E1	0.5	0.5	7.5
	E2	-3	-3	4		E2	0.5	0.5	7.5
	E3	-3	-3	4		E3	0.5	0.5	7.5

	E4	-3.5	-3.5	4.5		E4	0	0	8
	E5	-2.5	-2.5	3.5		E5	1	1	7
	E6	-2.5	-2.5	3.5		E6	1	1	7
					Solution:	V = 1 P = (0,0,0,0,1,0) Q = (0,1,0)			

Port 8	S/E	S1	S2	S3	→	S/E	S1	S2	S3
	E1	-3.5	5	4	d+ = 3.5	E1	0	8.5	7.5
	E2	-2.5	4	3		E2	1	7.5	6.5
	E3	-3	4.5	3.5		E3	0.5	8	7
	E4	-3.5	5	4		E4	0	8.5	7.5
	E5	-2.5	4	3		E5	1	7.5	6.5
	E6	-3.5	5	4		E6	0	8.5	7.5
					Solution:	V = 1 P = (0,1,0,0,0,0) Q = (1,0,0)			

In the previously described manner formed matrix models are solved as LP (Linear Programming) problems. More explicitly, the optimal solutions of the reward matrices have been found by LINGO software, based on the principal code shown in Table 9.
In lines 2] and 3] the rows and the columns of the reward matrix $REW(i,j)$ have been defined respectively. The reward matrix itself is defined in the line 4]. For each column "j", line 6] creates the constraint $\sum_i REW(i,j) \cdot X(i,j) \geq V$, where $X(i,j)$ corresponds to the probability that *players* will play (i,j) pair of strategies, and V is value of the game that is to be optimized. In line 7] it is ensured that the row player's probabilities sum to 1. The row 8] creates the objective function, while row 9] uses the @FREE statement to allow V to be negative. In rows 11] through 16], the reward matrix has been imputed into the model [40].

Table 9. LINGO code for matrix game

```
MODEL:
1]SETS:
2]ROWS/1..6/:X;
3]COLS/1..3/;
4]MATRIX(ROWS,COLS):REW;
5]ENDSETS
6]@FOR(COLS(J):@SUM(ROWS(I):
REW(I,J)*X(I))>V;); 7]@SUM(ROWS(I):X(I))=1;
8]MAX=V;
9]@FREE(V);
10]DATA:
11]REW=3,3,4,
12]1,4,4,
13]-2,2,3,
14]4,-3,4,
15]1,-2,-5,
16]2,-3,-5;
17]ENDDATA
18]END
```

Owing to this code, the optimal value of the matrix game and the corresponding mixed strategies can be obtained. The values Sum_C1 and Sum_C2 calculated as sum products of the optimal matrix games vectors and the appropriate weight coefficients are given in Table 10. The last column corresponds to the sum of Sum_C1 and Sum_C2 values.

Table 10. The matrix game solutions pondered by the weight coefficients

Criteria/ Port	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C2.1	C2.2	C2.3	Sum_C1	Sum_C2	Total
P1	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	4.50	2.88	7.38
P2	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	4.50	2.88	7.38
P3	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	4.13	2.88	7.00
P4	0.00	0.07	0.00	0.93	0.00	0.00	0.14	0.00	0.86	3.53	3.52	7.04
P5	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	4.00	3.63	7.63
P6	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3.88	3.63	7.50
P7	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	3.75	3.50	7.25
P8	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	3.88	2.88	6.75
Avg.	4.50	3.88	4.00	3.50	3.75	4.13	2.88	3.50	3.63			

Finally, according to the previously described calculus (i.e. referring to the last column in Table 10), the positions of the ports based on their developing policies in the near future, are determined and shown in Figure 3.

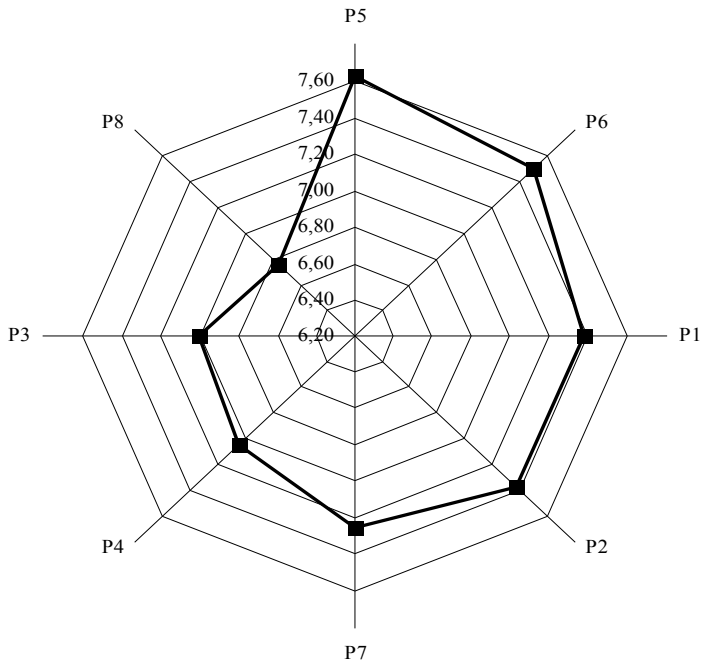

Fig. 3. The ports positions estimated by the matrix game approach

In confronting the preferred functions, compared to those more difficult to suppress, a space is being opened for port marketing repositioning. Based on numerical indicators, as per Fig. 3, the port of Piraeus has the largest space for port repositioning. Namely, the dominant strategy upon which it is necessary to put more efforts in advanced automatization of port processes and reduction of government participation in port management, should be the optimal solution for the port Piraeus development. Furthermore, this strategy is also optimal in the case of the Ploce port, which, having in mind the previous positioning (and in terms of quantitative and qualitative criteria) achieve an under average position, now gets a great *opportunity* for as good repositioning as possible.

The ports of Bar and Durres have equal *opportunities* for better repositioning, but, naturally, their strategies are different. The Port of Bar management faces the challenge of an intensified container transshipment compared to the general cargo handling. According to this model, the port of Durres should intensify the appliance of ICT technologies in terminals, while, on the other hand, it would be optimal to expect the reduction in the scope of handling general, conventionally packed cargo.

The port of Rijeka, having in mind its position above the average in terms of positioning based on qualitative criteria (see Fig. 2), as the repositioning strategy has an option of improving the prevention of risky situations in the port, but also the reduction in the number of employees, in accordance with current situation in this port.

The port of Koper is the only one of the analyzed in which the resolution of the matrix game is not in the domain of the so-called pure strategies, but in the domain of mixed ones. Thus, its positioning comprises activities in four directions. The automatization of processes needs to be developed, followed by the range of port services being expanded as the only segment of the total marketing activities of this port. On the other hand, it is recommended to intensify the reduction of government participation in port operations, as well as reduction in the scope of general cargo handling.

Considering the port of Constantza, its development should follow the direction of the dominant increase in the ICT solution implementation, in parallel with dominant reduction in general cargo handling. In the port of Thessaloniki, general recommendation in terms of optimal development is based on the dominant reduction in the scope of general cargo handling.

In this context, we should give several notes related to the weight coefficient values. Namely, the respondents have averagely estimated importance of the development function of port operations. The respondents decided that the highest importance is awarded to the reduction in the government participation in port management, then, reduction in the number of employees, and, finally, the reduction in the general cargo participation in the overall transshipment structure.

It is to be pointed here, that weight coefficients, as well as the reward matrixes, have been subjectively estimated by the top managers in the ports that are subject of this research, though the obtained results might be different in the case(s) that some other managers or administrative staff members in the ports have been asked for their opinions.

4. Conclusions

The paper analyzes the Adriatic, Aegean and Black Sea ports, based on quantitative, qualitative and development criteria. Quantitative and qualitative criteria, maintaining the existing situations in the analyzed ports, have been applied through a detailed development of benchmarking concepts. The development criteria, reflecting some kind of future

condition of the analyzed port systems, have been treated upon the concept of matrix game. The ports have been mutually positioned within the frame of applied benchmarking method, and their positions have been determined in relation to the imaginary leading and average port. The positioning strategy does not end with the existing presentation of the situation; it initiates *opening* of space for finding new, original ways for seaport repositioning. Therefore, in the context of applying the concept of matrix game, each port is determined by an optimum space and directions for its marketing repositioning.

The contribution of the paper is that it offered a comprehensive model combining the principles of strategic marketing, mathematical calculations anticipating benchmarking methods, thus well-known, structural and frequently applied concept of the matrix game. The general goal is to turn from internal business parameters of the eight researched ports towards the market ones. Naturally, internal performances were necessary in order to offer the respondents, primarily customers, the ranking scale for the criteria (quantitative, qualitative and development ones) being mostly preferred. This way, the opinions of the customers, combined with the fixed values of port capacity parameters, are descriptively presented on the perception maps. It is important to point out that ports are differently positioned in the case of analyzing quantitative, qualitative and development criteria. The positioning of the ports based on development criteria, to some extent, confirms the quality of the positioning in the previous two cases. Namely, if a port has a worse position based on the analyses of quantitative and qualitative criteria, this would, in case of positioning upon development criteria, imply the creation of a wider space for its repositioning, which has been proven through the obtained results in the paper.

For the purpose of future researches, in the models developed by combining the concepts of benchmarking and matrix game, efforts should be put in the reduction of the level of subjectivity in estimating the value of certain criteria, and this would be one of the ways of conducting research over a larger number of as competitive respondents as possible among experts, port management and port service customers.

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2.3. Positioning passenger ports due to the digital services

This research work positions the passenger sea ports in the context of cruise tourism on the basis of e-services they offer. The e-services of eleven passenger ports are categorized and then quantitatively evaluated by binary and ranking approaches. In general, the port e-services, or digital services, might be categorized according to their functionality as navigational, ship and passenger-related ones, logistics, business, marketing, entertainment, security, safety, environmental, etc. These services can be bidirectional informational and/or transactional. In this study, only those port e-services related directly to the passengers' needs, within the frame of cruise tourism, are taken into consideration and categorized as core, or as value-added ones, and as informational and/or transactional ones. Then, each of them is assigned an appropriate binary value (0/1), depending on whether the considered passenger port offers the related e-service or not. These values are employed in the evaluation of the analyzed passenger port e-services offered, and as a base for their positioning. The appropriate weights coefficients, obtained by ranking (Saaty method), were used in the process of the considered port final positioning on the cruise tourism e-market. Some additional analyses and recommendations in the direction of further positioning and promotion of the port of Kotor (Montenegro), as rising cruise tourism port (destination), are given as well.

1. Introduction

The trends on the global market induced ports to operate as enterprises, trying to reach maximum efficiency and competitiveness. Consequently, both freight and passenger ports need to transform the service (product) they offer by using modern information and communication technologies (ICT) [1, 2]. The innovative applications of ICT throughout the ports as enterprises, transform their functioning toward digital economy. The rapidly increased use of internet, intranets, extranets, e-business and e-commerce, social networks, and mobile computing has changed the way in which business is performed in almost all world ports being treated as enterprises. Also, the integration of port resource planning, customer relationship management and knowledge management with e-commerce is vitally important for the strengthening of their marketing approach. There is resurgence of intelligent systems and automated decision systems, both for facilitating security and increasing productivity and competitive advantage of a port. Besides managerial and artificial intelligence issues, ethical and legal issues are also of crucial importance within this context of growing ICT business and social implications everywhere, so as in the proper functioning of the contemporary passenger ports [3].

The web revolution is the most influential technological revolution in the modern era. The access and connectivity provided by the web keep transforming the way in which people work, shop, vote, invest, study, play, interact, and, of course, the way in which they decide when, where, and how to travel around the world and spend their leisure time. The e-services of passenger ports worldwide have changed the consumer behaviour enabling them to efficiently approach new distribution channels, combine different products and services, and ultimately improve the overall quality of lives. For example, a few years ago social networks were a novelty, but today approximately more than half a million people all around the globe participate in social networking as an instrument used in commerce, socialization, politics, healthcare, finance, entertainment, travel, and pleasure [3, 4]. Passenger ports might find these marketing tools not only to be generating faster and cheaper results than traditional focus groups, but also fostering ports feedback management. The passenger port feedback management should be interested not only in collected information, but also in interaction between customers and the port employees and/or management, and in properly distributing passengers' feedback throughout the port as an organization and destination.

Contemporary high sophisticated ICT solutions and tools have great impact on the entire economy and society, and consequently, on the ports as entrepreneur entities on the global market, and particularly on the passenger (cruise) ports as their special category. Regarding the passenger ports in the context of cruise tourism, along with the e-services which they offer they are under-researched; some rather recently written review and research papers represent efforts in acquiring more data/knowledge in this domain [5-8]. Also, within the following section of the paper the particular research attention is given to some actual *flows* in the nautical (cruise) tourism market, including the Port of Kotor (Montenegro) as its small, but growing segment in the Adriatic.

2. Cruise tourism trends and issues

Cruising (roundtrip) refers to tourist trip on a big boat for a period of several days, based on the itinerary or plan of roundtrip [9]. Cruise tourism has emerged relatively late in comparison to other forms of tourism. As product for the global tourism market, cruise tourism appeared in the 1960s.

From the aspect of tourism, a cruise ship plays the role of a floating hotel which may be considered as primary tourist destination, while the passing ports are considered as secondary ones. Cruise tourism provides tourists with vacation, fun and relaxation, docking at several ports and mainly returning to the port of departure. The size of the ship, equipment, and crew is adapted to the target group of tourists.

The broad concept of cruising includes port services of specialized loading and unloading of passengers on cruises that typically have special terminals for this purpose, then the shipyard focused on construction, equipment and repair of ships intended for cruising as well as the supply of ships [10-18].

The number of passengers on cruise travel in the world reached 20.6 million in 2012 (Figure 1), and it is estimated to reach 20.97 million passengers in 2013 [19].

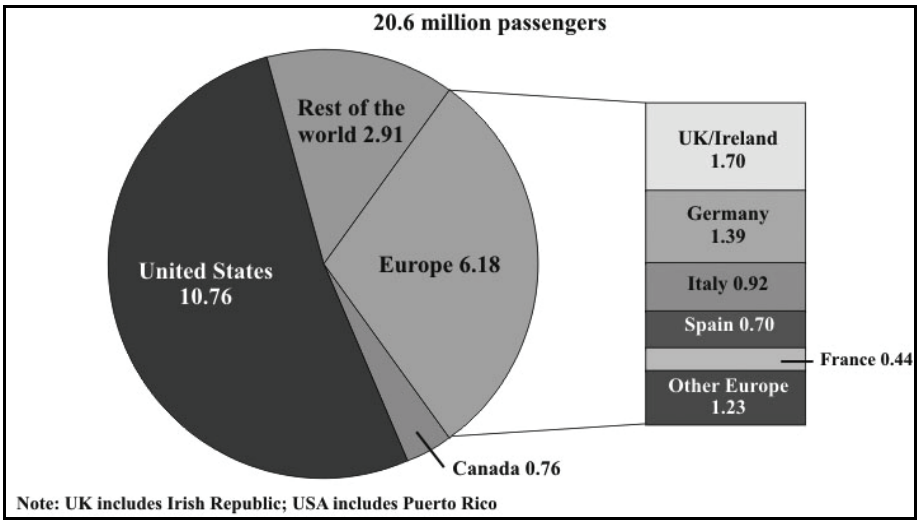

Fig. 1. Number of passengers on cruise travel in the world [19]

Demand for new destinations, increasing price competitiveness, branding cruise companies, shorter trips than in previous period, as well as changes in the profile of con-

sumers in the global tourism market have strongly influenced the continuity of growth in the number of cruise tourism passengers. Accordingly, the marketing approach to cruise tourism has gained in importance, as well as the fact that consumers of cruise tourism services are becoming more critical to the ratio between the quality and price. A new generation of cruisers is designed to meet the needs in growing segmentation of the cruise tourism market. Thus, the cruise tourism is not only a growing market, but also a growing segmented market. Accordingly, we can notice the evolution of the cruise vacation experience since cruise tourism may be described by the concept of experience economy (memory itself becomes the product - the "experience"). The best experience/popularity belongs to the following cruise tourism regions [19]:

1. Caribbean/North America (including Pacific Northwest and Alaska currently);
2. Europe and Mediterranean (largest percent of increased bookings for 2012);
4. Baltic fjords (summer only);
5. Asia/Australia;
6. South America; and
7. Middle East – an emerging region.

There are some specific characteristics of the cruise tourism [16] that attract tourists:

- Passengers have the opportunity to visit different destinations in a short period of time;
- Cruisers have the required autonomy and represent the destination for themselves;
- Cruisers have a staff that is fully committed to a pleasant and enjoyable stay of passengers on board;
- Availability of high quality gastro–offer and entertainment, etc.

Modern development projects in the area of cruise tourism are related to the increase of investment in passenger terminals at cruise destinations in order to meet the needs of a new generation of mega-cruisers. From the European perspective it is important to say that cruising makes significant contribution to the European economy, sustaining jobs in shipyards, creating employment in European ports and supporting overall European tourism development. However, there are also some significant obstacles to future cruising growth given in the economic crisis and rising fuel costs [19].

2.1 Port of Kotor as cruise tourism destination

In cruise tourism, seasonality is less emphasized, which gives the possibility of extended season, which is primarily the focus for Montenegrin tourism development in order to achieve sustainable development, as well as sustainable destination management. Due to constant demand for new destinations and few positioned Adriatic destinations, the Port of Kotor has a relevant potential for branding itself as a distinctive Mediterranean destination. In this field, the competition is growing, so the improvement of technological and organizational issues in the Port of Kotor, as well as the port services and standards are a necessity. This includes investments in infrastructure and superstructure in order to facilitate sustainable development and environmental protection, but also implementation of some measures, which include limitation of the number of tourists from the cruise ships, as well as giving priority to companies that organize cruising in low season. When it comes to cruising destinations such as Kotor, which is in the beginning stage of positioning itself on the global tourism market, there is a need to forestall the insufficiently controlled development of some distinctive cruising destinations (Figure 1). The travel

experience in some cruise tourism destinations consists of a number of different value chains with many participants involved, from employees at ports, tourist guides, those employed in retail, security guards, etc. This is because tourists tend to have the perception of "tourism experience of great value" only if all participants in the value chain maintain adequate quality of service and if there is perception of an integrated tourism destination product (Figure 2).

Besides previously noted, the contemporary ICT components must be included into the port offer, in order to increase the overall quality of its service. How the Port of Kotor is in fact positioned nowadays among the group of several considered European ports due to e-services they offer is analyzed in more detail in the next sections of the paper.

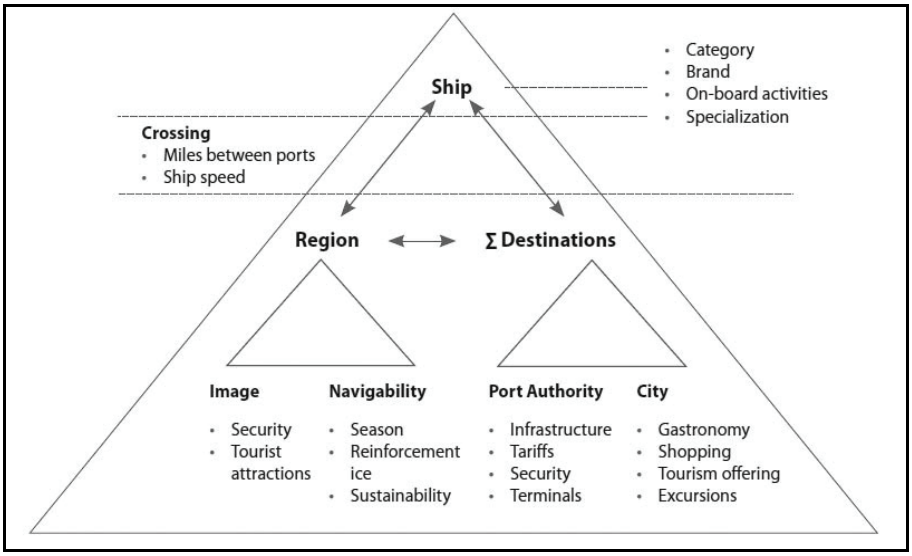

Fig. 2. Cruise tourism as a product from destination perspective [20]

3. ICT-based cruising port positioning

The purpose of the paper is two-fold: (a) to emphasize the growing demand in the sphere of cruising tourism in order to promote it, and (b) to identify, classify, and evaluate some crucial e-services of the passenger ports in this context. In the previous section some key points on the nautical (cruise) tourism phenomena with reference to the port of Kotor have been given, while in this section - ten most frequent EU passenger ports and the Port of Kotor have been analyzed [5, 6, 21-31] and mutually compared on the web-based ICT resources, i.e. according to the specific e-services they offer. At the end, the accent is given again to the port of Kotor [31], with the intention to position it properly, and to propose the potential solutions for its e-services and an enrichment of the general offer (in the wider sense) in the nearest future.

Within this context, prior to concrete analysis, the difference between ports of call (the geographical point where a cruise ship stops for a short time, especially on a journey [32]), and embarkation (home) ports (the geographic point in a routing scheme from which passengers and/or personnel depart [32]) should also be pointed out. The difference between these types of ports derives in fact from different needs they have to fulfil. There are also hybrid ports. Having this in mind, it must be highlighted that in this paper the considered ports:

– P1: Southampton (UK);
– P2: Limassol (CY);
– P3: Dover (UK);
– P4: Calais (FR);
– P5: Helsingborg (SE);
– P6: Barcelona (ES);
– P7: Palma de Mallorca (ES);
– P8: Venice (IT);
– P9: Genoa (IT);
– P10: Civitavecchia (IT); and,
– P11: Kotor (MN),

are all treated as ports of call. Then, by surveying the official web sites of the above listed cruise ports and previous research work in this field [5-8,21-31], more than seventy e-services have been recognized as relevant, and they are included in further analysis (web analyses have been done in July, 2012). The considered cruise ports e-services have been categorized in five different categories: c – core, v – value-added, i – informational, i/t – informational and/or transactional ones, and t – transactional. Then, for each of the considered ports it has been identified whether the port has (1) or has not (0) a certain e-service within its e-offer. The list of e-services and the corresponding binary values of each of the eleven examined passenger ports are given in Table 1.

Table 1. E-services of eleven considered passenger sea ports: categories and values (Research realized in July, 2012)

Some passenger's port e-services	c/v	i/t	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Tourist information center (virtual desk)	v	i	1	1	0	1	0	1	0	0	0	1	0
Accommodation	c	i/t	1	1	1	1	1	1	1	1	1	1	1
Booking possibilities	v	t	1	0	1	0	0	1	1	1	0	1	0
Transport	c	i/t	1	1	1	1	1	1	0	1	1	1	0
Car parking information	v	i/t	1	0	1	0	0	0	0	0	0	0	0
Information on parking charges	v	i/t	1	0	1	0	0	0	0	0	0	0	0
Map of the location of car parks	v	i/t	1	0	1	0	0	0	0	0	0	0	0
Spaces available (current state)	v	i/t	1	0	0	0	0	0	0	0	0	0	0
Bus information	c	i/t	1	0	1	1	1	1	0	0	0	1	0
Travel tickets	v	i/t	0	0	1	0	0	1	0	0	0	1	0
Discount card	v	i/t	0	0	0	0	0	1	0	0	0	0	0
Taxi	v	i/t	0	1	0	0	0	1	0	0	0	0	0
Renting vehicles	v	i/t	0	0	0	1	0	0	0	0	0	1	1
Renting vehicles on-line	v	i/t	0	0	0	1	0	0	0	0	0	1	0
Rail and coach information	c	i/t	1	0	1	1	1	1	0	0	0	1	0
Sea information	c	i/t	1	1	1	1	1	1	1	1	1	1	0

Airport	c	i/t	1	0	1	1	0	1	0	1	0	1	0
Airport guide: the latest news	v	i/t	1	0	1	0	0	0	0	0	0	1	1
Language	v	i	0	1	0	0	0	0	1	0	0	0	0
Currency	c	i	0	1	0	0	0	0	1	0	1	0	0
Calculator	v	i	0	0	0	0	0	0	0	0	1	0	0
Exchange offices	v	i	0	0	0	0	0	0	0	0	0	0	0
Bank services	v	i	0	0	0	0	0	0	0	0	0	0	0
Maps	c	i	1	1	1	1	1	1	1	1	1	1	1
Leaflets, brochures	v	i	0	1	0	0	0	1	1	1	0	1	0
Restaurants and bars	c	i	1	1	1	1	1	1	1	1	1	1	0
Shopping	c	i	1	1	1	1	1	1	1	1	1	1	0
Duty free shops	v	i	1	0	0	0	0	0	0	0	0	0	0
Malls, markets	v	i	0	0	0	0	0	1	0	1	0	0	0
Shopping on-line	v	i/t	0	1	0	0	0	1	0	0	0	0	0
Events	v	i	1	0	1	1	1	1	0	0	0	0	0
Special events tickets	v	i/t	1	0	0	0	0	1	0	0	0	0	1
Nightlife	v	i	1	0	0	0	0	1	0	0	0	0	0
Tickets on-line	v	i/t	1	0	0	0	0	0	0	0	0	0	0
Casinos	v	i	1	0	0	0	0	0	0	0	0	0	0
Casinos on-line	v	i/t	1	0	0	0	0	0	0	0	0	0	0
Excursions	v	i/t	0	1	1	1	1	1	0	1	0	1	0
Sightseeing	c	i	0	0	1	0	1	1	1	1	0	1	0
Gondola rides	v	i	0	0	0	0	0	0	0	1	0	0	0
Walking routes	v	i	1	0	0	0	1	1	0	0	0	1	0
Pedestrian routes	v	i	1	0	0	0	0	1	0	0	0	0	0
Biking zone	v	i	0	0	0	0	0	1	0	0	0	0	0
What to see and do?	c	i	1	0	1	0	1	1	1	1	0	1	0
Top free sights	c	i	0	0	0	0	1	1	0	1	0	0	1
Fisheye	v	i	0	0	0	0	0	0	0	1	0	0	1
Videos	v	i	0	0	0	0	0	0	0	1	0	0	1
Parks	v	i	1	0	0	0	0	1	0	0	0	0	0
Art Galleries	v	i/t	1	0	0	0	0	1	0	0	0	0	0
Museums	v	i/t	1	0	0	0	0	1	0	0	0	0	0
Theatres	v	i/t	1	0	0	0	0	0	0	0	0	0	1
Sports	v	i/t	1	0	0	0	0	0	0	0	0	0	0
Weather	c	i	0	1	1	1	1	1	1	1	0	0	0
Cruise passenger information	c	i	1	1	0	1	0	1	1	0	1	0	1
Cruise terminal(s) location (map)	c	i	1	0	0	1	0	1	0	0	0	0	1
Cruise terminal(s) facilities	c	i	1	1	0	1	0	1	0	0	0	0	0
Crew information	v	i	1	0	0	0	0	0	0	0	1	0	0
Crew members infor-mation	v	i	1	0	0	0	0	0	0	0	0	0	0
Seafarers center	v	i	1	0	0	0	0	0	0	0	0	0	0
Telecommunications	c	i	0	0	0	1	0	1	0	0	0	0	0

Telephone	c	i	0	0	0	0	0	1	0	0	0	0	1
Internet access	c	i	0	0	0	0	0	1	0	0	0	0	1
WiFi centers	c	i	0	0	0	1	0	1	0	0	0	0	0
Visitors with disabilities	v	i	1	0	0	0	0	0	0	0	0	0	0
Parking	v	i	1	0	0	0	0	0	0	0	0	0	0
Toilets	v	i	1	0	0	0	0	0	0	0	0	0	0
Shop mobility	v	i/t	1	0	0	0	0	0	0	0	0	0	0
Environmental protection	v	i	0	0	0	0	1	0	0	0	0	0	0
Links	c	i	1	1	1	1	1	1	1	1	1	1	0
Other	v	i	1	1	1	1	1	1	1	1	1	1	1

In the first step, for each of the ports, the overall scores (sums of values equal to one) for value-added e-services have been calculated in Excel by formula (1):

=SUM(IF(D2=1,IF($B2="v",1,0),0)) (1)

The obtained positions of the ports due to the value-added e-services they offer are shown in Figure 3. Similarly, in order to make the ports mutual positioning, according to the number of transactional, or informational and/or transactional e-services that they make available to the passengers, the following formula has been applied (2):

=SUM(IF(D2=1,IF(OR($C2="t",$C2="i/t"),1,0),0)) (2)

The positions of the ports gained by the calculus based on formula (2), according to the number of transactional, or informational and/or transactional e-services which they offer, are shown in the form of the perception map in Figure 4.

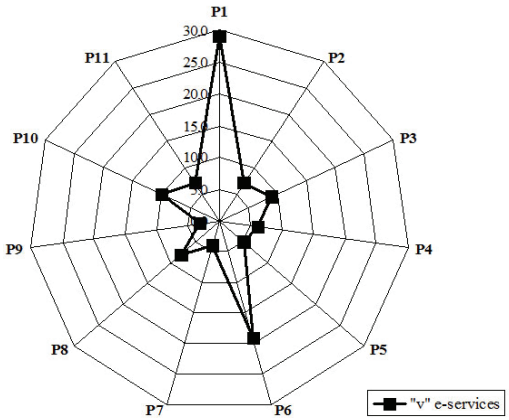

Fig. 3. Positions of passenger ports due to the value-added e-services

In the third analyzed case, the situation is a little bit more complex. Here, namely, there is an intention to position (rank) the considered passenger ports according to all the previously identified types of e-services they offer: c – core, v - value-added, i – informational, i/t – informational and/or transactional ones, and t – transactional. It is clear: if a certain port offers an e-service, that e-service will correspond to the numerical value 1, and otherwise, it will correspond to the numerical value 0. However, the main question is:

how will the different types of e-services be pondered, or how will they impact the total scores? In order to answer this question, the authors interviewed ten respondents who are experienced in passenger port operations, sea ports marketing, and (cruise) tourism, and who have high level of logical thinking to rank the considered types of e-services according to their importance to the passengers and ports development. It is important to emphasize here that the estimation, or opinion, of only one highly qualified expert may be more important than the estimates made by a number of inexperienced persons [33]. However, for the purpose of this research, the highly qualified and experienced respondents have been asked to compare each pair of different types of passenger port e-services (c, v, i, i/t, and t) according to the Saaty [34] scale by using the grades: 1 - same importance; 3 - slightly more importance, 5 - moderately more importance, and 7 - strongly more or absolute importance of the first over the second considered criterion; or, by the corresponding reciprocity values depending on the mutual importance of the compared elements composing certain criteria pair(s). Although ten competent persons were asked to create the Saaty matrices, only six matrices were taken into further consideration as the consistent ones. The selected matrices are given in Table 2.

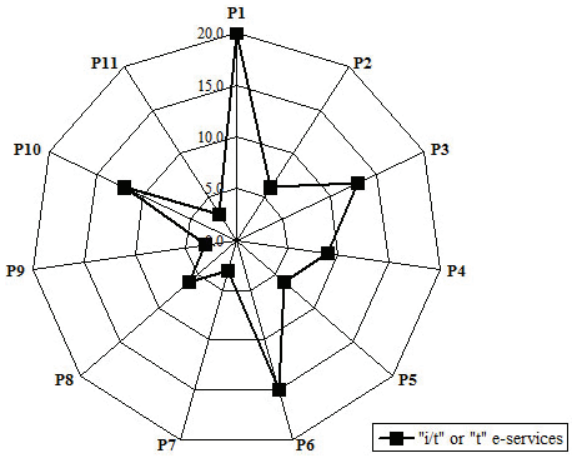

Fig. 4. Positions of passenger ports due to the transactional and informational/transactional e-services

Table 2. Saaty matrices formed by respondents and consistency indices

Respondent 1						Respondent 2					
	c	v	i	i/t	t		c	v	i	i/t	t
c	1	1/5	1	1/5	1/7	c	1	1/3	1/3	1/5	1/7
v	5	1	3	1/3	1/5	v	3	1	3	1/3	1/5
i	1	1/3	1	1/5	1/7	i	3	1/3	1	1/5	1/7
i/t	5	3	5	1	1/3	i/t	5	3	5	1	1/3
t	7	5	7	3	1	t	7	5	7	3	1
$\lambda_{max} = 5.22473$; $CI = 0.05618$; $CR = 0.05016$						$\lambda_{max} = 5.28557$; $CI = 0.07139$; $CR = 0.06374$					
Respondent 3						**Respondent 4**					
	c	v	i	i/t	t		c	v	i	i/t	t
c	1	1/3	1	1/5	1/7	c	1	1/5	1	1/5	1/7
v	3	1	1/3	1/3	1/5	v	5	1	3	1/3	1/5
i	1	3	1	1/3	1/5	i	1	1/3	1	1/5	1/7
i/t	5	3	3	1	1/3	i/t	5	3	5	1	1/5
t	7	5	5	3	1	t	7	5	7	5	1

$\lambda_{max} = 5.40989$; $CI = 0.10247$; $CR = 0.09149$						$\lambda_{max} = 5.34840$; $CI = 0.08710$; $CR = 0.07777$					
Respondent 5						**Respondent 6**					
	c	v	i	i/t	t		c	v	i	i/t	t
c	1	1/3	1	1/5	1/7	c	1	1/3	1	1/5	1/7
v	3	1	1	1/3	1/5	v	3	1	3	1/3	1/5
i	1	1	1	1/5	1/7	i	1	1/3	1	1/5	1/7
i/t	5	3	5	1	1/5	i/t	5	3	5	1	1/5
t	7	5	7	5	1	t	7	5	7	5	1
$\lambda_{max} = 5.25864$; $CI = 0.06466$; $CR = 0.05773$						$\lambda_{max} = 5.28520$; $CI = 0.07130$; $CR = 0.06366$					

By the normalized eigenvector values calculus, the ranks of the considered types of e-services have been calculated, along with the values of the largest eigenvalue λ_{max}, and the consistency index CI, while the random index RI is equal to 1.12 in all cases, since the number of criteria is constant and equal to five. It is obvious (Table 2) that all CR values, for each considered matrix, are less than 0.1, which is to be fulfilled in order to provide a satisfying degree of the Saaty matrix consistency [34].

The overall rank of the considered types of e-services which the analyzed ports offer is calculated by the standard statistical procedure and it is given in the last column of Table 3 [33,35]. It is based on subjectively estimated importance of the considered types of e-services by the interviewed experts. More explicitly, the idea of evaluating the final rank or normalized weight coefficients per each type of e-services is associated with the sum of ranks of each criterion c_q, with respect to the estimates of the respondents:

$$c_q = \sum_{r=1}^{6} c_{qr}\ ,\ q = \overline{1,5} \tag{3}$$

where:

c_q is the sum of ranks of each e-service type, while q is the number of different types of e-services (here 5), and r is the number of experts, or respondents (here 6); and,

c_{qr} is the rank of the q-th criterion estimated by the r-th respondent.

Now, the average weight coefficient for each of the analyzed type of the e-services can be calculated by the following formula:

$$\overline{w}_q = \left[c_q \Big/ \sum_{q=1}^{5} c_q \right]^{-1} . \tag{4}$$

Finally, the normalized average weight coefficients are to be calculated by formula (5):

$$\overline{w}_{qn} = \overline{w}_q \Big/ \sum_{q=1}^{5} \overline{w}_q . \tag{5}$$

Table 3. Ranks of different types of passenger port e-services

E-service types	Respondents						$\overline{W}_q$	$\overline{W}_{qn}$	Rank
	R1	R2	R3	R4	R5	R6			
c	5	5	5	5	5	5	3.000000	0.087848	**5**
v	3	3	4	3	3	3	4.736842	0.138707	**3**
i	4	4	3	4	4	4	3.913043	0.114584	**4**
i/t	2	2	2	2	2	2	7.500000	0.219620	**2**
t	1	1	1	1	1	1	15.000000	0.439240	**1**

In order to examine the level of consistency of the respondents' estimates (Table 2), as the last step of the e-service different types ranking, the concordance coefficient W is to be calculated as well, through the following calculus (6):

$$W = 12S / r^2 q\left(q^2 - 1\right) \tag{6}$$

where:

$S = \sum_{q=1}^{6}\left(c_q - \sum_{q=1}^{6} c_q\right)^2$ - is analogue to the variance of the ranks;

r is the number of the respondents (here 6); and,

q is the number of criteria, or the number of the e-service types (here 5).

Now, the smallest value of W, i.e. W_{min} is to be calculated by formula (7):

$$W_{min} = \chi^2_{\alpha,v} / r(q-1) \tag{7}$$

where:

$\chi^2_{\alpha,v}$ is the critical chi-square statistics, found in the table [33, 35, 36] by assuming the degree of freedom $v = 5 - 1$, and the significant level $\alpha = 0.010$. Here, it is $\chi^2_{\alpha,v} = 13.28$. By taking into account the previous assumptions $W_{min} = 0.553$, while $W = 0.972$. Since the condition $W_{min} \le W$ has been satisfied, it implies that the estimates of the respondents are quite consistent.

Finally, on the basis of the final values of normalized weight coefficients per each type of e-services (Table 3, i.e. by means of $\overline{w}_{qn}$ values), it becomes possible to calculate the positions of the eleven examined passenger ports by the following formula created in Excel (8):

=SUM(IF(D2=1,IF($B2="v",0.14,0.09),0),IF(D2=1,IF($C2="t",0.44,IF($C2="i/t",0.22,0.11)),0)) (8)

This means, as in the previously explained cases, that if the observed passenger port offers a certain e-service it is assigned 1, and otherwise, if it does not offer such service, it is assigned 0. Furthermore, if the noticed e-service is a core one (c), it will be pondered by 0.09, but if it is a value-added one (v), it will be pondered by 0.14.

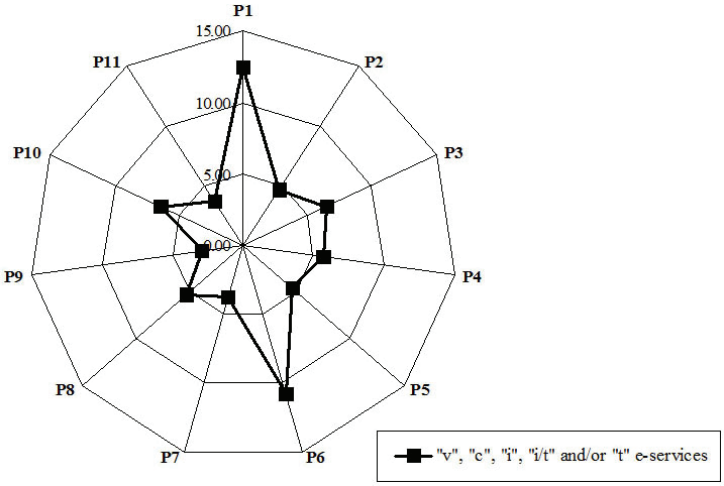

Fig. 5. Positions of cruise ports according to all considered e-services which they offer to the passengers

If a certain e-service is informational, it will be multiplied by 0.11, if it is informational and/or transactional (i/t), it will be pondered by 0.22, and finally, if it is transactional (t) one, it will be pondered by 0.44. The respective perception map of the positions of the analyzed ports from the aspect of e-services they offer and on the basis of the six experts' responds is shown in Figure 5. The obtained positions might be treated as relevant indicators of their competitiveness at the corresponding passenger (cruise) port e-market. The obtained *final* positions of the analyzed cruise ports according to e-services which they offer (on the basis of web surveys realized in July, 2012) are given in Table 4, as well.

Table 4. Positions of the analyzed ports according to available web-based e-services

Rank	**Port**	**Numerical values** (see Eqv. (8))
1	P1: Southampton (UK)	12.47
2	P6: Venice (IT)	10.82
3	P3: Dover (UK)	6.50
4	P10: Genoa (IT)	6.44
5	P4: Civitavecchia (IT)	5.69
6	P8: Helsingborg (SE)	5.28
7	P2: Barcelona (ES)	4.66
8	P5: Calais (FR)	4.51
9	P7: Limassol (CY)	3.75
10	P11: Kotor (MN)	3.70
11	P9: Palma de Mallorca (ES)	2.88

These positions (by this research obtained as *final* port rank) could not be treated as "absolutely" right ones, or as indeed "final" ones, but this survey should be used as an idea: how cruise ports (re)positioning might be done, or as the starting base for further more detailed and rigorous investigation in this domain. On the basis of these results, the port management, other responsible entities and/or stakeholders might get insight into what is to be done toward positive repositioning of the ports and through enriching their web-based e-service offer to the cruisers. It is to be mentioned as well, that there are some additional e-services that can be found on the web sites of some relevant passenger ports

which are not included into this research. Ports of New York [37] and Rotterdam [38] e.g., supply the customers with some e-services that are not included into the list of different e-services used in this research work. Such e-services are: detailed information about passenger embarking/disembarking (embarking from buses, limousines, taxies, private vehicles, and disembarking upon returning from the cruise in opposite order), etc. Also, the mentioned ports (New York and Rotterdam) offer actual lists of cruiser calls, as well as relevant nautical information about the port and the cruise terminals. Port of Rotterdam e.g. offers ship repair capabilities within cruise facilities and services. Some ports offer possibilities of authorisation for some special (intranet or extranet) services, some ports offer possibilities of authorisation for different types of green cards, etc. So, all these should be also included into further research work in this field.

4. Research results and Port of Kotor (re) positioning

There are many quantitative methods that can be used to measure the degree of port competitiveness and allow their mutual comparison and positioning on the market. The detailed survey of their applications in sea port positioning is given in [36]. In this paper the combination of binary approach for the purpose of sublimation of a rather large number of employed criteria (i.e. cruise port e-services) and Saaty method for ranking particular categories of considered criteria, or e-services here (core, value-added, informational, informational/transactional, and transactional) have been used. On the basis of the numerical results obtained by conducting these quantitative approaches and the related quantitative analysis of the passenger (cruise) port e-services, primarily in the function of cruise tourism promotion, it becomes obvious that the Port of Kotor is averagely positioned among analyzed ports according to the value-added e-services it offers (see Figure 3), and that it is rather low positioned for other and all (together) treated e-services (see Figures 4 and 5). One of the aims of the paper is to offer possible directions toward improving this situation, i.e. toward repositioning of the Port of Kotor and making it thus more competitive on the respective cruise tourism market. However, the following recommendations might be offered:

- Concerning the value-added e-services offered by the eleven ports analysed in this paper, the Port of Kotor is on the seventh position, which is an average score. The Port of Kotor is on this position owing to the following value-added services it offers: renting vehicle possibilities, airport guide existence, offering the latest relevant (local) news, special events tickets offering, etc. As models or *ideal* ports toward which the Port of Kotor should be repositioned in a positive sense are ports of Southampton and Venice in the first place (see Table 1 for more detailed insight into their value-added e-service offers).
- In case of the cruise ports mutual comparison or positioning according to the informational and/or transactional, or exclusively transactional e-services, the Port of Kotor is at the lowest position. It says that it offers the smallest number of such e-services, i.e. only: those about taxi services and airport services in general, and some information concerning local museums. Additionally, the information are (only) informational, not transactional, which is undoubtedly another huge qualitative disadvantage of Kotor as a cruise port of call.
- According to all types of considered e-services (see Figure 5), the Port of Kotor is on the tenth position, which is a pretty *poor* score, and it speaks in favour of immediate need for its repositioning towards a “better score”. As models for its repositioning in

a positive sense the ports of Southampton and Venice should be considered again, and some of e-services they offer (see Table 1) should be included into the Port of Kotor offer as a growing Adriatic/Mediterranean cruise destination. For instance, a broad palette of new services should be included into the Port of Kotor e-offer, such as: accommodation booking possibilities; some relevant sea information; information on exchange offices; news about cultural events; information about galleries; Wi-Fi access availability information; special information for visitors with special needs (disabilities), environmental protection information – these, of course, imply physical existence of related opportunities.

Within the Conclusion, some general recommendations, along with a few very precise quoted ones, obtained on the basis of quantitative analysis, aiming cruise port ICT modernisation, which can be applied in a certain manner to the Port of Kotor as well, are pointed out, in order to *reach* the responsible bodies for providing its sustainable development as a rising cruising destination in the Mediterranean.

5. Conclusions

The digital revolution has changed the business and consumer trends in general [3-6]. Consequently, it has certain reflections to the passenger ports and to the passengers' expectations in the context of cruise tourism. With advent of ICT-enabled smart networking business models and the passenger port services are nowadays considered as "augmented" procedures, since their traditional physical nature is on the road to be overplayed by informational and electronic transactions components. However, it is not to be forgotten, that cruising is still a physical act and all passenger (cruise) ports still need passenger terminals and all required, following, real-physical capacities and features. Thus, the ICT capacities are the *tip of the iceberg*, requiring adequate passenger port infra and suprastructural capacities, adequate organizational, strategic development and numerous other structural, financial, organizational and environmental issues which in fact form the core base of ICT virtual superstructures. Furthermore, a new, unique taxonomy for systematic identification, assessment and selection of individual passenger port e-services is to be adopted and it is to be based on additional, more extensive research and evaluation efforts in this domain [5, 6]. In line with the previously noted, the comparative analysis of the availability of e-services and traffic intensity should be realized as part of next research steps in this domain. Besides these rather general conclusions, on the basis of research conducted in the paper, the following more precise conclusions might be derived as well:

- Some relevant e-services of eleven analyzed cruising ports in EU, including the Montenegrin Port of Kotor as cruising one, have been identified and categorized;
- The relatively large number of identified e-services have been sublimed per each category by simple binary approach, as a way of data pre-processing for the following quantitative and qualitative analysis;
- Multi-expert choice expressed in the form of Saaty matrix and the corresponding mathematical analyses [33-36] have been used for ranking the considered e-service categories;
- The *final* rank of the analyzed cruise ports is determined by combining binary and Saaty approaches (see Table 4 for final numerical results);
- On the basis of conducted calculus for each (all) type(s) of considered e-services, it becomes clear that ports: Southampton and Venice should be treated as models or *ideal* cruise ports for positive repositioning of all the other ports considered in this

paper on the (global) cruise port market (see Table 1 for some more details on e-services they offer); and,

- The Port of Kotor should be repositioned according to all explored categories of e-services especially regarding the transactional ones.

These observations should be used as a particular base for further more detailed and rigorous investigation in this challenging sphere, concerning cruise ports development and their proper (re)positioning at the (global) permanently and rapidly developing cruise port market.

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Chapter 3:
Modeling general corrosion losses over ageing bulk carriers

3. Preface

This chapter includes three research studies on the damage of the ship's hull and fuel tanks of bulk carriers caused by general corrosion. As a basis for these researches, it was used an extensive database in the possession of an accredited private company for testing corrosion damage on ships by ultrasonic measurements. Key segments of the hull structure were analyzed, including fuel tanks, in order to develop a predictive model of corrosion damage during the exploitation cycle. The research used data from the ships that were in exploitation for shorter (5-15 years) and longer (15-25 years) periods.

For estimating the corrosion degree was initially used the Monte Carlo simulation model, and later the Weibull probabilistic method. Both have shown a large data scattering, which puts into question the reliability of these approaches. However, undoubtedly was confirmed that the inner bottom and hopper plating, as well as certain fuel tank segments, were the most sensitive to corrosion degradation. It was also unambiguously proved that early start with proper maintenance coincided with slowing down of corrosion process.

Further research in this area should be carried out on a larger sample of appropriate homogeneous historical data, with the inclusion of other probabilistic or heuristic models. This issue is very important, primarily due to the prevention of fatal ship hull damage and the avoidance of vessel sinking caused (or accelerated) by corrosion degradation.

3.1. On fuel tanks' of aged bulk carriers' corrosion wastage

This work deals with two different approaches in modeling corrosion wastage over the fuel tanks' structures at the exemplar of ten aged bulk carriers. The first applied method might be treated as a short term, rather random oriented one, and it is based on Monte Carlo simulation technique. This technique has been used in creating an appropriate predictive model for the characteristic steel damages over the bulk carriers' fuel tanks caused by general corrosion in relatively short time interval, of two years, within the period between the 5th and the 25th year of the bulks' operational life. The second employed method might be treated as a long term one, and it is based on some Weibull distribution analysis. The purpose of these analyses is optimal assessing of the average corrosion losses for the bulk carriers' fuel tanks areas at different points of time during the whole circle of the exploitation, within the ultimate goal of uprising the structural stability and safety of bulk carriers in operation.

1. Introduction

It is well-known that the corrosion is a serious problem for anything built of metal and exposed to the elements, but for any kind of ships, including here bulk carriers, it can be fatal. Corrosion is likely to be more extensive here and work more rapidly than on other structures, simply because the bulk carriers are under the complex influence of salt water, and simultaneously exposed to some unpredictable atmosphere, cargo and ballast effects. More precisely, aggressive environment, specifics of the trade routes, dry and wet ballast circles, ratio of ballast and cargo, frequencies of cargo loading/unloading operations, manipulative techniques, etc. often affected serious bulk carriers' deteriorations caused by the corrosion. It is also to be emphasized that the corrosion might be intensified by the negative effects of some cargoes, especially those like iron ore and coil [1]. Though, during the past two decades, several casualties of bulk carriers have occurred while they were under operation and the possible causes for such casualties is thought to be the structural failure affected by the corrosion being intensified by rough sea and weather conditions. While protective paintings, cathode protection, and (or) tanks careful washing out are often employed, this is not always the case and, for variety of reasons, they may not be wholly effective. Thus, the particular attention is to be given to the harsh nature of the cargoes, loading/unloading operational procedures, as well as, to the regular measurements and reporting on the ships' structural deterioration due to the corrosion. These, however, is much easier to say than to done [2;3;4].

The frequent references to the iron ore, or coal, are significant because once laden bulk cargo carriers get into trouble, the consequences can be very sudden. The bulk carriers are design to withstand bad conditions, but not to operate with several holds flooded and the combination of iron ore and a sudden inrush of sea water resulting in more weight than the structure can stand. Besides, cargo hendling methods (loading/unloading operations) have also be criticized. Part of the problem is that modern loadning and unloading techniques are developed long after the bulk carriers they are intended to load/unload be built. Due to the ispections of the corrosion lost, there is also a great deal of steelwork to be checked. It is usually a daunting task that requires spacial staging, artificial light and a great amount of stamina on the part of the surveyor or surveyors being involved [5]. But, nevertheless, the considerable efforts have been permanently done, aiming to prevent the huge accidents that can be caused by bulk carriers sinking, and causing people death and environmental pollution. Accordingly, this paper should be a modest contribution to this ultimate goal.

2. The problem definition

For the purpose of this research work a large data base has been provided by the recognized ultrasonic measurements Company1. These data were collected through the standardized, numerous, and very detailed measurements over all hull structure members of the group of ten aged bulk carriers. However, in this article, only bulk carriers' fuel tanks time-dependant deteriorations caused by the general corrosion have been analyzed in some detail, in both short and long terms. The main reason for this, lies in the fact that such kind of problem is not enough covered by the previous research works in the field, due to our knowledge and some literature surveys [1-4;6-9]. Previously were treated mostly cargo holds and ballast tanks [8;9]. Though, within the first part of the paper, Monte Carlo simulation method has been used for assessing the value of damaged steel, expressed in percentage of the standard steel thickness, over certain fuel tank area, that should be removed (replaced) during arbitrary selected two years intervals of the bulk's exploitation cycle, within the period between the 5th and the 25th year of its operational life. The second part of the paper contains some Weibull probability analysis upon some cumulative negative time-dependant fuel tanks corrosion effects in long terms, i.e. during the whole period of their exploitation, or in other words, within the complete time interval between the 5th and the 25th year of the vessels' operating. Let us note here that the corrosion process usually does not start before the 5th year of the exploitation [6-9].

Though the particular details related to the bulk carriers' structure in a pure mechanical and engineering sense are not included into the content of this research, it is to be mentioned that the fuel tanks may be found in the top side tanks, double bottom tanks, or deep tanks, but the subject of this article are oil (fuel) tanks placed only in double bottom areas. These oil tanks are usually spatially positioned along the main axis of the bulk carrier, but they can also be placed perpendicularly on it. These tanks placed along the main axis (Figure 1.a) can be arranged with pipe tunnel (Figure 1.b), or without it (Figure 1.c). The second mentioned case has been employed within the following simulations and probability analysis.

[1] Invar-Ivosevic Ltd., URL: http://www.invar.me/index.php?option=com_content&view=article&id=45:invar, last access: October, 2017

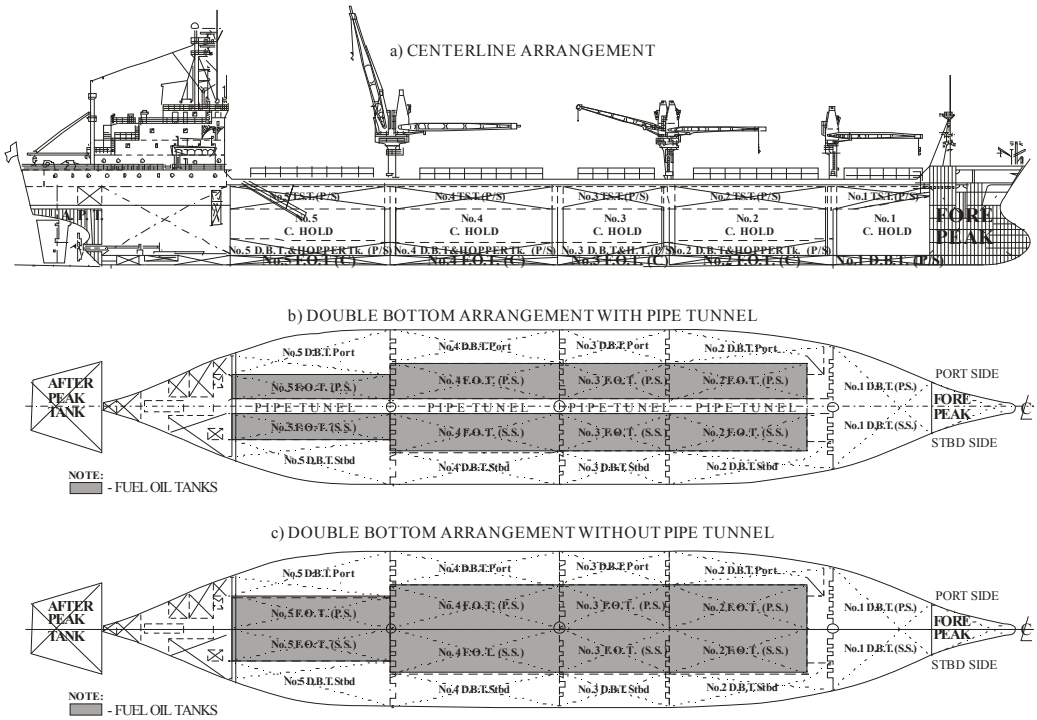
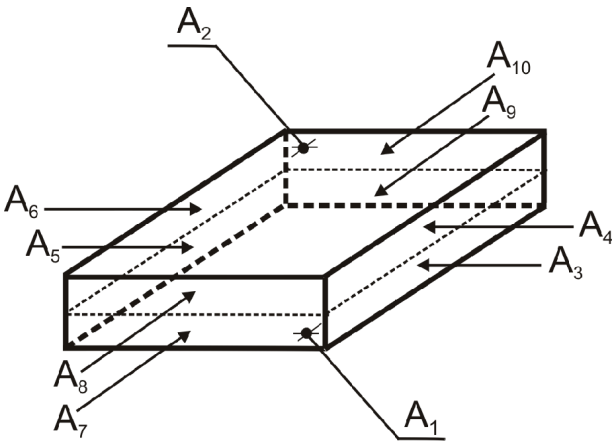


Fig. 1. Bulk carriers' different arrangements of fuel tanks: a) centerline, b) double bottom with pipe tunnel, c) double bottom without pipe tunnel

3. The input data set brief description

In accordance with the corrosion measuring standards and some characteristics operational parameters, the considered bulk carriers' fuel tanks are analyzed here throughout ten different segments, areas, or member locations. The analyzed segments are presented schematically and listed below in the form of the legend in Figure 2.

The cumulative data on the general corrosion lost expressed in percentages (%) of the standard average steel thickness, collected through the regular measurements (inspections on site), during the previous decade by the survey Company[1], are given in Table 1. The data are gathered over each of the previously noted area of the fuel tanks, through 10 ($BC_{1,7\text{-}10}$), or 20 different sections ($BC_{2\text{-}6}$), depending of the number of fuel tanks, with total 3,356 gauged points, for both the left, or portside (P) and the right, or starboard (S) side of the considered bulk carriers ($BC_{1\text{-}10}$). The data were collected by the regular, intermediate and special surveys, in a way that each tank has been divided into 5 sections: two sections for after and fore ends, and three sections at equal mutual distances in the middle, between ends of tanks.



Legend:
A_1 – Bottom plate
A_2 – Inner bottom plate
A_3 – Pipe tunnel (water tight), lower
A_4 – Pipe tunnel (water tight), upper
A_5 – Side (water tight) girder, lower
A_6 – Side (water tight) girder, upper
A_7 – Floor after (water tight), lower
A_8 – Floor after (water tight), upper
A_9 – Floor fore (water tight), lower
A_{10} – Floor fore (water tight), upper

Fig. 2. The basic structural scheme of a bulk carrier's fuel tank areas (A_1 to A_{10})

The bulk carriers: BC_1, and $BC_{7\text{-}10}$ are of the different construction than the rest of the examined vessels. Though, since they do not have, in fact, the areas A_5 and A_6, as the constitutive parts of their fuel tanks, they were in these segments partly excluded from some of the simulation analysis.

Table 1. Corrosion loss expressed in the percentages (%) of the standard steel thickness over different bulk carrier fuel tanks' areas during the 20 years of the bulks' exploitation circle (P-portside and S-starboard ship's side)

		Percentages (%) of the steel thickness damages									
Bulk carrier		BC_1		BC_2		BC_3		BC_4		BC_5	
Portside/Starboard		P	S	P	S	P	S	P	S	P	S
Fuel tanks' areas	A_1	1.8	1.9	1.2	1.1	1.7	2.1	1.3	1.4	1.3	1.3
	A_2	9.9	8.5	8.2	7.8	6.0	5.9	17.9	19.3	21.9	21.6
	A_3	1.5	1.6	1.1	1.2	1.9	1.5	0.0	0.0	0.0	0.0
	A_4	1.1	0.8	1.1	1.2	1.2	1.3	0.0	0.0	0.0	0.0
	A_5	0.0	0.0	13.3	16.5	19.6	28.0	2.1	1.9	6.2	9.2
	A_6	0.0	0.0	16.7	19.7	20.6	28.9	3.4	11.6	27.8	30.8
	A_7	1.7	1.4	11.6	13.1	13.1	12.7	2.7	2.8	9.1	8.8
	A_8	2.4	2.1	16.3	18.6	17.7	18.0	4.0	4.0	14.6	15.8

	A_9	1.5	1.4	29.4	29.0	31.0	31.3	4.3	3.7	2.2	2.3
	A_{10}	1.8	1.5	34.3	34.5	33.8	33.6	6.7	6.5	4.0	4.0
		Percentages (%) of the steel thickness damages									
Bulk carrier		BC_6		BC_7		BC_8		BC_9		BC_{10}	
Portside/Starboard		P	S	P	S	P	S	P	S	P	S
Fuel tanks' areas	A_1	2.5	3.2	1.3	1.3	3.7	4.7	1.4	1.3	2.6	2.0
	A_2	26.1	26.3	19.6	19.5	11.6	12.0	23.1	22.2	23.2	23.1
	A_3	0.0	0.0	1.7	1.4	1.3	1.2	1.9	1.7	1.8	2.9
	A_4	0.0	0.0	1.6	1.5	1.4	1.2	1.9	1.7	1.6	2.1
	A_5	3.9	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A_6	38.3	38.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	A_7	3.8	3.8	5.4	6.1	27.1	27.4	13.5	6.1	26.7	18.8
	A_8	22.5	31.0	9.2	14.9	28.8	29.5	16.7	22.2	28.2	23.0
	A_9	5.2	5.2	12.5	8.1	14.6	15.0	6.9	8.0	16.3	17.3
	A_{10}	9.8	9.3	12.6	17.3	15.6	15.3	16.2	23.5	22.2	21.7

The similar data to these given in Table 1, are given in Table 2, but in the form of the average percentages of damaged steel for the fuel tanks over both, portside and starboard of the bulk carriers, and previously *reduced* to the time period of two years of the ships' operational lives. Namely, the data are not expressed cumulatively, like in the previous case, for the complete period of twenty years of vessels' exploitation, but, for considerably smaller period of only two operational years. The question that may arise accordingly is: Why the input simulation data are presented as average values for two years interval of intensive exploitation? – The reason lies in the attempt to simulate the damaged percentages of the regular (normal) steel thickness that may be expected during two years period over certain fuel tank's area, i.e. at the relatively short time interval in comparison to the whole bulk's exploitation life. In such case it is more appropriate and effective to apply some simulation techniques, e.g. Monte Carlo, than mathematical expectation, or probability based analysis. In other words, in the short term, the corrosion lost may be quite different from the expected value, or probability values in the long term [10].

This is of importance in opening the prospective toward informing in a manner the owner of the bulk carrier which percentage of the steel might be, most probably, expected to be damaged by the corrosion, and removed/replaced over the fuel tanks, during the relatively short time interval of two years in the period of bulk carrier aging, i.e. between 5th and 25th year of its operation cycle. Consequently, through this research, and several similar ones [11;12], the particular efforts are given toward developing an appropriate Monte Carlo simulation model for assessing general corrosion wastage in short terms. Anyhow, it is to be noted that Monte Carlo simulation method has been employed successfully up to now in several research works in the domain of the different naval structures phenomenon analysis [13;14].

Table 2. The average percentages (%) of the corrosion losses over the considered bulk carriers' fuel tanks areas per two years

		Percentages (%) of the steel thickness damages per two years										
Bulk carrier		BC_1	BC_2	BC_3	BC_4	BC_5	BC_6	BC_7	BC_8	BC_9	BC_{10}	Average (%)
Fuel tanks' areas	A_1	0.18	0.11	0.19	0.14	0.13	0.29	0.13	0.42	0.14	0.23	0.20 %
	A_2	0.92	0.80	0.59	1.86	2.18	2.62	1.96	1.18	2.26	2.31	1.67 %
	A_3	0.16	0.12	0.17	0.00	0.00	0.00	0.15	0.13	0.18	2.40	0.33 %
	A_4	0.10	0.12	0.13	0.00	0.00	0.00	0.15	0.13	0.18	0.19	0.10 %
	A_5	0.00	1.49	2.38	0.20	0.77	0.40	0.00	0.00	0.00	0.00	0.52 %
	A_6	0.00	1.82	2.48	0.75	2.93	3.83	0.00	0.00	0.00	0.00	1.18 %
	A_7	0.15	1.24	1.29	0.28	0.90	0.38	0.58	2.72	0.98	2.27	1.10 %
	A_8	0.23	1.74	1.79	0.40	1.52	2.68	1.16	2.93	1.94	2.56	1.69 %
	A_9	0.15	2.92	3.11	0.40	0.23	0.52	1.03	1.48	0.75	1.68	1.23 %
	A_{10}	0.17	3.44	3.37	0.66	0.40	0.96	1.49	1.55	1.98	2.19	1.62 %

4. The realization and some results of Monte Carlo simulations

When a problem contains elements that exhibit chance, or probability, in their behavior, Monte Carlo method is recommended. The basic idea of this simulation method is to randomly generate values for the unknown variables in the model, through randomly sampling. The technique breaks down into three steps: a) establish a probability distribution for each variable in the model that is subject to change; b) using random numbers that simulate values from the probability distribution for each variable in the previous step; and, c) repeating the process for a series of replications (runs, or trials). The function of computer generation of random numbers, is the generation of decimal fractions randomly distributed over the interval from 0 up to, but not including 1, referring to the U(0,1) random number. The most common method of generating U(0,1) random numbers is called the *mixed congruential method* (MCM) [15]. The MCM generates a sequence of U(0,1) random numbers denoted by r_0, r_1, r_2, r_3,…, and so on. The first number in the sequence, r_0, is an arbitrary chosen decimal fraction between 0 and 1. Using r_0 to initialize the process, the MCM generates the next random number r_1 by using the previous random number and the following recurrent formula (1):

$$r_i = \frac{\left[\left(m \cdot a \cdot r_{i-1} + c\right)\left(\mathrm{mod}\,ulo(m)\right)\right]}{m} \tag{1}$$

Were, m is a pre-specified positive integer known as modulus; a is a pre-specified positive integer less than m known as the multiplier; and, c is a pre-specified nonnegative integer less than m known as the increment. Strictly speaking, the sequence of numbers generated by MCM is not random in the sense of being unpredictable and irreproducible.

Obviously, by specifying *m*, *a* and *c*, it is automatically determined what sequence of numbers shall be generated. For this reason, random numbers generated on a computer are often called *pseudo random* numbers. The looping behavior of the MCM is inevitable, regardless of the choice of values for *m*, *a*, and *c*. Thus, the question is not if the looping will occur, but when. Mathematicians have devised rules for choosing *m*, *a*, and *c* that delay the looping as long as possible and also lead to other desirable properties in the sequence of random numbers, but these rules are beyond the scope of this paper. For the needs of this paper the spreadsheet software has been used, i.e. the appropriate combination of Excel embedded functions, since here rather small-scale simulations have been performed.

The variable being taken here into the consideration is the average percentage of the damaged steel due to the corrosion over the previously identified bulk carriers' fuel tanks areas (see subsection 3), during two years long period of their exploitation lives. Namely, as a sound base for applying Monte Carlo method, the homogenous data collected by numerous measurements of the fuel tanks' structural steel thickness for the group of ten bulk carriers (BC_1-BC_{10}) during the years, for the period of twenty years between 5th and 25th year of the bulks' operation, have been used. Due to the frequencies of appearing in the model of some percentages of the damaged steel thickness, and total number of different percentages appearing, the probabilities of each possible outcome of the variable have been calculated [11;12].

Upon the probabilities determined for each percentage of damaged steel appearing in the data set, the cumulative probabilities are to be calculated by summing all the previous probabilities up to the current one. Later on, in the process of setting the simulation process, the cumulative probabilities are used for generating the pseudorandom numbers from the intervals that correspond to the boundaries of the cumulative probabilities. There are several ways to pick random numbers: using a ball, a table, a roulette wheel, etc. Naturally, temporary the most convenient method, based on a computer program, has been used in this paper. More explicitly, the Excel embedded functions RAND ( ), LOOKUP (*,*,*), and COUNTIF (*,*) have been exploited in the paper; and, it is to be mentioned, that these functions work properly for the simulation problems of relatively small dimensions (approximately up to 100,000 records). The adapted view of the Excel data sheet with the applied functions, and with several numerical examples among the series of Monte Carlo simulations is given in Table 3. Also, it has be noted here that with an aim to simplify the whole simulation procedure and to reduce the number of different simulation inputs, and meaningless scattering of the output data, few values close to the average percentage of the damaged steel thickness due to the corrosion over certain fuel tanks' areas, have been slightly modified before starting Monte Carlo simulation process [11;12]. Additionally, through the realization of the simulations, it becomes clear that the percentage with the highest frequency, i.e. with the greatest number of appearing in the input data set, has more chance to become a *winner* in the output set of the Monte Carlo simulation runs.

Within the next part of this section the overall results obtained after each of five sets of 50, 000 Monte Carlo simulation runs, or trials, for each of ten considered fuel tanks' areas, and for each of the considered bulk carriers, are presented numerically in Table 4.

Table 3. The Monte Carlo simulation realization and results for the percentages of the steel thickness losses due to the corrosion over different bulk carriers' fuel tanks structure areas

A_1_ Bottom plate							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.11	1	0.10000	0.10000	0.00000	0.90521	0.42	5052
0.13	2	0.20000	0.30000	0.10000	0.72922	0.22	10006
0.14	2	0.20000	0.50000	0.30000	0.78236	0.22	9924
0.22	3	0.30000	0.80000	0.50000	0.85119	0.23	**14957**
0.23	1	0.10000	0.90000	0.80000	0.75141	0.22	5048
0.42	1	0.10000	1.00000	0.90000	0.42761	0.14	5013
					0.79465	0.22	
Math. expectation: 0.196					0.11107	0.13	Total: 50,000
					…	…	
A2_Inner bottom plate							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.59	1	0.10000	0.10000	0.00000	0.69297	2.18	5010
0.80	1	0.10000	0.20000	0.10000	0.22192	0.92	4990
0.92	1	0.10000	0.30000	0.20000	0.63952	2.18	5142
1.66	3	0.30000	0.60000	0.30000	0.95453	2.62	**14942**
2.18	1	0.10000	0.70000	0.60000	0.60420	2.18	5003
2.26	1	0.10000	0.80000	0.70000	0.03791	0.59	4953
2.31	1	0.10000	0.90000	0.80000	0.53409	1.66	4998
2.62	1	0.10000	1.00000	0.90000	0.50527	1.66	
Math. expectation: 1.666					0.39343	1.66	Total: 50,000
					…	…	
A_3_Pipe tunnel (water tight), lower							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.00	3	0.30000	0.30000	0.00000	0.53666	0.16	15178
0.12	1	0.10000	0.40000	0.30000	0.35631	0.12	5081
0.13	1	0.10000	0.50000	0.40000	0.59048	0.16	5052
0.16	4	0.40000	0.90000	0.50000	0.67543	0.16	**19756**
2.40	1	0.10000	1.00000	0.90000	0.62188	0.16	4933
Math. expectation: 0.329					0.43994	0.13	Total: 50,000
					…	…	
A_4_Pipe tunnel (water tight), upper							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.00	3	0.30000	0.30000	0.00000	0.13794	0.00	14917
0.12	4	0.40000	0.70000	0.30000	0.92515	0.19	**20134**

0.15	1	0.10000	0.80000	0.70000	0.48546	0.12	5060
0.18	1	0.10000	0.90000	0.80000	0.06957	0.00	4993
0.19	1	0.10000	1.00000	0.90000	0.85255	0.18	4896
Math. expectation: 0.100					0.36990	0.12	Total: 50,000
					…	…	
A_5_Side (water tight) girder, lower							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.20	1	0.20000	0.20000	0.00000	0.35009	0.40	9998
0.40	1	0.20000	0.40000	0.20000	0.73395	1.13	10020
1.13	2	0.40000	0.80000	0.40000	0.65905	1.13	**19971**
2.38	1	0.20000	1.00000	0.80000	0.67462	1.13	10011
Math. expectation: 1.048					0.69082	1.13	Total: 50,000
					…	…	
A_6_Side (water tight) girder, upper							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
2.41	3	0.60000	0.60000	0.00000	0.31087	2.41	**30117**
0.75	1	0.20000	0.80000	0.60000	0.47980	2.41	9906
3.83	1	0.20000	1.00000	0.80000	0.50313	2.41	9977
Math. expectation: 2.362					0.51936	2.41	Total: 50,000
					…	…	
A_7_Floor after (water tight), lower							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.15	1	0.10000	0.10000	0.00000	0.30720	0.58	4979
0.28	1	0.10000	0.20000	0.10000	0.59781	1.14	4912
0.38	1	0.10000	0.30000	0.20000	0.29548	0.38	5058
0.58	1	0.10000	0.40000	0.30000	0.15796	0.28	5045
0.98	1	0.10000	0.50000	0.40000	0.54068	1.14	5030
1.14	3	0.30000	0.80000	0.50000	0.26319	0.38	**15059**
2.27	1	0.10000	0.90000	0.80000	0.04116	0.15	4935
2.72	1	0.10000	1.00000	0.90000	0.39843	0.58	Total:
Math. expectation: 1.078					0.20589	0.38	50,000
					…	…	
A_8_Floor after (water tight), upper							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.23	1	0.10000	0.10000	0.00000	0.76368	2.56	5024
0.40	1	0.10000	0.20000	0.10000	0.82827	2.68	5118
1.16	1	0.10000	0.30000	0.20000	0.67209	1.74	5099
1.74	4	0.40000	0.70000	0.30000	0.83943	2.68	**19764**

2.56	1	0.10000	0.80000	0.70000	0.22524	1.16	4898
2.68	1	0.10000	0.90000	0.80000	0.30643	1.74	5042
2.93	1	0.10000	1.00000	0.90000	0.63356	1.74	Total:
Math. expectation: 1.692					0.44435	1.74	50,000
					…	…	
A_9_Floor fore (water tight), lower							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.15	1	0.10000	0.10000	0.00000	0.02676	0.15	5038
0.23	1	0.10000	0.20000	0.10000	0.44128	0.75	4991
0.40	1	0.10000	0.30000	0.20000	0.01334	0.15	5014
0.52	1	0.10000	0.40000	0.30000	0.25972	0.40	4961
0.75	1	0.10000	0.50000	0.40000	0.96024	3.11	5111
1.39	3	0.30000	0.80000	0.50000	0.69831	1.39	**14983**
2.92	1	0.10000	0.90000	0.80000	0.33012	0.52	4946
3.11	1	0.10000	1.00000	0.90000	0.34960	0.52	Total:
Math. expectation: 1.225					0.64992	1.39	50,000
					…	…	
A_{10}_Floor fore (water tight), upper							
Damaged steel [%] per two years	Frequency	Probability	Cumulative probability	Interval of random numbers	RN	LOOKUP	COUNTIF
0.17	1	0.10000	0.10000	0.00000	0.57061	1.67	5022
0.40	1	0.10000	0.20000	0.10000	0.60320	1.67	5045
0.66	1	0.10000	0.30000	0.20000	0.28173	0.66	5096
0.96	1	0.10000	0.40000	0.30000	0.08195	0.17	4981
1.67	3	0.30000	0.70000	0.40000	0.01657	0.17	**14906**
2.19	1	0.10000	0.80000	0.70000	0.98636	3.44	4934
3.37	1	0.10000	0.90000	0.80000	0.21789	0.66	5076
3.44	1	0.10000	1.00000	0.90000	0.08199	0.17	Total:
Math. expectation: 0.620					0.47888	1.67	50,000
					…	…	

Table 4. The output Monte Carlo simulation results after five sequences of 50,000 trials

Area	Steel loss [%]	Rang due to the corrosion deterioration	1st 50,000 runs	2nd 50,000 runs	3rd 50,000 runs	4th 50,000 runs	5th 50,000 runs
			Max. no. of app.	Max. no. of app.	Max. no. of app.	Max. no. of app.	Max. no. of app.
A_1	0.22	8	14 989	15 039	15 289	14 976	14 818
A_2	1.66	4	14 902	15 037	15 126	15 003	14 928
A_3	0.16	9	19 988	20 096	20 123	19 972	20 015
A_4	0.12	10	19 908	20 086	19 960	19 995	20 207

A_5^*	1.13	6	29 921	30 008	29 915	30 218	30 157
A_6^*	2.41	1	29 941	30 185	29 798	30 077	29 989
A_7	1.14	7	15 055	15 211	14 991	15 107	14 928
A_8	1.74	2	20 116	19 931	19 984	20 032	20 148
A_9	1.39	5	15 069	15 018	15 019	15 016	14 958
A_{10}	1.67	3	15 001	14 968	15 035	15 053	15 014

It is obvious that the percentages (%) of the steel thickness losses caused by the general corrosion over certain fuel tanks areas (A_1-A_{10}), given in the second column, have the greatest number of appearances within the each cycle of the output data of Monte Carlo simulation 50,000 trials. Though, these values are most likely to be expected to "occur" in the reality, within two years period, as those indicating in fact the amounts of the damaged steel which is to be eliminated and replaced with the new steel, aiming to keep bulk carriers' fuel tanks and overall bulks' structural integrity, stability and maritime safety, i.e. to prevent any possible accident(s).

By looking through the set of the Monte Carlo simulations obtained data, it can be concluded that the fuel tanks' *pair* of areas: A_5 – side (water tight) girder lower and A_6 – side (water tight) girder upper areas have the greatest deteriorations caused by the corrosion. Also, it can be concluded that the areas A_2, A_8 and A_{10}, are seriously deteriorated by the corrosion. Within the next section, an attempt to give some qualitative explanations of this phenomenon has been done.

5. Some qualitative observations

Due to the numerical results on corrosion wastage in the case of ten considered aged bulk carriers' fuel tanks areas, obtained by Monte Carlo simulations within the previous section, several observations about the fuel tanks' deteriorations caused by the general corrosion, can be given. Firstly, corrosion starts and progresses from the outside of the oil tanks, i.e. from the area intensively exposed to the changeable (mostly unpredictable) atmosphere, cargo and ballast effects. Also, it mast be pointed out that the inner sides of the fuel tanks usually are not exposed to the corrosion in the greater extent, since the fuel is considerably less corrosive than salt water and marine environment in general. Furthermore, due to the obtained numerical results, three characteristic zones may be identified:

- Fuel tanks' areas with the corrosion deterioration less than 0.5 (%) over the area per two years interval of exploitation. This should be denoted like minor or negligible deterioration (A_1, A_3, A_4);
- Fuel tanks' areas with the corrosion deterioration between 0.5 and 1.5 (%) over the area per two years period during aging. It can be marked as considerable deterioration (A_5, A_7, A_9); and,
- Fuel tanks' areas with the corrosion deterioration greater than 1.5 (%) over the area per two years intervals, that must be considered as serious, or critical deterioration (A_2, A_6, A_8, A_{10}).

The appropriate illustration of these areas arrangement over the outside *shell* of a fuel tank is given in Figure 3. The first, the second and the third zones with the different grades of the steel time-depended corrosion deterioration are marked as the legend in the

Figure 3 shows. The greatest deteriorations are noticed over the boundary areas between fuel and ballast tanks; especially in the upper areas, caused by the ballast movement and frequent exchanges of its dry and wet circles. Additionally, the serious deteriorations have been noticed in the upper areas of the after and fore floors of the fuel tanks, as well as in the areas of inner bottom plates due to the frequent (different) cargo(s) loading/uploading operations.

It seems that the upper areas of the boundary zones between ballast and fuel tanks, as well as upper zones of the after and fore floors, deserves the particular attention in a sense of more frequent thickness measurements and taking care more seriously about the coatings of these zones. The inner bottom plate is to be treated carefully, too; through cleaning cargo tanks, paintings and regular coating controlling and measurements of the steel thickness. Anyway, some more extensive investigation should be done in this field, toward gathering some more relevant data about corrosion wastage and zones over which the wastage is more intensive.

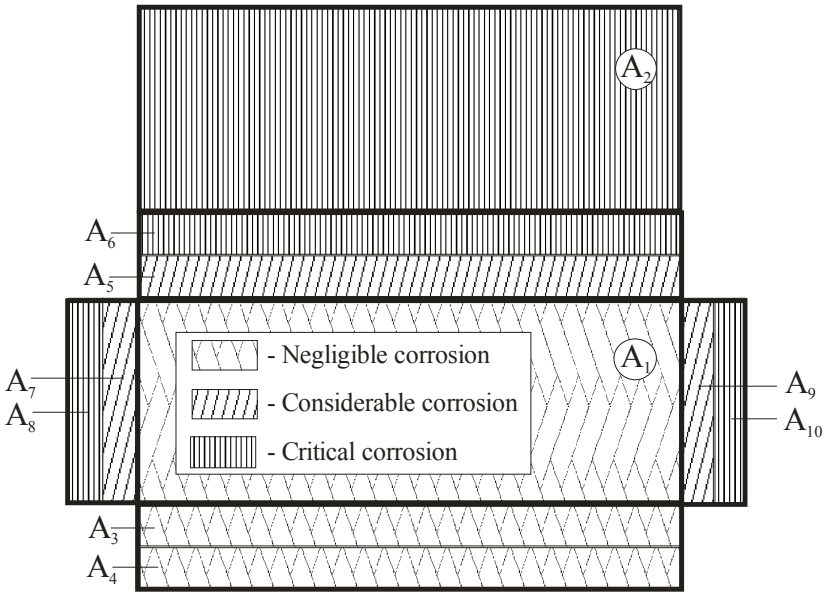


Fig. 3. The different zones of the fuel tank (outside) deterioration

6. The Weibull distribution in describing fuel tanks' corrosion lost

The previously presented Monte Carlo simulation outcomes and corresponding analysis of the corrosion wastage over different fuel tanks areas for the considered group of ten aged bulk carriers, on the basis of the homogenous historical data, are rather short terms oriented. In aim to scan the behavior of the corrosion deterioration over the bulk carriers' oil tanks in long terms, some probabilistic analyses based on Weibull distribution are realized in this part of the article.

Namely, Weibull distribution can be successfully applied in describing the corrosion loss, i.e. the steel depth reduction [16], over different bulk carriers' fuel tanks member locations during the time. In general, Weibull distribution is suitable for engineering analysis when small number of samples is available, what is not the case with other statis-

tical distributions. It allows in a manner "economic" engineering analysis and offers simple and very useful graphic for characteristic parameters scanning and analyzing. Though, Weibull distribution is widely used in (un)reliability analysis, including here examined problem of the bulk carriers' fuel tanks structural strength reliability that is commonly affected by the corrosion.

The probability density function of the percentage of the damaged steel due to the standard (regular, normal) fuel tanks' steel depth (thickness) might be assumed to follow the most general three-parameter form of the Weibull distribution (2):

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] \tag{2}$$

Where, η is scale parameter; β is shape parameter (or slope), and γ is location parameter. The ReliaSoft_Weibill++ program has been employed here for determining and analyzing Weibull distribution parameters. The available data set on the bulk carriers' fuel tanks thickness reduction due to the corrosion, collected during the time, i.e. from the 5th to the 25th year of the ships' exploitation has been plotted at the Weibull paper, and the parameters β and η, as most relevant for this research, have been automatically calculated (Figure 4).

In the Figure 5, the horizontal axis denotes the time of the considered vessels' exploitation, and it is in certain correlation to the corrosion degradation of the steel over time. In other words, as time (t) increases, the unreliability F(t) of the oil tanks integrity and structural stability increases. Or, more simply, the older the vessel, the deeper the averaged steel depth caused by the corrosion. The vertical axis represents the "life" of steel, or the (critical) percentage of the steel that is to be removed and replaced by new steel at certain point of time. According to the values obtained for the parameters β and η (Figure 4) it can be concluded that approximately after 28 years of bulk carriers' exploitation, more than 60%, or exactly, 63.2% of the fuel tanks areas constitutive steel is to be replaced. Additionally, parameter $\beta \geq 1$, or, more precisely $\beta = 3.049$, denotes the period of the intensified corrosion degradation. The data upon which the Weibull graphic has been constructed in Figure 4, and some additional ones are given in Table 5 (case 4). On the basis of these data it is also possible, by the simple linear approximation method, to scan the corrosion degradation versus time under the assumptions that the corrosion process starts, e.g. at the 5th, 7.5th, 10th, 12.5th, or at the 15th year of vessels' exploitation (cases 1-5, in Table 5). These might broaden in a way the boundaries of the analysis and offer an additional insight into the Weibull β and η parameters qualitative analysis, what should be the subject of further more rigorous investigations on larger revealed sample data set(s).

Table 5. The bulk carriers' fuel tanks corrosion lost versus time and corresponding Weibull distribution parameters β and η calculated by ReliaSoft_Weibill++ program

Case1		**Case 2**		**Case 3**		**Case 4**		**Case 5**	
Years	Corrosion loss (%)	Years	Corrosion loss (%)	Years	Corrosion loss (%)	Years	Corrosion loss (%)	Years	Corrosion loss (%)
5	2 %	7.5	1 %	10	3 %	12.5	4 %	15	3 %
7.5	5 %	10	6 %	12.5	9 %	15	12 %	17.5	13 %
10	9 %	12.5	12 %	15	15 %	17.5	20 %	20	22 %
12.5	14 %	15	17 %	17.5	23 %	20	28 %	22.5	33 %
15	18 %	17.5	22 %	20	30 %	22.5	32 %	25	45 %
17.5	23 %	20	27 %	22.5	36 %	25	43 %		
20	28 %	22.5	32 %	25	42 %				
22.5	32 %	25	40 %						
25	39 %								
$\beta = 1.939$		$\beta = 2.946$		$\beta = 3.049$		$\beta = 3.564$		$\beta = 5.596$	
$\eta = 35.177$		$\eta = 28.977$		$\eta = 28.640$		$\eta = 28.319$		$\eta = 26.463$	

The considered vessels are classified by four classification societies: Bureau Veritas, Det Norske Veritas, L'loyds Register, and American Bureau Shipping. These societies have recommendations in their Rules for the levels of the acceptable corrosion deterioration for each element of the hull construction. In the analyzed case, the deterioration for each area of the fuel tanks is in the boundaries between 20 and 25%, depending on the classification society.

In the more restrictive conditions, i.e. in the situations when the fuel tanks are investigated as whole, the average amount of the damaged steel should not exceed 10% of the regular thickness [17-20]. Under such, more rigorous condition, the parameters of the Weibull distribution differ than those obtained upon the real data collected on site, like in the previously presented cases. These additional oil tanks structural stability and safety requirements implies the smaller values of Weibull parameters β and η, what is illustrated in Figure 5. Simply, in such strict conditions, more than 60% of the steel has to be removed/replaced over oil tanks structures during the 15th year of their exploitation lives, which is considerably earlier than in the previously presented cases (see Table 5).

To summarize, such approach based on the Weibull distribution parameters analysis might be recommended as a practical tool for determination of both scale and shape parameters, i.e. the time when more than half of the fuel tanks' structures in general will be seriously damaged by the corrosion and necessarily replaced by new steel, or it might denote the time when the bulk carrier should be retreating from operation. This is of upmost importance in controlling the structural strength and reliability of the fuel tanks and the whole bulk's hull structure, primarily due to the security and maritime safety reasons. Though, the practical aspect of such analysis must be emphasized and further, more extensive and more rigorous investigations in this direction are to be encouraged.

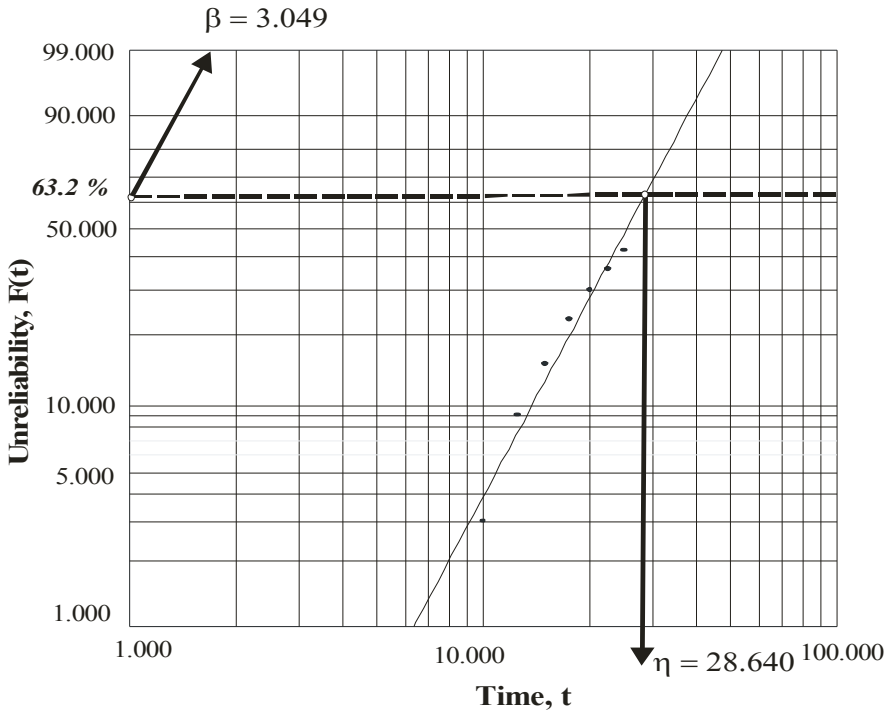


Fig. 4. The percentages (%) of the corrosion lost over bulk carriers' fuel tanks areas versus ages of the vessels' exploitation plotted on the Weibull paper

Also, it must be noted that some areas of the bulk carriers' fuel tanks are not exposed in a great extend to the corrosion mechanisms, like A_1, A_3, A_4, and even A_5, A_7, and A_9, while some others, like A_2, A_6, A_8, and A_{10}, are seriously deteriorated. Accordingly, the analysts and the surveyors have to be aware that some deeper operational insight into this problematic is required besides pure statistical analysis. In other words, in addition to the simulations and statistical observations, some more detail qualitative analysis and discussions among the operators and experts are unavoidable, as well.

7. Conclusions

The simulation (Monte Carlo) and the probabilistic (Weibull) rather simple models for scanning the corrosion lost over bulk carriers' fuel tanks member locations have been developed as experimental approaches to analyzing corrosion data collected during the years, by the ultrasonic thickness measurement Company[1]. While the simulation model gave the information on the percentage of steel depth reduction by the corrosion over the fuel tanks due to the normal (standard) steel depth, in relatively short period of time, i.e. two years, within the vessels' aging period; the probabilistic-Weibull model gave a sight to the long term behavior of the steel degradation during the whole period of fuel tanks exploitation. Both models are from the experimental point of view rather satisfying; but, it is to be pointed out that the provided data from the vessels' regular, standardized inspections are unavoidably full of uncertainties owing to the specific nature of the bulk carriers and their fuel tanks constructions, and especially owing to the uncertain nature of marine environment and very specific sea water corrosion mechanisms. However, if con-

siderably more data can be revealed, the prediction models should be improved to achieve a high accuracy of the proposed fuel tanks' steel depth reduction due to the marine corrosion phenomenon, at any point of time, i.e. year of bulk carrier's exploitation cycle.

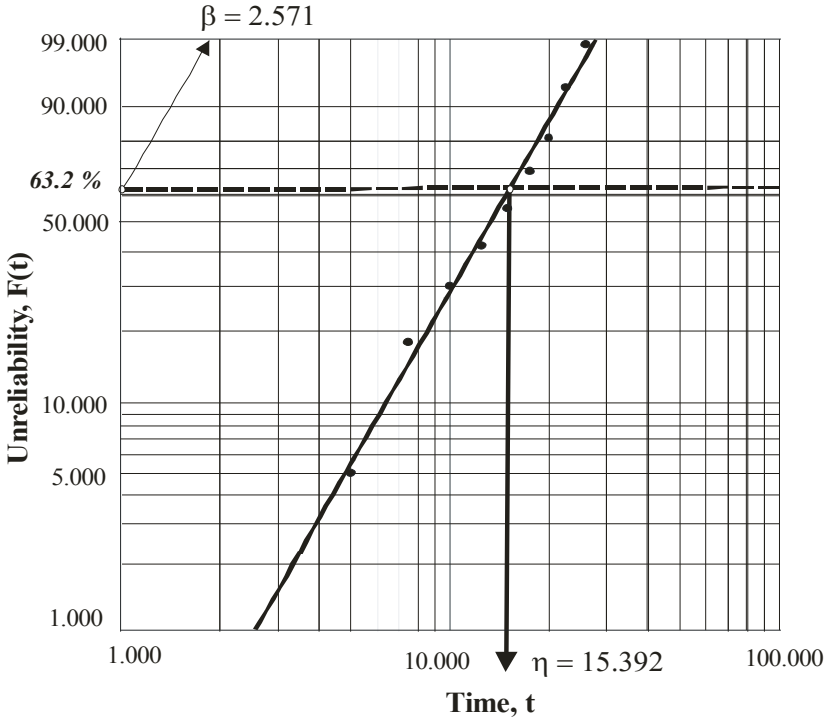


Fig. 5. The percentages (%) of the corrosion lost over bulk carriers' fuel tanks areas versus time for restrictive conditions

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3.2. Corrosion wastage modeling for different member locations of bulk carriers

This research work considers two corrosion wastage models for some pre-specified member locations of several aged bulk carriers. Accordingly, the available statistical data of regular corrosion measurements for existing bulk carriers' structures have been analyzed by using two simulation models. The first considered model is based on Monte Carlo simulation method and it is developed upon cumulative data collected by measuring eleven structure categories of ten bulk carriers during the period between the twentieth and the thirtieth year of their operational life. The second considered model employs an inverse analysis of the corrosion process in the case of seven bulk carriers' inner bottoms plating areas at different ages of the ships' operational life, i.e. their exposure to the corrosion. Both models show certain convergence and enable predicting the steel amounts that are to be removed (replaced) from different corroded structural members in order to keep the ultimate bulk carriers' both transversal and longitudinal strength within the boundaries of required safety level.

1. Introduction

In ageing process of bulk carriers, corrosion and fatigue cracks are two most important factors affecting structural safety and integrity. There are several types of corrosion. The most common ones are: general (uniform) corrosion, which uniformly reduces the member wall thickness, and localized (pitting or grooving) corrosion, that causes degradation in local regions. The corrosion, in general, is influenced by many factors including the corrosion protection system and various operational parameters. Most often, the corrosion protection systems for vessels are coatings and anodes. Among the operational parameters, the following might be included: maintenance, repair, type of cargo, kind of loading/unloading operations, i.e. manipulation techniques and equipment, percentage of time in ballast, frequency of tank cleaning, temperature profiles, use of heating coils, humidity conditions, water and sludge accumulation, microbial contamination, atmosphere effects, composition of fuels and inert gases, etc. Also, the various uncertainties associated with corrosion are to be taken into consideration, where a probabilistic treatment is essential. Now-a-days, the lack of understanding of all these factors and their mutual interactions is present, although related experiences for each of them looking solely have been documented and sometimes analyzed [1;4;5;6;7;8].

Within this paper, two problems related to two groups of ten ageing bulk carriers shall be considered as well as their general (uniform) corrosion processes: (1) - predicting the appropriate value of the steel amount that is to be replaced at a certain member of the structure per year, by Monte Carlo simulations, and (2) - modeling the corrosion depth inverse function due to the past data collected on removed/replaced steel amounts during the various time segments (periods) of the observed bulk carriers operational life.

2. Monte Carlo simulation and predictive corrosion wastage model for bulk carriers structures

Generally speaking, the concept of simulation involves developing a mathematical model that attempts to describe a real-world situation. The model's goal is to incorporate important variables and their interrelationships in such way that we can study the impact of different decisions on functioning of the whole system. This approach has many advantages over other decision modeling techniques and it is especially useful, when a problem is too complex or difficult to solve by other means. The Monte Carlo method of simulation uses random numbers to generate random variable values from probability

distributions. The simulation procedure is conducted for several time periods to evaluate the long-term impact of each policy value being studied [9].

2.1. Generating random numbers and setting up the simulation

The function of computer generation of random numbers is the generation of decimal fractions (e.g. 0.67185) randomly distributed over the interval from 0 up to, but not including, 1. Hereafter we refer to such random number as a U(0,1) random number. The most common method of generating U(0,1) random numbers is called the *mixed congruential method* (MCM). The MCM generates a sequence of U(0,1) random numbers denoted by r_0, r_1, r_2, r_3,…, and so on. The first number in the sequence, r_0, is an arbitrary chosen decimal fraction between 0 and 1. Using r_0 to initialize the process, the MCM generates the next random number using the previous random number and the following formula:

$$r_i = \frac{\left[\left(m \cdot a \cdot r_{i-1} + c\right)\left(\mathrm{mod}\,ulo\left(m\right)\right)\right]}{m} \tag{1}$$

Were,
m – is prespecified positive integer known as modulus;
a – is prespecified positive integer less than m known as the multiplier; and,
c – is prespecified nonnegative integer less than m known as the increment.

Strictly speaking, the sequence of numbers generated by MCM is not random in the sense of being unpredictable and irreproducible. It is obvious, by specifying *m*, *a* and *c*, it is automatically determined what sequence of numbers shall be generated. For this reason, random numbers generated on a computer are often called pseudo random numbers. A computer needs only to generate U(0,1) random numbers because they in turn can be used to simulate any desired probability distribution [9].

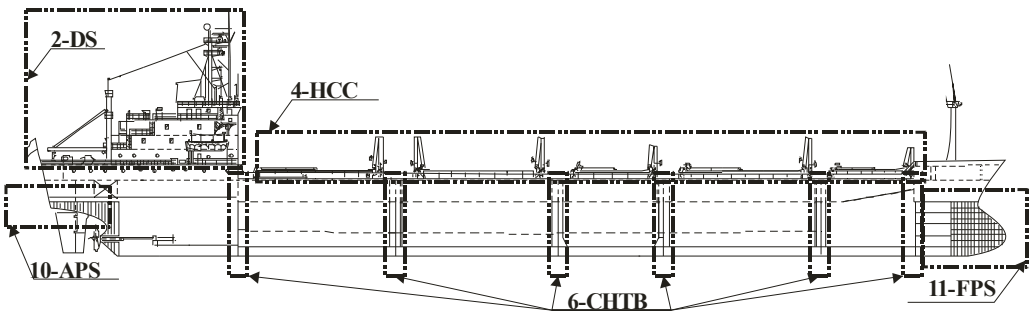
The Monte Carlo simulation method has been used in the paper in creating the corrosion wastage predictive model in the sense of which amount of the steel in tons is to be removed/replaced at a certain member location of the considered bulk carriers overall hull structure. Accordingly, first of all, 11 member locations/categories have been specified, including both transversal and longitudinal segments. Some of these member locations/categories consist of only longitudinal members (UD, DS, BSSP, IBHP), or, only transversal members (CHTB, CHMF), while some consist of both longitudinal and transversal members (HCC, ISTST, ISDBT, APS, FPS). It is to be pointed out here that the previous studies in this domain included and treated mostly the longitudinal elements, only [4;5;6;7;8]. The suggested division of the bulk carrier structure members/categories is given in Table 1.

Table 1. The primary members of the bulk carriers being taken into consideration

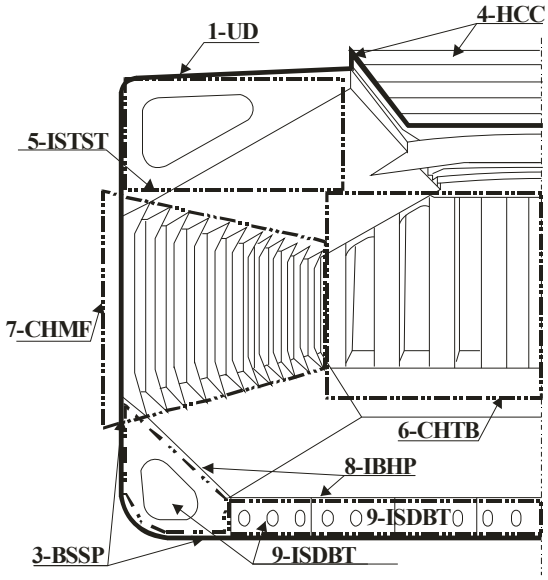
No.	Bulk carrier structure members/categories	Acronyms
1.	Upper deck	UD
2.	Deck superstructure	DS
3.	Bottom and side shell plating	BSSP
4.	Hatch cover and coamings	HCC
5.	Internal structure in top side tanks	ISTST
6.	Cargo hold transverse bulkheads	CHTB
7.	Cargo hold main frames	CHMF
8.	Inner bottom and hopper plating	IBHP
9.	Internal structure in double bottom tanks	ISDBT
10.	After peak structures	APS
11.	Fore peak structures	FPS

In aim to get better insight into locations of the members distributed throughout the bulk carrier hull structure (Table 1), 2D bulk carrier's longitudinal view, and 3D cargo hold cross-section, are given in Figure 1.

To predict likely corrosion damage tolerance, or a steel amount to be replaced at a certain area *a priori*, it is necessary to make estimates of the corrosion rates for various structural members grouped by location and some other relevant parameters as it is previously done. The appropriate estimations are done in this research at two different levels. The first is the experimental one, realized by Monte Carlo simulation method, and the other one is experience based, i.e. it is based on the expert's knowledge in the domain, being gathered during the years of the working experiences, and later used in making corrections in the results obtained by Monte Carlo method. In other words, Monte Carlo has been used in predicting the amounts of the steel which are to be replaced at each of above identified bulk carriers' structure members per year. Afterwards, the comparison with the expert's knowledge has been performed and the proper corrections have been made in a way described later in the paper.



(a) 2D longitudinal view



(b) 3D cargo hold cross-section

Legend:

(a) 2D longitudinal view
DS - Deck superstructure
HCC - Hatch cover and coamings
CHTB - Cargo hold transverse bulk-heads
APS - After peak structures
FPS - Fore peak structures

(b) 3D cargo hold cross-section
UD - Upper deck
BSSP - Bottom and side shell plating
HCC - Hatch cover and coamings
ISTST - Internal structure in top side tanks
CHTB - Cargo hold transverse bulk-heads
CHMF - Cargo hold main frames
IBHP - Inner bottom and hopper plating
ISDBT - Internal structure in double bottom tanks

Fig. 1. Structural categories identification

In aim to realize Monte Carlo simulation the set of homogenous historical data are collected over the previously specified primary transversal and longitudinal bulk carriers' structure members by the recommended standard measurements during the ten years period, that is, during the period between the twentieth and the thirtieth year of the ships operation life. The cumulative data, collected by measuring ten bulk carriers (BC_1-BC_{10}), or more precisely, by measuring more than 300.000 gauged points properly distributed throughout the bulk carriers' hull structures, are given in Table 2.

Table 2. The cumulative data on steel amounts [t] removed/replaced at ten bulk carriers structure members between its 20th and 30th year of operation

No.	Memb.	BC_1	BC_2	BC_3	BC_4	BC_5	BC_6	BC_7	BC_8	BC_9	BC_{10}
1.	UD	1	22	1	30	150	7	165	80	1	12
2.	DS	3	6	1	2	4	6	22	5	0	0
3.	BSSP	3	65	3	45	10	5	60	25	5	3
4.	HCC	7	15	3	15	35	32	40	35	3	25
5.	ISTST	8	9	25	30	45	75	160	120	45	6
6.	CHTB	2	65	25	170	32	45	145	220	24	16
7.	CHMF	3	45	16	85	22	32	85	110	26	25
8.	IBHP	5	550	15	650	440	150	650	85	120	110
9.	ISDBT	20	50	30	35	40	45	55	45	22	2
10.	APS	5	40	25	5	30	14	30	12	9	2
11.	UD	1	6	14	5	20	32	60	55	16	3

As numerous other simulation methods, Monte Carlo method is an experiment in which we attempt to understand how something will behave in reality by imitating its behavior in an artificial environment that approximates reality as closely as possible. Thus, a Monte Carlo simulation creates an artificial environment that approximates reality – here, in this paper, the real corrosion time-dependent process at the group of aged bulk carriers. It conducts computer based experiments over past data that would be too costly and time-consuming to perform in reality. Because Monte Carlo simulation generates random numbers (data), obtaining accurate results requires the simulation to consist of large number of repetitions or runs, or trials. Since it generates random data, there is no guarantee that the chosen policy is actually the optimal one, but the simulation results, undoubtedly, can offer some effective directives for further investigations and comparative analysis due to the expert knowledge.

2.2. Results and discussion

The simulation procedure has been realized using Microsoft Excel and it's built-in functions RAND ( ) and LOOKUP (*.*) [2] over the data set presented in Table 2. In accordance to the Monte Carlo simulation method, the frequencies of each steel amounts [t] which are replaced at the certain ships' structure members are determined. Then, the probabilities of these amounts appearances in the model are calculated. Later on, the cumulative probabilities and the corresponding random numbers intervals have been set up. The Monte Carlo simulation has been realized throughout two sub-sets of 50.000 runs or trials, i.e. through 100.000 passes in total. Some of the simulation results obtained for the most specific, or, corrosion most sensitive segment of the observed bulk carrierrs' structures – IBHP, are shown in Table 3.

Table 3. Some Monte Carlo simulation results gained for the bulk carriers' IBHP structure members by Excel functions (RN, LOOKUP, COUNTIF)

Steel amounts [t] replaced per year	Frequency	Simulation results				
		RN		LOOKUP		COUNTIF
0.5	1	0.20390	0.04756	8.5	0.5	4981
1.5	1	0.84065	0.78524	65	55	5090
8.5	1	0.94182	0.84977	65	65	5203
11	1	0.97472	0.55561	65	15	4952
12	1	0.08724	0.42820	0.5	12	4944
15	1	0.25933	0.66248	8.5	44	4925
44	1	0.66063	0.97846	44	65	4942
55	1	0.56119	0.30718	15	11	4969
65	2	0.88060	0.68039	65	44	9994
		0.91545	0.61109	65	44	50000
		0.78696	0.08944	55	0.5	
		0.85812	0.30362	65	11	
		0.38058	0.92609	11	65	
		0.32778	0.66141	11	44	
		0.10183	0.44175	1.5	12	

		0.99021	0.15439	65	1.5	
		0.19375	0.93025	1.5	65	
		0.42175	0.79236	12	55	
		0.60576	0.97135	44	65	
		0.80586	0.16350	65	1.5	
		0.94447	0.96588	65	65	
		0.31684	0.17888	11	1.5	
		0.41117	0.26860	12	8.5	
		0.93964	0.00113	65	0.5	
		0.47111	0.25392	12	8.5	
		0.33747	0.99960	11	65	
		…	…	…	…	
			up to 50000 trials		up to 50000 trials	

The simulations presented in Table 3 have been realized through 50000 trials. This number of trials can be multiplied due to the level of simulation model reliability requirements. Similarly, the above presented procedure has been realized for the rest of considered bulk carriers' structure members, and the obtained results are presented in Table 4. Latter on, the obtained results have been confronted with the experts' expectations.

Table 4. The estimated steel amounts [t] that should be replaced at the certain ship structure member per year (shadowed fields), obtained by Monte Carlo simulation method

Member	Steel amounts[t] / number of random appearances through the simulation process												Total number of runs
UD	Amount Freq.	0.1^{3}	0.7^{1}	1.2^{1}	2.2^{1}	3.0^{1}	8.0^{1}	15.0^{1}	16.5^{1}				$\Sigma\ 10^{5}$
	Appearing no.	29964	9795	10088	10150	10055	9906	10085	9957				
DS	Amount Freq.	0.0^{2}	0.1^{1}	0.2^{1}	0.3^{1}	0.4^{1}	0.5^{1}	0.6^{2}	2.2^{1}				$\Sigma\ 10^{5}$
	Appearing no.	19978	10072	10103	10058	9793	10085	19811	10100				
BSSP	Amount Freq.	0.3^{3}	0.5^{2}	1.0^{1}	2.5^{1}	4.5^{1}	6.0^{1}	6.5^{1}					$\Sigma\ 10^{5}$
	Appearing no.	30068	20048	10029	10027	10026	9809	9993					
HCC	Amount Freq.	0.3^{2}	0.7^{1}	1.5^{2}	2.5^{1}	3.2^{1}	3.5^{2}	4.0^{1}					$\Sigma\ 10^{5}$
	Appearing no.	19958	9977	19962	9944	10088	20074	9997					
ISTST	Amount Freq.	0.6^{1}	0.8^{1}	0.9^{1}	2.5^{1}	3.0^{1}	4.5^{2}	7.5^{1}	12.0^{1}	16.0^{1}			$\Sigma\ 10^{5}$
	Appearing no.	9996	9968	9986	10031	9773	20114	10079	10032	10020			
CHTB	Amount Freq.	0.2^{1}	1.6^{1}	2.4^{1}	2.5^{1}	3.2^{1}	4.5^{1}	6.5^{1}	14.5^{1}	17.0^{1}	22.0^{1}		$\Sigma\ 10^{5}$
	Appearing no.	9872	9992	10146	9968	10130	9923	9988	10045	10046	9890		

CHMF	Amount Freq.	0.3^1	1.6^1	2.2^1	2.5^1	2.6^1	3.2^1	4.5^1	8.5^2	11.0^1		$\Sigma\ 10^5$
	Appearing no.	10053	9943	10066	9805	9994	10105	10096	20002	9936		
IBHP	Amount Freq.	0.5^1	1.5^1	8.5^1	11.0^1	12.0^1	15.0^1	44.0^1	55.0^1	65.0^2		$\Sigma\ 10^5$
	Appearing no.	10185	9985	9817	9965	9970	10052	9957	10099	19970		
ISDBT	Amount Freq.	0.2^1	2.0^1	2.2^1	3.0^1	3.5^1	4.0^1	4.5^2	5.0^1	5.5^1		$\Sigma\ 10^5$
	Appearing no.	9884	10138	9942	10122	9901	9901	9918	20071	9988		
APS	Amount Freq.	0.2^1	0.5^2	0.9^1	1.2^1	1.4^1	2.5^1	3.0^2	4.0^1			$\Sigma\ 10^5$
	Appearing no.	10013	19905	10156	10000	10111	9995	19962	9858			
UD	Amount Freq.	0.1^1	0.3^1	0.5^1	0.6^1	1.4^1	1.6^1	2.0^1	3.2^1	5.5^1	6.0^1	$\Sigma\ 10^5$
	Appearing no.	10243	10164	9789	10022	10026	10039	9962	10016	9860	9879	

The shadowed steel amounts represent the amounts that randomly appear in the biggest number of simulation trials. Those values should be the optimal ones to be replaced at the certain ship structure member per year, but since the simulation method includes random processes, random variables and their random values, it can not guarante that the obtained simulation results are indeed the optimal ones. Though, they are to be tested in such way to be compared later to the expert knowledge.

2.3. Improving the model

Due to the experts' knowledge, internal structure in top side tanks (ISTST), cargo hold transverse bulkheads (CHTB) and inner bottom and hopper plating (IBHP) are the most sensitive and important for the bulk carrier strength, though they should need additional analyzing and simulating in the process of finding optimal solution. Again, according to the experts' experiences the average value of the steel amounts which have to be replaced per year at certain member/category of the ship's structure might be the right orienteer in achieving improvements in the simulation model. In other words, the simulation model should be satisfying *reliable* if it gives *optimal* values that are close to the average values of the steel amounts [t] to be removed/replaced at above pointed member structure areas. The schematic representations of the experts' suggestions in the direction of Monte Carlo simulation model improving and the way of attempting to achieve them, is presented in Figure 2.

Afterwards, the question is drawn: how to achieve the suggested *improvements* of the proposed and here applied Monte Carlo simulation model? - The simplest and the most effective way is to *artificially* adjust some values in the model (i.e. for ISTST, CHTB and IBHP) to be close, or closer, to the average values of steel amounts that are to be removed/replaced at each considered area. This could be done by adding/subtracting *artificially* appropriate small amounts of steel to the listed ones (see tables 3 and 4) in aim to increase frequencies of appearing the values close to the average one for the certain ship's structure member in the model. In such way, the possibilities for the *right* values appearance as the optimal ones at the end of numerous runs of the Monte Carlo simulation process shall be undoubtedly higher.

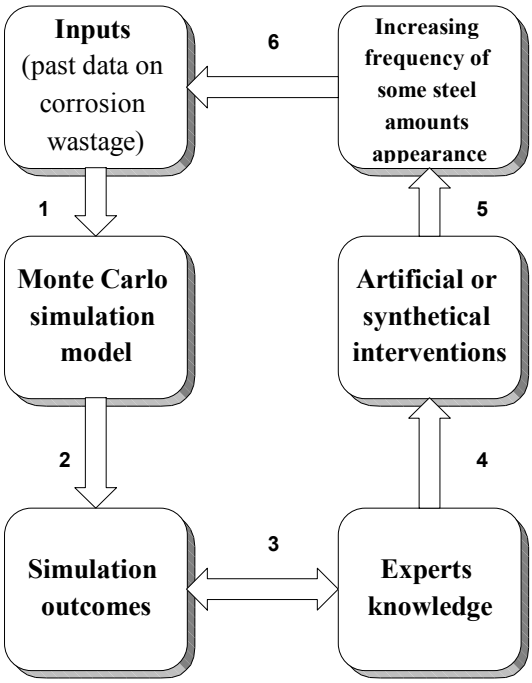


Fig. 2. The scheme of possible improvements of the Monte Carlo simulation modeling

The frequency of a certain value appearance in the model initial (input) matrix of data is of the crucial importance for obtaining *wanted* or valid (final) results for the considered problem. Thus, the main qualitative contribution of these experiments might be: the frequency of a certain value appearing in the model input matrix is the crucial in obtaining the optimal solution after series of simulation runs. Additionally, due to the experts' knowledge in this domain, the best way to make simulation results closer to the real situation it is to adapt the initial model in a way to increase *artificially* frequencies of appearing the values close to the average one (by adding/subtracting enough small values for steel amounts). By such interventions model can be generally used in predicting the optimal amounts of the steel to be removed/replaced at each bulk carrier's structure area on the bases of the past collected data and their slight corrections due to experts' knowledge in the field.

The achieved improvements in the case of the considered problem are presented in the Table 5. It is obvious that the optimal results obtained by Monte Carlo simulation are considerably closer to the average amounts for ISTST, CHTB and IBHP bulk carrier's structure members, than in the first sequence of experiments (Table 4).

Table 5. The improved results of Monte Carlo simulation achieved owing to the experts' knowledge in the domain

Mem-ber	Steel amounts[t] / number of random appearances through the simulation process											Total num-ber of runs
ISTST	Amou. Freq.	0.6^1	0.8^1	0.9^1	2.5^1	3.0^1	4.5^2	7.5^1	12.0^1	16.0^1		0.52 (avg)
	Appear. no.	9996	9968	9986	10031	9773	20114	10079	10032	10020		Σ 100 000
ISTST (1)	Amou. Freq.	0.5^3			2.5^1	3.0^1	4.5^2	7.5^1	12.0^1	16.0^1		
	Appear. no.	30284			10164	9882	19822	9796	10057	9995		$\Sigma\ 10^5$
CHTB	Amount Freq.	0.2^1	1.6^1	2.4^1	2.5^1	3.2^1	4.5^1	6.5^1	14.5^1	17.0^1	22.0^1	0.74 (avg)
	Appear. no.	9872	9992	10146	9968	10130	9923	9988	10045	10046	9890	$\Sigma\ 10^5$
CHTB (1)	Amount Freq.	0.7^3			2.5^1	3.2^1	4.5^1	6.5^1	14.5^1	17.0^1	22.0^1	
	Appear. no.	30108			9946	9963	10135	9961	9882	9930	10075	$\Sigma\ 10^5$
IBHP	Amou. Freq.	0.5^1	1.5^1	8.5^1	11.0^1	12.0^1	15.0^1	44.0^1	55.0^1	65.0^2		2.78 (avg)
	Appear. no.	10185	9985	9817	9965	9970	10052	9957	10099	19970		$\Sigma\ 10^5$
IBHP (1)	Amount Freq.	3.0^3			11.0^1	12.0^1	15.0^1	44.0^1	55.0^1	65.0^2		
	Appear. no.	30039			10125	9869	9965	9926	10190	19886		$\Sigma\ 10^5$

The proposed way of improving *reliability* of Monte Carlo should be tested at greater amount of data, collected for example by different companies and/or ships' classification societies. Afterwards, the whole process should be *automated* by developing the appropriate software application for easier and quicker model realization.

Within the next section, the second corresponding corrosion predictive model based upon rather uncommon inverse analysis of the time-dependent bulk carriers' corrosion wastage.

3. Some analysis of time-dependent corrosion wastage model

Up to now, several time-dependent corrosion wastage models have been developed upon the appropriate homogenous historical (statistical) data [4;5;6;7;8;10]. Most of these models consider depth of steel degradation (d [mm/year]) at a certain ship's area. Here, within this paper an effort has been done to represent corrosion degradation through the amounts of steel which have been replaced at the certain bulk carrier's areas due to the severe corrosion wastage of the structure material.

Accordingly, the data collected by regular thickness measurements at the group of seven bulk carriers have been used. Since the inner bottom plating (IBHP) areas are in the greatest measure exposed to the corrosion, only these structure members were examined here. The Figure 3 shows the histogram of corrosion wastage (replaced amounts of steel [t]) of inner bottom plating at selected ship's ages (15, 20, 25, 27) over the examined set of seven bulk carriers.

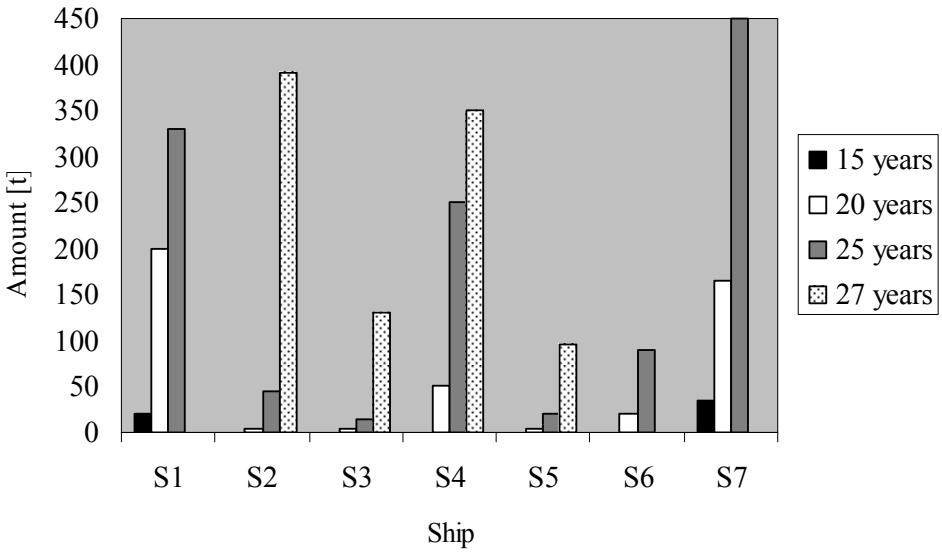


Fig. 3. The histogram of corrosion wastage of inner bottom plating at selected ship's ages at an exemplar of seven bulk carriers

The durability of coating, transition between coating durability and corrosion initiation, and the process of corrosion, might be represented with a time-dependent functional equation of the following type [3]:

$$d(t) = d_{\infty}\left(1 - e^{-\frac{t-\tau_c}{\tau_t}}\right) \tag{2}$$

Where,

$d(t)$ - is the corrosion wastage at time t;

d_{∞} - is the long-corrosion wastage;

τ_c - is the time without corrosion to the start of failure of the corrosion protecting coating;

τ_t - is the transition time duration.

Since corrosion data has a very large variability, the time-dependent functional equation (2) should not be taken into the consideration as "the only" or as "the best" one. It has been used here as an equation that satisfies the requirements of an approximation of corrosion wastage considered in the paper. Namely, it is well known, that most corrosion data are relatively largely scattered. What can be treated as novel here, due to the authors' experience is an attempt to realize some *inverse* analysis of the equation (2) in manner to find an approximate function which corresponds to the amounts of steel replaced during the ship exploitation circle. Mostly, previous works in this domain were oriented toward the depths of steel damages caused by the corrosion processes [3;4;5;6;7;8]. However, here is presented an attempt to determine approximately functional equation that corre-

sponds to the removed (replaced) steel amounts over certain ship structure area. After some analytical analysis and numerous simulation trials (in Matlab) it has been realized that function of type (3) might be used, with satisfying accuracy, in modeling the steel amounts to be replaced at bulk carriers' inner bottom plating areas during the time:

$$Q(t) = e^{\frac{t-\tau_c}{\tau_t}} - 1 \tag{3}$$

Where,

$Q(t)$ - is the steel amount replaced/removed over certain ship's area;

τ_c - is the time without corrosion to the start of failure of the corrosion protecting coating;

τ_t - is the transition time duration.

Figure 4 shows both functional equations (2) and (3), i.e. time-dependant corrosion depth expressed in [mm/year], and time-dependant removed/replaced steel amounts expressed in [t] units. Additionally, the time-variant removed/replaced steel amounts over pre-specified areas have been presented for different τ_c, i.e. $\tau_c \in [10,12,15]$ years.

The curves Q[t] in Figure 4 have been *transposed* to the scheme of average removed/replaced steel amounts over bulk carriers' inner bottom plating areas in the case of examined set of seven aging bulk carriers, and the results are shown in Figure 5.

In the case of the experimental set of data collected from seven aged bulk carriers (Figure 5) the predicted Q(t) approximates curve for $\tau_c = 15$ best feats to the average values of steel replaced at 15, 20, and 25 year of ships' exposure to the corrosion process in the marine environment. The inner bottom plating areas were only considered here, since these areas are in the greatest extend exposed to the corrosion. An analog approach might be used in comparing each bulk carrier's member structure and proposed approximated functional equation (3). The proposed equation (3) should be evaluated by the larger amount of the statistical data, being collected by few companies and/or ships' classification societies. In the case of observed bulk carriers' inner bottom plating areas, for $\tau_c = 15$, rather complete steel construction amounts have been replaced at 25th year of the ships' exploitation life. The last noted might be an indicative fact for forthcoming investigations in this domain.

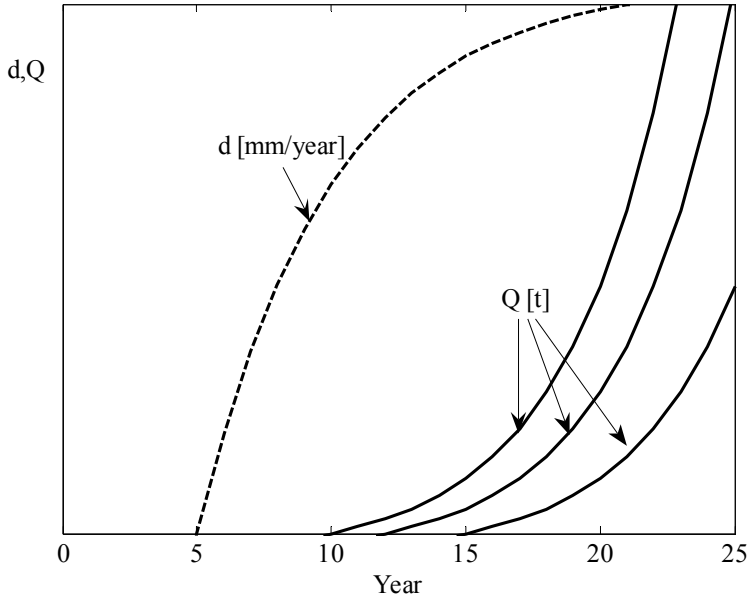


Fig. 4. Scheme of two different functional approximations for corrosion degradation of the bulk carrier's structure members (d, Q)

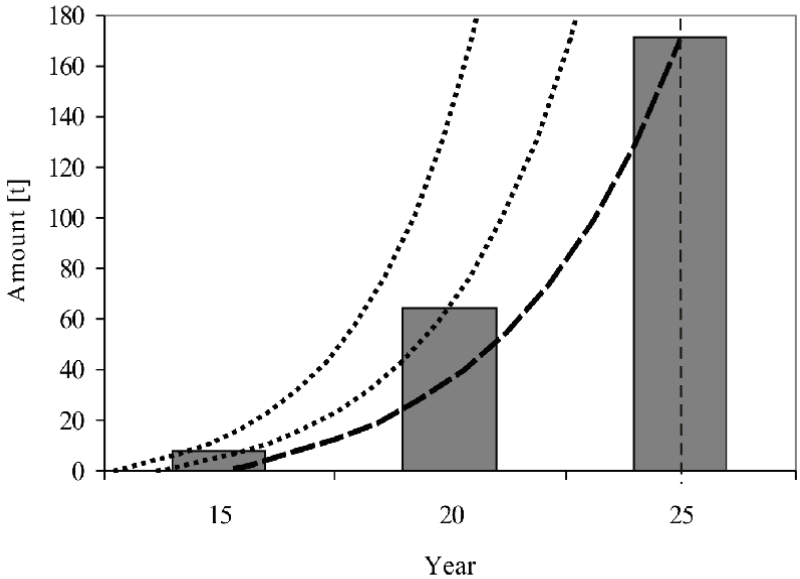


Fig. 5. The inner bottom plating degradation: comparison of average removed steel amounts and predicted ones for different τ_c

4. Conclusions

In this paper, on the exemplar of a set of aged bulk carriers, Monte Carlo simulation method has been employed in predicting steel amounts that are to be replaced at a certain ships' structure category per year. Some improvements of the results obtained by the usage of *pure* Monte Carlo method have been suggested. The improvements should comprise a kind of "synthetic" or "artificial" interventions in the historical (empirical) simulation input data, in order to increase the frequency of appearing the most common amount of steel (due to the experts experiences) which is to be removed/replaced over the certain bulk carrier structure category (member) area per year. This might be treated as a particular *syncretism* of some quantitative and qualitative simulations analysis in the process of predicting steel amounts that are to be replaced over each longitudinal and transversal element of bulk carriers' structures, caused by the corrosion degradation during the period of the operational life. Toward further, more extensive, investigations in this domain, the larger input data base and its deeper proper segregation of each bulk carrier's structural areas into the considerably smaller segments are necessary.

The paper also proposes a novel approximate, predictive, time-variant functional model for steel amounts that might be replaced/removed over bulk carriers' inner bottom plating locations. The proposed model might be treated as rather original one in comparison to the previously developed several time-variant corrosion wastage depth models. But, it has to be tested (validated) over the larger input statistical data base. Though, the last mentioned is to become the subject of further more rigorous investigations in the wide domain of bulk carriers' hull structures corrosion damages modeling.

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3.3. Weibull distribution and Monte Carlo simulation in predicting corrosion losses

This research study gives an overview of main operational parameters that influence corrosion over ageing bulk-carriers' member locations. The particular vessels' hull structure locations being affected by these parameters are identified, as well. Then, by the appropriate matching of some crucial operational parameters and the member locations, the most sensitive zone of ageing bulk carriers' has been identified. The zone identified as the most vulnerable one, i.e, inner bottom and hopper plating, has been latter on probabilistically treated. Within the extensive previous probabilistic analysis of the corrosion losses over aging bulk carriers, it has been shown that the considered data exhibit great scattering. The same was with the data which were available to us for the purpose of this research work. In fact, it was difficult to fit the data collected by the regular and standardized ships' measurements on board by the UTM company Invar-Ivosevic Ltd., to the most commonly used Weibull distribution, which usually (along with normal and lognormal distribution) in the best manner fits the corrosion wear over considered ageing ships. Consequently, it was necessary to find out an optimal way of pre-processing the collected data in order to better fit them into the Weibull distribution function. For this purpose, generator of random numbers from inverse Weibull distribution function has been employed. The proposed algorithm, being used in this research work, should be explained briefly through the following steps: (a) inserting the measured values of the corrosion depth [mm] over the ageing bulk carriers' inner bottom and hopper plating member locations into the program; (b) generating random numbers (Monte Carlo simulation approach) from the inverse Weibull distribution function with predefined subjectively estimated distribution parameters (α, β, γ); (c) examining where the measured values of corrosion wear on board ships correspond to the pseudo randomly generated numbers, and then forming the new series of that values; (d) identifying the frequencies of appearing of each different measured values in the new-formed series, and finally, (e) by the appropriate software, finding out which of the standard distributions best fit the selected data from the input set of measured values. Finally, it has been shown, on the basis of several considered numerical examples, that the selected input (measured) data best follow the Weibull probability density function.

1. Introduction

The corrosion is one of the most important factors affecting structural safety and integrity of ageing bulk carriers. Though, the operational life extension of the bulk carriers' steel structures requires permanent consideration of the plates' thickness losses due to the corrosion. For commercial naval ships, like bulk carriers, the extent of the corrosion losses is usually measured through the classification society 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 [4]. In order to provoke and support more intensive maintain measures, several bulk carriers' time-variant corrosion losses probability models have been developed up to now [5-8]. However, the researchers in this domain are usually faced with some serious difficulties, like: very complex character of the interaction of the ship with its environment and 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 [9]. The large scattering of the data obtained by the different established corrosion probability, 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.

2. On the bulk carriers' structural member locations

Up to now, the group of authors (Sone, Magaino, Yamamoto, and Harada) have analyzed some longitudinal and transversal elements of bulk carriers, i.e. twenty elements of the bulk carriers with the capacity over 50 000 DWT, and fourteen elements of the bulk carriers with the capacity less than 50 000 DWT, registered under the Japanese ClassNK register [16]. In the work of Gardiner and Melchers, the cargo holds were examined [10; 17], while the ballast tanks have been examined in the study works of Noor, Soares, Gudze, et. al [18-20], as the bulk carriers' areas with the highest risk of the structural errors occurrence. The authors of this paper have analyzed fuel tanks [2] as those located between several different media (fuel, cargo, ballast, air spaces, etc.) and consequently in great extent affect by the corrosion processes. Paik and others [6] have analyzed the degree of corrosion over twenty-three different longitudinal structural elements of the ship, etc.

The shortage of the most of the previous research works in this domain is reflected in a limited number of available data on corrosion losses over ageing bulk carriers, and in detail investigation on only few structural elements of the ship. Though, due to our knowledge, there is no studies in this field considering the ship as a whole, including its both longitudinal and transversal structural elements (areas, zones), but only its segments. In this paper, the complete bulk carrier structure has been divided into eleven structural zones that include both longitudinal and transversal elements, and then they were matched with the operational parameters being previously identified and briefly described.

Within this article, through defining eleven distinguished zones, an effort has been done toward the entire ship analyzing due to the corrosion deteriorations, through both transversal and longitudinal stiffening and plates of its structure [21-23]. In such manner, the key areas of degradation, due to the operational factors that affect corrosion can be identified, and ultimately the ship's structural strength and stability can be analyzed more easily and effectively. Further analysis in this direction, within each area can determine the corrosion processes, and eventually allow their modeling for the entire ship's structure. The identified eleven areas of the bulk carriers are shown in Figure 1, and listed in Table 1.

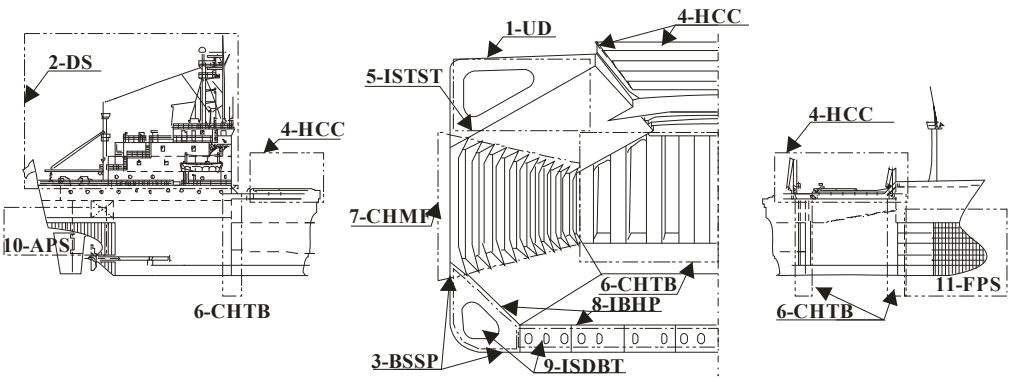


Fig. 1. Member locations (longitudinal and transversal ones) of the bulk carrier hull structure

Table 1. Longitudinal and transversal member locations of bulk carriers

Member location/category	Abbreviation	Longitudinal components	Transversal components
1. Upper deck	UD	X	
2. Deck superstructure	DS	X	
3. Bottom and side shell plating	BSSP	X	
4. Hatch cover and coamings	HCC	X	X
5. Structure in top side tanks	STST	X	X
6. Cargo holds transverse bulkheads	CHTB		X
7. Cargo holds main frames	CHMF		X
8. Inner bottom and hopper plating	IBHP	X	X
9. Internal structure in double bottom tanks	ISDBT	X	X
10. After peak structure	APS	X	X
11. Fore peak structure	FPS	X	X

The main structural features of the above listed eleven member locations of bulk carriers (see Figure 1, and Table 1) are described in some more details in [3;21-23]. Some operation parameters that usually affected bulk carriers' member locations are described in [4;10], and they are only listed here, in Table 2.

Table 2. The operational parameters that usually influence corrosion

Operational parameters affecting corrosion over bulk carriers in explotation	
1. Sea water	6. Atmosphere (semi-closed, voided spaces)
2. Ballast water	7. Manipulative equipment
3. Fuel	8. Maintenance
4. Cargo	9. Contact zones
5. Atmosphere (open atmospheric conditions)	10. Temperature, etc.

Through the authors' previous research work [3;21-23], it has been found out that the most *vulnerable* member location of aging bulk carriers due to the above listed operational parameters (see Table 2), is the inner bottom and hoper plating (IBNP). Namely, during the operational cycle of ships, they carry various kinds of more or less corrosive cargo. The physical-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 (coal, iron ore), while the less corrosive materials (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 abstraction 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 process. Cleaning and scraping double bottom cover, or IBHP 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 deforma-

tion 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 IBHP structural zone is much higher than over other zones.

Though, the further analysis are directed toward examining data on IBHP deterioration caused by the corrosion, being measured on board ships by UTM "Invar-Ivosevic" Company, and establishing the probabilistic time-dependent model of the corrosion depth over this member location. For this purpose, the particular combination of Weibull distribution function and Monte Carlo simulations has been employed, and the applied methodology is explained in some more detail within the next part of the paper.

3. Applied methodology

As it is still pointed out, in the previous probabilistic analysis of the corrosion losses over aging bulk carriers, it has been shown that the considered data exhibit great scattering [5-9;11-12;20-25]. The same was with the data which were available for the purpose of this research. Namely, we were in position to realize some probabilistic analyses over 21 aging bulk carriers, i.e. over 1841 gauged points. More precisely, the measured data on corrosion wear for four bulk carriers being in exploitation 15 years (297 gauged points), for eight bulks being in exploitation 20 years (637 gauged points), and for nine bulk carriers being in operation 25 years (917 gauged points), have been given to our disposal. The collected data set represent the corrosion wear (loss) in the form of corrosion depth [mm]. Namely, these data were provided by UTM company Invar-Ivosevic Ltd. However, 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 [5-9]. Consequently, it was necessary to find out an optimal way of pre-processing the collected data in the attempt to fit them better into Weibull distribution function. For that purpose generator of random numbers for inverse Weibull distribution function has been used. The proposed algorithm, being employed in the paper, should be explained briefly through the following steps:

- Inserting into the Excel worksheet measured values of the corrosion depth [mm], over the ageing bulk carriers' inner bottom and hopper plating member locations;
- 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, on board, correspond to the pseudo randomly generated numbers, and then forming the new series of that values;
- Identifying the frequencies of appearing of each different measured values in the new-formed series, and
- Finally, by the EasyFit software (ver. 5.5), finding out which of the numerous offered distributions within this software model database best fit 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.

These steps were realized by the Excel special function NTRANDWEIBULL (α, β, γ), and Excel imbedded functions LOOKUP (value, range) and COUNTIF (range, criteria). The function NTRANDWEIBULL returns Weibull pseudo random numbers based on Mersenne Twister algorithm [26]. The function LOOKUP (value, range) returns values from the input data set on corrosion losses being measured on site 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. An example of NTRANDWEIBULL (α, β, γ) function realization along with Monte Carlo simulations in Excel worksheet is shown in Table 3.

Table 3. An example of combining random generated numbers from inverse Weibull pdf and Monte Carlo simulation method (segment of the Excel worksheet)

	A	B	C	D	E	F	G	
1	Corrosion [mm]	Weibull RAND	LOOKUP	Diff. corr. ware values	No. of appearing	Frequency		
2	0.0	4.181834	3.1	0.0	35.0	0.062724	Mean:	1.5
3	0.0	2.125919	2.1	0.1	60.0	0.107527	St. dev.:	1.5
4	0.1	1.448396	1.4	0.2	0.0	0.000000	Var.:	2.3
5	0.1	1.209807	1.2	0.3	26.0	0.046595		
6	0.1	2.525701	2.5	0.4	30.0	0.053763		
7	0.1	0.922361	0.9	0.5	37.0	0.066308		
8	0.1	2.065580	2.0	0.6	45.0	0.080645		
9	0.1	7.218747	4.7	0.7	0.0	0.000000		
10	0.1	2.609389	2.6	0.8	35.0	0.062724		
11	0.1	2.382233	2.3	0.9	0.0	0.000000		
12	0.1	0.823797	0.8	1.0	21.0	0.037634		
13	0.1	3.279766	3.1	1.1	22.0	0.039427		
14	0.1	0.093471	0.0	1.2	13.0	0.023297		
15	0.1	0.300497	0.3	1.3	14.0	0.025090		

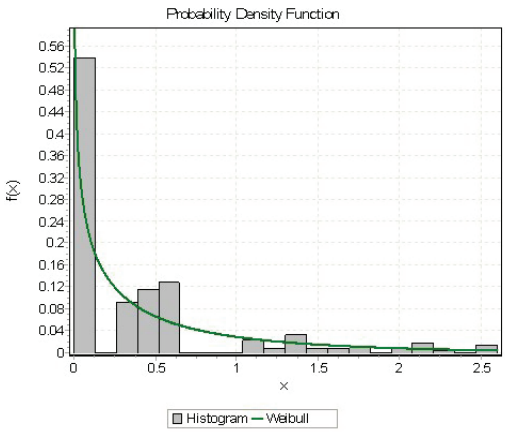
20 years grain / 20 years iron

4. Numerical results

Within this subsection are presented some of the numerical, i.e. graphical results obtained by NTRANDWEIBULL function being 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 IBHP member location of analyzed aging bulk carriers. Thus, probabilistically have been analyzed the data on the corrosion losses over ageing bulk carries within three different points of time, i.e. after 15th, 20th and 25th year of the ships' exploitation. Both bulk carriers for grain and other smallness (dusty) bulk cargos, and those for iron ore and coil 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 and coil, than over those carrying grain or other light cargos, these two groups of bulks were treated separately by the previously proposed probabilistic-simulation method, and the following results have been obtained:

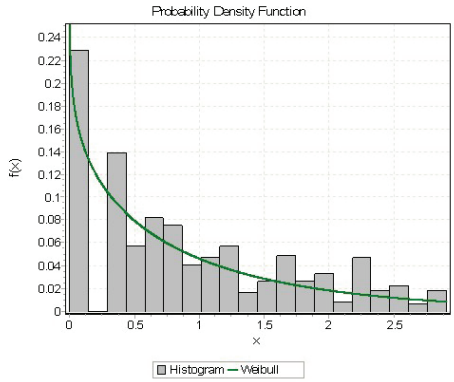
- In the case of four ships for grain cargo, being in exploitation 15 years, the Weibull distribution function with noted parameters was found out as one that best fits the collected data on site, at 297 gauge points (see Figure 2);

- In the case of seven ships for grain and other smallness, dusty bulk cargos, being in exploitation 20 years, the Weibull distribution function, with below given parameters, has been found as one that best fits the collected data over 558 gauge points (see Figure 3);
- In the case of only one available ageing bulk carrier for iron ore and coil, being in service 20 years, the Weibull distribution has been identified again as one which best fits the gathered data over 79 gauge points (see Figure 4);
- In the case of six bulk carries for transportation of iron ore and , being in exploitation 25 years, the Weibull distribution, with given parameters, was found out to best fits the collected data on the corrosion loss over even 679 gauged points (see Figure 5).



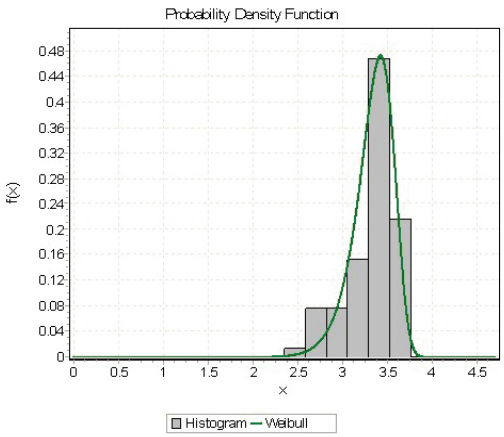
Parameters of the Weibull distribution function: $\alpha = 0.7$; $\beta = 0.51365$; $\gamma = 0$; Mean: .65019; Var.: 0.95085 ; St. Dev.: 1.4624

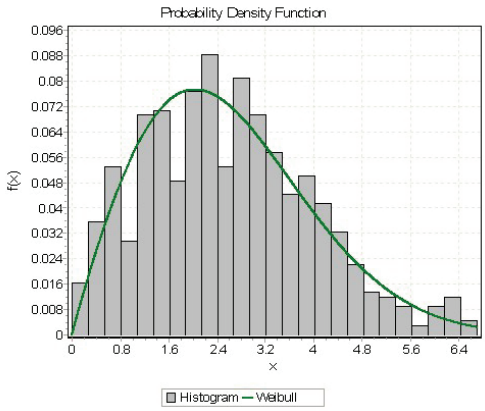
Fig. 2. Corrosion depth [mm] measured over the bulk carriers being in exploitation **15 years** (cargo: **grain**)



Parameters of the Weibull distribution function: $\alpha = 0.87$; $\beta = 1.0$; $\gamma = 0$; Mean: 1.5; Var.: 2.3; St. Dev.: 1.5

Fig. 3. Corrosion depth [mm] measured over the bulk carriers being in exploitation **20 years** (cargo: **grain**)





Parameters of the Weibull distribution function: $\alpha = 18.7$; $\beta = 3.4292$; $\gamma = 0$; Mean: 3.3326; Var.: 0.04858; St. Dev.: 0.22041

Fig. 4. Corrosion depth [mm] measured over the bulk carriers being in exploitation **20 years** (cargo: **iron ore**)

Parameters of the Weibull distribution function: $\alpha = 1.9548$; $\beta = 2.9351$; $\gamma = 0$; Mean: 2.6024; Var.: 1.9283; St. Dev.: 1.3886

Fig. 5. Corrosion depth [mm] measured over the bulk carriers being in exploitation **25 years** (cargo: **iron ore**)

These probabilistic data may be the subject of further more rigorous and detail analysis, but, they can give a general overview how and to what extent corrosion affects ageing bulk carriers in the certain point of time. What is obvious is 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 and coil, 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 (measured values of the corrosion losses on site) it is achieved that some of the collected data are well fitted into the Weibull distribution function, what 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 form the inverse Weibull distribution with arbitrary chosen parameters. This model might be proposed as general one for pre-processing data which are likely to be properly fitted to the Weibull distribution function.

5. Conclusions

The structural member locations of ageing bulk carriers are exposed to a range of corrosive environments. The existence and also the influence of each environment do not remain constant throughout the bulk carriers' service lives. Though, the attempts are directed toward developing as reliable as possible time-variant probabilistic based patterns of corrosion that are characteristic to each, and particularly to those spaces that are the most influenced due to the corrosion wear. Due to some previous analysis [3;22-24] the IBHP has been identified as the most vulnerable member location (area/zone) of aging bulk carriers, and it was probabilistically treated on the basis of the set of original data on the corrosion losses over several analyzed bulk carriers on sites. The measured data have been pre-processed, or filtered, in accordance with randomly generated numbers from inverse Weibull distribution. It has been shown that the pre-processed measured data well follow the Weibull theoretical probability density function, and their main parameters (mean value, standard deviation, and variance) have been calculated for the bulk carriers' being in service 15, 20 and 25 years (in cases of grain and iron ore cargos). The observed scatterings in the Weibull functions parameters over analyzed data sets of measured corrosion depths, pointed the need for further more rigorous investigation in this field above the larger set of the original data being collected in shorter time intervals. Consequently, corrosion losses over ageing bulk carriers' member locations require paramagnet monitoring and profound analysis over each particular segment, and over the vessel hull structure as a whole, simultaneously.

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Chapter 4:
New media in seafarers' education and training

4. Preface

This chapter contains several research works on blended learning. It provides the possibilities of using the Camtasia Studio program in "reviving" PowerPoint presentations, and creating more interesting and more engaging instructional materials. It also shows that Camtasia Studio can be used in self-evaluating the acquired knowledge, and generally in creating interactive educational content. This chapter points to some contemporary post-production resources, regarding audio, video, and screencapturing recordings, intended simply for exporting to the web, or creating a repository of on-line instructional and educational content. An example is the instructional material created in the field of electronic nautical charts. This is an original material, accompanied with narration of teacher, and exported to the Moodle Portal of the Faculty of Maritime Studies (University of Montenegro), for a couple of years back. The goal of this project was to move a part of the classical educational process into a virtual domain, primarily due to the specific profession of seafarers, who often need to sail and educate themselves at the same time.

In addition, there are research studies on the assessment of students' satisfaction with newly introduced distance learning opportunities. The tests were carried out on selected groups of students from the Faculty of Maritime Studies (Montenegro), and the Mediterranean University (Montenegro). For this purpose was used AHP method, DeLone success model of information system, and Kano (dys)functional model. A similar methodology could also be applied to the different and/or more extensive structure of the responders, providing a more credible picture of the satisfaction and needs of the distance learning users in blended environment.

Within this chapter is also a research study that attempts to answer the question: should education be moved to Cloud? The focus is on the developing environments, which are still exposed to the negative effects of digital divide. The study points to some current problems in overcoming the second and the third wave of digital divide between developed and developing parts of the world. Here is suggested a methodological framework that could be used to assess the real needs and preferences of developing environments regarding the transfer of education into the sphere of Cloud services, i.e., dislocated digitized repositories of instructional contents in the virtual world.

4.1. Camtasia Studio in teaching ECDIS

The basic idea of this research work is to motivate teachers/instructors of maritime schools and colleges to create interesting and engaging screencasts for teaching students (future seafarers) ECDIS basis, by using new contemporary media and didactical solutions. Camtasia Studio has been proposed as suitable applied software for doing so. It is a multi-media, user-friendly environment, providing the customers with the variety of possibilities for editing PowerPoint presentations with the introduction of audio, video and different animations, in order to make teaching/learning content more interesting and to point out the most important issues. It allows computer screen video capturing, and adding of audio and numerous animated effects to it, as well as augmenting video recordings into the Camtasia project(s). Even though the proposed software tool possesses a broad palette of advanced features for recording and editing "lively" and edifying recordings, within this study only brief descriptions of "reviving" classical PowerPoint presentations, taking the screen captures over Transas demo ECDIS software, and their editing is presented. Several examples of instructional recordings concerning ECDIS operational basis, and possibility of students' self-evaluation have been given, too.

1. Introduction

Contemporary sophisticated navigation equipment requires permanent rising the quality of teaching/learning level(s) at MET (Maritime Education and Training) institutions. Students, future seafarers, should have available resources in order to learn more: quickly and easily. It should be borne in mind that students are increasingly exposed to the dual pressure nowadays, i.e. most of them have to study and work at the same time. Offering them e- or blended learning materials is a kind of relief. On the software market there are a lot of new media tools that are available to teachers for creating e-learning educational/training materials. Some of them are free, which is an additional benefit. By exchanging experiences and through persistent experimentation, teachers can relatively easy create instructional materials that will encourage students to learn, in parallel with greatly facilitating their cognitive processes and acquiring new knowledge and skills.

Often, the prevailing students' motivation factor for choosing the profession of seafarer has been the income. Following this motif, seafarers (e.g. from Montenegro and the entire region) have been employed by mainly bad companies. This practice is to be gradually changed. With improved education, the students would become competent for finding employment in better and more successful companies investing in their staff and their professional training. This would create a new "class" of experienced seafarers, who could later take part in education and raise its quality to an enviable level. In other words, by introducing students to the space which facilitate easy acquisition of even theoretical knowledge, and getting more quickly competencies of considerably higher level, the previous mentioned should be slightly change in the future. To this end, the paper presents a few ideas on how to teach, and consequently easier learn basics of ECDIS (Electronic Chart Display and Information System) on the exemplar of Camtasia Studio software tool employment at METs in more efficient knowledge transfer.

The paper is organized in the following way: (a) A short description of ECDIS is given in order to emphasize its importance in providing safe and effective maritime navigation; (b) An overview on software tools that can be used in creating more interesting and engaging educational materials is given, with a particular emphasize on Camtasia Studio being used here; (c) Several examples of using Camtasia Studio in teaching/learning ECDIS are given, and (d) Some conclusion remarks, along with the directions for further research work in this field are given, as well.

2. ECDIS: as a content of the instructional materials

The ECDIS is an entirely electronically based navigation system that integrates real-time navigational data from ship sensors (GPS, Radar, AIS, etc.) and electronic navigational charts (ENCs - Electronic Nautical Charts) [17;18]. In its very nature, it is a centralizing instrument with the unique function of integrating many aspects of navigation [15]. More explicitly, it allows the integration of numerous operational data, such as ship's course and speed, depth soundings, and radar data into the display. Furthermore, it allows automation of alarm systems to alert the navigator of potentially dangerous situations, and gives him/her a complete picture of the instantaneous situation of the vessel and all charted dangers in the area [9]. ECDIS has been conceived in such a way to support and enforce the transition to the e-Navigation concept [17].

Although the International Maritime Organization (IMO) officially approved it as the equivalent to the classical paper charts in November 1995 [9], the transition to its full usage in practical maritime navigation is still slow. The causes are the lack of the official ENCs, the high cost of ECDIS, and a dose of skepticism in accepting this new technology by the traditional marine community. However, ECDIS has benefits in terms of time saving in route planning and monitoring, preventing accidents and thus protecting the ship and marine environment. ECDIS functions can be used effectively especially in restrictive waterway areas, during periods of poor visibility, i.e. under conditions of mist and during the night. In coastal waters it is generally very easy to derive the position with the view from the bridge windows, as well as with the information from other prime navigational devices. But, care must be taken to ensure that radar is always used as the primary collision avoidance aid and ECDIS as the primary charting aid [18].

The key components of ECDIS display, i.e. most of the visualized commands of ECDIS (on the exemplar of Navi-Trainer Professional NTPro 4000 nautical simulator manufactured by the Transas Marine) have been described in detail within some previously published papers by the author in this field and cited in [1]. Also, the basic and some advance features of ECDIS have been covered by numerous referential literature resources, e.g. like [9-17;20-22;25-31]. Though, the focus will be given here on using new media tools in better teaching/learning ECDIS principles.

3. Camtasia Studio: as a tool for creating the instructional materials

Nowadays there is a quite large offer of different application software which can be used for producing:

- *audio* (Audacity, NCH Wave Pod, Adobe Audition, Cubase Steinberg, Logic Studio, Kristal Audio Engine, etc);
- *video* (Windows Movie Maker, Adobe Premiere, Avidemux, Magix Video, Video Spin, AVIedit, etc); and,
- *sreencapturing* (Adobe Capticate, Capture Fox, Camtasia Studio, Jing, ActivePresenter, BB Flashback, BB Flashback Express, ScreenPresso, VirtualDub, etc).

  Web can be used, of course, as a resource for further search in the field [32;33].

Some of these software tools are proprietary commercial, while some are freeware. And it is difficult to give the recommendation which one should be used. Exploring *pros* and *cons* of these and numerous other software is beyond the scope of this article. However, at this moment of the authors' work in this domain, the most appropriate *seems* here employed and briefly presented Camtasia Studio software. However, this does not mean

that the teachers/educators at METs should not experiment with other tools, and that the authors will not do so, what should undoubtedly create new opportunities for exchanging and mutual enriching experiences in this MET sphere in the future.

Hence, the following part of this section will provide the reader with some basic Camtasia Studio features. Camtasia Studio is a set of software applications for creating professional-looking presentations, video tutorials and/or screen captures, published by TechSmith [23]. It allows: creating professional videos easily, recording on-screen activity, customizing and editing content, adding interactive elements, and sharing videos with anyone, on nearly any device.

More precisely, the PowerPoint presentation recordings along with a variety of animated effects, the narrator's voice, background sounds (music), and web camera recordings of the presenter are enabled by this software. Additionally, the whole screen, or the exact pre-specified screen area (of any PC program, or, here the ECDIS Transas demo version) can be captured, and audio may be recorded simultaneously, or embedded latter, from any standard input source device. During the content production the presenter is able to *jump* from one application to another without interrupting the recording process. The presenter is able to stop recording with a hotkey combination at any time, at which point the software renders the input that has been captured, and applies user-defined settings. After the presentation had been captured, it is possible to revise it by cutting and/or pasting different parts, as needed.

The presenter is also able to overlay the voice sequences, sound effects or music onto the presentation, if it is needed. Camtasia allows audio recording while screen-capturing is in progress, so the presenter can narrate the demonstration as it is carried out. Most presenters, however, prefer to wait until they have finished the screen-capture, and then record the narration from a script as the application is playing back the recorded capture. The program allows files to be stored in its own proprietary format, which is only readable by Camtasia itself; this format allows fairly small file sizes as well as longer presentations [23;24].

The completed video recordings can be also output to several different, popular common (video) file formats, such as AVI, Flash, SWF, Quick Time, RealMedia, etc., which can be easily read by most computers. Camtasia Studio can be used for quickly recording, editing and submitting variety of contents in variety of manners.

Within this context of learning ECDIS fundamentals, and some of its advanced functions – more efficient knowledge transfer and its acquisition by the students, particularly future seafarers among them, it is Camtasia Studio primary task.

3.1. On recording Power Point presentations about ECDIS basis

In general, recording PowerPoint presentations should be realized in two ways: recordings can be done directly from PowerPoint by using Camtasia Studio PowerPoint Add-in tool, or by saving each PowerPoint presentation slide in JPEG format, and importing them into the Camtasia Studio Clip Bin, and latter on, transferring them sequentially to the Timeline. Then, the JPEG files can be edited by associating them with voice narration, web camera recordings, different animated and transitioning effects, etc. The detail description on both procedures can be found in [23]. In introducing students with the ECDIS basis: historical facts, standards, types of navigational charts, performances, educational-training requirements, etc., both ways of PowerPoint recording have been applied by the authors. Also, the authors have realized some experiments with

Web camera and inserted recordings into the video as Picture-in-Picture (PIP) augmentation, what makes the presentations more interesting and engaging for the students. Due to the voice narration, background sounding, and web camera recordings, along with the different animations, above listed topics became undoubtedly more interesting; firstly, in terms of keeping up students' attention and most probably, making them curios to learn more on this topic in the perspective.

Undoubtedly, it is more interesting and "lively" to present some examples of using Camtasia Studio in recording screen captures over ECDIS Transas demo software. Thus, in the following section some of these examples will be presented and briefly explained.

3.2. On recording the screen captures over ECDIS software

In the process of recording screen captures on ECDIS, the Transas demo version 2.00.012 (2010) has been used as a base upon which the recordings are done. The whole screen is recorded, along with the presenter narration, and after the recording had been finished, the capture is imported to the Camtasia Studio and edited. Different animated effects (callouts, captions, smart-focus tools: zoom, pan, etc.) are added, in order to make the captures more interesting, and ultimately more edifying to students. Although, all necessary details on screen recording, audio adding, and editing the recordings can be found in [23] – it is on a presenter, here teacher/instructor, to optimally allocate the place and duration of each animated effect within the presentation, aiming to make engaging and really worth audio/video record, prepared to be shared among students, colleges, and/or wider, e.g. Web audience.

Some screencasts which present the process of capturing the screen and editing the screen captures taken over ECDIS demo version software are given below (Fig. 1-5).

Example 1: The main object of the screen shot shown in Fig. 1, along with the voice narration of the presenter, was the route creating graphically, and scheduling it by entering ETD (Estimated Time of Departure) and ETA (Estimated Time of Arrival). The process of route saving (for later reference and potential output to the autopilot), along with the possibility of deleting some of its segments, or inserting new ones has been presented. The possibility of waypoints' parameter tracking in the control panel from the route data sub-window has been explained, as well, and it is marked on the screen (Fig. 1) as an important segment of ECDIS route monitoring. Within this context of route planning it is to be pointed that the operator should control the route parameters related to the alarms and indicators, like [9]:

- Cross-track error: set the distance to either side of the track the vessel can stay before an alarm sounds. This will depend on the phase of navigation, weather and traffic;
- Safety contour: set the depth contour line which will alert the navigator that the vessel is approaching shallow water;
- Course deviation: set the number of degrees off course the vessel's heading should be allowed to stray before an alarm sounds;
- Critical point approach: set the distance before approaching each waypoint or other critical point that an alarm will sound;
- Datum: set the datum of the positioning system to the datum of the chart, if different, etc.

Because of the demo version of ECDIS by means of which the Camtasia Studio presentation features have been applied in this work, there are certain limitations in setting on the critical values of the above listed parameters by the user, though for the purpose of

continuing to meet the students with the functions of ECDIS, the real ECDIS simulator should be necessarily used (e.g. Navi-Trainer Professional NTPro 4000 nautical simulator, or an advanced version).

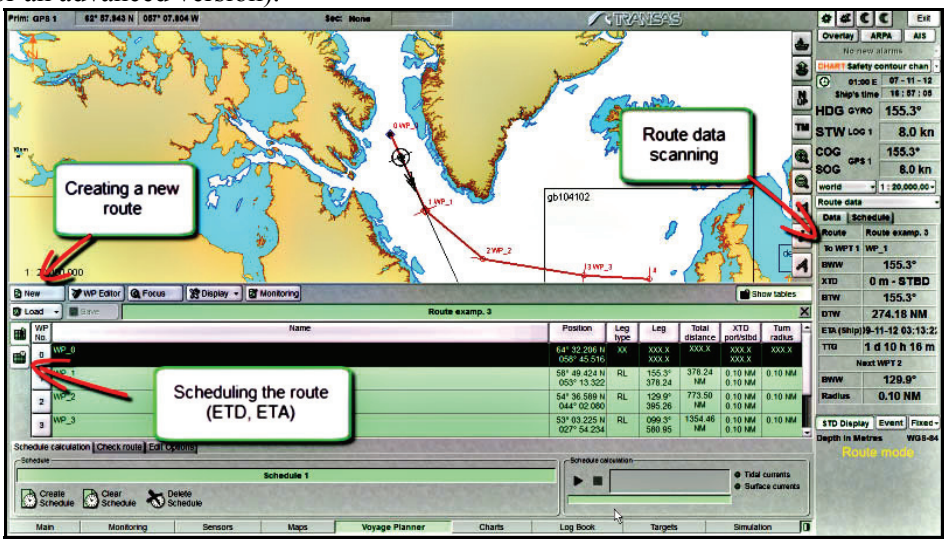

Fig. 1. Route planning procedure

Example 2: Here, the process of acquisition of the AIS (Automatic Identification System) target data (in manual, not in random mode in here employed ECDIS demo version) has been also shown in the short video presentation (Fig. 2). For the purpose of making AIS targets visible and selecting one of them, the AIS overlay command button must be pressed in the command panel in the upper right corner of the display. In the simulation panel the random button has to be switched off and certain available AIS target is to be selected and enabled. Its position can be controlled by inserting manually its coordinates and course, or by cursor, i.e. by positioning it directly at the proper place, along with the direction onto the chart panel. These options are zoom in by zoom and pad (zoom-n-pan) Camtasia Studio tool, and marked in red by the callouts in Fig. 2.

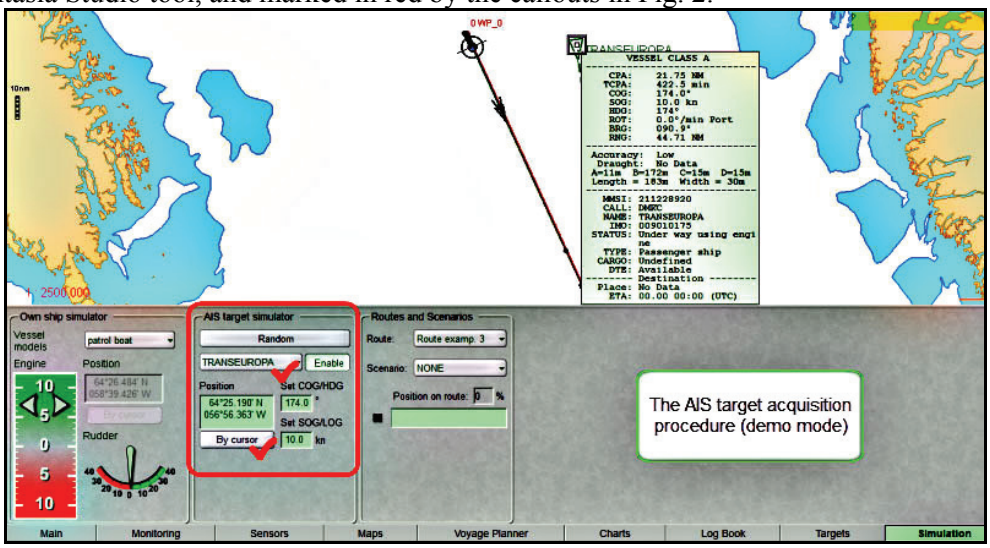

Fig. 2. AIS target acquisition

Example 3: In the Fig. 3 the imitation of the chart update procedure is outlined. The ECDIS operator has to find the available update of certain chart in Chart functional panel and to upload it into the system, i.e. to replace the old chart by the new one. The updates are marked in orange (in here used demo ECDIS version) in the new chart version, and the renewed data can be seen for each marked object in the updated chart, simply, by clicking the info button. It is to be mentioned that each vessel should have up-to-date charts for safe navigation. That is the requirement of SOLAS Convention regulationV/27. Updates can be manual or official (automatic or semiautomatic). The manual update is used for navigational warnings sent as MSI (Maritime Safety Information) by NAVTEX, or EGC (Exchange Group Call). Official updates are distributed by RENCs (Regional Electronic Navigational Chart Coordinating Center) throughout the update discs [17].

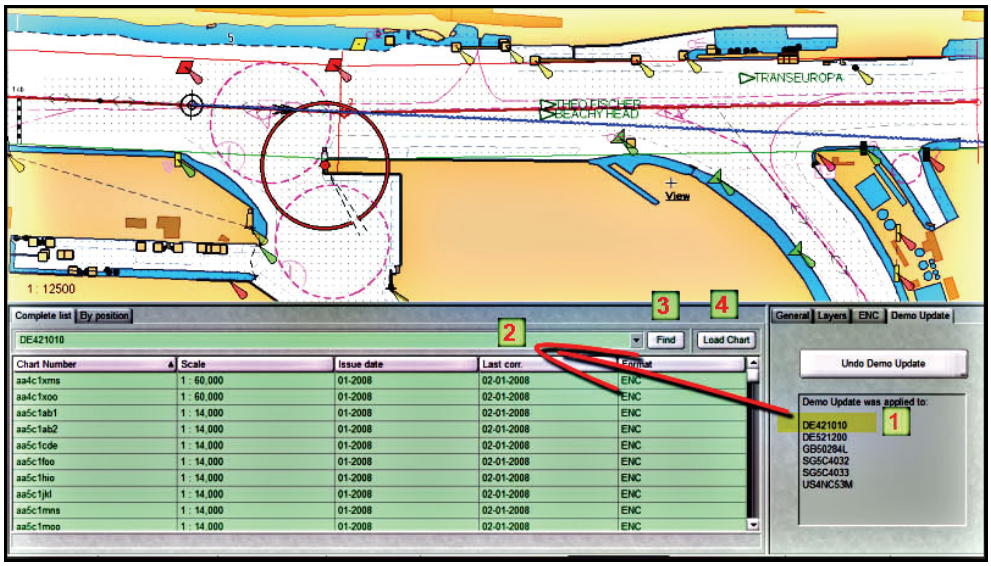

Fig. 3. Imitating charts updating procedure

Example 4: In the Fig. 4 and 5, is graphically presented the principle of checking primary (acquired by GPS) and secondary (acquired by referential object at the coast) position of the ship. Through such "picturesque" presentation it becomes clearer, i.e. more understandable to the students how they can realize this very important procedure of checking the position. Of course, the variations in manus and options are present from one to another version of ECDIS software, but the very basic idea of this common officer on watch action is similar.

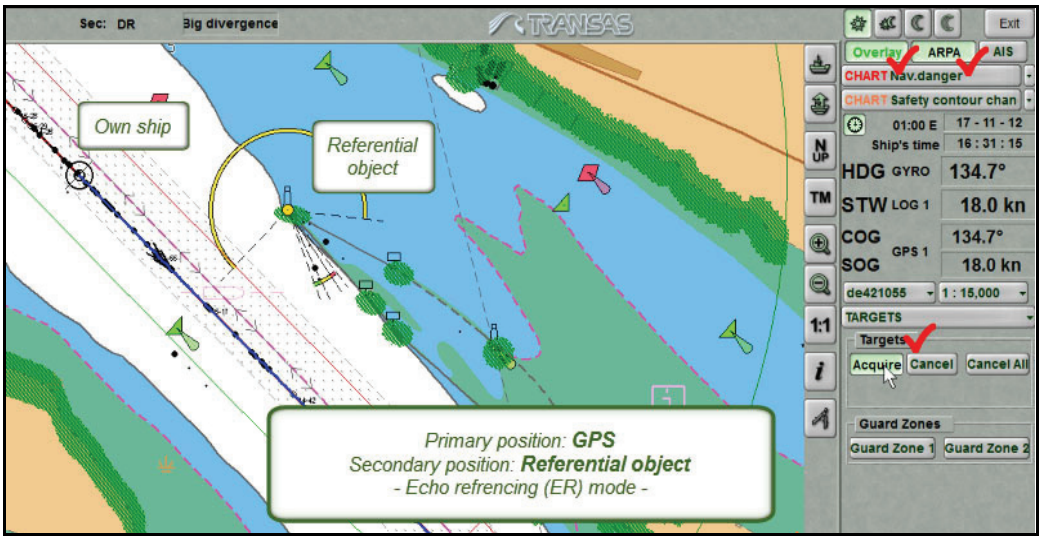

Fig. 4. Comparing primary and secondary position: GPS vs. referential object position on the coast

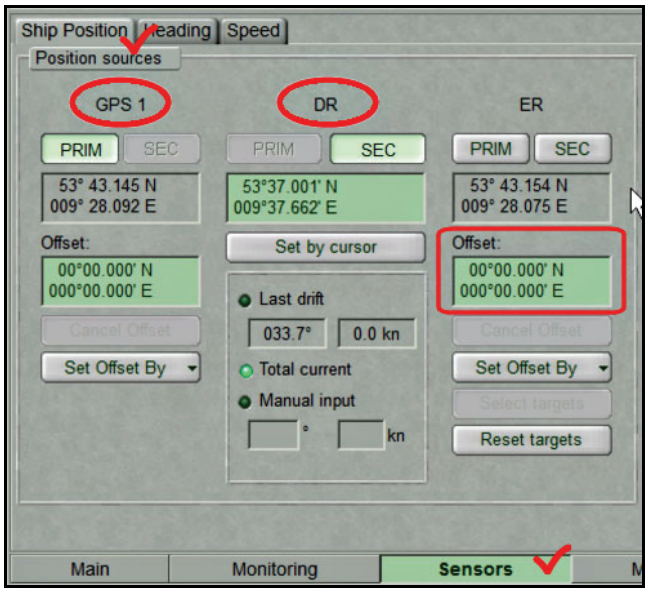

Fig. 5. Comparing primary and secondary position: offset checking

It is to be pointed out once again that by using the available preset scenarios in ECDIS Transas demo version 2.00.012 (2010) the ARPA overlay and the NAVTEX messages observing are available, as well as the possibility of imitating chart updating procedure. However, since the demo version of ECDIS is in matter, these options are available only for some preset route scenarios, but not in the free route planning mode. Of course, these and others, rather numerous restrictions, as those related to some relevant route parameters tracking (cross-track error, safety contour, course deviation, critical point approach, etc.) should be overcome by using *real* ECDIS simulator, or through underway exercise sequences on real ECDIS [14;15], as the sound and confident platforms for re-

cording, editing, and post-producing educational/training videos by new media equipment and software tools devoted to providing more efficient knowledge transfer in this domain.

Though, such approach might be a challenge for forthcoming, more extensive and rigorous investigation work in this field. Also, instead of Camtasia Studio, some other applied software can be applied, e.g. Adobe Premiere, since it offers some advanced possibilities of video recording, editing and post-producing educational materials of higher quality.

4. Towards achieving better interactivity

The reader may get the impression that Camtasia Studio does not provide enough space to interact with the students. But still, there is a way that this lack of interactive dimension can "catch up", and that is through the creation of self-evaluation tests for students. With the intention to approach the procedural level in Camtasia Studio for creating self-evaluation tests, then it is to begin by using the options (Camtasia Studio ver.7): Tools => Quizzing ... => Add quiz ..., and then the options Move => Quizzing ..., are to be consulted. Tests may include the questions of the following types:

- Multiple choice;
- Fill in the blank; and,
- Short answer (which is not scored).

Within one quiz, or self-evaluation test all these types of questions may be included and combined in different ways, depending of the instructional material and the teacher's conceive of that how the test should be. Immediately after answering the question the students can get the score, and though check their knowledge about the topic(s). In Fig. 6 is given an example of self evaluation test (segments) with multiple choices and fill in blank options of providing answers, along with the form in which the students can see the score.

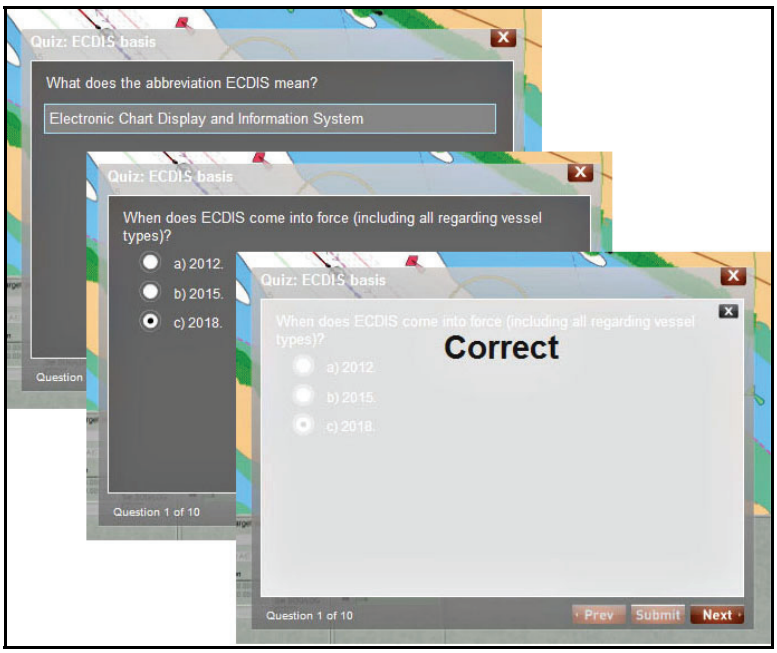

Fig. 6. An example of Camtasia Studio quiz on ECDIS basis

5. Some general recommendations

What should be treated as general recommendations for recording and editing engaging ECDIS learning captures? - Regardless of the content of the presentation, the answer is almost the same [19]. First of all, the presenter must have a good knowledge of the area which he/she presents. Additionally, he/she should be well prepared in a sense of having very clear idea about what, in what extent, and in which order it is to be said. The presentation should be clear and concise. And, the presenter should not be "in rush", at all, during the narration/explanation phase(s). Leaving some *free* or *silence* sequences is recommended, as well. The following animated effects should be of the appropriate length, and given in the appropriate amount. Students should be allowed to hear and understand what the presentation is about.

Since teaching/learning ECDIS is a very important issue, which directly touches the fully electronic integration of almost all vital navigational equipment and acquisition of the information that they provide, which ultimately implies the safety of navigation – these particularly reinforce previously given, rather general, suggestions.

6. Conclusions

The paper contains short description of ECDIS and its importance to the safe navigation, as it is previously mentioned, in terms of recalling the author's previous published papers referred in [1] and some well-known references in this field [9-17;20-22;25-31]. An emphasis is put on introducing contemporary methods and techniques into the process of learning students of maritime schools and colleges ECDIS principles and operational basis. Consequently, Camtasia Studio applied software has been recommended as a quite suitable tool by the authors, and briefly presented in order to draw the attention of teachers and instructors at METs in a manner how to make their lectures more interesting and engaging for students. The engagement of students is of crucial importance of the appropriate acquiring of the knowledge. Besides Camtasia Studio, many new technological solutions are available on the software market for educators to create a kind of alternative learning environment in which students learning should be expanded and reinforced [19]. Learning ECDIS by involving advanced media tools, such as Camtasia Studio, should be undoubtedly an interesting platform for developing more stimulating learning environment, and new active knowledge transfer (tele)channels between educators/trainers and students and/or trainees in the field of electronic navigation and in another fields, as well.

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4.2. Web based learning at maritime education: A case study

The purpose of this research study is threefold. Firstly, it considers the real needs which led to the idea of conceiving and developing new study program supported by web based e-learning system (WELS) at the Faculty of Maritime Studies (University of Montenegro) as maritime higher education and training institution. In this part of the study the collaborative projects which enhanced this idea and its implementation are briefly described, as well. Secondly, the results of the polls realized among certain number of involved students, teachers, and experts in related activities, are presented and discussed in order to identify main features along with pros and cons of the WELS being here examined. And, thirdly, some empirically based suggestions when it comes to choose the appropriate software tools for creating more interesting, engaging, inciting, and thus of higher quality instructional materials being available through WELS, are given.

1. Introduction

Now-a-days numerous recognized and respectful maritime educational and/or training institutions and companies offer e-learning courses, like: Loyd's Maritime Academy, Maritime and Coastguard Agency, MPI Group, USCG Maritime Institute, etc. Of, course the list is long and should not be limited to the above given one. Also, there are a considerable number of scholars' analyses that support the concept of web based e-learning as additional mode of acquiring/transferring knowledge and skills, not only in maritime education, but in general [1;2;6;7;8;9]. However, like in the previous case, the readers should not be limited to these quotations. What supports additionally using WELS at maritime higher educational institutions is the document "The Manila amendments to the Standards of Training, Certification and Watchkeeping for Seafarers Convention and Code" (Philippines, 21-25 June 2010), which concerns, among other numerous issues: <<the introduction of modern training methodology including distance learning and web-based learning into maritime education and training>>. This strongly supports the efforts of conceiving, implementing and developing WELS at maritime higher educational and/or training institutions.

2. Background

The Faculty of Maritime Studies of Kotor (FMS) has long lasting tradition being founded even in the medieval times, when captain Marko Martinović has his own nautical school for Russian feudal lords (in 17th century) in Perast, a little seaside town near Kotor (today Montenegro). Later on, this nautical school continues to exist in Kotor, and it still works as FMS, educating students and seamen for variety of both ship and port vacations. Also, graduated students can find employment in the agencies and firms which are focused on different maritime affairs. Although the tradition of nautical and maritime studies in general is long lasting and rich one in Kotor, and along the whole Montenegrin littoral zone, the awareness of existing new and demanding requirements of the actual world living and working flows is necessary. Above all, this awareness is unavoidable since the situation in Montenegro, in the sphere of maritime affairs, is not *flourishing* one. Accordingly, the management of the FMS recently came up to the idea of introducing web based e-learning environment for the needs of the students, especially seamen among them, and all other persons being interested in this mode of education and knowledge transfer. It is to be mentioned in this context that FMS, several years ago, was *forced* in a way to adapt the curricula to the Bologna system which recommends, among other things, presence of the students at almost all classes during the semester. Though, if the students are not present, or if they are usually absent from their classes, there is a risk that they will not pass the examinations! This is particularly case with the students who have to

sail, i.e. to work as seamen to earn their salaries, and to study simultaneously. During the past few years, there were numerous requirements from their side to the FMS's management to organize for them condensed courses several times a year, or to develop and offer them e-learning educational modules. Consequently, the FMS's management decided to meet their requirements and objective needs, and to develop and implement an appropriate web based e-learning study program.

3. Perpetuators

What caused developing e-learning instructional modules at the Faculty of Maritime Studies (FMS), University of Montenegro, besides the enthusiasm of few teachers and their desire to enrich traditional channels of knowledge transfer - are three projects briefly presented below.

Project 1: The first one is the Tempus project (2010-2013): "Enhancing the quality of distance learning at Western Balkan higher education institutions" (www.dlweb.kg.ac.rs, last access: January, 2013). The objectives of this project are: to improve the quality and relevance of distance education at Western Balkan higher education institutions and to enable easier inclusion of partner country institutions into European Higher Education Area. These implies the specific objectives: to improve, develop and implement accreditation standards, guidelines and procedures for quality assurance of distance education study programs according to EU practices at national level in Western Balkan (WB) beneficiary countries; to establish the framework for improving distance learning (DL) quality assurance and e-learning methodology on higher education (HE) institutional level in WB countries; to provide training for relevant members of HE educational and public authorities responsible for accreditation and evaluation of DL programs and trainers involved in DL from each partner country, etc. The project leader is University of Kragujevac (Serbia). Owing to this large project, University's of Montenegro Center of Information System "set up" Moodle (1.94) server, what creates the opportunity for FMS to use its capacities in preparing and realizing web based educational activities. Through this project a few teachers and assistants from FMS also had opportunities to attend short training courses being dedicated to e-learning, several times, and to participate in discussion process along with the experts from EU in this domain.

Project 2: The second is the small project of bilateral cooperation realized between FMS and the Academy for New Media and Knowledge Transfer – ANMKT (University of Graz). This project entitled: "Developing an e-learning module at Faculty of Maritime Studies (Kotor, Montenegro) for the seamen educational needs" had as its main aim: conceiving a new web based educational program at FMS devoted primarily to the seamen (among the students) needs. However, this module should be used by all other potential users, besides seamen, who are interesting in such kind of acquiring knowledge. The University of Graz supported the project by bringing in perennial expert knowledge in novel e-based didactical methods and techniques. In return developed e-learning methods and tools were tested on the basis of a concrete case study. Within this project (2011-2013) experts from ANMKT transferred very useful practical skills on the use of Moodle Management Learning System (MLS) in the effective implementation of e-learning to the teachers and system engineers of FMS throughout several trainings.

Project 3: The third important project within this context is a follow-up of the previously mentioned project of bilateral cooperation between FMS and ANMKT. This project entitled: "Distant learning implementation at the Faculty of Maritime Studies, University

of Montenegro, as the additional mode of education" aims effective implementing and developing of web based e-learning at the FMS as additional mode of knowledge transfer, devoted, again, primarily to the seamen needs. ANMKT was the partner in conceiving this e-based instructional module and through this project it will support its effective implementation. In the mean time, this e-learning module has been accredited by the Montenegrin National Council for High Education, and the study program started officially in September, 2012. This e-learning module is still implemented by Moodle platform, and currently it is available at the FMS web portal: fzp.moodle.ac.me/login/index.php. The materials for some of the planned courses are uploaded at the platform, and they are currently available to the certain number of teachers and students who can test it on-line and suggest the improvements. In this second phase of the project, possibilities of enriching on-line resources by introducing audio/video/screencapturing records shall be considered, as well. The possibilities of extending this e-learning aid toward the mobile-learning one, by the Windows 7 Phone [11] and some other similar applications, for mobile devices like i-Phones, shall be considered as well. This project is approved and it will be realized within the ongoing two years period (2013-2014).

These three projects are in fact perpetrators of implementing and developing web based e-learning resources at the FMS as maritime higher education and training (MHET) institution.

4. Survey analysis

From the beginning of the WELS project implementation at FMS, several surveys among the students (e-learners) have been conducted in order to examine in a way how their perceptions of the advantages and disadvantages of WELS correspond with the creators' of this course ideas. In total, 110 students at the postgraduate level have been involved into the survey. Specifically, the interviewed students were supposed to identify the WELS advantages and disadvantages, according to their visions, among the offered options (Table 1). What is indicative, more than 50% of the respondents agreed that the suggested advantages of WELS: A1, A2, and A3, are *indeed* benefits of WELS, as it was predicted by the creators of this system. On the other side, among the disadvantages of WELS, more than 50% of respondents identified only predefined disadvantage D2 as *real* disadvantage (Figure 1).

Table 1. The WELS advantages and disadvantages taken into consideration

	Advantages
A1:	The possibility of learning from home and working place (during the breaks)
A2:	Reducing the traveling costs and time saving
A3:	Easier access to the instructional materials
A4:	Possibility of self knowledge evaluation through on-line tests
A5:	Ability to communicate via the net with teachers and other candidates
A6:	More effective learning
	Disadvantages
D1:	Lack of *direct* contact with teachers
D2:	Inability to put a question, and get the answer immediately, when there is some ambiguity in knowledge transfer
D3:	A nonstandard form of learning that requires a strong will, self-discipline, and high level of concentration
D4:	Some exams are taken on-line, which is sometimes stressful, due to limited time, and present fear if the technique will/will not function properly

How the obtained results (Figure 1) can be interpreted? - Most of the surveyed students are still not convinced that the possibilities of self-controlling learning process, learning community activities, and more effective learning are the advantages of the WELS (A5 and A6 are lower than 50%). What does it imply? – It implies that students should be convinced into these WELS benefits, i.e. more intensive communication to the teachers and among the students themselves should be enabled, as well as more interesting and inciting self evaluation tests and educational games, etc. Consequently, the learning outcomes should be obviously higher.

If we now consider the supposed disadvantages of WELS, the e-learners do not see as big problems: on/line testing, need for a strong self motivation, and lack of direct contact to the teachers, otherwise offered through the traditional classroom teaching/learning. But, what e-learners really need is undoubtedly more frequent consultations with the teachers, in accordance to *one-to-one* principle. This conclusion directly corresponds to the recognized disadvantage D2. On the other hand, by achieving this, the WELS will give better results due to uprising learning effectiveness. Since this is only a preliminary study, it is to be extended throughout the future research activities planed by the authors, with the aim of scanning e-learners' satisfaction, and concerning the directions toward increasing the overall effects of WELS based learning process.

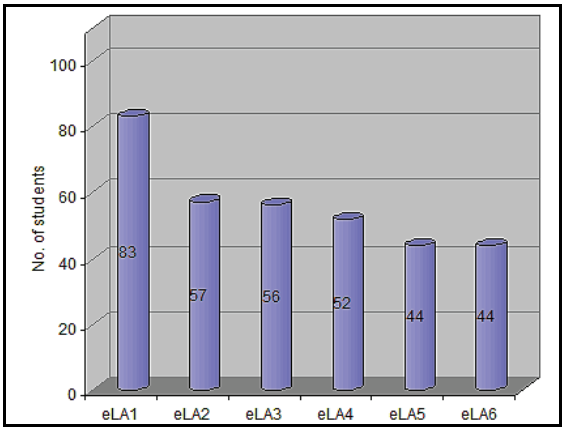

Fig. 1. Number of e-learners (students) who opted for the offered WELS advantages (ref. Table 1)

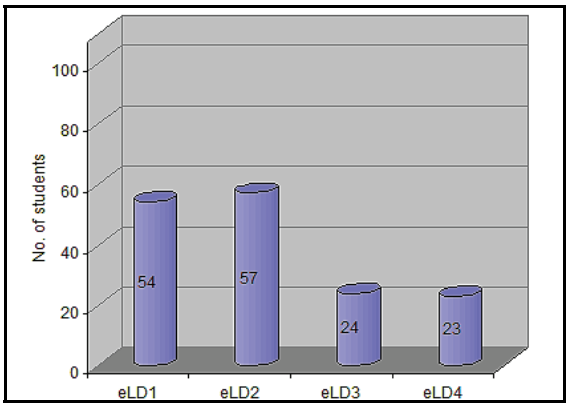

Fig. 2. Number of e-learners (students) who opted for the offered WELS disadvantages (ref. Table 1)

In order to obtain as complete as possible feedback in the current moment on the realized WELS, besides the surveys among the students of the specialist studies at the FMS, one survey is conducted among teachers at the FMS and experts in developing new IT-supported didactic methods from the ANMKT. The poll conducted among the teachers and the experts has been based on the well-known and in literature extensively used Saaty's AHP (Analytical Hierarchy Process) method and the author's previous research papers [3;5]. This approach enabled us to rank some WELS features, which have been in the context of this study identified as important ones (Table 2). The ranks are determined by the values of normalized average weight coefficients being previously calculated for each considered criteria, i.e. WELS feature. Certainly, the readers should not be limited by them in the sense that it is underlined the need for further, more extensive and rigorous research in this area.

Table 2. The rank of the analyzed WELS features by AHP approach, on the basis of the survey among experts (ANMKT) and teachers (FMS)

Features	***Rank***
- Availability on-line and high quality of all necessary materials for preparing the exam in a subject	1
- Stability and speed of the Internet connection (what is not always the case at the sea and in some ports)	2
- The existence of the tests for self evaluation of the acquired knowledge	3
- Possibility of regular communication with teachers via forum, chat and/or e-mail	4
- Possibilities of doing and evaluating tests and final exam on-line	5
- Conducting regular students' surveys	6

The obtained ranks of in the paper analyzed WELS features could be qualified in following manner:

- The teachers and the experts involved in this research assigned numerically by the largest marks, and gave consequently the greatest importance in the qualitative sense, to the availability on the web of the instructional materials (which implies their appropriateness and quality);
- In the second place, they positioned stability of Internet connection, which is understandable, since here examined WELS is devoted mostly to the seafarers. Namely, it is often not possible to establish Internet connection on the vast sea, or it is usually unstable. Another interpretation should be that the teachers and the experts consider a stable Internet connection fundamental pre-condition for WELS establishing;
- On the third position is the availability of tests for students' (here mostly seafarers') self-evaluation during the process of acquiring knowledge, what is also a very important segment of e-learning, which indirectly should involve the existence of *smart* educational games, as well;
- The fourth position is reserved here to the possibilities for the students to communicate to teachers via forum, chat, e-mail, etc, which is of course very important segment of e-learning, but it is sometimes difficult to achieve this due to the previously mentioned problems with Internet connection and its stability at the sea (and sometimes in the ports). On the other side, teachers are usually too busy, and they are practically sometimes *physically* prevented to devote more time to the communication to students; and,
- At the lowest positions are WELS technical possibilities of doing exams on-line, and conducting regular on-line (or classical) surveys among the students, related to their

degree of satisfaction with offered e-learning services, respectively. This is understandable, since the Internet as an *open* communication channel is not *perfect* for testing students on-line. In addition, even surveys conducted among students are very important, in comparison with the previously considered components of e-learning they are for sure slightly less important. However, this does not mean at all that they should be ignored.

This conducted survey reflexes profoundly very subtle nuances in mutual positions of the analyzed e-learning features, and it remains us to associate them to the high degree of expertise and sensitivity of the responders in this domain [3].

Further analysis should be directed toward evaluating e-learners' satisfaction with offered WELS and this will be realized by multi-criteria evaluation technique based on Saaty's AHP [10;12;13]. Since the large number of respondents is necessary for conducting such analysis, the possibility of involving some other institutions that offer WELS is in consideration. Namely, a large number of responders is a kind of guaranty that the survey will be successful and reliable, i.e. that the largest number of responds will be consistent in accordance to the Saay's AHP method requirements.

5. Choosing the software tools for creating inciting instructional materials

If we look at the above presented ranking of the WELS features, it is evident that the availability and quality of the instructional materials are rated as the most important factors by teachers and experts in WELS. Undoubtedly, the quality of the instructional material is one of the key factors for successful implementation of WELS. Since the appropriate IS/IT solutions and tools are necessary in their creating, this part of the article offers a short overview of some available up-to-date software tools for creating interesting and engaging instructional WELS materials, along with the recommendations, based mostly on the authors' experience, which of them is the most appropriate for certain application.

Today, there is a quite large offer of different proprietary commercial and freeware application software which can be used for producing (Table 3):

- *Audio*: Audacity, NCH Wave Pod, Adobe Audition, Cubase Steinberg, Logic Studio, Kristal Audio Engine, etc.;
- *Video*: Windows Movie Maker, Adobe Premiere, Avidemux, Magix Video, Video Spin, AVIedit, etc.; and,
- *Sreencapturing*: Adobe Capticate, Capture Fox, Camtasia Studio, Jing, ActivePresenter, BB Flashback, BB Flashback Express, ScreenPresso, VirtualDub, etc.

Web can be used as a resource for further search [14;15].

Table 3. List of the software tools for post-production of e-learning teaching materials

Software / Feature	**A**	**V**	**S**	**C**	**F**
Audacity	X				X
NCH Wave Pod	X				X
Cubase Steinberg	X			X	
Logic Studio	X			X	
Kristal Audio Engine	X				X
Windows Movie Maker		X			X
Lightworks		X			X
Avidemux		X			X
Magix Video		X		X	
Adobe Premiere		X		X	
Video Spin		X			X

AVIedit		X			X
Adobe Captivate			X	X	
Camtasia Studio			X	X	
Jing			X		X
CamStudio			X		X

Legend: **A**-audio; **V**-video; **S**-screencapturing; **C**-commercial; **F**-freeware

The list above is not exhaustive as there are many more software tools on the market, proprietary commercial, as well as, freeware and shareware. Of course, there is also a difference concerning the available functions but it is definitely possible to produce up to professional results with selected freeware software.

The following recommendations can be done according to the authors' experiences:

- The open source software *Audacity* is the most powerful freeware tool for audio editing. It offers various effects and analyzing tools for the signal processing, e.g. powerful noise reduction (even adaptive noise reduction) and dynamic processing as well as equalizing, multi-track editing for sophisticated mixes and of course supports recording from any microphone or signal source connected to the computer. Professional commercial audio editing software mainly aims at professionals like sound engineers or sound designers. These professional tools provide further interfaces to audio hardware and various 3rd party plugins for high end audio editing.
- In the field of video editing it is the freeware *Lightworks* that offers the most functions and editing tools. Even commercial movies have been cut and produced with that software but however it is not especially designed for beginners, so it requires time to get familiar with the production workflow. A more intuitive way and therefore more appropriate for beginners is the *Windows Movie Maker* (last built version is No. 12). It does support most of the latest video formats and has also build in effects to make transitions and/or color effects and animated titles. It also supports most picture formats so that the producer can combine still and moving pictures in the project. Background sound or speech can be added and mixed.
- Screenrecording tools have become very popular as it is very easy to make engaging tutorials or presentations of what is happening on the monitor. The freeware tools *Camstudio*, *Jing* and *AutoScreenrecorder* offer the general possibility to record the screen but do also include restrictions which can be watermarks, a limited time for recordings or not supported audio recordings along with the screenrecording. Also the choice of output formats is limited in freeware tools.
- Two market leaders offer a professional tool that combines the above mentioned types of recording: *Adobe Captivate*, and *Camtasia Studio*. Camtasia Studio lets the user create professional screenrecordings, you can include other media like pictures, movies or sound. The footage can be arranged in multi track layers, with additional zoom or pan effects as well as highlighting options you can increase the professional look of the production. Below are given some examples of employing Camtasia Studio (ver. 7) in teaching students ECDIS simulator basis. Though, in Figures 3, 4, and 5 are shown some examples of using callouts and zoom or pan effects in teaching students ECDIS (Electronic Chart Display and Information System) basis over Transas NAVI Sailor 4000 demo version simulator [4].

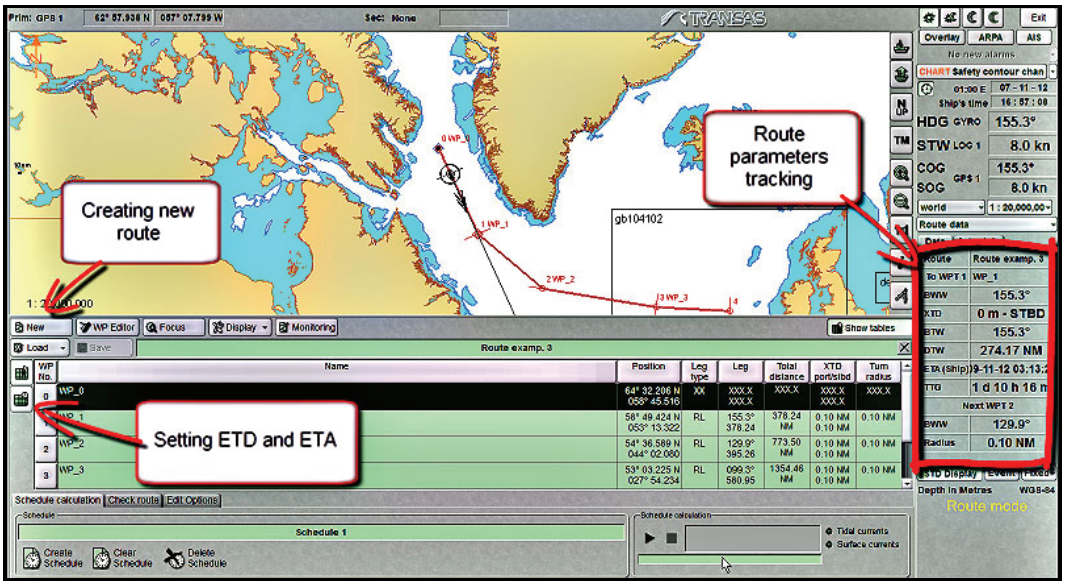

Fig. 3. Callouts for route planning and scheduling in graphical mode

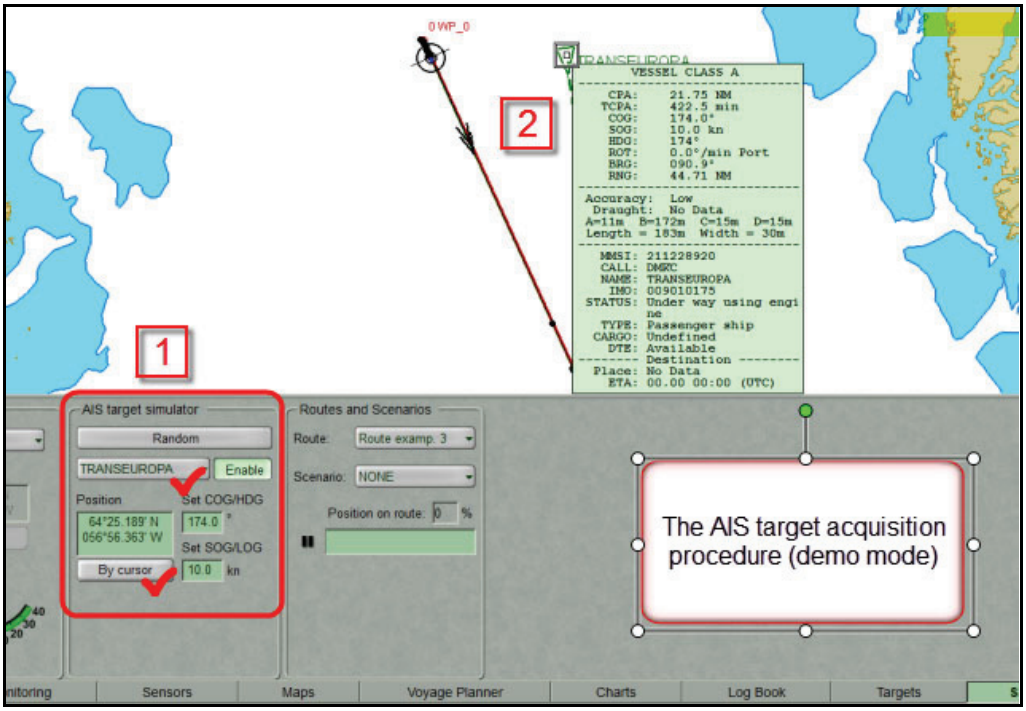

Fig. 4. Callouts and zoom-n-pan effects for explanation of AIS target acquisition

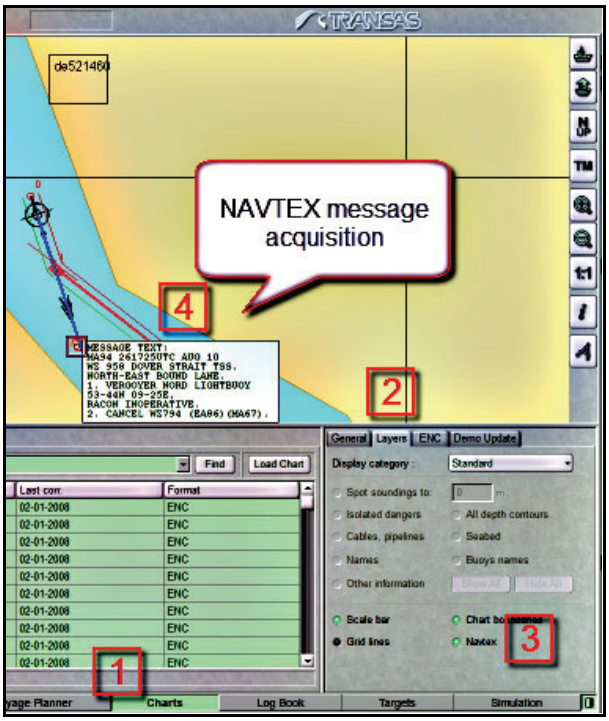

Fig. 5. Callouts and zoom-n-pan effects for explanation of NAVTEX message acquisition

6. Conclusions

All previously mentioned efforts over the introduction and development of e-learning resources at the FMS should improve the overall educational quality standards at MHETs in the Region. However, the need for greater investment in seafarers' higher education (HE) in terms of personnel and infrastructure is indisputable. The networking is also very important, and not "networking just for networking", but a real one is necessary, being based on professional cooperation (on the EU level) among the MHET institutions, through more intensive exchanges of teachers and students for the sake of mutual enrichment of knowledge and implementation of joint projects. It is necessary to establish permanent connections with the maritime industry, e.g., shipping companies interested in providing practical training onboard ships, as well. The national legislation has to be modernized in the sphere of higher education in terms of recognition and proper interpretation and implementation of the STCW (Standards of Training, Certification and Watchkeeping) requirements in terms of faster deployment of virtual learning as a supplement to the traditional education and training of the seafarers. The newest STCW Code amendments concern, and recommend: the introduction of modern training methodology including distance learning and web-based learning in seafarers' knowledge acquiring and upgrading. Within this context, it should not be lost the sight of the fact that STCW Convention itself calls for a proper education - as the foundation of successful training and acquiring competences (see for more data: "The Manila Amendments" - Chapter II, Section B-II/1, Paragraph 14, 2010). It is to be expected that at least some of these recommendations should be shortly considered and accepted by the responsible HE bodies.

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4.3. Adopting e-learning into seafarers' education and training

This research work considers beginning steps in introducing e-learning into seafarers' education, as additional mode of acquiring knowledge at the Faculty of Maritime Studies which is a part of the University of Montenegro. Related activities are the result of the enthusiasm of few professors and they are partly supported by a small, initial project of bilateral scientific and technological cooperation between Austria and Montenegro. The study is conceived in a way that it considers following issues: (a) a brief discussion of some current shortages in maritime education and training in general; (b) possibilities of getting advantages through introducing e-learning into this respectable field of education; (c) some advantages and disadvantages of Moodle which has been used as a technological platform for introducing e-learning in the analyzed case; (d) results of the surveys conducted among involved students, teachers, and professionals in the field of employing new media techniques into the knowledge transfer, and (e) some conclusion remarks regarding possibilities of optimal combining maritime and virtual education.

1. Introduction

The education and training of seafarers should represent very responsible posts, and consequently appreciated ones. However, it is evident that in the world, at the level of national legislation, there are large differences in the interpretation of the STCW (Standards of Training, Certification and Watchkeeping) Convention and its realization through teaching programs at MET (Maritime Education and Training) institutions [3]. This causes the issuance of a large number of certificates, which do not correspond to objectively sufficient knowledge, skills and competencies of future seamen, that is, of those who may in the perspective educate the next generations of seafarers. This is, of course, a serious problem that could be overcome only by serious top-down approach and far greater investment in education and training (i.e. wages and mobility of teachers/trainers; simulators and other supporting equipment; literature; providing training onboard ships, or so called *underway* training, etc). It is necessary to engage and motivate competent teachers in the field of theoretical teaching (education) of seafarers (people with academic titles and corresponding references) as well as experienced (active) captains and officers in the field of practical teaching (training) to establish active cooperation with referential METs in EU and worldwide, and also with successful shipping companies that should provide students with the appropriate training. All mentioned above is far beyond the scope of this paper in which the authors can only focus on one small segment related to the improvement of education of (future) seafarers based on the implementation of e-learning. So, the following chapters contain the discussion about the motives for the introduction of blended learning at the Faculty of Maritime Studies (FMS), University of Montenegro, and the potential benefits that primarily students (active and future sailors), then teachers, and consequently, the MET at which such kind of education is realized, might have.

2. Motives for implementing e-learning

The main motive for the introduction of e-learning in the case examined in the paper were numerous seafarers' demands to enable them to have an alternative possibility of upgrading the education that goes beyond the limits of the Bologna Declaration, which has been applied at the FMS since 2006 year. Namely, the strict requirements for attendance of lectures and exercises and limited number of terms for the exams are absolutely inappropriate to the needs of active sailors, who are for a few months, half a year, or longer onboard ships but would like to, or are pressured to improve their knowledge in order to preserve their jobs and/or get career advancement. Another motive was quite

natural attempt of a few professors to do something about modernizing traditional ways of teaching through the introduction of new technological solutions. What also has contributed is the fact that the FMS indirectly participated in the Tempus project: "Enhancing the quality of distance learning at Western Balkan higher education institutions" (http://www.dlweb.kg.ac.rs), since it is a part of the University of Montenegro as one of the formal partners on this project. Though, this was a big project, based on which the FMS got the possibility of using the University server by means of which Moodle system was 'set up' and a few teachers had the opportunity to attend short training courses being dedicated to e-learning several times. In addition, the FMS and the Academy for New Media in the Transfer of Knowledge – ANMKT (University of Graz), have successfully implemented a project of bilateral cooperation: "Developing an e-learning module for the educational needs" (2011-2012) and they are currently working on preparations for the realization of the second, follow-up one: "Distant learning implementation at the Faculty of Maritime Studies (University of Montenegro) as an additional mode of education" (2013-2014). Colleagues from Graz transferred very useful practical skills on the use of Moodle in the effective implementation of e-learning to the teachers and system engineers of FMS through several trainings. The results of polls conducted among students during the past (2011-2012) and this academic year (2012-2013), which are depicted and analyzed in the separate parts of this article, speak in favor of success of this collaboration.

3. Advantages and disadvantages of the used platform

In the implementation of e-learning at the FMS as an additional type of education the Moodle platform (1.9.4.) has been used [1;4;5;6;11]. The Web portal to access the on-line courses is available on the location: http://fzp.moodle.ac.me. Moodle is an open source course management system, also known as a learning management system or a virtual learning environment. It can be relatively easily used by teachers for creating online dynamic web sites for students. It is very sound tool to manage and promote learning. Some institutions use it as the platform to conduct fully online courses while some use it simply to augment "face-to-face" courses, i.e. as blended learning, what is in fact the case of the FMS as a MET institution. In other words, Moodle is used to support and combine "face-to-face" interaction with e-learning, mobile learning and other forms of learning. According to enabling mobile learning there were some plans at the FMS for implementing Windows 7 Phone application [9] that can be viewed as a proxy for Moodle sites, simplifying and adapting user interface for mobile devices. But this currently remains only on the level of the potential future solution.

Within the following parts of the paper some advantages and disadvantages of a Moodle (1.9.4) will be listed. It is indisputable that the number of benefits is larger, but after dealing with some limitations of the used version of Moodle, in this particular case, we started work on the "raising" of the new (experimental) server with more advanced Moodle (2.3) version. However, since a lot of information on Moodle can be found on the website: https://moodle.org, so much attention will not be given to them, but to some of our personal observations and experiences related to the use of Moodle (1.9.4).

Since the currently released version of Moodle is 2.4 it has to be explained why at the FMS there is still a rather old version of the platform in use. When Moodle was installed at the FMS release 1.6 was the current version. This version was regularly updated until version 1.9.4. Since the program surface of Moodle rather changed with the release of

Moodle 2.x FMS decided to stick to the older version. Mainly this is due to two reasons: 1) Teachers and students are used to the look and feel of the 1.9.x versions and it seemed problematical for them to grow accustomed to a new surface especially at an early stage of working with the platform; and/or 2) The installation of Moodle 2.x demands an enhanced technical environment which is not totally available at the FMS at the moment.

3.1. Advantages of Moodle (1.9.4.)

From the standpoint of teachers (educators) the advantages of Moodle (in comparison of not using a course management system) are numerous. First of all using electronic boards, forums and/or mail teachers can very elegantly direct students to the sites which contain meticulously prepared materials (textual, audio and video recordings) including links to the relevant Web sites, educational games, tests for self-evaluation and others. In the considered case, students are mostly sailors, who spend most of the time of the year on the ship (i.e. at the sea or in the ports located all around the world). While students use on-line educational materials available and mostly are self-taught (here we are talking about students at the postgraduate level), teachers may do the research work, or e.g. work on projects. Thus, they improve their own competence and enhance the reputation and quality of the MET institution at which they are employed. So, the benefits are undeniable manifold. From the standpoint of students, especially seafarers among them, the availability of materials and the opportunity to learn while they are on board is of up most importance. That enables them to work, learn and gain achievements in the career, in parallel. In acquiring new knowledge they can be guided by their own living and working paces because they are in a "classroom without walls" and not in a traditional one with, abstractly saying, „multiple walls“.

In using Moodle (1.9.4) platform, the possibilities of students' self-testing and playing educational games (of course, with the automatic generation of the results in both cases) are of particular importance and worth. When it comes to educational games, we used a special software package Hot Potatoes (which includes options: JCloze, JQuiz, JCross, JMatch, and JMix). More about this package can be found on the Web location: http://hotpot.uvic.ca. At the first sight, one might conclude that the last is a trivial tool, but it is in fact a very useful didactic approach, which encourages students to achieve a better result by continuously playing the game and consequently to learn more. What some of the involved students have concluded in the affirmative sense according to this (for them new) aspect of the knowledge acquisition, readers can find out from the section in which the analysis of students' surveys are given.

3.2. Disadvantages of Moodle (1.9.4)

When the disadvantages of using Moodle, specifically of version 1.9.4., are on the board, we should say that our experience in working with mathematical expressions, lessons, wikis and the setting up of an online survey for students were not completely satisfying in the sense that we have encountered (in fact as the end users) some obstacles in the implementation of some of our ideas. That actually encouraged us to start thinking more intensively about the rapid transition to Moodle 2.3 version. What some of the involved students have noticed as shortcomings (not only for the Moodle as a platform, but in general for the whole concept of blended learning) readers also can find out in the section where the results of students' surveys are analyzed.

4. Realization of the surveys

In order to obtain a feedback on the realized program of e-learning for students of the specialist studies at the FMS we conducted several surveys. One survey was conducted among professors at the FMS and experts in developing new IT-supported didactic methods from the ANMKT. The other one was realized among students (seafarers), i.e. users of this new IT tools enriched type of education, in two different time intervals, i.e. in the academic years 2011-2012 and 2012-2013.

4.1. Survey conducted among the teachers and the experts: AHP approach

The survey conducted among the teachers at the FMS and the experts from the ANMKT is based on the Saaty AHP (Analytical Hierarchy Process) method [12-18] and this approach has actually enabled us to rank some features of e-learning, which are in the framework of this study identified as important. But certainly we are not limited by them in the sense that we underline the need for further, more extensive and detail research in this area.

Namely, the idea of certain e-learning features (eFs) ranking is associated with AHP with respect to the estimates of the respondents (here professors at the FMS and professionals from ANMKT). In general, ranking is a procedure, where the most significant e-learning feature is given the highest rank and the last significant feature is given the lowest rank while the other considered features are somewhere in between these two upper and down rank boundary values.

Here, the respondents were asked to compare each pair of the criteria sets eF1-eF6 (Table 1) according to the Saaty scale by using grades: 1-same importance; 3-weakly more importance, 5-moderately more importance, 7-strongly more importance, and 9-absolutely more importance of the first than the second considered criterion; or, by the corresponding reciprocity values depending on the mutual importance of the compared elements composing the certain pair(s).

Table 1. Considered e-learning features

eFs	Features
eF_1	Stability and speed of the Internet connection (what is not always the case at the sea)
eF_2	Availability on-line of all necessary materials for preparing the exam in a subject
eF_3	The existence of the tests for self evaluation of the acquired knowledge
eF_4	Conducting regular students' surveys
eF_5	Possibility of regular communication with teachers via forum, chat and/or e-mail
eF_6	Possibility of making tests and final exam on-line

The example of the Saaty matrix created by one of the respondents (experts) for the purpose of the conducted case study and then used in determining the rank of criteria is given below:

$$\begin{bmatrix} eFs & eF_1 & eF_2 & eF_3 & eF_4 & eF_5 & eF_6 \\ eF_1 & 1 & 1 & 1 & 1 & 1 & 3 \\ eF_2 & 1 & 1 & 1 & 3 & 3 & 5 \\ eF_3 & 1 & 1 & 1 & 3 & 3 & 5 \\ eF_4 & 1 & 1/3 & 1/3 & 1 & 1/3 & 3 \\ eF_5 & 1 & 1/3 & 1/3 & 3 & 1 & 5 \\ eF_6 & 1/3 & 1/5 & 1/5 & 1/3 & 1/5 & 1 \end{bmatrix}.$$

Although, for the purpose of this research work, twenty competent persons were asked to create the Saaty matrixes, only ten of these matrixes have been taken into further consideration since they were consistent. By the normalized eigenvector values calculus [19;20], the ranks of the considered criteria eF1-eF6 (per each respondent) have been calculated (Table 2), along with the values of the largest eigenvalue λ_{max}, and the ratio of consistency index CR, while the random index RI is equal to 1.24 in all cases, since the number of criteria is constant and equal to six, in this case. It is obvious that all λ_{max} values, for each considered matrix, are less than 0.01, which is to be fulfilled in order to provide a satisfying degree of the Saaty matrix consistency (Table 3). For these calculus, the appropriate Mathematica (5.1) programs have been used [2].

Table 2. The ranks of the considered eFs assigned by each of the ten competitive respondents

eFs/Rs	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
eF_1	2	1	1	1	2	1	3	1	2	1
eF_2	1	1	1	1	1	2	1	2	1	2
eF_3	1	2	1	2	3	3	4	3	3	2
eF_4	4	5	3	5	5	5	5	4	4	3
eF_5	3	3	1	3	1	4	2	2	2	4
eF_6	5	4	2	4	4	2	6	5	5	5

Table 3. The largest eigenvalue and relative consistency index for each matrix estimated by the respondents

Rs	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
λ_{max}	6.36016	6.60484	6.03873	6.56456	6.53663	6.53540	6.54947	6.54948	6.05530	6.56732
CR	0.05809	0.09755	0.00625	0.09106	0.08655	0.08862	0.08862	0.08866	0.09766	0.09150

The results presented in Tables 2 and 3 have been realized in Mathematica (5.1) program, and the following pseudo-code is given in Table 4 [2].

Table 4. Mathematica program pseudo-code for determining eFs rank per each responder [2]

```
Pseudo-code 1: Off[General::spell1]
(*n=Input["Number of criteria is (n):"];*)
(*A=Table[0,{n},{n}];
  For [i=1,i≤n,i++,
   For [j=1,j≤n,j++,
    A[[i,j]]=Input["Input Saaty matrix A ["<>ToString[i]<> ","<>ToString[i]<> "]:"];
If [A=[[i,j]]= =$ Canceled ∨ A[[i,j]]= =Null, Abort[]]]];*)
n=6;
A={{1,5,9,3,5,5},{1/5,1,7,3,3,3},{1/9,1/7,1,1/5,1/5,1/3},
{1/3,1/3,5,1,3,3},{1/5,1/3,5,1/3,1,3},{1/5,1/3,3,1/3,1/3,1}};
wn=Table[0,{n}]; wp=Table[0,{n}];
```

```
For[i=1;ws=0, i≤n,i++,wn[[i]]= ∏_{j=1}^{n} A[[i, j]] ;wp[[i]]=wn[[i]]^(1/n);ws=ws+wp[[i]]]
w=Table[0,{n},{1}];
For[i=1;i≤n,i++,wn[[i,1]]=wp[[i]]/ws]
V=A·w; l=V/w;
λ= 1/n ∑_{i=1}^{n} l[[i,1]];
CI=( λ-n)/(n-1);
RI={0,0,0.58,0.9,1.12,1.24,1.32,1.41,1.45};
CR=CI/RI[[n]];
Print ["λ= ",N[λ]];
Print ["CI= ", N[CI]];
Print ["RI= ", N[RI]];
Print ["CR= ", N[CR]]; If CR≤0.1,
Print ["Saaty's matrix is consistant"],
Print ["Saaty's matrix is not consistant"].
```

The main point is to determine the overall rank of in the paper considered features of e-learning (Fe1-Fe6) on the basis of the individual ranks establish by Saaty matrix, i.e. given by each of the experts individually. For this purpose it is necessary to determine the weight coefficients for each of the considered eF criteria and the process of their determination follows.

The idea of evaluating above mentioned weight coefficients is associated with the sum of ranks of each criterion c_q, with respect to the estimates of respondents (1):

$$c_q = \sum_{r=1}^{10} c_{qr}, q = \overline{1,6}. \tag{1}$$

Where,

c_q - is the sum of ranks of each criterion (eF), while q is the number of considered features (here 6), and r is number of experts, or respondents (here 10); and,

c_{qr} - is rank of the q-th criterion estimated by the r-th respondent. Now, the average weight coefficient for each criteria ($q = \overline{1,6}$) can be calculated by the following formulae (2):

$$w_q = \left[\frac{c_q}{\sum_{q=1}^{6} c_q} \right]^{-1}. \tag{2}$$

Finally, the normalized average weight coefficients are to be calculated for each concerned criterion (3):

$$\overline{w}_q = \frac{w_q}{\sum_{q=1}^{6} w_q}. \tag{3}$$

The overall ranking of eF_1-eF_6 criteria according to their significance, carried out by ten respondents, is demonstrated in Table 5.

Table 5. The final rank of the eF_1-eF_6 criteria formed on the basis of the respondents' questionnaires

eFs	Features	$\overline{W}_q$	Rank
eF_1	Stability and speed of the Internet connection (what is not always the case at the sea)	0.244808	**2**
eF_2	Availability on-line of all necessary materials for preparing the exam in a subject	0.282471	**1**
eF_3	The existence of the tests for self evaluation of the acquired knowledge	0.153005	**3**
eF_4	Conducting regular students' surveys	0.085398	**6**
eF_5	Possibility of regular communication with teachers via forum, chat and/or e-mail	0.146885	**4**
eF_6	Possibility of making tests and final exams on-line	0.087432	**5**

In order to examine the level of consistency of the respondents' estimates, the concordance coefficient W is to be calculated by (4):

$$W = 12S / r^2 q\left(q^2 - 1\right). \tag{4}$$

Where,

$S = \sum_{q=1}^{6}\left(c_q - \sum_{q=1}^{6} c_q\right)^2$ - is analogue to the variance of the ranks;

r – is the number of the respondents (10); and,
q – is the number of the considered eF criteria (6).

Now, the smallest value of W, i.e. W_{min} is to be calculated by the formulae (5):

$$W_{min} = \chi^2_{\alpha,v} / r(q-1). \tag{5}$$

Where, $\chi^2_{\alpha,v}$ - is critical chi-square statistics, found in the table [7] by assuming the degree of freedom $v = 6 - 1 = 5$, and the significant level $\alpha = 0.010$. Here, it is $\chi^2_{\alpha,v} = 15.09$. By taking into account the previous assumptions $W_{min} = 0.3018$, while $W = 0.476571$. Since the condition $W_{min} \le W$ has been satisfied, it implies that the estimates of the respondents are consistent, what means the previously obtained rang of criteria eF1-eF6 (Table 4) is the valid one. The previous calculi have been realized by Mathematica (5.1) program and the associated pseudo-code is given in Table 6 [2].

Table 6. Mathematica program pseudo-code for testing the consistency of the respondents' estimates [2]

```
Pseudo-code 2: Off[General::spell1]
n=Input["Number of criteria is(n):"];
m=Input["Number of respondents is (m):"];
Cm=Table[0,{n},{m}];
For [i=1,i≤n,i++,
For [j=1,j≤n,j++,
Cm[[i,j]]=Input["Input rank for the criterion "<>ToString[i]<> "and respondent"<>ToString[i]<>"]:"];
If [Cm=[[i,j]]= =$Canceled ∨ Cm[[i,j]]= =Null,Abort[]]]];*)
c=Table[0,{n}];
```

```
For[i=1;cs=0, i≤n,i++,c[[i]]= ∑_{j=1}^{m} Cm[[i, j]] ;cs=cs+c[[i]]]/n
```

$$S = \sum_{i=1}^{n} \left(c[[i]] - cs\right)^2 \;;$$

$$W = \frac{12S}{m^2 n\left(n^2 - 1\right)} \;;$$

$$\chi^2 = Wm\left(n - 1\right) \;;$$

$\chi^2_{\alpha,v}$ =Input["Input the critical chi-square, from the statistical table: "];

$$W_{min} = \frac{\chi^2_{\alpha,v}}{m\left(n - 1\right)} \;;$$

```
Print["S= ",S];
Print["W= ",W];
Print[" χ^2 = ", χ^2 ];
Print["", W_min ];
If[ W_min ≤W, Print["The estimates of the respondents are consistent."],
Print["The estimates of the respondents are not consistent"].
```

Quantified results of the survey among the experts in the field of e-learning could be qualified as follows:

- The experts involved in this research assigned numerically by the largest marks and gave consequently the greatest importance in the qualitative sense, to the availability of educational materials (which implies their appropriateness and quality).
- In the second place, the experts positioned stability of Internet connection, which is understandable, since in the paper very specific application of e-learning related primarily to the needs of seafarers has been considered. Namely, it is often not possible to establish Internet connection on the vast sea, or it is usually unstable. Another reason for the second highest rating of this parameter might be that the experts might consider a stable Internet connection as a fundamental basis for the establishment of e-learning offers.
- Experts put on the third position the availability of tests for students' (here seafarers') self-evaluation, which is also a very important segment of e-learning, which indirectly should involve the existence of *smart* educational games, as well.
- The fourth position is reserved here to the possibilities for the students to communicate with teachers via forum, chat, e-mail, etc, which is of course very important segment of e-learning, but it is sometimes difficult to achieve this due to the previously mentioned problems with Internet connection and its stability at the sea (and sometimes in the ports). On the other side, teachers are usually too busy, and they are practically sometimes *physically* prevented to devote more time for communication with students.
- On the last positions are technical possibilities of doing exams on-line, and conducting regular on-line (or classical) surveys among the students, related to their degree of satisfaction with offered e-learning services, respectively. This is understandable, since the Internet as an *open* communication channel is not *perfect* for testing students on-line. In addition, surveys conducted among students are very important, but in comparison with the previously considered components of e-learning are for sure

slightly less important. However, this does not mean at all that they should be ignored.

This survey reflexes profoundly very subtle nuances in mutual positions of the analyzed e-learning features, and it remains us to associate them to the high degree of expertise and sensitivity of the interviewed experts in this field.

4.2. Survey conducted among students

The survey was implemented among the students at the FMS and it was done on a larger sample than the previous one. It is considerably simpler in terms of the content and results analysis, but not less revealing. Respondents were students from the different FMS departments and with different experiences according to their employment and the length of the navigation service. The survey was conducted in two rounds, i.e. in two different time sections: during the academic years 2011-2012 and 2012-2013.

Some of the results are presented in Table 7. Thus, the table shows the percentage of surveyed students who had opted for the offered advantages and disadvantages of e-learning. Distinctly the highest percentage of students opted for "the possibility of learning from home and working place", while for the disadvantages of e-learning the highest percentage of students opted for "lack of direct contact with teachers" (2011-2012) and "inability to interrupt the class, put a question, and get the answer immediately when there is some ambiguity in knowledge transfer" (2012-2013).

When it comes to the results of surveys conducted among students, some inconsistencies have to be noticed, as for example a quite large discrepancies in some results obtained in (2011-2012) and (2012-2013). The largest differences are observed when it comes to e-learning advantages regarding the possibilities of students' self-evaluation of acquired knowledge, and more effective learning that allows e-learning. This discrepancy inspired us to think about it, and led to the conclusion that the results obtained in (2012-2013) should be taken, however, as more reliable. The question is why? – The e-learning facilities that are offered to students this year are far more extensive and of higher quality than those of the previous year.

Table 7. The results of the students' surveys
(conducted in 2011-2012 and 2012-2013 academic years)

Academic year:		**2011-2012**	**2012-2013**
No.	**Advantages of e-learning**	„Yes" answers	„Yes" answers
1.	The possibility of learning from home and working place (during the breaks)	60.78 %	91.38 %
2.	Reducing the traveling costs and time saving	25.49 %	79.31 %
3.	Easier access to the instructional materials	27.45 %	74.14 %
4.	Possibility of self knowledge evaluation through on-line tests	13.73 %	79.31 %
5.	Ability to communicate via the net with teachers and other candidates	15.69 %	63.79 %
6.	More effective learning	13.73 %	65.52 %
No.	**Disadvantages of e-learning**	„Yes" answers	„Yes" answers
1.	Lack of direct contact with teachers	45.10 %	53.45 %
2.	Inability to "interrupt" the class, put a question, and get the answer immediately when there is some ambiguity in knowledge transfer	43.14 %	60.34 %

3.	A nonstandard form of learning that requires a strong will, self-discipline, and high level of concentration	13.73 %	31.03 %
4.	Some colloquiums are taken on-line, which is sometimes stressful, due to limited time, and present fear if the technique will/will not function properly	11.76 %	29.31 %
Number of students involved into the survey:		51	58

Additionally, some of interviewed students were using e-learning services at the FMS for two years continuously, and therefore they should be treated as more competent to judge what is important to them due e-learning and to what extent. Though, if we focus on the assessment of the students in the "second round" (2012-2013), then we should make the following conclusions:

- Due to the **benefits** of e-learning, the opportunity to learn from home or from work or at leisure time was identified as the greatest advantage. This is not really remarkable because learning anytime and anyhow is an – meanwhile well known – essential benefit of e-learning.
- The second position in terms of the students surveyed is shared by the reduction of commuting costs and the possibility of self-evaluation (either through on-line tests and different educational games). Again, reducing travelling costs and saving time is a rather obvious advantage of e-learning. More interesting is the fact that the availability of self-evaluation is very important for almost 80% of the students. This rating shows that students are very well aware of additional educational possibilities that come along with e-learning and that students are willing to use these possibilities for their own learning purposes. Moreover evaluations of the use of the Moodle courses show that self evaluations are very popular among the students especially immediately before exams.
- The third place belongs to the greater availability of educational materials than in the case of traditional teaching. This good rating is probably owed to the fact that the polled students are seafarers with a lot of travel activities who do not have the chance to spend much time in the classroom.
- In the fourth position is placed the possibility of learning more effective, which could mean that it is still in some ways easier to the students to learn if they have a teacher "in front of them", i.e. physically present (even this conclusion should be treated as hypothetical one).
- The last place among the advantages of e-learning belongs to the ability to communicate (regularly) with teachers. How can this be explained? - Teachers are often not able to meet the requirements of the students (all their questions sent by e-mail, e.g.) and to be available though the chat and/or forum sessions. Therefore, the most likely students agreed that this possibility is not (unfortunately) of essential importance to them. This should of course be considered and corrected in the perspective.
- Due to the **disadvantages** of e-learning, students have cited the inability to directly ask the teacher what they do not understand in the learning materials as the greatest shortcoming. Thus, this greatly complicates their understanding and learning processes. Anyway, the rating is consistent with the rather poor rating of the ability to communicate with teacher as an advantage.
- In the second place, students positioned the lack of physical presence of the teacher, which is directly linked to the previous and therefore quite logical. And this can be explained as indeed the biggest and the most profound dilemma concerning traditional vice-versa e-learning.

- The necessity of students' strong will, concentration and learning self-discipline is placed in the third position. This should be fortunately interpreted in the way that most of the students fulfilled these very important preconditions of successful e-learning.
- The fourth place among the disadvantages of e-learning, students have associated to the stress caused by taking some colloquiums and tests on-line. This is logical, since most of the students are familiar with PCs and doing the tests on-line, in the technical sense, is not a big problem for them.

Within the additional survey conducted at the end of the semester of 2012-2013 the students should respond affirmatively/negatively to these three questions [10]:

- E-learning has a future in the sense that it will be increasingly used? (Answer "Yes": 100%);
- E-learning will lose its importance in the coming years? (Answer "No": 100%); and,
- Do you (personally) prefer e-learning than traditional lecture "face-to-face"? (Answer "Yes": 76%).

In the brackets next to these questions are given the percentages of surveyed students (58 of them) who responded affirmatively/negatively (depending on question). There is no doubt, according to the results of this short survey conducted among the students at the FMS, that the future learning channels shall be based on novel technical and didactical e-learning solutions.

5. Conclusions

By comparing some observations from the first part of the paper to those of the following sections, it could be concluded that it is about building *a new roof on the old and damaged walls*. And what does it really matter? – A vain job, or however something else? - We believe, it is still something else. All this effort over the introduction and development of e-learning at the FMS should be one more in a series of incentives toward improving the educational process at the MET institutions in terms of recommendations which are generally given in the introduction. Thus, the need for greater investment in seafarers' higher education in terms of personnel and infrastructure is indisputable. Additionally, the networking is very important, not just for networking, but a real one is essential, based on professional cooperation and reciprocity on the EU level and among the referential MET institutions, exchanges of teachers and students for the sake of mutual enrichment of knowledge, the launch and implementation of joint projects, etc. All of this is to be done to the extent that is feasible and before it becomes too late. Also, it is necessary to establish a connection with the maritime industry, e.g., shipping companies interested in providing practical training onboard ships. The national legislation has to be modernized in the sphere of higher education in terms of recognition and proper interpretation and implementation of the STCW Convention requirements and in terms of faster deployment of virtual learning as a supplement to the traditional education and training of the seafarers. Within this context we should not lose the sight of the fact that STCW Convention itself calls for a proper education as the foundation of successful training and acquiring competences [8]. In order to confirm this observation the quotations from the STCW Manila Amendments, Chapter II, Section B-II / 1, Paragraph 14 are given: "Scope of knowledge is implicit in the concept of competence. This includes relevant knowledge, theory, principles and cognitive skills which, to varying degrees, underpin all levels of competence. It also encompasses proficiency in what to do, how and when to do it, and

why it should be done. Properly applied, this will help to ensure that a candidate can: work competently in different ships and across a range of circumstances; anticipate, prepare for and deal with contingencies; and adapt to new and changing requirements." Additionally, of importance within the context of this paper is that the newest STCW Code amendments concern and not only concern, but strongly recommend - the introduction of modern training methodology including distance learning and web-based learning in seafarers' knowledge acquiring and upgrading.

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4.4. Assessing students' satisfaction with a web-based learning system

Blended learning became the most popular educational model that universities apply for teaching and learning. This model combines online and face-to-face learning environments, in order to enhance learning with implementation of new web technologies and tools in learning process. In this research work principles of DeLone and Mclean success model for information system are applied to Kano two-dimensional model, for categorizing quality attributes related to satisfaction of students with web based learning system used in blended learning model. Survey results are obtained among the students at "Mediterranean" University in Montenegro. The (dys)functional dimensions of Kano model including Kano basic matrix for assessment of the degree of students' satisfaction level, have been considered in some more detail through corresponding numerical, graphical and statistical analysis.

1. Introduction

Facing many rapid changes and challenges brought by new technologies and competitive pressure, higher education institutions are trying to innovate their service and raise their public reputation concerned by their learners. Education is undergoing a dramatic transformation. Technology plays a powerful role in the life of today's students and institutions can no longer meet their needs through classroom-based instruction alone. Higher education institutions are increasingly focusing on determining the right model to integrate technologies in teaching and learning in order to fulfill students' needs and provide education and skills needed for the future society.

Blended learning is one way in which institutions can prepare themselves for the next era in education (Garrison, & Kanuka, 2004; Owston, 2013). It offers new opportunities for combining face-to-face and online teaching and learning. This includes different learning or instructional methods (lecture, discussion, guided practice, reading, games, case study, simulation), different delivery methods (live classroom or computer mediated), different scheduling (synchronous or asynchronous), and different levels of guidance (individual, instructor or expert led, or group/social learning).

There are many definitions of blended learning and yet no single accepted one. In the scope of this study we should refer blended learning to a formal education program in which a student learns at least in part through online learning, with some elements of student control over time, place, path, and/or pace (Clayton Christensen Institute for Disruptive Innovation, 2012-2013).

Measuring student satisfaction with web based learning systems has been an important issue for the researchers and academia. At the AMCIS (Americas Conference on Information Systems) as early as 2001, e-learning was identified as one of the nine meta-tracks for information systems (IS) discipline, and multiple studies in both education and the IS literature measure student satisfaction with the online courses (Summers et al., 2005). Research shows that perceived usability, value, and quality are critical factors that affect user satisfaction with e-learning systems (Chiu et al., 2005; Seddon, 1997). However, there are insufficient studies investigating students' satisfaction with web based learning system used to support teaching and learning in blended environment. Clearly, understanding the factors influencing students' satisfaction with online component of blended learning is a critical issue. Given the role of information and system design in online customer satisfaction, McKinney et al. (2002) study has synthesized the IS research on users' satisfaction with marketing research on customer satisfaction to gain insight on web-based system satisfaction. Similarly, this study draws from both IS and marketing research to examine the factors that contribute to web-based learning systems benefits.

This research paper is organized in five sections. The first one examines literature and discuss models for IS success relating to user satisfaction. The second section gives theoretical overview of the considered problem and gives reference to the appropriate literature sources. The third and the fourth sections describe our study and the method of data analysis along with the obtained results discussion. Section five concludes the paper and presents directions for future work in this domain.

2. Theoretical background

Satisfaction of the users in the computer based and information systems is very important for developers and administrators of these systems, since the success of the computer based systems is generally associated within the users' satisfaction (Ives et al. 1983; Muylle et al., 2004). For the information systems quality and usability, there are international standards such as ISO 9241-11 which explain that information should be retrieved in a way that satisfy the standards in terms of measures of user performance and satisfaction. In the case of information technology systems, satisfaction is an outcome of a function or an interaction occurring when the results fit to expectations of a person; or it is a function of how well a product fits his requirement; or solutions within an acceptable range (Tessier et al., 1977). Satisfaction also can be defined as achieving success in the designated tasks (Beeler, 1981; Momenee, 1987).

Constructing theory and the measurement methods for user satisfaction is investigated by researchers and these efforts resulted in some models showing the components of users' satisfaction (Khalifa, & Vanessa, 2004; Applegate, 1993; Hinterhuter et al., 1997; Paechter, 2010). End-user computing satisfaction model (Doll, & Torkzadeh, 1988; Doll et al., 2004) is one of users' satisfaction models specified for information systems with five sub-categories which are: content, accuracy, format, ease of use, and timeliness. Additionally, DeLone and Mclean (2003) proposed a generic model for the information systems in order to understand the system success relating to user satisfaction with the six components: systems quality, service quality, information quality, use, user satisfaction, and net benefits. Another analysis have been done by Ozkan and Koseler (2009) who proposed a conceptual hexagonal e-learning assessment model, suggesting a multidimensional approach for Learning Management System (LMS) evaluation in six dimensions: system quality, service quality, content quality, learning perspective, instructor attitudes, and supportive issues. The explanatory factor analysis conducted showed that each of the six dimensions of the proposed model had a significant effect on the learners' perceived satisfaction. Lee et al. (2009) analyzed learners' acceptance of the e-learning system throughout four independent variables: instructor characteristics, teaching materials, design of learning contents and playfulness; two belief variables: perceived usefulness and perceived ease of use; and one dependant variable: intention to use e-learning. They all confirmed several hypotheses within the researched field, but noticed that their study has certain limitations and that there is a requirement for larger, cross-cultural studies within this ever-growing area of this novel learning channel.

Considering e-learning systems as a part of information system there are also studies to measure and model the user satisfaction for e-learning system. For example, Matsatsinis et al. (2003) proposed a multi-criteria model to evaluate users' satisfaction on e-learning program using linear programming to measure a satisfaction index and to compute criteria weights. Since DeLone and McLean (D&M) developed their model of IS success, there has been much research on the topic of success as well as extensions and

tests of their model. In her recent study Lee-Post (2009) interpreted the success model of DeLone and Mclean throughout an e-learning success model stating the related metrics of the model as in Fig.1.

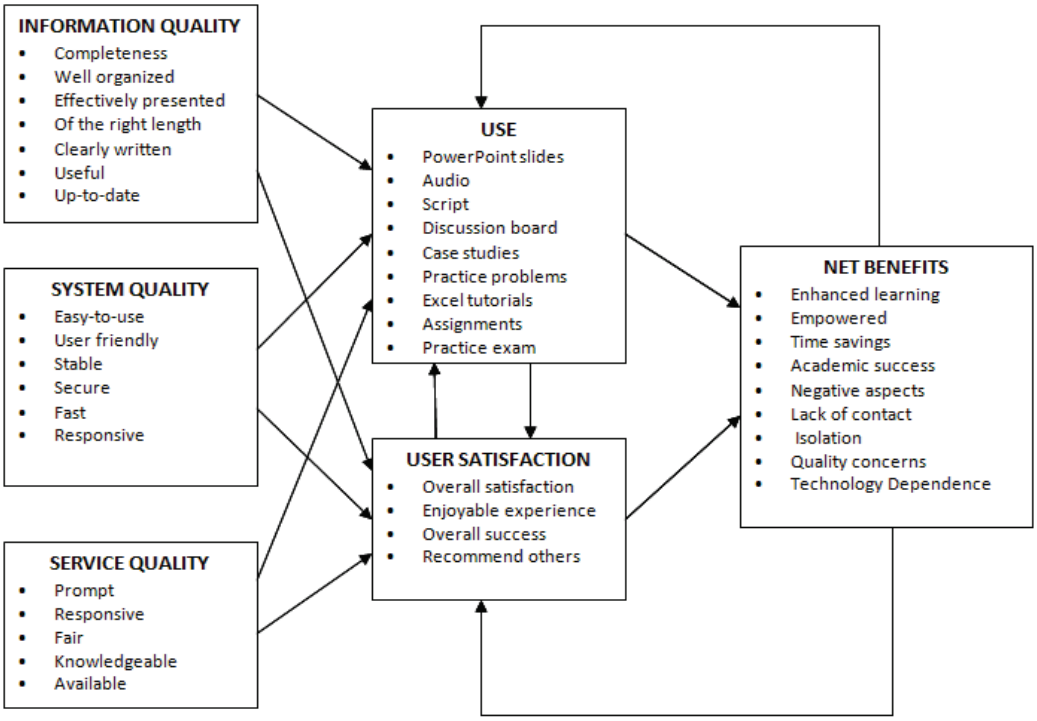

Fig. 1. DeLone and Mclean IS success model with e-learning success metrics

Extensive and valuable analyses in the domain of determining users' satisfaction with web based learning systems upon similar dimensions-category model have been done by Wang (2003) and Daniel and Wang (2008). Also, a number of studies used Kano two-way quality model to measure e-learning system satisfaction of users (Chen, & Lin, 2007). The review of Kano model previous applications in estimating e-learners satisfaction with e-learning courses/system is given in (Dominici, & Palumbo, 2013).

As in the above examples, there are research studies trying to establish a model to determine the success metrics for e-learning related with satisfaction of usage. In those models satisfaction is considered as a function of interaction between users and system or services provided via these systems. End results and outcomes fitting to user expectations and requirements are defined as the criteria of the success. There are limited research studies that clearly identify satisfaction of users with web based systems and no model showing the role of the students' satisfaction with web based system in the blended learning success models. Hence, the educational institutions and policy makers should consider in more detail students' satisfaction within this context, in order to success in their activities and operations.

3. Kano model

In the past, customer satisfaction has been perceived in one-dimensional terms: the greater the fulfillment of desired quality attributes, the higher would be customer satisfaction. However, there are some quality attributes that fulfill individual customer expectations to a great extent without necessarily implying a higher level of customer satisfaction (Matzler, & Hinterhuter, 1998). Several studies have therefore attempted to link the physical and psychological aspects of quality to see how specific attributes of a product or service actually relate to customer satisfaction or dissatisfaction, where the physical aspect is concerned with the physical state or extent of the specific attributes, and the psychological aspect is related to the customer's subjective response in terms of personal satisfaction (Schvaneveldt et al., 1991). Similarly, Kano (1984) considered two aspects of any given quality attribute: an objective aspect involving the fulfillment of quality, and a subjective aspect involving the customers' perception of satisfaction. Using this model, quality attributes are classified into six categories (first four of them are shown in Fig.2):

- *attractive quality attribute* (A): an attribute that gives satisfaction if present, but that produces no dissatisfaction if absent;
- *one-dimensional quality attribute* (O): an attribute that is positively and linearly related to customer satisfaction – that is, the greater the degree of fulfillment of the attribute, the greater the degree of customer satisfaction;
- *must-be quality attribute* (M): the presence of these product/service attributes will not increase customers' satisfaction level significantly, while their absence will cause extreme dissatisfaction;
- *indifferent quality attribute* (I): an attribute whose presence or absence does not cause any satisfaction or dissatisfaction to customers;
- *reverse quality attribute* (R): an attribute whose presence causes customer dissatisfaction, and whose absence results in customer satisfaction; and
- *questionable quality attribute* (Q): it means that is not clear weather customers expect these attributes since they gave unusable responds due to misunderstanding the questions on the survey, or making an error when filling out the questionnaire.

It is critical to identify must-be quality attributes and to meet demand for these at a minimum threshold level at least. Universities must also do their best on the one-dimensional attributes, which are typically articulated by customers as functionality they desire. The attractive quality attributes can be selected as competitive weapons to draw the attention of students, especially new ones (Bayus et al., 1997).

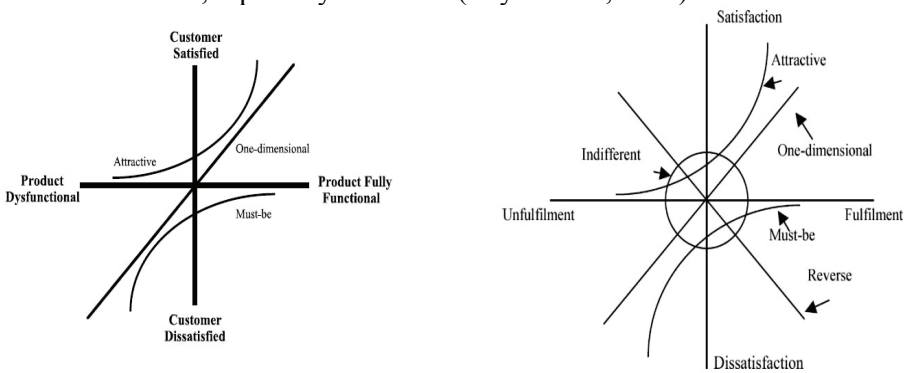

Fig. 2. Kano 2D graph with functional and dysfunctional dimensions

4. Research methodology

Within conducted study Kano model questionnaire is used to understand students' satisfaction with the web based learning system. In order to define quality attributes for Kano model, five quality components of DeLone and Mclean (D&M) model have been used (Table 1). The questions for each quality attribute of web based learning system: systems quality, service quality, information quality, use, and net benefits, have been created.

Table 1. Kano model quality attributes questionnaire defined by D&M model

Quality attribute	Kano model questionnaire
System quality	– Technical stability/reliability of the system – User-friendly interface
Service quality	– Available access to the system at any time
Information quality	– Quality/quantity of e-instructional materials
Use	– Presence of audio/video recordings (besides textual ones) – Mandatory e-test and assignments – Student self assessment possibilities – Collaborative activities – Presence/existing of e-tutor(s)
Net benefits	– Enhanced learning with combination of web based and traditional learning (blended learning model)

The responders have been asked about their mindset due to functional and dysfunctional dimension of web based e-learning system quality attribute, e.g. the offered answers in both cases, in accordance to Kano model, are: *I like it*; *It must be that way*; *I am neutral*; *I can tolerate it*; or, *I dislike it*. The respondents have to choose one of the offered options (answers) for both functional and dysfunctional dimension of the question. Due to the chosen pairs the reviewers may get an overview of the students' satisfaction of the web based learning system quality attributes.

The population sampled was 115 students at the University "Mediterranean" (Montenegro). Among the interview results, 63 were valid, i.e. these students understood the basic principle of applied model and propositions for providing the researchers with the proper answers. More precisely, 52 students did not understand in fact that they have to give answers to the questions about both functional and dysfunctional components of a considered blended learning system features, or they were not enough motivated to do so.

The following section provides some more detail about blended learning model at University "Mediterranean" at which the described analysis has been done.

5. Blended learning at University "Mediterranean" (Montenegro)

University "Mediterranean" (UNIM) is a first private university in Montenegro established in 2006. It consists of six faculties located in tree different cities in Montenegro. A major element of UNIM's distinction relates to learning and teaching. During the early stages of the development of blended learning a plan for the utilization of learning technology at UNIM was created. The heart of the model of learning within UNIM is the method of optimal mixing ICT-based and human tuition within web based learning systems. The University has positioned itself part way from the traditional university with strong emphasis on online approaches. All of six faculties established and started to use

blended learning (about 60% of courses) and core blended learning practices have been demonstrated within Faculty of Information Technology (100% of courses). In addition, UNIM participated in number of EU e-learning projects which brought important progress in the practice. UNIM is employing significant efforts to improve the quality of the teaching process in traditional and distance learning.

Across the University, students can study modules by: face-to-face tuition or using video-conferencing, both asynchronous and synchronous. Lectures and seminars are backed up by the use of a virtual learning environment (Moodle). The use of videoconferencing in particular enables small groups of students from remote locations to join together to form a single cohort for a module. This strategy enables students to undertake university study while based in their own cities.

Depending of particular subject lecturers can create different assignment types in web based systems with the support of Moodle tools for e-learning. Additionally, students can use web based learning system for discussion (forum) and communication with other students and lecturer (chat, message, e-mail) and they can create their own virtual communities of interest. This mixture of pedagogies characterizes UNIM's approach to blended learning. These pedagogies are not without challenge. This may be because cohort sizes are a disincentive for a blended approach, or because the subject requires a face-to-face experience. For example many elements of engineering or visual arts, would fall into this category, as students require physical access to facilities and equipment, or need to paint in studio.

6. Research results and analysis

In the following sub-sections are presented the results obtained by the analysis of:

- frequencies of certain Kano categories appearance in the set of responds;
- customers', here students', (dis)satisfaction indexes;
- two-dimensional (linear) graphical schemes; and
- some basic statistical parameters.

6.1. Evaluation according to the frequencies of Kano categories appearance

By analyzing the results of the survey conducted among the students who have used web based learning system in blended model at the University "Mediterranean" (Montenegro), the following has been noticed:

- The indifferent (I) category of applied Kano model has the greatest frequency of appearance among all the categories in even nine of offered ten questions! Simplified and looked though the eyes of Kano model, it means that customers, here students as e-learners, do not care about these features either way. How this could be explained? It could be realized that most of students among the responders are not interested in e-learning system, or, it was difficult for them to be "consistent" in giving answers on both functional and dysfunctional features/dimensions of the e-learning system at the same time, so the easiest for them was to be "indifferent". Or, they just want to fulfill the "form" by answering the questions, but they did not think deeply about the questions and scope of doing the interview. Anyhow, in our further analysis we have ignored the "indifferent" answers in the case of questions where they are present in the greatest number (these numbers are put in brackets in Table 2), and we focused on the second and/or third most frequent answers as rather indicative ones. As a kind of ex-

ception can be treated answers in cases Q5, Q6, Q7, and Q9 (collaborative activities; self-evaluation possibilities; mandatory exercises, tests, essays, etc., and availability of e-tutor). Namely, it has sense that students are indifferent about collaborative activities within e-learning platform, since they have a lot of another possibilities to collaborate through different social networks (Facebook, e.g.). Additionally, students are not usually aware about the importance of self-evaluation possibilities in making them learning easier and more interesting, though it can be reasonable that they do not care about this feature. But, the teachers should explain them the benefits of self-evaluation process and "convince" them in a way to treat this category as more important one. Further, students usually do not like obligations like mandatory exercises, tests, essays, etc. Therefore, this can be accepted as well as a category they estimated as irrelevant for them. And, finally, when we take into consideration the question of availability of e-tutor, then it is to be emphasized that most of the students are familiar with contemporary ICT, and though they do not have special requirements for e-tutor.

– Also the numbers of "questionable" answers were present, i.e. in three cases (Q2, Q5, and Q7), so they have been neglected (symbolically by putting into the brackets, see Table 2) and the accent were given to the next greatest numbers related to the other more relevant categories within the considered context. This can be again treated as a result of the lack of some students' understanding basic principle of the questionnaire. Hence, we have to be focused on, let's say, those answers which can be treated as more valid and relevant ones, and ignore these which do not have importance for planning an attractive e-learning systems in blended model due to learners' (reasonable) wishes/expectations. Sometimes, students are not aware what is indeed useful for them, and the obligation of e-learning systems designers, teachers and e-tutors is to find the optimal solution(s). However, the judgments and feeling of the students should not be neglected.

Table 2. Classification of the requirements in accordance to the Kano model

Question	M	O	A	I	Q	R	Category
Q1: Technical stability/reliability of the system	**17**	10	6	(21)	5	4	Must-be
Q2: User-friendly interface	**9**	**9**	5	(23)	(12)	5	Must-be / One-dimensional
Q3: Quality/quantity of instructional materials	**13**	**13**	4	(23)	7	3	Must-be / One-dimensional
Q4: Presence of audio/video recordings	**14**	13	6	(17)	9	4	Must-be
Q5: Collaborative activities	**12**	9	4	(24*)	(12)	2	Must-be / Indifferent
Q6: Self-evaluation possibilities	10	**18**	3	(22*)	8	2	One-dimensional / Indifferent
Q7: Mandatory exercises, tests, essays, etc.	6	**10**	5	(25*)	(12)	5	One-dimensional / Indifferent
Q8: Combination of web based and traditional learning (blended learning model)	10	**15**	5	(21)	8	4	One-dimensional
Q9: Presence/existing of e-tutor(s)	10	**15**	4	(25*)	5	4	One-dimensional / Indifferent
Q10: Available access to the system at any time	14	**25**	7	8	8	1	One-dimensional

In order to explain better the meaning of marked (bold and italic) first, second, or third greatest frequency numbers among Kano categories per each question corresponding to certain e-learning system dimension/feature, it is to be recall the meaning of "must-be" and "one-dimensional" categories due to the obtained and above presented results:

– *Must-be* (M) means that customers, here e-learners, consider these requirements as basic factors; thus, their presence will not increase their satisfaction level significantly, while their absence will cause extreme dissatisfaction. In here conducted survey, after certain approximations explained above: technical stability/reliability of the web based e-learning system; presence of audio/video recordings; and, collaborative activities are within the domain of this category.
– *One-dimension* (O) means that these factors cause satisfaction if their performance is high, while they cause dissatisfaction if their performance is low. These attributes are linear and symmetric because they are typically considered customers' (here e-learners') explicit needs and desires. Within this survey and by taking into account certain approximations: self-evaluation capacities; mandatory tests, exercises, essays, etc.; blended learning possibilities; presence/existing e-tutor(s); and, available access to the system at any time are of one-dimensional category.

Concerning the dimensions of the system: "user-friendly" and quality/quantity of the available instructional materials in a system of e-learning, it can be noticed that the frequencies of (M) and (O) are the same. Having in mind that (M) is stronger due to the hierarchical rule of category importance (i.e. M>O>A>I) (Dominici, & Palumbo, 2013), then to these attributes of the system - must-be (M) category should be assigned as more preferably one. It is important to note that such evaluation of the e-learners' responds to the questionnaire are rather fuzzy, particularly since in most of the cases the second, or even the third score in a series of frequencies, starting with the greatest one, have been considered as referral. The above results are obtained on the basis of Kano evaluation table being modified by Fred Poliot (Walden, 1993). The categories which are changed in comparison to primer Kano functional-dysfunctional matrix are marked (bold) in Table 3. In fact, Pilot changed only two values (2,2) and (4,4) replacing indifferent (I) with questionable (Q) categories in comparison to the Kano basic model. The detail logical and following graphical explanations of these two replacements are given in Walden (1993) work. Simply, the pairs of students' (here e-learners, or customers, more generally) responds, are "overlapped" over this etalon matrix (Table 3) being generated by Kano view (slightly modified), and the scores are acquired per each responder and per each question related to certain blended/e-learning system feature.

Table 3. Kano modified evaluation model with reversals

Customer requirement			**Dysfunctional**				
			1	**2**	**3**	**4**	**5**
			I like it	It must be that way	I am neutral	I can tolerate it	I dislike it
Functional	**1**	I like it	Q	A	A	A	O
	2	It must be that way	R	**Q**	I	I	M
	3	I am neutral	R	I	I	I	M
	4	I can tolerate it	R	I	I	**Q**	M
	5	I dislike it	R	R	R	R	Q

Customer requirements might be following ones:	
M: must-be O: one-dimensional A: attractive	I: indifferent Q: questionable R: reversal

6.2. Evaluation according to customers' satisfaction indexes

Since the results of the analysis in the previous case are fuzzy, we do here an effort to "sharp" them slightly, throughout the further analysis being based upon Berger, et al. (1993) model (Dominici, & Palumbo, 2013, p. 92; Walden, 1993, p. 17). Namely, instead of concerning must-be (M), one-dimensional (O), and attractive (A) features, the responds of the customers are reduced here to two numbers: a positive number that is the relative value of meeting this customer requirement (versus the competition), and a negative number that is the relative cost of not meeting the customer requirement. These numbers are labeled as "better" (1) and "worse" (2) indexes and calculated in the following way, i.e. by equations (1) and (2):

$$\text{Better} = \frac{A + O}{A + O + M + I} \tag{1}$$

$$\text{Worse} = -\frac{O + M}{A + O + M + I} \tag{2}$$

Better (or, satisfaction index) indicates how much customer satisfaction is increased by providing certain feature of a system which is intended to be developed, while worse (or, dissatisfaction) indicates how much customer satisfaction is decreased by not providing the feature. More precisely, the positive better numbers are indicative of the situation where, on average, customer satisfaction will be increased by providing attractive and one-dimensional elements. The negative worse numbers are indicative of the situation where customer satisfaction will be decreased if these one-dimensional and must-be elements are not included into "ex-ante" blended/e-learning system which designers, teachers, e-tutors, etc., are intended to develop by meeting the learners' (customers') expectations.

Now, let's consider in the light of these two coefficients the results of the survey being conducted here and try to create more specified picture of the customers' expectations. The indexes better and worse are calculated and presented in Table 4.

Table 4. Satisfaction (better) and dissatisfaction (worse) indexes

The learning system requirement	"Better" index	"Worse" index
Q1: Technical stability/reliability of the system	0.296296	-0.50000
Q2: User-friendly interface	0.339623	-0.39623
Q3: Quality/quantity of instructional materials	0.357143	-0.46429
Q4: Presence of audio/video recordings	0.415094	-0.50943
Q5: Collaborative activities	0.368421	-0.42105
Q6: Self-evaluation possibilities	0.310345	-0.48276
Q7: Mandatory exercises, tests, essays, etc.	0.301887	-0.41509
Q8: Combination of e- and traditional learning	0.333333	-0.46296
Q9: Presence/existing of e-tutor(s)	0.272727	-0.45455
Q10: Available access to the system at any time	0.290909	-0.40000

By analyzing the results of the survey on the basis of previously described model, the following points can be derived due to the positive indexes:

- Presence of audio/video recordings seems very important for the customers, i.e. it implies must-be requirement. Its absence will cause consequently great dissatisfaction (the better index is the largest for Q4);
- Collaborative activities, quality/quantity of instructional materials, as well as user-friendly environment (Q5, Q3, Q2) have large better indexes what mean that their absence will also cause dissatisfaction among the users;
- To the availability of the access to the system at any time, as well as technical stability/reliability of the systems (Q10, Q1), the customers did not give high scores. This can be explained as something that they take for grand a priori. Or, in other words, it is quite normal for them that these two conditions are present, so they do not think they require special concerning. However, this statement should be taken with a certain dose of reserve; and
- Presence of e-tutor(s) is considered unimportant for the students (the smallest better index for Q9). This could be explained by the fact that students are sufficiently familiar with information systems, and that they do not need e-tutor.

Now, by taking into the consideration the negative indexes, the following can be observed:

- Absence of audio/video instructional materials causes dissatisfaction among the customers (the worse index absolutely value is the largest for Q4). This is completely in accordance to the previous statements due to this feature;
- Also, absence of e-learning system stability/reliability will imply customers' great dissatisfaction. This is logical, even it is not completely in accordance to the previous customers' judgments about this feature;
- The requirement that causes the lowest degree of dissatisfaction among users it is not providing user-friendly environment (the worse index absolutely value is the smallest for Q2). It can be concluded that its presence is convenient, but its absence will not cause excessive dissatisfaction; and,
- The levels of dissatisfaction which can be caused by the absence of the rest features are rather of equal level, what implies that their absence will not extremely affected the customers' needs.

Because of the slight fuzziness in the above (based of (dys)satisfaction indexes) and in the previous sub-section given statements (based on frequencies of categories appearances), the third assessment method, based on the graphical analysis of the survey results will be considered within the next part of the paper.

6.3. Graphical analysis of the survey results

The basic of graphical analysis implies that there are Q pairs of questions, $j = 1, \ldots, Q$, and N respondents, $i = 1, \ldots, N$. In accordance to Kano model, there may be two basic scores for each potential customer requirement being investigated: functional and dysfunctional ones. These two scores can be coded as follows (Walden, 1993):

- *Functional*: (dislake), -1 (live with), 0 (neutral), 2 (must-be), 4 (like); and
- *Dysfunctional*: (like), -1 (must-be), 0 (neutral), 2 (live with), 4 (dislake).

Since each answer of the respondents (here students) has been assigned by the appropriate numerical value it is possible to calculate average values for functional ($Y_{avg}(j)$) and dys-functional ($X_{avg}(j)$) dimensions of the answers in a following manner, i.e. by equations (3) and (4):

$$Y_{avg}(j) = \frac{\sum_i Y_{ij}}{N} \tag{3}$$

$$X_{avg}(j) = \frac{\sum_i X_{ij}}{N} \tag{4}$$

These average pairs of values can be plotted on two-dimensional coordinate system with four quadrants representing key categories of Kano model: attractive, one-dimensional, indifferent, and must-be (like in Fig.2). For the purpose of this research, based on the collected students' answers, we take into consideration only must-be and like functional dimensions, and live with and dislike dysfunctional dimensions. Since neutral category implies pondering responds with zero value, it has in fact no impact on the total score and considered average values. Questionable and reversal answers were ignored, too. Thus, all average values are in positive quadrants (between 0 and 4 per X and Y axis) and given as points in Fig.3.

On the basis of the plots in Fig.3, it is obvious that the most of average values are in indifferent quadrant, what is in correspondence with the analysis based of the greatest frequencies of appearance of certain answers. In a manner could be understandable that respondents (students) are indifferent according to the obligatory exercises, tests, essays, etc. (Q7), because they usually do not like them. Similarly, since students are commonly familiar with information and communication technologies, it sounds reasonable that they are indifferent when having available e-tutors is in question (Q9). It has also a sense that responders are indifferent toward collaborative activities existence within the system of blended/e-learning, though they have available such activities within different social net-works, (Q5). And, social networks might be more comfortable in a way for collaborative activities than a conventional e-learning system, e.g.

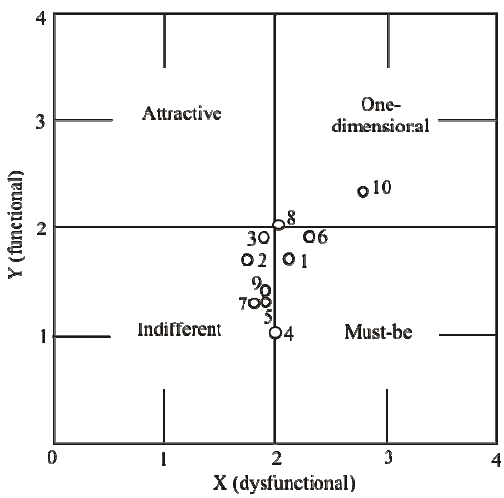

Fig. 3. Plots of average functional and dysfunctional points for the questions (Q1-Q10)

However, some interventions should be done by the evaluators and latter planers of a better system, for example: questions of optimal quality and/or quantity of available e-instructional materials (Q3) and presence of user-friendly environment (Q2) should be "shifted" into the attractive quadrant as it is symbolically shown in Fig.4 (dashed line). With better instructional materials and user-friendly environment the system will be more competitive on e-learning market within blended learning environment.

Average value which correspond to the answers on the question of presence of audio and video materials besides more traditional textual ones (Q4) is on the line between indifferent and must-be zone, and it could be more logical, from the researchers' and system creators' point of view, to move it to the must-be zone. Technical stability of the system represented by point 1 in Fig.3 is in the must-be zone what means that e-learners are more dissatisfied when the system has lower stability in technical sense; however, their satisfaction never rises above neutral no matter how functional this feature of the system becomes. Point 10 corresponding to the question of accessibility of the system at any time (Q10) is in one-dimensional zone. This means more functionality of this feature leads to more students' satisfaction.

Points 6 and 8, which correspond to the questions of self-evaluation possibilities within the system (Q6) and blended learning features (Q8) are rather fuzzy and we consider they should be shifted to the one-dimensional zone in a future system planning in order to satisfy in greater extend users objective needs. All suggested "shifts" by the authors are given in Fig.4 (dashed lines).

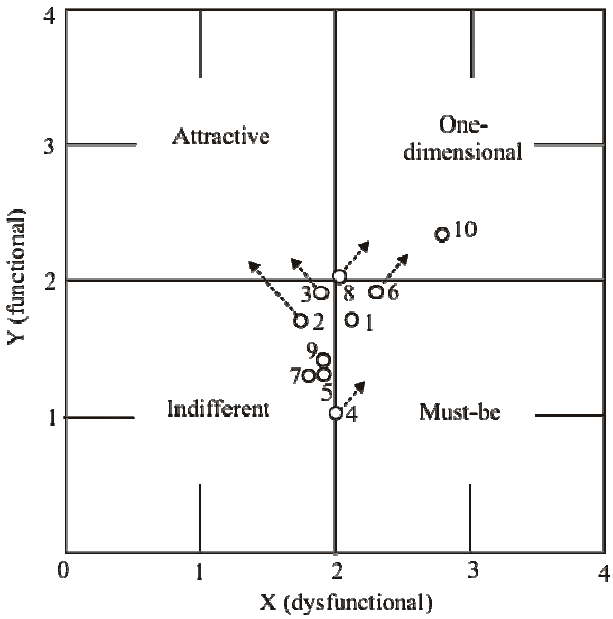

Fig. 4. Repositioning the plots of average functional and dysfunctional points for the questions (Q2, Q3, Q4, Q6, and Q8)

6.4. Some statistical refinements of the analyzed data by graphical method

In further analysis over the data set consisting of $(X_{avg}(j), Y_{avg}(j))$ pairs, where $X_{avg}(j)$ and $Y_{avg}(j)$ are calculated by expressions (3) and (4) for $j = \overline{1,10}$, following statistical

values have been calculated: mean value, standard deviation or variance, covariance, correlation coefficient (Bertsekas, & Tsitsiklis, 2008; Weltner et al., 2009). The numerical values of these statistical measures are given in Table 5. Used notation is simplified and the analyzed data sets (pairs) are shown simply as X, Y and (X,Y).

Table 5. Values of some statistical indicators

Statistical measures	Values
Mean (X)	2.064
Mean (Y)	1.724
Var (X)	0.310
Var (Y)	0.341
Cov (X,Y)	0.074
Correl (X,Y)	0.779

Upon the calculated values of the statistical measures (Table 5) the following can be observed:

- If we consider the mean value for the parent population, then it is the hypothetical "true" value of the variable. This means that Mean (X) and Mean (Y) might be treated as a pair which represents "true" value of general answer to all ten considered questions within the questionnaire. Consequently, the general answer is equivalent to *must-be* category of Kano model. This has sense if we assume that questionnaire has been proposed by the experienced researcher and staff at the Universities in Montenegro, in consultations with the expert from the University of Graz. Truly, this pair is not in the lower right corner of the must-be guardant of Kano 2D graph, but it is within must-be quadrant and should be taken at the end as indicative one;
- Variations Var (X) and Var (Y), as well as covariance Cov (X,Y) are used as pre-calculus for determining correlation coefficient Correl (X,Y). In fact, the higher the absolute value of the correlation coefficient, the stronger the correlation.
- Relatively high value of correlation coefficient $[\mathrm{Correl}(X,Y)] = 0.779$, or the coefficient of determination $[\mathrm{Correl}(X,Y)]^2 = 0.607$ means that there is a strong correlation between X and Y variables. This is understandable if we concern the linguistic descriptors and corresponding numerical values for pairs of opposite (functional and dysfunctional) categories of Kano model. What makes that correlation stronger is that neutral (indifferent), questionable, and reversal responds have been excluded from the graphical analysis. In another words, $[\mathrm{Correl}(X,Y)]^2 = 0.607$ means that more than 60% of the total variation in X can be explained by variations in Y. Or, another explanation might be that the ellipse representing correlation in this case should enclose more than 60% of the N considered points, i.e. (X_j, Y_j), $j = \overline{1,10}$ pairs on which it is based (Tailor, 1990).

Above given short analysis over the numerical values of some relevant statistical measures provides a certain refinement of the observations made upon graphical interpretation of Kano model based on plotting pairs of responders' quantified answers on both functional and dysfunctional aspects of the questions. These refinements will be better, i.e. more reliable, by introducing greater number of respondents and/or by having a greater number of questions forming the questionnaire, or by uprising the parent population in statistical terms, what should be a subject of further more extensive research.

7. Conclusions

This study aims to identify critical elements of web based learning system within blended environment using Kano (dys)functional model (Walden, 1993) and DeLone and McLean (2003) generic model for the information systems success, providing though the recommendations for creating better new teaching/learning system.

The population sampled was composed of students at University "Mediterranean" (in Montenegro). A total of 63 valid questionnaires were collected, with a response rate of 55% in comparison to the total number of interviewed students. Firstly, frequencies of each Kano model categories appearances have been measured and some approximations have been done in order to make the responds more meaningful. Also some additional analysis based on determination of "better" and "worse" indexes have been made with and aim to reduce the fuzziness in observations as much as it is possible. Some two-dimensional graphical analyses have been realized, as well. This analysis results in "shifting" some points to other more appropriate Kano categories, or 2D graphic quadrants, due to the researchers' empirical point of view.

It is to be noted that there is a scattering among the obtained results, and that this is to be reduced throughout: repeating the questionnaire among another, considerably larger target group(s) of students, modifying the questions, and/or including some additional questions into the model.

In any case, it is to be recommended to the designers of e-learning systems in blended environment - using the combination of methods employed in this research work along with some other available analytical and/or stochastic methods for assessing degree of customers' satisfaction and their expectations of such learning systems. A holistic approach based on users' satisfaction level and the appropriate measurement analysis should give support to the designers in improving existing and designing new more attractive web based learning models in the contemporary educational blended schemes.

And finally, speaking more generally, as a powerful communications and commerce medium, the Internet is a communication and IS phenomenon that lends itself to a measurement framework (e.g. Kano and D&M models). Within the e-commerce context, the primary system users are customers or suppliers rather than internal users. Customers (students/learners) and suppliers (teachers/instructors) use the e-system for learning, but as well for buying or selling learning courses and kind of execute business transactions. These will undoubtedly impact in greater extend the whole process of learning including individual learners, universities, industries, and even national economies in the future.

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4.5. Challenges of moving education into the Cloud

This research study considers moving education into Cloud under the conditions of digital turbulence from one side, and the digital divide from the other. The content of the paper is organized into three parts: (a) in the first part, an overview of some author's experiences as a researcher and lecturer regarding the topic is given; (b) in the second one, the focus is on digital divide, since it greatly affects the issue. Also, this part of the paper provides an overview of (potential) applications of the Internet of Things (IoT) as a new form of digital divide which will undoubtedly increase the imbalance between those who have and those who do not have access to modern Information and Communication Technology (ICT) resources; (c) in the third part, a model for adapting Cloud in educational environment is proposed, with the emphasise on the needs of so called developing countries, which suffer consequences of the digital inequality. After all, a brief conclusion along with some guidelines for the future research work in the field is given.

1. Introduction

Today, education has already been moved to Cloud to a great extent. But, regardless, still there is a need for human encounter in the public education and/or academic enviroinment, so that experiences could be exchanged and new knowledge acquired.

(i) If, as a researcher, I ask myself a question: "Should education be moved into the Cloud?", I must confess that I have been educating myself for decades by means of Cloud resources mostly, i.e., on the resources which are free of charge (for now). In other words, I use whatever is available. In my spare time, I still read books, in the classical sense of the word, but this can be considered a hobby. For the purpose of professional development, in a certain way, I am forced to search the Internet for what I am interested in and what I need in given circumstances. I would rather have the latest issues of leading professional magazines and books available, but unfortunately this is not the case. So, by (mis)fortune, I have to find my way round through the jungle of content offered by the web. Many useful things can be found on the web if one is interested and persistant, but in my judgment, that is far from an ideal way of acquiring new knowledge.

(ii) If I ask myself the same question as a professor at the Maritime College at University of Montenegro, then the answer is quite different. Namely, a couple of years ago I have invested a lot of time and effort to prepare, record and adapt video materials for students of the Maritime College for export to the Internet. Those materials were related to the theoretical basics and elements of the use of ECDIS (Electronic Chart Display and Information System), as an advanced ICT navigation tool, which will most likely be intensively used in the context of e-navigation and maritime Cloud in the future. In my opinion, these instructional video materials were both substantive and technically sound. Unfortunately, after a certain time, the number of visits to these materials by the students was very small. On the other hand, I have to say that most students come to my lectures regularly and follow them carefully. This brings me to a conclusion that students in Montenegro prefer to be given the answers rather than to seek them out themselves because they simply got used to such an approach during their education in elementary and high schools. No one has taught them to ask questions and look for the answers by themselves. Nobody has made them interested in such an approach.

(iii) If, now, I ask myself the same question as someone who, on two occasions for a couple of months, has taken part in teaching at Lund University in Sweden, then the answer is somewhere in between these two previous ones. Lecturers at the University of Lund are also researchers (implicitly), they travel around the world, get the newest books from New York, London, Berlin, Sydney, regularly receive magazines that they choose

themselves in the mailing boxes, read a lot, visit the headmost conferences in the field around the world, but during the lectures they remain in the background. They by their own estimation recommend literature at the beginning of the semester, i.e., new, important editions of books in the subject area, and then ask questions so that students could independently or in groups look for answers, as well as ways to respond better and more convincingly to lecturers and other students, their colleagues. The lecturer is there to listen to them and to point out their critical thinking, i.e., to praise them, point out what could have been better, and sometimes (sharply) criticize what they think is not good. After that, students write assignments, or their articles, on a topic they select on the subject matter, and the teacher then evaluates them. In the meantime, during the semester, the teacher holds only 3-4 ex-cathedra lectures and organizes 2-3 guest lectures. Visiting lecturers are not necessarily from the academy, i.e., they can be experts from industry and business sectors (usually from the leading companies in the field).

Of course, some kind of general conclusion could only be drawn on the basis of a larger set of individual experiences of this type, and the analysis could be based on various aspects of education, e.g., formal -primary, -secondary, -undergraduate, -postgraduate, informal, lifelong, etc., as well as those in the Cloud environment, in different socioeconomic and cultural environments. It should certainly include the possibilities of access to ICT resources, their use, health and property status of a user, social status, age, sex, gender etc. The research should include also the so-called non-users, i.e., those who knowingly refuse to use new technologies.

In the world today there are technologically highly developed countries (e.g., countries of North America and Canada, some countries of Europe, Japan, Australia and others), those which are in expansive (apparent) development (e.g., China and India) and those conditionally referred to as developing countries or countries of the third and fourth world (e.g., sub-Saharan Africa, some countries of South America, some Asian countries, some Balkan countries, and others). Of course, the level of economic and technological development directly reflects the level of education, as well as the level of digital divide. It is a, in a cause-and-effect sense, closed system, where special effort is needed to overcome some barriers and make positive steps forward. Not only is there a major imbalance in the level of education and achievements in using ICT opportunities between more and less developed countries, but also within the very borders of those most developed countries in Europe and in the world (Cruz-Jesus et al., 2016).

2. Digital divide: Availability and use of ICT

At the World Summit on the Information Society of the United Nations (WSIS, 2013), it is stated that the global challenge of the new millennium is an establishment of the society "in which everyone will be able to create information and knowledge, access, use and exchange them, enabling individuals, communities and nations to achieve their full potential in terms of promoting their own sustainable development and improvement of quality of life." On the other hand, the existence of a digital imbalance between and within countries is the main obstacle to achieving ICT potential. Digital imbalance or digital divide is defined as "the existence of differences when it comes to individuals, households, business and geographical regions at different socioeconomic levels in the ability to access ICT resources and use the Internet for different purposes." (OECD, 2011)

Regardless of many advantages that ICTs can bring, not everything related to them leads to positive outcomes. The idea that ICT will create a new world of unlimited possi-

bilities, free of the influence of problematic socio-cultural aspects: race, age, gender, geographical origin, living standards, etc., has proved to be utopian (Gunkel, 2003). In addition, many of the promises originally given by ICT have failed (Bauk, 2016; Galliers & Currie, 2011):

- They did not reduce the gap between the rich and the poor. On the contrary, according to some statistics, currently 1% of the world's population has over 50% of the world's wealth at their disposal;
- There are many settlements of the poor, or so-called black holes of socially excluded in the world's major metropolises;
- Apart from failing the promise of economic prosperity, ICT has failed the green concept. For instance, ITC devices are the largest energy consumers per unit of area they occupy;
- Not only has the green concept failed, but the paperless office idea is also lost. In 2013, 400 million tones of paper were consumed in the world, and it is estimated that consumption will increase to 500 million tones by 2025;
- Annually around 20-50 million tons of e-waste is disposed of worldwide, of which only about 12% properly. The rest is transported illegally and improperly disposed to the countries of the third and fourth world;
- Despite the propagation of rapid industrial development based on ICT innovative solutions, scientifically based claims about the un-sustainability of modern lifestyles predominate due to growing climate change (increased rainfall, sea level rise, vast areas of contaminated land, ocean acidification, etc.);
- In addition to economic and environmental problems, the problem of cyber crime, which is on the rise, can not be overlooked. Criminals increasingly use the speed, comfort, and anonymity of the Internet for a wide range of criminal activities which do not know the boundaries, either physical or virtual, and thus cause serious harm;
- Instead of a more comfortable life in the informational era, which was propagated, paradoxically, people are increasingly pressured to work hard as machines;
- The problem of replacing real interpersonal contact is present due to communication through social networks in a hyper connected society can not be neglected. More and more people are suffering from various forms of Internet addiction;
- In the realization of the so-called "human-centric computing", i.e., ICT solutions that put man and (her)his needs first through the development of intuitive interfaces with simple navigation also have many flaws that tend to be solved through the so-called testbeds or tests in real situations;
- As for education, regardless of the possibility of accessing numerous and extensive open repositories of instructional materials on the Internet, the question is whether more information generates more knowledge or, on the contrary, creates confusion and reduces clarity, and much more.

With the development of ICT, it became clear to researchers and politicians that the access and use of ICT resources can not be universal and immediate. There was the emergence of the term digital divide. The US Department of Commerce defined the digital divide very simply as: "a divide between those who have access to new technologies and those who do not have it." (USDC, 2002)

3. Digital divide waves

Various approaches to digital divide are present in the literature. One of them refers to the digital divide of the first and second order. Digital divide of the first order is binded to the disparity in access to ICT resources, while the second is related to differences in models of using new technologies between individuals and/or organizations which already have access to ICT. For example, some use the Internet only to search the web or email, while others use it for e-learning social networks, job applications, e-banking, e-health, e-government, etc. Studies have shown that these divisions are caused by socio-economic inequalities between individuals, groups and states. Those who are economically and socially in a worse position are more exposed to digital inequality (e.g., individuals with lower incomes and poorer education, those with special needs, those living in rural areas, those belonging to ethnic minorities, women and elderly people, etc.). Also, one should not overlook the big difference in the behavior of users after the implementation of the ICT solution. For example, in Spain, research has shown that regardless of the presence of ICT infrastructure, its use varies from region to region depending on the personal income of members of the inquired households, the level of their education and age (Novo-Corti & Barreiro-Gen, 2015). Some studies have shown that there are major differences in the use of ICT when it comes to children without and with learning disabilities, for example, in Taiwan (Wu, 2014). Epstein et al. (2014) have shown that different types of imbalances require a different approach: inequalities in the approach can be overcome by subsidizing new technologies, while their lack is largely conditioned by economic constraints that lead to access restrictions. On the other hand, the imparity in use, in this respect, depends mainly on the ability and the awareness of users, where education and training for the use of ICT are considered key factors.

There is another approach to the digital divide that distinguishes: the first, the second and the third wave of the digital divide (Bauk, 2016; Pepper, 2015). The first wave binds to the availability and use of mobile phones, the second to the availability and use of the Internet, while the third is binded to the development and application of the concept of the Internet of Things (IoT) and so-called smart environments.

The first wave of digital divide in relation to the availability of mobile phones can be considered surmounted, according to numbers at least. Namely, in 2005, the percentage of mobile phones in regard to population in developed countries was 82%, and in those less developed or underdeveloped, about 23%. In 2015, this percentage changed significantly: in developed countries it was 121%, and in the others 92%. Of course, there remains an open question about the purpose and the ultimate goal of mobile phones usage, but in any case, according to numbers, the first major wave of digital divide has been overcome.

The second wave of digital divide which is related to the ability to access the Internet has not yet been scaled. According to some estimates, in 2015, 3 billion people worldwide had access to the Internet, of which 76% of the population in developed parts of the world, and only 30% in developing ones (see Table 1). Therefore, according to United Nations' data, more than half of the world's population still has no access to the Internet (around 4.2 billion people) (Lyell, 2016). According to estimates from the same source, it would take around 450 billion dollars to provide 1.5 billion people with access to the Internet by 2020. In order to accelerate this process, the use of the "white-fi" spectrum, simultaneous installation of multiple optical cables at the same locations as well as devel-

opment of the suitable content for the potential users in certain geographic regions, are recommended.

Table 1. The first and the second wave of the digital divide
(percentage per capita)

Year	2005		2015	
Users	**Developing countries**	**Developed countries**	**Developing countries**	**Developed countries**
I wave **Mobile telephony**	23%	82%	92%	121%
II wave **Internet**	8%	51%	30%	76%

Although the second wave of digital divide is still not surmounted, the third one related to the implementation of the Internet of Things is already coming up quickly. The following chapter provides an overview and a brief description of (potential) application of the Internet of Things in the industry, health care and *smart* cities, since this new technological concept will greatly affect the change in the lifestyle and open new opportunities in the domain of education, even when it comes to developed parts of the world.

4. Internet of Things as a new wave of digital divide

The Internet of Things (IoT) enables a large number of industrial and user applications. While devices and networks provide physical connectivity, IoT applications/apps allow communication on a device-device or human-device relation in a reliable and robust way. The device-device applications usually does not require visualization while more and more applications/apps which involve man as the end user provide visualization to display information in an intuitive way. It is important for IoT applications/apps to be intelligent so that devices can record the environment, communicate with each other, identify and solve specific problems without the necessary intervention of a human being.

According to the Cisco Visual Networking Index from 2015, over 10.5 billion Machine-to-Machine (M2M - Machine-to-Machine) devices that communicate with each other and perform non-human actions will be networked. How things stand in this respect in certain parts of the world, numbers show in Table 2.

Internet of Things in industry

Logistics and product quality control. The important industrial application of the IoT concept is in the domain of logistics and supply chains. RFID (Radio Frequency Identification) tags, sensors and/or microchips are joined with objects and used to identify products (clothing, furniture, various equipment, food products, etc.). The use of tagged objects increases the efficiency of storage and sales management, simplifies inventory by providing accurate data on the stock status in real time, and similar. It is also possible to automatically monitor the entire "life" cycle of the product. The advanced concept of using *smart* shelfs should be mentioned, as well. It reduces the possibility of material loss

and automatically generates the information on quantity of available merchandise. It is interesting that sales are reduced by about 10% if the shelfs are only partially emptied (Borgia, 2014), which even further points out the importance of this IoT tool. Using sensors, it is possible to detect damage of easily perishable goods in real time (e.g. fruit, vegetables, frozen food, etc.). Sensors record temperature and humidity inside refrigerators continuously, and actuators modify them to ensure preservation of the groceries. Additionally, the integrity of the product can be provided by using the RFID authentication process, etc.

Table 2. The third wave of the digital divide
(number of M2M devices in billions per capita).

Part of the world / Year	2014	2019 (an approximation)
USA	6.1	11.6
Western Europe	4.4	8.2
Latin America	2.0	2.9
Central and Eastern Africa	1.0	1.4

Another useful IoT application is an intelligent shopping system. This system records consumer habits, track purchases via a mobile phone, and later leads customers through entertainment parks, shops, supermarkets and/or malls, suggesting that they buy products on discount (e.g., Disney's MagicBand, Kroger's, Macy's shop Beacons or iBeacons, etc.), and it also allows quick payment, that is, automatic checking through the reading of biometric data.

Agriculture. Internet of Things can be used in agronomy and livestock breeding. Control of agricultural products and animal food (e.g., determining the presence of GMOs, additives, melanin, etc.) using advanced sensor systems is one of the technologies in development. In the domain of agriculture, advanced IoT applications which speed up the management process of registering, changing purpose, or closing agricultural farms, controlling their work and issuing appropriate sanitary certificates should be mentioned. By using IoT, agricultural producers can shorten the supply chain by establishing a direct link and opening the so-called *publicity windows* where they can show their products, which customers then order via a computer or mobile phone.

Industrial processes. IoT provides advanced solutions for the car industry (e.g., BMW, Tesla Motors, etc.). Real-time malfunction diagnostics is a key application. Almost all important parameters can be controlled via special sensors: tire pressure, engine condition, fuel consumption, location, speed, distance from other vehicles, duration of the ride (V2V - vehicle-to-vehicle communication), etc. The recorded data is sent to the control center. It is also possible to dynamically optimize the route to the destination, depending on the current road conditions. To park the car automatically is possible, as well. In *smart* cars, there are smart games to interact with a smart environment. There are also self-propelled vehicles (without driver), for example, Google's self-driving cars. It is assumed that by 2020 250,000 vehicles will be connected to the Internet. In addition, using the combination of RFID, GPS, sensors and appropriate software, in the IoT context, it is possible to monitor dangerous loads in transport (e.g., controlling the temperature of plutonium inside special containers during their transportation, etc.).

Internet of Things in health

Medicine and health care. Medicine and health care will be strongly influenced by IoT. Advanced sensory devices already allow real-time monitoring of medical parameters and vital functions of patients (e.g., body temperature, blood pressure, heart rate, acceleration, body position, glucose level, cholesterol, etc.). The gathered data is transmitted through standard or special communication technologies (e.g., Bluetooth, ZigBee, WirelessHart, ISA100, etc.) to medical personnel to diagnose and control the patient's health. Wireless networks in the range of the human body (BANs - Body Area Networks), formed by wearable, non-intrusive sensors, in collaboration with appropriate access points, allow physicians to continuously monitor patients outside the hospital. Another important application is related to the identification and monitoring of medical equipment and materials. For example, the use of *smart* labels on medical equipment prevents the loss, or forgetting of material (e.g., gauze) in the patient's body during, i.e., after the operation. Furthermore, efficient hospital managing systems include optimum energy use and climate control (HVAC - Heat Ventilation and Air Conditioning). In this context, it is also important to mention access to the hospital and some departments, through active RFID badges (bracelets) and fixed readers set in key positions. There is also an effort to ensure that hospital beds are equipped with screentouch entertainment terminals, which will allow access to TV, Internet, enable communication with family, etc. In this way, patients of school age and students will be enabled to monitor on-line teaching and similar.

Independent life of people with special needs. IoT can also improve the quality of life of elderly people and people with disabilities. Monitoring the health status and emulating medical consultations at home are two basic applications. By capturing physiological signals through appropriate sensors in real time, the system is able to turn on the alarm at the earliest stage in cases of a person falls down, when hospitalization is required or when dementia is diagnosed (e.g., Parkinson's or Alzheimer's disease) etc. Assuming that elderly people tend to move less, IoT can enable them to become engaged in various social networks, participate in debates and/or discussion groups, and so on (e-inclusion). IoT can also provide assistance to the elderly and/or people with disabilities when moving around city and using public transport. By combining data collected via a mobile phone (positions, orientation, obstacles, etc.) and sensors set in the surrounding area, special systems based on artificial intelligence can reconstruct the perception of the environment and then in synthetic voice give instructions to a person how to move or react in a particular situation. Such systems can be of help to people with impaired sight.

Services related to improving the quality of life. These services record user habits and give appropriate advice. Positive feedback on the amount of calories burnt during a walk can be an incentive in a sense that they motivate patients to exercise an activity of some kind every day. Also, there is a tendency to determine the correlation between individual behavior and the impact it has on the environment.

Internet of Things in smart cities

IoT should transform a traditional city into a *smart* one. Networks of the sensors, cameras, screens, speakers, etc., collect information, and then the operating platform processes and adapts it for various services/infrastructures in the city. For example, sensors in vehicles, or in mobile phones, collect information on roads (traffic intensity, road conditions, etc.) and forward it to the control center. A smart parking system can guide a

driver to a free parking place, which saves time and fuel, while reducing the emission of harmful fumes. Parking sensors can also serve the city administration to identify improper parking (for example, in a space for people with disabilities) and send a tow truck to remove an improperly parked vehicle. Furthermore, the payment system becomes simpler and faster. Instead of using coins, drivers can use NFC (Near Field Communication) technology and pay via mobile phones. Similarly, the RFID card and reader system is used to charge highway tolls. Here we should mention possibilities of smart services when it comes to amusing tourists. With the help of special mobile phones apps, tourists can get acquainted with the main features and history of a city, etc.

Smart grids. More intensive use of renewable energy sources has caused changes in conventional energy distribution systems. Thus, the concept of smart grids, or intelligent energy transfer systems from amanufacturer to users, is introduced, and it is two-way. Unlike traditional distribution networks where energy was generated in several central plants and distributed to customers through a large network of cables, transformers and transformer substations, with smart grids, consumers become also producers of energy. The energy produced in consumer micro-grids (for example, solar panels, wind turbines, etc.) is sent to the main grid, where it is managed by an energy control system and stored in a special energy storage (batteries). Using special, *smart* meters, the plants are automatically controlled so that the grid can determine in advance the amount of consumption and coordinate production and consumption to avoid overloads and eliminate power outages or complete power failure. Also, users are provided with information about the amount of energy they have spent, with the goal of raising awareness about the need to change their habits and use energy more rationally. The scope of consumption can be tied to the possibility of variable, flexible payment, etc. E-stations for charging e-vehicles/bicycles batteries should also be mentioned here.

Smart buildings/houses. Automatic systems in buildings/houses are very attractive, because they allow remote control via web applications/apps: video surveillance, care of plants (exposure to sunlight and irrigation), control of heating, cooling and ventilation, use of smart ovens, washing machine, etc. More complex applications/apps allow the interaction between electrical appliances and smart meters in order to optimize energy consumption, etc.

Smart schools. Smart schools, similarly to other smart buildings, use IoT to control access to school, or its separate departments; for climate control and saving energy, etc. So-called *smart* markers are very popular nowadays. They are used to transfer marked parts of printed text directly to a computer or mobile device (THP, 2016). Apart from pupils/students, these markers are often used by lawyers and researchers, for example. Smart boards and suitable web-based platforms through which teachers and students exchange instructional materials and project tasks more quickly and work together on the same projects. *Smart* schools aim, among other things, to prepare students to become highly high-tech literate.

Table 3 gives an overview of the areas in which IoT is used. More precisely, it is a review of some of the IoT applications/apps which are already largely in use, as well as those that are still under development (adoptet from (Borgia, 2014)). Undoubtedly, IoT will improve the quality of life and positively affect the preservation of the environment in the developed parts of the world. The question is: what about the other, less developed part? So, it is about whether the IoT will deepen the digital divide and the gap between an even smaller number of the rich and growing numbers of the poor in the world. It is pos-

sible that stronger advocacy of the principles of solidarity would be effective, in a sense that one part of the money for the development and implementation of new, futuristic IoT solutions is systematically directed towards the development of underdeveloped. In the beginning, providing them with the most basic needs, and adjusting transfer and diffusion of new technologies to their individual needs and preferences.

Table 3. An overview of some areas in which IoT solutions are used (Adopted from: (Borgia, 2014)).

1. Industry
1.1. Logistics (SCM[1]) and quality control of goods
- Detecting damage or deterioration of easily-perishable goods (e.g., groceries/foodstuffs)
- Warehouse management (stock/supplies), retail and inventory
- Quick purchase and payment, etc.
1.2. Agriculture
- Animal tracking
- Certification of animals
- Controlling the purchase of animals
- Irrigation control
- Agricultural production and control of animal feed
- Registration of agricultural holdings (farms), etc.
1.3. Industrial and supporting processes
- Monitoring of industrial plants
- Automatic assembly
- Malfunction diagnostics (e.g., vehicles)
- Driving assistance
- Managing boarding of passengers, luggage/cargo loading
- Electronic card/ticket managing, etc.
2. Health
2.1. Medical care
- Remote control of the patient's medical and health parameters and tele-diagnostics
- Monitoring medical equipment
- Input/output control in health institutions
- *Smart* hospital services
- Providing on-line educational and entertaining services to patients, etc.
2.2. Supporting an independent, healthy life
- Help elderly
- Help people with disabilities (special needs)
- Remote support for social inclusion
- Analyzes of the impact of the behavior of individuals and their state of health on society, etc.
3. Smart cities
3.1. Smart traffic and tourism
- Transport and traffic management
- Recording the road conditions
- Control of free parking spaces
- Waste managing
- Payment managing
- Providing entertaining content
- Tourist guides, etc.

[1] SCM – Supply Chain Management.

3.2. Smart grids/networks
- Manage generation, distribution and energy consumption
- Managing network load and energy accumulation
- Identification (recognition) of users
- Checking and charging
- Ensuring sustainable mobility, etc.
3.3. Smart buildings/houses
- Plant maintenance (lighting, watering, etc.)
- Heating, ventilation and cooling
- Video surveillance / entry control / child protection
- Entertainment and comfortable life, etc.
3.4. Smart schools
- School access control (through smart cards or bracelets)
- Climate and energy consumption control
- Using MLS[2] (e.g., Moodle, etc.)
- Using smart boards
- Using smart markers, etc.
3.5. Public safety and environment protection
- Monitoring territory
- Video/radar/satellite surveillance
- Stations for emergency cases
- Monitoring people in danger
- Plans for emergency and safety situations
- Control of environmental parameters (ecosystems), etc.

In order to provide an answer to the question of how things are regarding education and its moving to Cloud, in the context of digital divide and in terms of the ability to access the Internet, alongside with the rapid development of the Internet of Things technology including a wide range of its applications - only some, so to say, explanatory interpretations and recommendations for further research are given in the following section.

5. The level of education, socio-economic status and digital imbalance

Differences in the level of education of individuals are among major causes of digital divide. This cause-and-effect relationship is multiple and can be explained by several theories. According to Diffusion of Innovation (DoI) theory, complexity is the main obstacle to the adoption of new technologies. Therefore, simpler technology is, sooner it gets accepted. Education plays a key role here. Namely, more educated people are more willing to cope with more complex problems and effectively overcome complex requirements set by new technology and its implementation. In other words, a higher level of education makes it easier to overcome the barrier to the use of new ICTs. Higher education enables better acceptance and understanding of information, which again leads to informational divide between those with higher and those with lower levels of education. This is basically the main argument on which theory of educational differences relies on (Tichenor, 1970). The theory is developed in the context of mass media spread (TV, radio, etc.). Namely, Tichenor et al. (1970) claim that "the infusion of mass media information into the social system is on the rise in a way that a portion of the population with a higher socio-economic status adopts information faster than the part of the population with a lower status of this type, which shows that the disparity has a trend of growth

[2] MLS – Management Learning System.

rather than decline." If this is the case with mass media, which are far less complex and demanding than the Internet; in the case of the Internet, the previously identified problem of divide will be even more pronounced. Namely, mass media technologies are not as demanding as ICT's, as they do not require much engagement by users. Instead of being only the recipients of what is offered to them, as is the case with unilateral mass-media content, users are required to navigate through a large amount of information by ICT and Internet activities. In addition, in the case of the Internet, although availability is a pre-requisite, it is not sufficient *per se* to achieve all of the advantages that this technology can bring, so the important differences can remain in the domain of the nature (manner) of its use. Vicente & Lopez (2006) emphasize: "not only does a user need access to infrastructure, but she/he also needs the ability to access information, i.e., the ability to find them and use them." Also, the hypothesis that educated people will work in information-intensive industries, i.e., that they will use ICT more intensively both at work and at home, makes sense. In accordance with this Howard et al. (2001) came to a conclusion that more educated people use the Internet more productively and with a higher economic impact compared to those with a lower level of education. Peng et al. (2011) have shown that people using PCs at work and at school are more likely to adopt new ICT solutions. Tengtrakul & Peha (2013) have shown that "the higher educational level of a student, the greater possibility of accepting ICT in households" (which these students belong to). Based on the summarized results of several (pilot) research studies presented here, it is clear that there is a positive correlation between the level of education, the socio-economic opportunities of individuals and the adaptation of new ICT solutions. Implicitly, this hypothesis could also extend to the use of Cloud in the generation and dissemination of knowledge, i.e., in education.

6. A model for moving education into Cloud in developing regions

Today, when it comes to using computer infrastructure, various platforms and software solutions, Cloud computing is an ubiquitous paradigm which has introduced significant changes in the way services are provided. Simply, Cloud computing is the Internet-based computing. Cloud can also be described as a set of clusters of distributed computers (with farms of servers, as enormous centres for data collection and processing), which provide resources and services via network medium, i.e., Internet. Customers used to use applications installed on their own (physical) computers or company (local) servers, while today these applications are moved to Cloud. For example, when users check their g-mail account, bank account status online, or update their facebook status - they are, in fact, in Cloud.

The question is why such a large number of activities, including education, is moved into Cloud. Numerous literary sources say that this is in order to increase the flexibility and scalability of user needs, to free the users of capital investments in infrastructure and software, "pay as you go" services, as well as automatic software updates, increasing the possibilities of collaboration, the ability to access resources from any place, more efficient group work on the same projects, increasing competitiveness (SUK&IB, 2015), etc.

Apart from this, this section undoubtedly has an expansive and less and less controllable growth of technical forms of material culture, which we are often, in a certain way, forced to adopt. It is, in fact, a kind of imperative of the new era. On the other hand, education is more and more treated as an expense, rather than an investment (and not only in developing countries, but also in developed ones). So, this is also one of the reasons for

moving education into Cloud. All the challenges of moving education into Cloud in developed parts of the world are even more emphasised in developing environments, and that is, above all, willingness to manage knowledge and (confidential) human resources data in Cloud. Therefore, taking into account contextual factors, socio-economic and political constraints, above all, an attempt has been made to present a model for the implementation of Cloud in these environments.

If we start off with the assumption that the increase in the adoption of Cloud computing will also be present in the field of education (especially higher and lifelong), indisputably, new opportunities in this domain will arise for developing countries, as well. For these countries, small capital investments and flexibility in the use of resources are of particular importance. By opening Cloud capabilities, developing countries should be able to use the same infrastructure and resources as technologically highly developed countries (Kshetri, 2010).

In developing countries, there is very little preliminary research on the adaptation of Cloud resources in education. The model proposed here (see Figure 1) is based on a study which was carried out in sub-Saharan Africa (Humphrey, 2016) and it represents the basis for designing a questionnaire by means of which the readiness of the higher education institutions in some developing countries (e.g., Western Balkans) to implement this type of education could be analyzed.

This model is based on triangulation (reconciliation) of two theories of adoption and expansion of ICT: (i) theory of diffusion of innovations (DoI - Diffusion of Innovation) (Rogers, 2003) and (ii) the theory of a technologically acceptable model (TAM - Technology Acceptance Model) (Davis, 1989).

The proposed model (based on (Humphey, 2016)) includes two dependent variables: (dv.a) The intention to introduce Cloud into education and (dv.b) Actual use of Cloud in education. The independent variables in the model are organized in several subgroups: (iv.a) Economic factors (expenses); (iv.b) Technical factors (risks, data safety); (iv.c) Contextual factors (infrastructural, socioeconomic, educational) and (iv.d) Innovative factors (relative advantages over existing/other solutions, complexity, compatibility, possibility of beforehand testing of new solutions, etc.) Also, the domain of independent variables includes: (iv.e) Factors related to use (utility and simplicity of use) and (iv.f) Organizational attributes (average age of employees, size and location of the organization). In Figure 1, direct and indirect links between dependent and independent factors in the model are presented.

A survey based on this model for the Western Balkan countries could be implemented by creating a questionnaire for experts in the field of education, for instance. Its analysis would show the correlation between some dependent and independent variables, as well as the correlations between the sets of dependent variables. Certain qualitative guidelines for the implementation of Cloud could be given on the basis of the obtained correlation coefficients. Also, with the help of multi-criteria regression analysis, the degree to which individual independent variables affect dependent might be determined, etc.

A preliminary version of the questionnaire should be sent to experts so that they could give their recommendations, and by doing so, improve clarity, i.e., avoid ambiguity of the questions, all in order to achieve the most relevant conclusions after the conducted analyzes. Also, one should not reject the possibility of excluding some of here proposed independent variables, that is, including some new ones which experts may estimate to have an embodiment in the theory and/or empiricism.

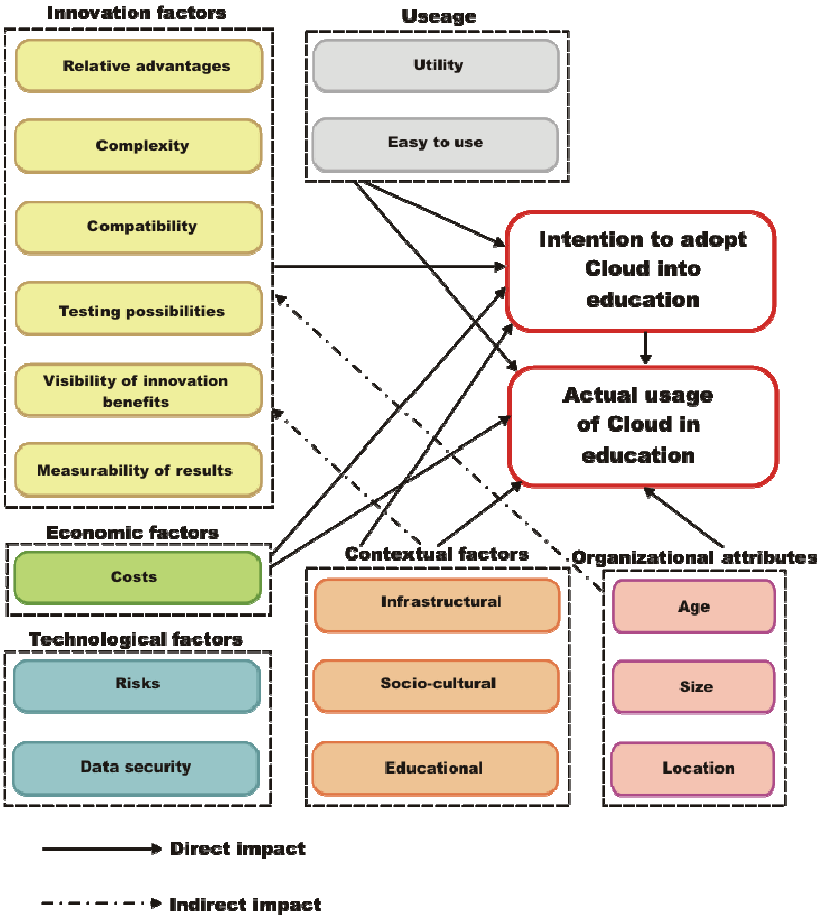

Fig. 1. Relations between relevant factors for moving education into Cloud in developing regions

A questionnaire which would be sent to experts/managers in higher education institutions should contain at least two parts. In the first part, respondents should answer a set of demographic questions related to the institution, and in the second part they respond to several subgroups of questions related to the various structural components of the proposed model, which should confirm the preliminary hypotheses of the type:

H1: Cost effectiveness is in a positive correlation with tendency of introducing Cloud computing into (higher) education;

H2: The risk is in a negative correlation with the introduction of Cloud into education;

H3: Data safety is positively correlated with adaptation of Cloud computing in this domain;

H4: The availability of ICT infrastructure is also positively correlated with the introduction of this new concept into education;

H5: The age of the user is in a negative correlation with the Cloud adaptation. In other words, young people are usually pro innovation unlike older generation;

H6: Compatibility with existing ICT solutions is also in a positive correlation with dependent variables;

H7: Complexity is in a negative correlation with dependent variables;

H8: Being able to try out new solutions before adaptation is in a positive correlation with the adaptation of new technology;

H9: Simplicity of use is positively correlated with adaptation;

H10: The utility is in a positive correlation with the introduction and use of Cloud computing in the sphere of education, etc

In addition, the multidimensional nature of accepting ICT innovations brings with it different levels of acceptance which can not be explained exclusively by economic and technological factors, but must inevitably involve socio-cultural factors, as well. In developing countries these factors are significantly different from those in (highly) developed countries.

Through the proposed model, in the case of multi-criteria linear regression analysis, it would be possible to determine to what extent these factors influence the intent of introduction, that is, the use of Cloud computing in education. It would also be possible to determine how many analyzed sets of independent variables affect the dependent in a model, that is, whether the model should include a larger number of independent variables, etc. All this should be done in order to create the best possible prerequisites for gradual move of education into Cloud.

7. Conclusions

In the literature, there are different answers to a question if education should be moved into the sphere of Cloud. Some sources advocate the transition to Cloud as the only acceptable solution today, as the imperative of the new digital age, which ensures higher efficiency in education (SUK&IB, 2015; Ellucian, 2016). Others look at the transition primarily as an attempt to reduce the cost of education, especially higher education, but not as an entirely successful one. Moving from well-established, traditional, routine face-to-face education to new forms of technologically supported education creates greater initial costs, alongside with uncertain outcomes (Bown, 2013).

Despite the divided opinions, it can be concluded that the decision to move education in the domain of Cloud computing/services still depends on individual preferences and numerous contextual factors, especially in the developing regions (countries) where a noticeable digital divide is still present. Therefore, further efforts should be made to develop efficient approaches for the assessment of real needs, when it comes to providing access, adopting and disseminating new ICT solutions for generating and distributing (new) knowledge. In other words, solutions that suit the individual needs and abilities of diverse educational entities should be sought out in the regions (countries) with different geolocations, and consequently economic, technological and socio-cultural attributes.

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Chapter 5:
Intelligent use of ICT in maritime business and some Cloud perspectives

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5. Preface

This chapter contains two pilot studies on the intelligent use of information and communication technologies in the marine business organizations. The top managers were interviewed and tests were carried out in several maritime companies in Italy, Slovenia, Croatia, Montenegro, and Albania. The ultimate goal was to determine the level of readiness of the analyzed organizations to cope with the challenges of introducing and implementing new information-communication systems in digital turbulence conditions.

As key preconditions for greater achievement in this regard, knowledge, ICT strategy, and organizational culture are singled out. The research has shown that the managers are aware of the importance of these and some other factors, but, unfortunately, the general level of intelligent use of available ICT solutions has proven to be insufficient. The study was carried out mainly in developing environments. However, the research results in technologically developed or emerging economies would probably be significantly different.

This chapter also contains a research study on tagging goods in supply chains in some developing environments. For this purpose were interviewed managers and academic experts in the field of logistics, with many years of professional experience in transition economies, regarding the advantages and disadvantages of tagging, that is, the chipping of goods. Based on the analysis of their estimations and theoretical considerations was suggested a methodological framework for the use of Cloud services in the process of automating the monitoring of products in the supply chains, taking into account the extremely restrictive and unstable conditions in which the analyzed environments operate (some countries in the Balkans).

Further research should be carried out on a larger sample of responders, with their clear vertical positioning in the supply chain. This would certainly show a greater precision in assessing the need for tagging or chipping of goods, and a clearer view on the outsourcing model in Cloud.

5.1. Intelligent ICT exploitation in some maritime organizations

This research work examines to which extent some maritime business organizations intelligently use their Information and Communication Technology (ICT) resources. The research is done as a pilot study, since it includes relatively small number of maritime business entities from Montenegro, Albania, Croatia, Slovenia and Italy. The intention was to indirectly check are these organizations ready for adoption and routinization of novel ICT systems like e-Navigation, Maritime Cloud, e-Maritime, National/Maritime Single Window (N/MSW) etc., through assessing how intelligently they exploit existing ICT solutions. Even though all interviewed managers have highly evaluated knowledge, organizational culture and managerial skills, as constructs that provide the business organizations' success, the level of intelligent exploitation of the available ICT resources is not at the high level. This is problematic, especially if one bears in mind necessity of making quick adaptation to considerably more complex, sophisticated and demanding ICT solutions within the context of actual huge digital turbulence in maritime community.

1. Introduction

Although about 90% of the world trade (by volume) and 60% (by value) is performed by the sea [1], maritime business and transport are lagging behind other industries in terms of digitization. The efforts at world scale are made in the direction of more intensive digitization of both ports and ships. However, there are numerous impediments connected with the differences among countries, due to the level of their economical development, along with complex, political and legal issues. There are many of non-Safety of Life at Sea Convention (SOLAS) ships. Besides, maritime community is generally more traditional oriented than other business and industry communities.

The Electronic Chart Display and Information System (ECDIS) revolutionary changed traditional way of navigation at the second half of the 1990s, and there is tendency for its full implementation at the global level. The concept of e-Navigation is a steep forward in comparison to ECDIS navigational support system. It should provide smooth communications at bidirectional relations ships-ports-on shore safety, legal, business, industry and other entities. It should reduce risks of accidents, environmental impacts, and costs [2, 3, 4]. The Maritime Cloud is conceived in a way to support these communications by means of old, e.g., radio, Navigation Telex (NavTex), Automatic Identification System (AIS), etc., and new communication channels, e.g., VHF (Very High Frequency) Data Exchange (VDES), Navigation Data (NavDat), Narrow-Band Digital Printing (NBDP), and much more over the seas [5].

On the other side, sea ports as enablers of berth-to-berth navigation and key nodes of sea-land transportation use different ICT solutions like: Electronic Data Interchange (EDI), Vessel Traffic Service (VTS), Vessel Traffic Management Information System (VTMIS), Port Community System (PCS), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM) system, access to the Electronic Logistics Marketplace (ELM), etc. Additionally, the concepts of e-Maritime [6], National/Maritime Single Window (N/MSW) and/or Single Window Environment (SWE) are currently in the focus of maritime research community [7, 8].

All these speak in favor of rapid and huge digital turbulence in maritime community, especially for those organizations that function in transitional environments with rigid administrations and without clear development strategies. Within this context, we considered important to do an examination how intelligently some maritime business entities in South-Europe (Montenegro, Albania, Croatia, Slovenia and Italy) exploit presently available ICT resources, since obviously their rapid development and expansion are on the

road. The research is realized with an aim to identify weak points and to propose directions for their smooth overcoming.

2. Methodology and hypothesis

In some of our previous research studies we were focused on the problems of initiation, adoption and adaptation of contemporary ICT solutions in transitional environments [9, 10]. The examinations have been motivated by the users' needs and preferences in developing economies, which are usually faced with permanent reproduction of crises, and constant lack of funds for providing up-to-date, comprehensive and sophisticated ICT systems. Let us note that we were faced with scarce secondary literature resources in the field [11, 12, 13]. In such conditions, we have also considered several theories as a kind of referential framework for our research endeavors under the transitional conditions: Diffusion of Innovation (DOI) theory [14], Technology Acceptance Model (TAM) [15], Theory of Reasoned Action (TRA) [16], Theory of Planed Behavior (TPB) [17], etc.

For the purpose of this pilot study we primary used Intelligent ICT Exploiter model [18, 19, 20, 21]. Additionally, it is worth to mention that respected Information Technology (IT) experts Weil and Ross [22] claime that success in the digital economy will go to the companies that are smart about how they use ICT. Also, we have used references [23, 24] as an inspiration for conceiving our methodological framework.

Intelligent ICT Exploiter model is developed upon several basic constructs connected with business entities and ways in which they realize their businesses activities: knowledge, IT management, internal and external communications, organizational culture, ICT strategy and manager's mindset as key construct which has to bind intelligently all other components. The scheme of this model is given in Figure 1. The detail description of these constructs has been given in [18], and it helps us to set below described hypothesis.

Information and knowledge. Knowledge is metaphorically a stair of the knowledge ladder which includes data, information, knowledge and wisdom. It is to be emphasized that there is a gap between information technology revolution, and information revolution. The primary idea of free and unlimited share of information failed, since it did not take into account the commercial dimension of the process. Today, information are sharing asymmetrically, and those who control the fastest and the biggest computers set the roles [25]. Therefore, the path: data, information, knowledge and wisdom is not easy one, and it requires considerable efforts towards achieving professional and business success. Accordingly, two most vital tasks in the modern enterprise are: (a) to speed up the creation of new knowledge by both individuals and communities, and (b) to accelerate sharing of knowledge within and across communities. On the basis of the above stated, we set the first hypothesis in our research framework:

H1. Knowledge is of key importance for the intelligent use of ICT.

Roles and skills. This construct is based on tree pillars: IT users, IT builders and IT managers, or information-knowledge professionals. A person or management team, which communicates the needs of ICT users in direction of IT builders, is knowledge navigator or information resource manager. There are business organizations, which recognized this triangle, and which are working on filling and improving all necessary skills of their employees in this direction [26, 27]. Accordingly, we set the second hypothesis:

H2. Besides IT users and IT builders, IT managers enable more intelligent use of ICT.

Effective system. Such system can be achieved by setting and communicating so-called Critical Success Factors (CSF) [28], and developing them steadily. The first step is to use technology to create an effective operational platform, primarily with internal information. Then, the CSFs can be widened to foster improved skills to use technology. This will start with employees, and then extend to suppliers and customers. Once when these two steps are working well, the CSFs can be broadened to encompass external information about markets, customers and competitors. After these steps comes business intelligence (see Figure 1), which enable the organizations to identify and manage risk while developing new products, services and markets, which are going to ensure the organization's future.

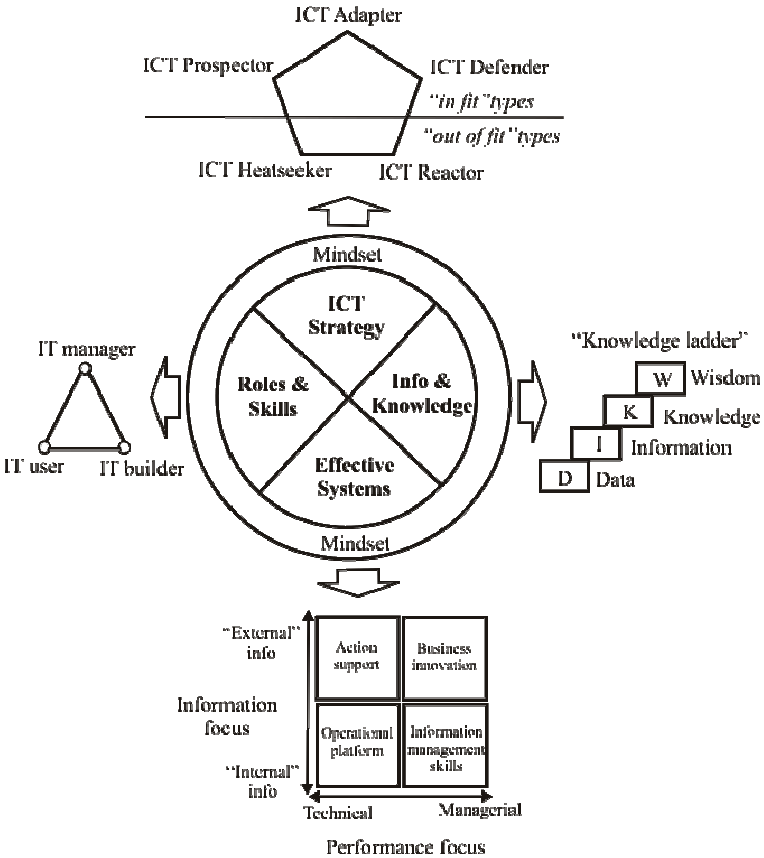

Fig. 1. Intelligent ICT Exploiter model [18]

The CSFs can be condensed into the third hypothesis:

H3. Effective business systems have to manage and exploit both internal and external information.

In this context organizational culture is also of particular importance, and we analyzed it as the fourth construct in our model implied by the hypothesis:

H4. Positive organizational culture enhances intelligent use of ICT.

While there is universal agreement that it exists, and that it plays an important role in shaping behavior in organizations, there is little consensus on what organizational culture

actually is. We selected several expressions that can be used in absence of an universally accepted definition [29]: “Culture is how organizations do things”; “Organizational culture is the sum of values and rituals which serve as glue to integrate the members of the organization”; “Organizational culture is civilization in the workplace”, etc.

Mindset. For top manager or Top Management Team (TMT), here is used a metaphor: their role is to weave a fabric of horizontal (information, technology, people and organization), and vertical (direction, knowledge, process and climate) threads mutually intertwined. In organizations where knowledge is a core dimension, managers have frequently identified people skills as the major influence, commonly along with climate. Switching from the information-based to the knowledge-based enterprise is a major challenge for today’s companies [30]. Therefore, managers have to combine well notions from several different domains: organizational behavior, human resource management, artificial intelligence, ICT, etc. Technology is invariably cited as a key enabler, but not usually a significant overall as skills and climate. TMT mindset unites all considered constructs and it affects the dependant variable intelligent use of ICT. Therefore, the fifth hypotheses should be formulated in a manner:

H5. The TMT mindset is of crucial importance for intelligent use of ICT.

ICT Strategy. It is strategy, which has to link business and technology. It has to ensure “C” in ICT for communication, which has to be fully integrated into strategic business thinking in both technological and a human sense. It is an assessment tool to help the organization to identify its behavior regarding ICT adoption, and it has five strategic orientations, listed below.

- *Prospector*: Systematically seeks and selectively exploits relevant ICT trends to gain competitive advantage and enable entry into new markets. Prospector is willing to experiment with novel ICT.
- *Defender*: Carefully evaluates ICT investment for its efficient orientation, and applies ICT primary to reduce costs of investments and to increase communication processes rather than to open new markets. Defender is control orientated and slow to innovate.
- *Analyzer*: Operates in two types of market domain - one relatively stable and focused on efficiency, and the other where ICT plays an increasing important role. Analyzer applies different rates of technological uptake in each.
- *Heatseeker*: Sized upon ICT fashioned instead of strategically analyzing the best ICT fit for its business problems. Heatseeker is typical for an organization whose structure is in constant flux, moving to frequent new initiatives before obtaining sustained business performance.
- *Reactor*: Reactor is a characteristic for an organization where technology is not seen as a strategic tool. It responds slowly to change, and tends to view ICT applications as standalone tools.

The ICT strategies we treated as three moderate variables in our research model, since they are influenced by previously considered constructs on one side, and also they have impact on ICT intelligent exploitation on another one:

H6.a. ICT prospector, defender and analyzer strategies help intelligent use of ICT.
H6.b. ICT heatseaker supports in lower extent intelligent use of ICT.
H6.c. ICT reactor impedes intelligent use of ICT.

Since our respondents are from different environments we supposed that H6.a hypothesis works well, depending on the particular organization and the conditions in which it operates. Heatseakers, we see as those who rarely can provide so called "3S" (smart, safety and sustainable) solutions [31], while reactors might have mostly negative impacts of intelligent use of ICT in highly turbulent technological conditions.

In accordance to the above stated, as a kind of control variable in our research methodology we use a gap between technology-led potential and everyday reality [32]. On this idea we set the seventh-control hypothesis:

H7. A gap between ICT capacities and degree of their exploitation inhibit intelligent use of ICT.

Dependent variable in our model expressed in which extent examined organizations are savvy ICT exploiters. We assess it through several indirect questions and it should be covered by the eighth hypothesis in the following manner:

H8. Developed and harmonized communication between tasks, technologies and employees strengthens intelligent use of ICT.

Figure 2 shows the research framework. On the basis of realized survey we analyzed correlations between independent variables: knowledge, IT management resources, communications, organization culture and manager's mindset; moderate variables: ICT-prospector, -defender, -analyzer, -heatseeker, and -reactor; control variable: a gap between ICT capacities and exploitation; and, dependent variable: intelligent use of ICT. Through this methodological framework, we have tested our hypothesis and open a space for further discussion(s).

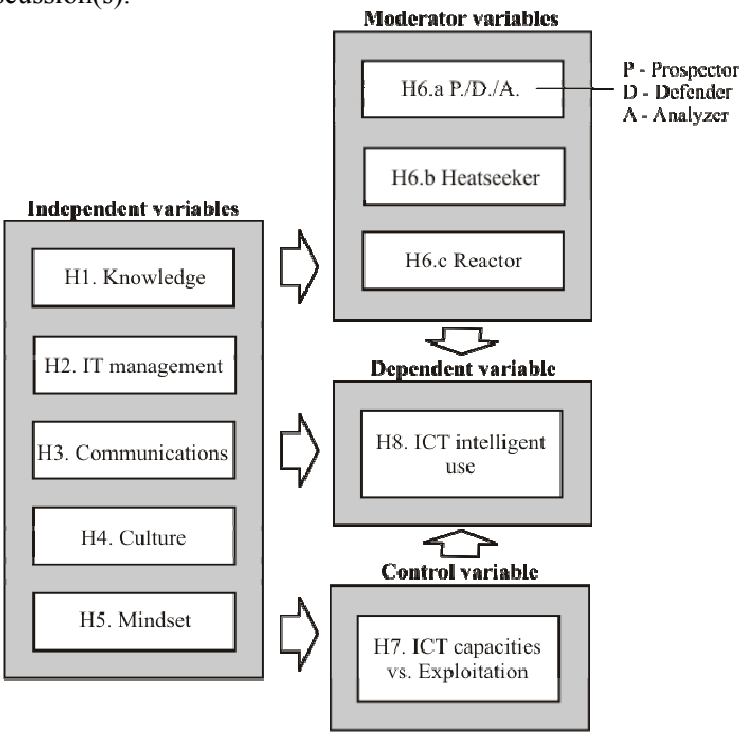

Fig. 2. Research framework

3. Research results and discussion

For this research, we have conceived questionnaires in accordance to the previously presented theoretical Intelligent ICT Exploiter model and proposed hypothesis. In total 20 highly qualified persons from top management teams at several maritime business institutions in Montenegro (5), Albania (2), Croatia (3), Slovenia (1), and Italy (1) are interviewed. They all have sound experiences in different maritime business sectors, high qualifications and also high level of logical thinking. Before we sent them questionnaires, we had asked several qualified persons from academia to do semantic reviews and give us suggestions how to improve them, i.e., how to avoid redundancies and overtax of respondents' patience. The respondents have to answer 25 questions in total. The constructs from our framework were measured with 1-5 point Likert-type multi-item scales. In addition, some questions require descriptive answers, e.g., those which concern methods of communications within the organization with the customers, and those that can help developing business strategies due to the actual flows at the maritime business market. The descriptions given by the respondents helped us also to identify which ICT strategy prefers each organization. The analysis of the obtained quantitative results are performed in SPSS (ver. 16) [33] by an Inter(R) Core™ i5 processor on 2.4 GHz (4GB RAM). Table 1 presents the descriptive statistics for the main analyzed constructs.

Table 1. Means, standard deviations (SD) and correlations

	Overall sample		Correlations in the overall sample (N=20)									
	Mean	SD	H1	H2	H3	H4	H5	H6.a	H6.b	H6.c	H7	H8
H1	4.5335	0.41074	1									
H2	4.1000	0.80459	-0.008	1								
H3	4.0500	0.56471	0.210	0.567**	1							
H4	4.3000	0.56471	-0.402	0.301	0.129	1						
H5	4.2995	0.57124	-0.284	0.287	0.021	0.793**	1					
H6.a	3.7000	0.44508	0.153	0.306	0.279	-0.022	-0.069	1				
H6.b	3.1000	0.46904	-0.036	0.202	0.450*	-0.076	-0.242	0.355	1			
H6.c	1.4000	0.78807	0.338	-0.283	-0.262	-0.041	-0.018	-0.412	-0.554*	1		
H7	2.2000	0.50262	-0.120	-0.377	-0.515*	0.0200	0.260	-0.182	-0.423	0.554*	1	
H8	3.9500	1.00525	0.072	0.474*	0.463*	-0.199	-0.187	0.562**	0.649**	-0.763**	-7.90**	1

(**p<0.01; *p<0.05)

According to the statistical results presented in Table 1, it is clear that there is strong positive correlation (we have used nonparametric Spearman's rho, since the overall sample is small) between the dependant variable H8 (communication between tasks, technology and employees) and the moderate variable H6.a (ICT strategy: prospector, defender, or analyzer). Also there is medium correlation between H8 (communication between tasks, technology and employees), and variables H2 (roles and skills) and H3 (effective system). On the contrary, the intelligent use of available ICT is in strong negative correlation with control variable H7 (a gap between ICT capacities and use), i.e., the gap in capacities of ICT and their exploitation. In analyzing the responds, we have realized that respondents highly assessed the importance of knowledge for organizational success, as well as organizational culture and advanced managerial mindsets. However, their estimates obviously do not correspond well with real level of intelligent exploitation of existing ICT solutions. It means that in all examined organizations more attention and efforts should be done on improving corporate knowledge, organizational culture and climate, and on refining managerial skills and mindsets. Even though dependent variable is in positive correlation with H2 (roles and skills) and H3 (effective system), descriptive re-

sults indicate that IT resource management, and internal and external communications should be improved due to the moderate correlation values. The statistics additionally show that there is a strong positive correlation between H4 (organizational culture) and H5 (managers' mindset). The similar is with H3 (internal and external communications) and H2 (roles and skills, or good functioning of IT management).

In order to refine these primary statistical analyses, we have performed factor analysis and identified variables: H2 (roles and skills), H3 (effective system), H6.a, H6.b (ICT strategies), and H8 (communication between tasks, technology and employees), as those with high factor loading values (λ_j). For these selected group of variables Cronbach's alpha is 0.79, which is acceptable, while average variance extracted (AVE) is 0.543, i.e., it is over threshold (AVE>0.5), and composite reliability (CR) is 0.891, and it is also above acceptable limit (CR>0.7) [34, 35]. Values of AVE and CR are calculated by standardized formulas (1) and (2):

$$AVE = \frac{\sum \lambda_j^{\,2}}{n} \tag{1}$$

$$CR = \frac{(\lambda_j)^2}{\left(\sum \lambda_j\right)^2 + \varepsilon_j} \tag{2}$$

Where,

n - is number of selected constructs ($j = \overline{1,5}$; n=5),

λ - is factor loading, and

ε - is the error variance ($\varepsilon = 1 - \lambda$).

As a result of linear regression analysis we obtained relations between dependent variable H8, and independent ones H6.a, H6.b and H6.c. The results are present in Table 2. The ANOVA tests in SPSS show that the linear models are significant (Significance, or p-value is in all considered cases lower than 0.05 threshold). All slopes β are positive ($\forall \beta_i \geq 0, i = \overline{1,3}$). Negative correlation between H8 and H6.c is in accordance with negative coefficient α_3 that corresponds to the independent variable H6.c, i.e., ICT reactor strategy, which is considerably less popular in comparison to other analyzed ICT strategies.

Table 2. The linear regression analysis results

Independent moderator variables	$\alpha_i \left(i = \overline{1,3}\right)$	$\beta_i \left(i = \overline{1,3}\right)$	Significance	$r_i \left(i = \overline{1,3}\right)$
*H6.a	0.748	1.206	0.008 (<0.05)	0.575
*H6.b	0.475	2.479	0.004 (<0.05)	0.618
*H6.c	- 0.854	5.146	0.000 (<0.05)	0.710

*Dependant variable: H8 (communication between tasks, technology and employees)

In other words, data given in Table 2 can be used in establishing linear regressions between dependant variable H8 and independent ones Hb.a, H6.b, and H6.c. All linear relations have statistical significance (Table 2), while correlation coefficients are also high ($\forall r_i \geq 0.5, i = \overline{1,3}$). Dependant variable, i.e., the degree of intelligent use of ICT is in positive correlations with ICT prospector, defender, analyzer and heatseeker strategies, and in negative one with ICT reactor strategy. Of course, the choice of certain ICT strategy, which belongs to H6.a and H6.b sets, will depend on the individual preferences and needs of the business enteritis.

It is important to mention that we did not ask respondents directly in which extent ICT solutions are intelligently used in their organizations. On the contrary, we asked them about this indirectly through the questions: (Q21) To what extent is developed communication between tasks, technologies and employees in your organization?; and, (Q22) To what extent do ICT serve as a connective tissue in your organization? We consider these as a more reliable way to get information about that how intelligently they use their ICT resources. Also, we ask the respondents about ICT strategies they prefer through the series of questions, which imply both quantitative and qualitative answers. Some of these questions are listed below:

- (Q12) In which extent it is important to carefully analyze the existing ICT solutions prior to their introduction into the organization? + Description. (→Prospector, Defender);
- (Q13) To what extent is the introduction of new ICT solutions risky for the organization? + Description. (→Prospector, Defender, Reactor);
- (Q14) To what extent do ICT solutions reduce operating costs of the organization? + Description. (→Prospector, Defender, Reactor);
- (Q15) To which extent do ICT accelerate business communications and processes? + Description. (→Prospector, Defender, Analyzer, Reactor);
- (Q16) To what extent could ICT affect the strategic development of the organization? + Description. (→Prospector, Defender, Analyzer, Reactor);
- (Q17) To what extent can the existing ICT solutions be adapted to the current business needs of your organization? + Description. (→Prospector, Defender, Reactor, Analyzer);
- (Q18) Are the latest ICT solutions also the best ones? (→Heatseeker);
- (Q19) To what extent is the way of doing business in your organization stabile? + Description. (→Analyzer), etc.

According to the given quantitative and qualitative answers, we have concluded that most of the respondents are prospectors, and also heatseekers, while almost none of them are ICT reactors. A bit surprising is that most of the respondents highly estimated the latest ICT solutions in terms that they are at the same time the best ones. This leaves space for further discussion. It is also important and promising that all of the respondents treat ICT as an important factor for providing business success. Albeit, the level in which the tested maritime organizations intelligently use their present ICT resources has a mean value of 3.95. This assessment indicates the need for further reducing the gap between technology potentials and its real use, as well as, the necessity of extended managerial skills.

The greatest maturity in the mindset and explored constructs can be noticed on Italian side. The interviewed respondents from Albania come from the maritime company which works in cooperation with an Austrian partner. This cooperation surely supports more mature managerial mindset in the context of ICT "3S" (smart, safety and sustainable) use. Montenegro is since decades in transitional flux without clear strategic orientation and it permanently suffers the lack of funds for providing maritime ICT systems compatible with EU ones. It seems that the problem in this case is beyond the knowledge and efforts of managers. It could be overcome only through closer and more fruitful collaboration between maritime organizations, stakeholders and the governmental bodies, which are in charge of maritime sector.

4. Conclusions

The paper points out the digital turbulence in maritime community caused particularly by new concepts such as: e-Navigation, Maritime Cloud, e-Marine, National/Maritime Single Window, etc. This requires well-prepared maritime business and industry actors in terms of the efficient use of existing ICT solutions and their readiness to adopt new ones. In this regard we did a pilot study among several maritime organizations in Montenegro, Albania, Croatia, Slovenia and Italy (South-Europe) with the aim to evaluate how intelligently they exploit present ICT business solutions. They all highly appreciate key analyzed constructs within the methodological framework: knowledge, IT management resources, communications, organization culture, and manager's mindset. Also, they are all prospectors or heatseekers in terms of ICT strategy, but still the level of intelligent use of the available ICT solutions is not at the optimal stratum. The gap between ICT potentials and their real exploitation is still relatively high. The most promising results are gained on the Italian side, and it is not surprising, since Italy is for a long time EU member state and enjoys certain benefits in comparison to Slovenia which is considerably smaller and less developed member state, Croatia which recently joined EU (in 2013), and particularly in comparison to Montenegro and Albania which are non-EU member states. By analyzing the respondents' descriptive replies, the differences in maturity of using ICT solutions become obvious. Montenegro and Albania should use Italian, Slovenian and Croatian experiences, since they share the same Adriatic Sea market, as models in terms of transfer and progressive diffusion of good practices in the domain of ICT effective exploitation and further development. It would be desirable that these countries cooperate while adapting common ICT solutions that would be compatible with current ICT trends in wider maritime community. This should provide them greater competitiveness at the growing, EU and global maritime market. Montenegro and Albania which lag behind Italy, Slovenia and Croatia in this context, should establish closer collaboration with stakeholders and responsible governmental bodies. It can help them to overcome existing gap between ICT potentials and their actual use in everyday reality. Further research experiments in the field should include more respondents from larger number of maritime institutions and also in-depth interviews instead of, or besides the polls. New ICT concepts like e-Navigation, Maritime Cloud, e-Maritime, National/Maritime Single Window, etc., should be explicitly included in the interviews by taking into account the respondents' attitudes towards (each of) them.

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5.2. Deploying *Intelligent ICT Exploiter* model in maritime business sector

This research study examines to what extent some maritime business organizations use intelligently available Information and Communication Technology (ICT) solutions, and in which manners the existing gap between ICT potentials and their real use on daily basis can be mitigated. As a focus group are identified ten maritime business entities from Albania, Croatia, Italy, Montenegro and Slovenia, which share the common Adriatic Sea market. Selected representatives of these maritime organizations have advisedly given responds to the questionnaire, and in such way supported identifying some core problems in the afore mentioned regard, along with deriving some recommendations towards their overcoming in the future. Better internal and external business communications are recognized as key enablers of more effective and efficient exploitation of the existing ICT solutions. Also, better knowledge, skills and organizational culture among management teams and employees are pointed out as main facilitators of more rational and fortunate usage of the ICT systems and tools.

1. Introduction

The term "maritime" ultimately deals with the world's ocean. The world's ocean belongs to everyone and it is an essential life support system. Among other things it: absorbs carbon dioxin from the atmosphere; generates up to half of the world's supply of oxygen; provides essential protein for nearly three billion of people; regulates global climate; provides many resources used by humans (Barth and Cowen, 2016; CIT, 2012). Besides, it enables performing more than 90% by volume and 60% by value of the world trade, since sea transportation is still the most-effective way of transporting row materials and goods around the globe (IMO, 2017). On the other side, marine habitats, near shore ecosystems and coastal communities, face huge pressures that threaten their sustainability, as: climate change; ocean acidification; rising sea levels; variable fish stocks; natural and human-caused disasters, and much more. Albeit the fact, that the world's ocean is playing so many significant roles, the digitalization in the maritime environment legs considerably behind the digitalization in other environments. Additionally, there is a gap between available ICT maritime solutions and their real usage. Certain efforts at world scale are made in the direction of more intensive onboard and ashore digitalization. However, there are a lot of impediments on this road caused by the differences among the countries, due to the level of their economic development, more or less complex political, legal, and administrative barriers, etc. Moreover, maritime community is generally more traditional oriented than other business and industry communities.

2. On maritime digitalization

The Electronic Chart Display and Information System (ECDIS) revolutionary changed traditional way of navigation during the last decade of the 1990s, and there is tendency for its full implementation at the global level. The main related problems are numerous non-Safety of Life at Sea (SOLAS) Convention ships. Furthermore, the concept of e-Navigation is to be mentioned as a steep forward in comparison to ECDIS navigation support system. International Maritime Organization (IMO) defines e-Navigation as: "a harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment" (Baldauf and Hong, 2016; Benton et al., 2016; Hahn et al. 2016). Consequently, the Maritime Cloud is developing for the purpose of enabling e-Navigation wider implementation, and it is conceived in such manner to support all related communications by

means of old communication channels, like: Navigation Telex (NavTex), Maritime Safety Information (MSI), Automatic Identification System (AIS), Satellite-Automatic Identification System (S-AIS), etc., and new ones, like: VHF (Very High Frequency) Data Exchange (VDES), Navigation Data (NavDat), Narrow-Band Digital Printing (NBDP), and more (Bauk, 2017).

Besides marine navigation, sea ports as enablers of berth-to-berth navigation and key nodes of sea-land transportation, along with other maritime ashore based entities, use different ICT solutions, like: Electronic Data Interchange (EDI), Port Community System (PCS), Enterprise Resource Planning (ERP), Customer Relationship Management (CRM) system, access to Electronic Logistics Marketplace (ELM), Vessel Traffic Service (VTS), Vessel Traffic Management Information System (VTMIS), etc. Furthermore, the developing concepts as e-Maritime (Morrall et al., 2016), National / Maritime Single Window (N/MSW), or Single Window / Environment (SW/E) are presently in the focus of both maritime research and business communities (Niculescu and Minea, 2016; Rodseth and Kapidani, 2017).

Afore stated speaks in favor of a huge digital turbulence in maritime community, especially for developing business entities, and those which function in transitional environments, i.e., in constant flux, with rather rigid administration structures and without clear development strategies. Within this context, we considered important to do an examination in terms how intelligently some maritime business entities in South-Europe, i.e., in Albania, Croatia, Italy, Montenegro and Slovenia exploit currently available ICT resources, since obviously their rapid development and expansion are on the way. The research is realized with a goal to identify weak points and to propose directions for their seamless overcoming in the nearest future.

3. Research background in brief

Within some of our previous research works in the domain of intelligent exploitation of contemporary ICT solutions, we were dealing with the problems of conceiving tailored-made ICT models for developing environments, which function in transitional economies (Bauk, 2017). In these attempts, we were faced with the lack of literature resources (Hoskisson et al., 2000; Lau, 2011; Roztocki and Weistroffer, 2015). Nevertheless, while considering intelligent adoption, implementation and reutilization of the appropriate ICT models in above mentioned transitional and/or developing conditions, we have considered several theoretical frameworks, as: Diffusion of Innovation - DoI (Rogers, 2003), Technology Acceptance Model - TAM (Davis, 1989), Theory of Reasoned Action – TRA (Fishbein, 1975), Theory of Planned Behavior – TPB (Ajzen, 1991), etc. For the purpose of this pilot research study we have used the intelligent ICT Exploiter model (Holtham and Corney, 2010; Holtham et al., 2006; Holtham at al., 2004; Stace at al., 2001). It comprises five core elements: business system effectiveness, information and knowledge, specific roles and skills, ICT strategy, and managerial mindset, which integrates the first four components. The scheme of this model is given in Figure 1.

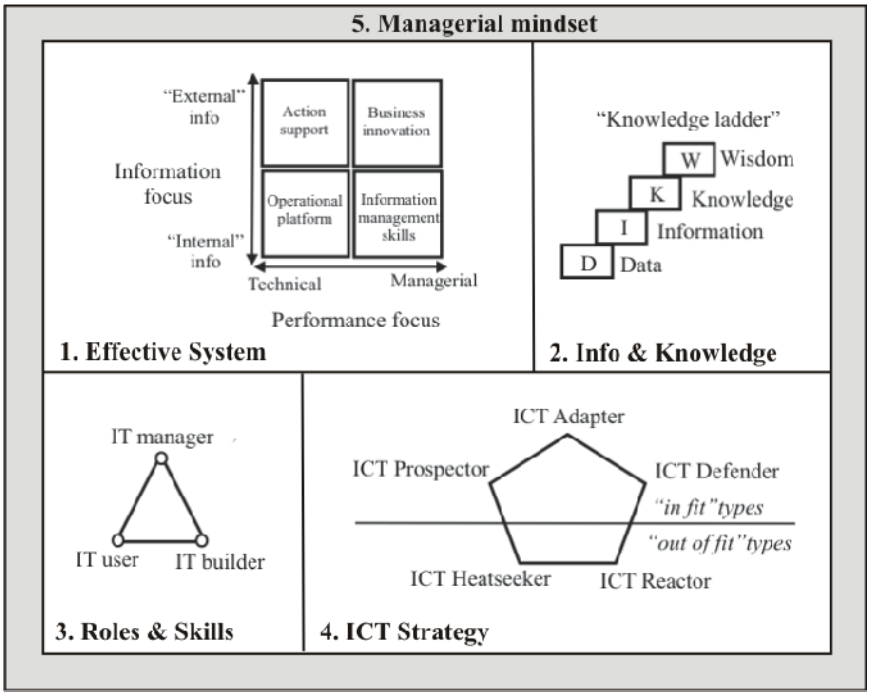

Figure 1. A scheme of Intelligent ICT Exploiter model
[adapted from: (Holtham and Corney, 2010)]

This model is based on several premises, which are listed below:

- Knowledge is of key importance for the intelligent use of ICT;
- Besides Information Technology (IT) users and IT builders, IT managers are very important and they enable more intelligent use of ICT;
- An effective business system has to manage and exploit both internal and external information;
- Positive organizational culture enhances intelligent use of ICT;
- The top management team's, or managerial mindset is of crucial importance for intelligent use of ICT;
- The appropriate ICT strategy is of core importance for effective use of ICT;
- A gap between ICT capacities and the level of their real exploitation inhibits intelligent use of ICT;
- Developed and harmonized communication between tasks, technologies and employees strengthens intelligent exploitation of ICT, etc.

4. Methodology

For the purpose of this study, which is a kind of supplement to the previous research works published in the field of intensifying *smart* marine digitalization (Bauk, 2017), we were conceived a questionnaire, which should support the following hypothesis:

H1. Developed communication between tasks, technologies, and employees within a maritime organization can be achieved if there are managers' positive attitudes towards knowledge, meetings, and importance of ICT for business success.

H2. Intelligent use of ICT implies successful internal and external maritime business communications.

H3. A gap in intelligent use of ICT in maritime business organizations is caused by the lack of the appropriate knowledge, skills, and organizational culture.

In order to test above given hypotheses, ten highly qualified persons, with high logical thinking capabilities, from top management teams at several maritime organizations in Albania (2), Croatia (2), Italy (1), Montenegro (4) and Slovenia (1) were interviewed. Before we sent them questionnaires, we had asked few highly qualified persons from academia to do the semantic review and give us suggestions how to improve the questionnaire, and how to avoid redundancies and overtax of respondents' cognitive load. The respondents have to answer twenty-five questions in total. The constructs from our framework were measured with 1-5 Likert's scale (Kenzey, 2017). In addition, some questions require descriptive answers in order to give us better insight into the respondents' mindsets due to the examined issue. The list of selected maritime organizations and respondents is given in Table 1. The order of respondents in the following section, which contains simulation results, is randomly chosen and it does not correspond to the order given in the table below.

Table 1. Respondents from the analyzed maritime business organizations

No.	Country	Organization	Respondent
1.	Albania	Sigal UNIQA GROUP Austria	Sokol Kapidani
2.	Albania	TCN sh.p.k.	Petri Deti
3.	Croatia	Hrvatska udruga brodara – Mare Nostrum	Sandro Vidas
4.	Croatia	IN2 d.o.o.	Bojan Colnago
5.	Italy	Italian Coast Guard	Piero Pellizzari
6.	Montenegro	Jadroagent Bar	Dragana Radović
7.	Montenegro	Crnogorska plovidba a.d. Kotor	Branislav Kordić
8.	Montenegro	Maritime Safety Department	Nexhat Kapidani
9.	Montenegro	Maritime Safety Department	Žarko Lukšić
10.	Slovenia	Actual IT	Petelin Boštejan

5. The results of the linear regression models

In the previous section set hypothesis are tested in this section by the linear regression models in MS Excel, by means of specially imbedded ExcelModules function for this purpose. The analysis of the obtained quantitative results through the poll are performed by an Intel(R) Core^{TM} i5 processor at 2.4 GHz (4GB RAM). Below are described proposed linear regression models, along with the corresponding numerical and graphical results.

Testing H1: Here, we have tested linear regression model established between the dependent variable (dv) and the independent variables (iv_1, iv_2, and iv_3) as follows:
dv: To what extent ICT serve as a "connective" tissue in your organization?

iv_1: In which extent do you use ICT for operational tasks within your organization (e.g., accounting operations; database of employees; database of business partners, etc.)?

iv_2: In which extent can the customers use ICT resources of your organization (e.g., your organizational web site; various on-line users' applications, etc.)?
iv_3: In which extent does ICT allow you to become familiar with the current market trends in the area of your business?

The obtained results are given in Table 2, while the comparison of the real numerical data acquired by the questionnaire (through the Likert's scale) and those obtained by the proposed multiple regression model is presented in Figure 2.

Table 2. Efficient and effective use of ICT caused by flawless internal and external communications

Respondent	***dv***	***iv_1***	***iv_2***	***iv_3***	Forecast	Error	Absolute error	Squared error	Absolute % error
R_1	3.00	3.00	2.00	4.00	3.058	-0.058	0.058	0.003	1.93%
R_2	5.00	5.00	5.00	5.00	4.720	0.280	0.280	0.078	5.60%
R_3	5.00	5.00	4.00	4.00	4.596	0.404	0.404	0.164	8.09%
R_4	5.00	5.00	5.00	3.00	4.898	0.102	0.102	0.010	2.04%
R_5	4.00	5.00	4.00	4.00	4.596	-0.596	0.596	0.355	14.89%
R_6	4.00	3.00	4.00	3.00	3.573	0.427	0.427	0.182	10.67%
R_7	4.00	5.00	5.00	4.00	4.809	-0.809	0.809	0.654	20.22%
R_8	5.00	5.00	5.00	5.00	4.720	0.280	0.280	0.078	5.60%
R_9	3.00	4.00	3.00	5.00	3.738	-0.738	0.738	0.544	24.59%
R_10	5.00	5.00	3.00	5.00	4.293	0.707	0.707	0.499	14.13%
Intercept:	1.320					Average:	MAD	MSE	MAPE
Slopes:		0.556	0.213	-0.089			0.440	0.257	10.78%
	Regression coefficients					multiple-r	0.761	r-squared	0.579

*MAD – Mead Absolute Deviation; MSE – Mean Squared Error; MAPE – Mean Absolute Percent Error (Balakrishan, 2007)

Although there is no specific rule to decide when two variables can be deemed to be highly correlated, in general, correlation coefficient magnitudes of 0.6 and greater, indicate strong relationship. In this example, correlation coefficient, i.e., multiple-r is 0.76, which indicates high correlation among considered variables. Besides, 58% of the variability in the ICT serving as a "connective" tissue in a maritime organization is explained by this multiple linear regression model. So, a good connectivity provided by the appropriate use of ICT implies suitable internal and external communications. Also, it can lead the organization towards better and more meaningful market analysis, i.e., towards achieving business intelligence benefits. If we realize additional Anova test in SPSS Statistics (ver. 17.0) program (Coakes, 2013; Pallet, 2011), it becomes obvious that this model works as we have previously interpreted for our pilot study, but it does not have, unfortunately, statistical significance. Namely, there is a considerable difference between r square (0.579) and adjuster r square (0.135), and statistical significance is 0.135 that is greater than boundary value 0.05.

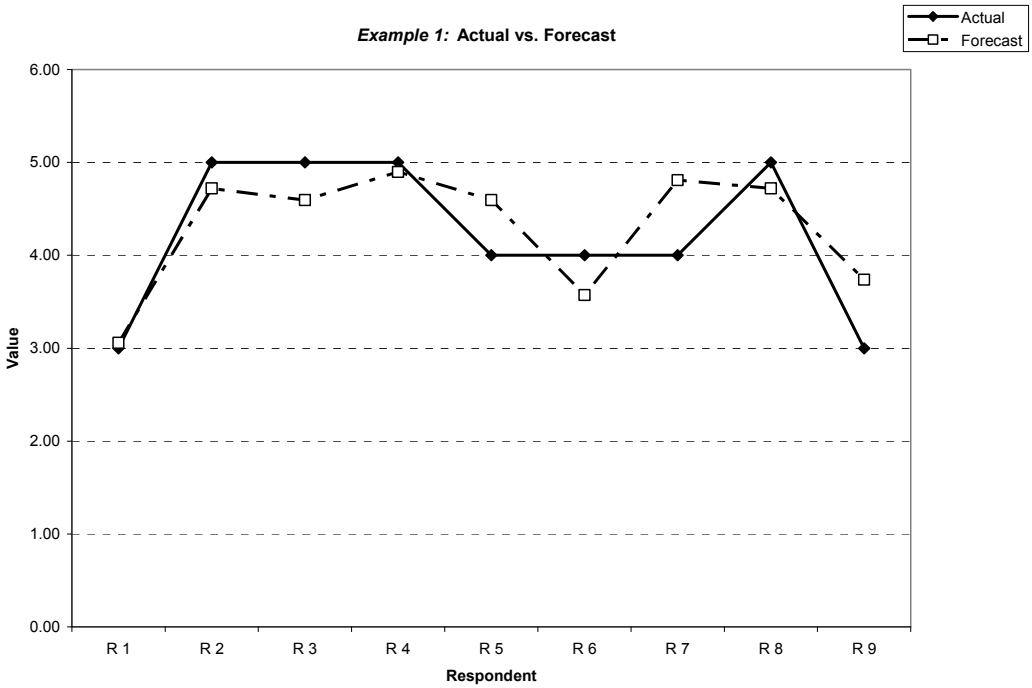

Figure 2. Intelligent use of ICT in the context of successful internal and external business communications: actual values vs. modeled ones

Testing H2: Here, we have tested linear regression model established between the dependent variable (dv) and the independent variables (iv_1, iv_2, and iv_3) as follows:

dv: To what extent is developed communication between tasks, technologies and employees in your organization?

iv_1: How much knowledge is important for successful business?
iv_2: How much meetings are important for your organization?
iv_3: How much are ICT important for the successful functioning of the organization and for its business success?

The obtained results are presented in Table 3, while the comparison of the real numerical data acquired through the questionnaire (i.e., through the Likert's scale) and those obtained by the linear regression model are presented in Figure 3.

Table 3. Relation between realizing "C" within ICT and respondents' perceptions of importance of knowledge, meetings and ICT for business success

Respondent	***dv***	***iv_1***	***iv_2***	***iv_3***	Forecast	Error	Absolute error	Squared error	Absolute % error
R_1	4.00	5.00	4.00	5.00	3.769	0.231	0.231	0.053	5.77%
R_2	5.00	5.00	5.00	5.00	4.346	0.654	0.654	0.428	13.08%
R_3	3.00	4.00	3.00	5.00	2.731	0.269	0.269	0.072	8.97%
R_4	5.00	5.00	5.00	5.00	4.346	0.654	0.654	0.428	13.08%
R_5	4.00	5.00	4.00	4.00	3.731	0.269	0.269	0.072	6.73%
R_6	3.00	5.00	5.00	5.00	4.346	-1.346	1.346	1.812	44.87%

R_7	4.00	5.00	5.00	5.00	4.346	-0.346	0.346	0.120	8.65%
R_8	5.00	5.00	5.00	5.00	4.346	0.654	0.654	0.428	13.08%
R_9	3.00	5.00	4.00	5.00	3.769	-0.769	0.769	0.592	25.64%
R_10	3.00	4.00	4.00	4.00	3.269	-0.269	0.269	0.072	8.97%
Inter-cept:	-1.038					Average:	MAD	MSE	MAPE
Slopes:		0.462	0.577	0.038			0.546	0.408	14.88%
	Regression coefficients					multiple-r	0.640	r-squared	0.409

*MAD – Mead Absolute Deviation; MSE – Mean Squared Error; MAPE – Mean Absolute Percent Error (Balakrishan, 2007)

According to the results given in Table 3, it is obvious that there is a strong correlation between dependent and independent variables in this case, and it is 0.640. Here chosen independent variables described the dependent one in the percentage of about 40%. It means that positive attitudes of the respondents towards knowledge, meetings and ICT importance for business success are not enough to describe using full potential of "C"in ICT (communication among tasks, technologies, and employees). Also, one can conclude that there are some additional factors that might be included into the model, as well. For instance, it might be organizational culture, ICT strategy, narrow specialized knowledge of IT builders, managers, and users, etc. However, this might be the subject area of further investigations in the field. If we want to go a steep further, and test the statistical significance of our model by SPSS Statistics (ver. 17.0) Anova test, then we can obtain that there is again a quite large difference between r square (0.409) and adjusted r square (0.114), while statistical significance is 0.335, which higher than 0.05. This means that the model works as we have above described for the purpose of our case study, but it is unfortunately useless in terms of statistics. To achieve the statistical significance, the second hypothesis should be modified and/or more respondents should be involved into the poll.

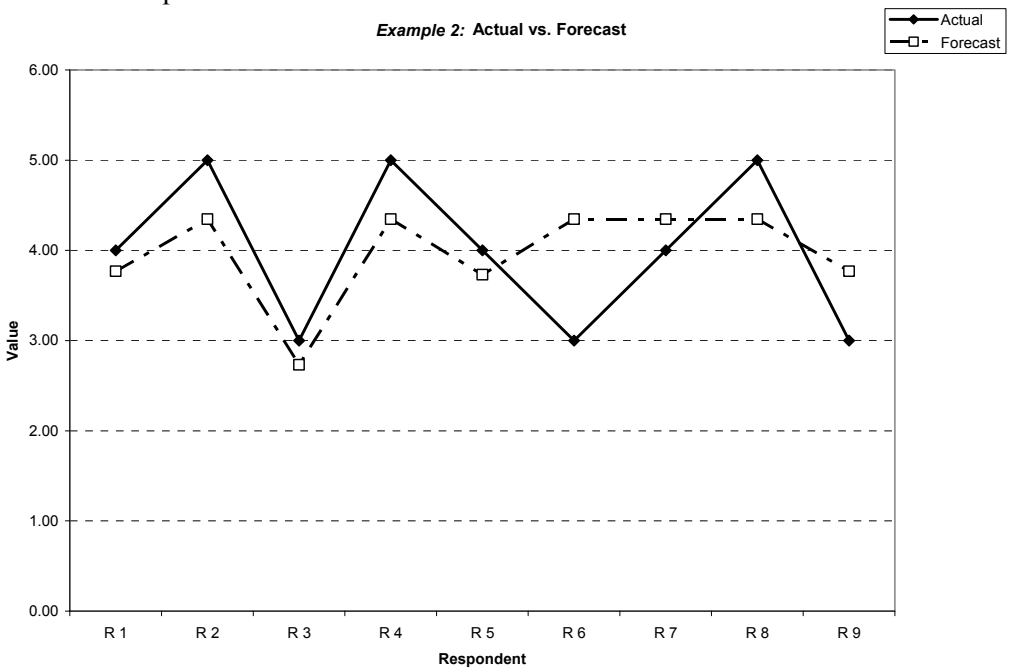

Figure 3. Relation between realizing "C" within ICT and respondents' perceptions of importance of knowledge, meetings and ICT for business success: actual vales vs. modeled ones

Testing H3: Here, we examined the relationship between a gap in intelligent use of ICT within maritime business organizations and the respondents' awareness of the importance of managers' and employees' knowledge and skills, and presence of organizational culture.

dv: To what extent there is a divergence between the ICT capacities and their real application at daily basis in your organization?

iv_1: How managerial skills are important for effective use of ICT?
iv_2: To what extension are the knowledge and skills of employees important for the efficient and effective use of ICT?
iv_3: How much positive organizational culture and climate are important for the effective use of ICT?

The obtained numerical results are given in Table 4, while the visual comparison of the real numerical data acquired through the questionnaires (i.e., through the Likert's scale) and those obtained by the linear multiple regression model are given in Figure 4.

Table 4. A gap between ICT potentials and real usage caused by the lack of knowledge, skills and organizational culture

Respondent	***dv***	***iv_1***	***iv_2***	***iv_3***	Forecast	Error	Absolute error	Squared error	Absolute % error
R_1	3.00	4.00	4.00	3.00	2.739	0.261	0.261	0.068	8.70%
R_2	1.00	4.00	5.00	4.00	2.261	-1.261	1.261	1.590	126.09%
R_3	3.00	5.00	4.00	5.00	3.522	-0.522	0.522	0.272	17.39%
R_4	3.00	4.00	5.00	4.00	2.261	0.739	0.739	0.546	24.64%
R_5	2.00	4.00	4.00	4.00	2.565	-0.565	0.565	0.319	28.26%
R_6	2.00	4.00	4.00	4.00	2.565	-0.565	0.565	0.319	28.26%
R_7	2.00	3.00	3.00	4.00	1.739	0.261	0.261	0.068	13.04%
R_8	3.00	4.00	4.00	4.00	2.565	0.435	0.435	0.189	14.49%
R_9	4.00	5.00	5.00	5.00	3.217	0.783	0.783	0.612	19.57%
R_10	3.00	4.00	4.00	4.00	2.565	0.435	0.435	0.189	14.49%
Intercept:	-0.043					Average:	MAD	MSE	MAPE
Slopes:		1.130	0.304	0.174			0.583	0.417	29.49%
	Regression coefficients					multiple-r	0.590	r-squared	0.348

*MAD – Mead Absolute Deviation; MSE – Mean Squared Error; MAPE – Mean Absolute Percent Error (Balakrishan, 2007)

The obtained statistical results indicates that even there is a near to the strong relationship among the variables (multiple-r is 0.590), only 35% of the variability in the gap between ICT potentials and their objective use at daily basis is explained by the model. It means, that awareness of the respondents about the importance of managerial skills, employees competences and organizational culture is not enough strong to neutralize the existing gap. Real managers' and employees' skills and knowledge, along with the organizational culture implemented on the spot, are much more important, and they are the key prerogatives to reduce or neutralize currently obviously present discordance between the

ICT capacities and their efficient and effective use in the analyzed maritime business organizations. However, it is not easy to measure them exactly. Like in previous cases, there is a big difference between r square and adjuster r square, and statistical significance of the model is not at the satisfying level. This invokes the need for a larger poll, or modifications of the third hypothesis in our model.

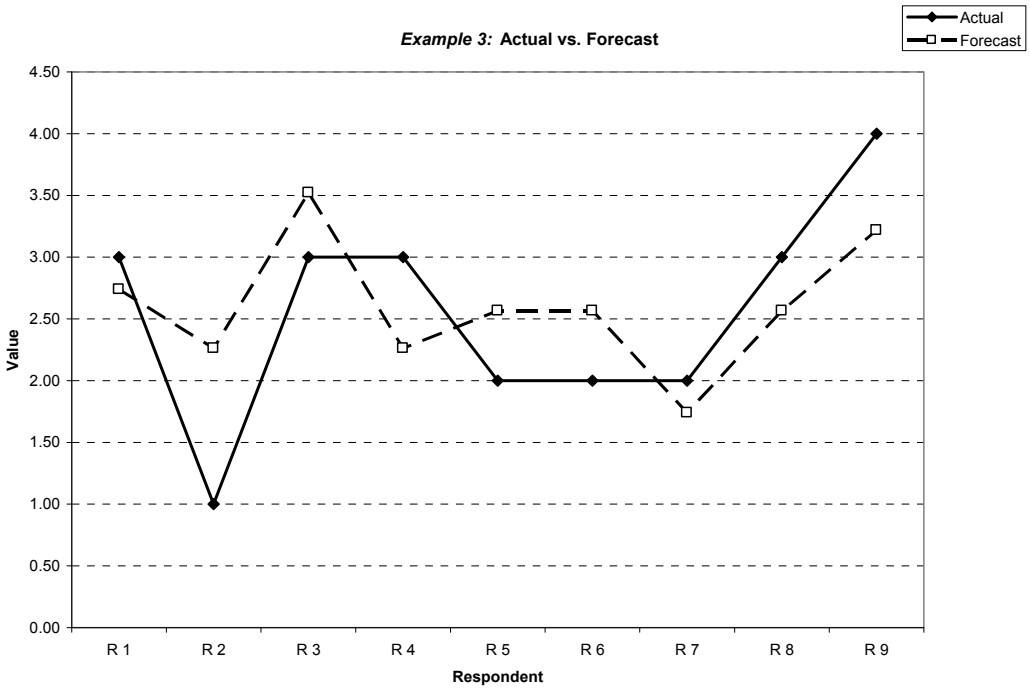

Figure 4. A gap in intelligent use of ICT caused by the lack of knowledge, skills and organizational culture: actual values vs. modeled ones

6. Conclusions

The paper considers digital turbulence in maritime sector, along with the digital divide among different industries and among developed and developing countries. In the focus are put maritime organizations, which share the Adriatic Sea market: two from Albania, two from Croatia, one from Italy, four from Montenegro and one from Slovenia. Most of them function in developing environment and they are in constant flux. On the other side, like mostly stabile might be treated those from Italy and Slovenia, since they function for a quite long period within joint European Union market and enjoy some of the corresponding benefits. Croatia has recently joined EU. Montenegro and Albania therefore leg behind Italy, Slovenia and Croatia, and they should establish closer and more efficient collaboration with responsible ministries and stakeholders in order to get better positions at growing and developing maritime market.

According to the quantitative analysis of the respondents' answers, the following can be concluded:

– All respondents are highly aware of the importance of knowledge, skills and organizational culture, but there is still considerable gap between existing ICT systems potentials and their real use in everyday business activities.

- Real knowledge and skills of managers and other employees, including organizational culture, are not generally at the satisfying level, since in most of the analyzed maritime business organizations, the ICT tools are not used in their full potential.
- In most of the analyzed organizations, internal and external communications are to be improved in order to allow achieving business success through developing and deploying business intelligence principles and analytical tolls.
- On the other side, due to the analysis of the questions which required descriptive answers, we have concluded:
- Most of the respondents are heatseekers or prospectors in terms of ICT strategy. It means that they believe that the latest ICT solutions are at the same time the best ones. Or, in other words, they are mostly willing to experiment with novel ICT.
- Almost all respondents highly appreciate knowledge and skills of both managers and employees.
- They also consider important organizing trainings for employees in terms of getting more knowledge and skills when it comes to more efficient and effective exploitation of available ICT systems/tolls.
- Also, they all consider organizational culture very important for the appropriate use of existing ICT solutions and achieving business success.

Further analysis should include larger sets of both maritime business entities and respondents. Also, some modifications of the proposed hypothesis are to be considered in order to achieve statistical significance in multiple linear regression and other types of cross-correlation analysis among the variables in the model. This is very important in an attempt to ensure intelligent use of the existing ICT solutions, along with the business intelligence benefits for the developing maritime companies in the forthcoming period.

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5.3. Tagging goods and a Cloud perspective in some transitional economies

This research work considers some of the barriers in implementing the RFID (radio frequency identification) technology for identifying, locating, tracking and tracing goods in supply chains, along with a model for adopting cloud services that can mitigate these obstacles in the transitional environment. The analysis is based on the assessments of the implementation impediments, given by the experts in the field of logistics: university professors, assistants and entrepreneurs from three Western Balkans countries (Montenegro, Serbia, and Bosnia and Herzegovina). Since the professionals' assessments are influenced by their experiences from the transitional economies, which are faced with limited abilities to invest in expensive business information systems, the main hypothesis is that moving the logistics into the Cloud may resolve or at least alleviate the considered problems. On the basis of the available secondary literature resources on pros and cons of RFID implementation into supply chains, and the statistical analysis of the consciously completed questionnaires in the survey, the model for adopting Cloud services for providing RFID-enabled goods and related activities in the considered economies is proposed at a logical level. The study also gives some directions for further research work in this domain.

1. Introduction

Radio frequency identification (RFID) is a prevailing technology that uses radio waves to identify, describe, localize, track and trace the products in supply chains. Each product in a supply chain has a tag affixed to it, which contains a unique identifier that can be used to identify a product by all supply chain participants [1]. Considering the great importance of supply chain integration, Huq et al. (2010) emphasize the importance of control over the flows of resources, goods and products [2]. In order to implement and constantly improve the efficiency of the control, it is necessary to receive reliable information in real time. The RFID provides such information as an automatic identification and data capturing system. Zhang et al. (2011) point out that the main aims of installing this system are higher security, reduced costs, improved quality and larger speed of logistics services, better identifying bottlenecks and operational disadvantages, as well as reducing the possibilities of loss or theft of cargo [3]. Yang et al. (2010) emphasize that the continuous tracking and tracing of cargo are of particular importance in the cases of high specific value shipments and increasing the overall efficiency of logistics management [4]. Besides barcode, GPS (Global Positioning System) and GSM (Global System for Mobile Communications), the main technology used for logistics tracking and tracing is the RFID. In supporting the importance of this technology, Musa et al. (2014) emphasize the RFID capabilities of identifying intra- and inter-enterprise location and visibility of resources, along with providing collaboration and integration through the whole supply chain network [5]. The great importance of visibility of goods in transport in terms of their monitoring and transparency in real time, since a decade and a half, was in focus of a number of authors [6,7]. Later on, the importance of complete logistics information integration in the supply chain, which contributes to the efficient cooperation of all participants, has been highlighted [8,9]. Current studies of RFID in supply chains are focused on inventory management, logistics and transport, assembly and manufacturing, asset tracking and object location, environment sensors [10,11], etc. Also, by maturing RFID and cloud computing, using web based software to track and trace RFID-enabled objects around the world became mainstream business tool [12].

Undoubtedly, the deployment of RFID technology is a challenging task in terms of costs, complexity, difficulties pertaining data management and maintenance, etc., especially for small and medium size enterprises, as well as for those which function in the transitional economies (e.g., some Western Balkans countries). Accordingly, the rest of

the paper is organized as follows: Section 2 gives overview of some pros and cons of deploying RFID tagging and advanced back-end info-communication systems; Section 3 presents the outcomes of the survey conducted among the experts in logistics (i.e., among university professors, assistants, and entrepreneurs with university diplomas from Montenegro, Serbia, and Bosnia and Herzegovina) with the aim to stress key difficulties while introducing RFID technology into supply chains in the transitional environment; and, Section 4 proposes a model for adopting cloud services in such conditions in order to overcome or mitigate the existing impediments.

2. Pros and cons of tagging goods in supply chains

The RFID technology has many advantages compared to bar code. It has a much higher capacity for the transmission of information. Also it has the ability of parallel, simultaneous reading multiple tags, and not exclusively in the line of sight. It can save additional information about the location, past events related to the products, information on the destination, quantity in stock, etc. This technology co-works at hybrid-platforms with wireless sensors that can monitor the conditions of perishable foods in transport, e.g., and trigger the actuators that automatically regulate the temperature and humidity inside refrigerators and/or frigo containers. In addition, the RFID provides higher security, accuracy and efficiency; it speeds up the processes and reduces the cost of storage, handling and distribution. It has impact on improving sales at the expense of reducing the number of products disappeared in stocks [13]. Besides Wamba et al. (2013) emphasize the importance of RFID for enabling interaction with other supply chain information systems, intra- and inter-organizational business transactions, creating the potential for business transformation in the supply chain and initiating transactions called „smart processes“ [14]. They also highlighted the positive impact of RFID on reducing administration costs through re-engineering of the supply chain. Furthermore, the RFID is today one of the pillars of the Internet of Things (IoT) paradigm, in addition to the networks of wireless sensors, middleware, cloud computing and IoT software. Also, it can be considered as one of the basic constituent elements of Cloud Internet of Things (CIoT) concept [15,16], which is particularly interesting from the standpoint of further development of supply chain management, 3PL and 4PL services.

On the other side, Li et al. (2006) point out that the usage of RFID is debatable and controversial, due to three main reasons: „(1) technical standards are not final; (2) business benefits or return on investments are unclear; and (3) there is a lack of industry-wide adoption“ [13]. Even it is stated ten years ago, these statements are still actual to a certain extent. Technical standards are improved, but standardization in this domain is not completed, e.g., there are different types of RFID-WSN (wireless sensor network) integration architectures [17], but due to the best of our knowledge, there is no common RFID-WSN platform at the physical and transmission layers. Namely, RFID and WSNs are conceived like different technologies, but they have to co-work along the supply chains (of perishable food, dangerous goods, etc). There are also some barriers due to the lack of understanding the approaches to integrate the RFID technology into the existing IT/IS front- and back-end infrastructure. Another big problem is that RFID creates huge volumes of data (10-100 times the data of a bar code) that are difficult to manage with conventional computers [18]. Knowledge discovery in RFID-enabled goods, or in the sphere of so-called RFID-cuboids, requires

novel big data approaches and it is a new and underexplored field [19]. In addition, there are certain problems related to inventory inaccuracy, so-called bullwhip effects, and the needs for rethinking replenishment policies and techniques, etc. The scheme given in Figure 1 summarizes some RFID pros and cons.

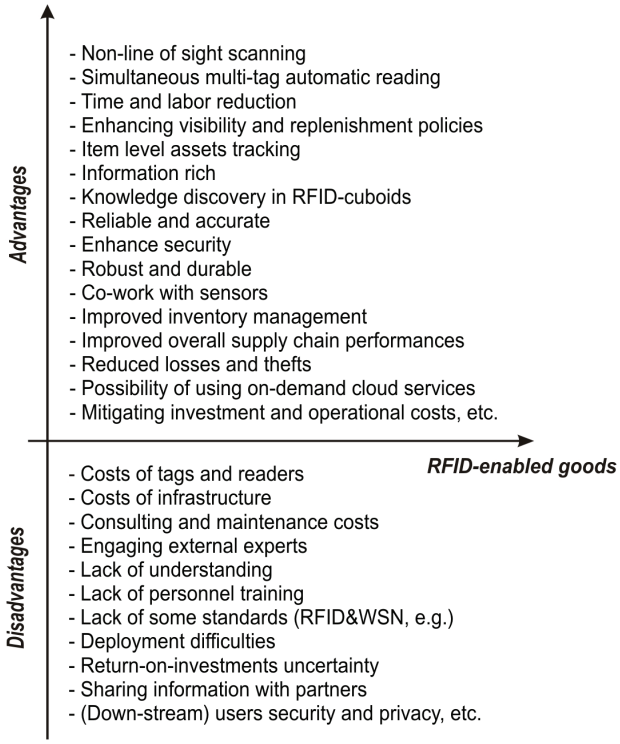

Fig. 1. Some (dis)advantages of implementing RFID into supply chains
Source: adapted from [18]

3. Pilot study of tagging goods in supply chains: challenges in the transitional economies

In addition to the above given short review in the field of (dis)advantages of implementing the RFID in supply chains, throughout the survey, we ranked and analyzed some of the key challenges in adopting this technology in the transitional environment. It should be pointed out that we were faced with discontinuity in publishing review articles on RFID pros and cons in leading journals during the recent years. Namely, the reference [20] is the latest one of this kind, while some other, rather fragmental aspects of monitoring and controlling goods in supply chains are recently considered [21,22]. It seems that with the development of this technology and after its adaptation by the biggest companies, this became a "cold" research field. However, this issue deserves to be put on the agenda again, particularly if we consider transitional economies, with the attempt to overcome or alleviate digital gaps. In this regard, we have realized a survey among experts in the field of logistics (university professors and assistants, as well as entrepreneurs with university degrees), selected from three countries of the Western Balkans (Montenegro, Serbia, and Bosnia and Herzegovina). We were trying to provide a larger number of respondents with appropriate competences and with a high level of logical thinking. Since

we have the most professional and personal contacts in Montenegro, Serbia and Bosnia and Herzegovina that was a pragmatic motive to do our research over this sample. Besides, we have recently realized a similar analysis over considerably smaller sample of respondents [23] from Montenegro, and we aim at broadening our observations over a larger number of consciously and knowingly answered polls. We succeed, after several attempts, to collect approximately 50 answered polls from each of these countries, while the number of responders from academia was considerably greater in comparison to those from the field of industry and logistics. Besides, it is worth to mention that we have done previously some analysis on the low level of institutional rationality in these three transitional economies, and concluded that it has a huge impact on the progressive transformations in these countries, including digital divide overcoming [24].

3.1. Survey analysis and their validity

The respondents ($n = 150$) were firstly asked to rank the complexity of some crucial problems of implementing RFID technology in supply chains: C1-security and privacy, C2-technology issues, C3 costs, and C4-standardization. Each of these criteria is composed of the set of corresponding sub-criteria (Table 1). These dimensions are recognized in [20], i.e., in the latest review paper of such kind published in a highly rated journal, due to the best of our knowledge. If we take into account the last stated, and the gap in adopting and exploiting advanced info-communications systems in the considered lands, then it can serve as a justification of our choice.

The ranking is made in a way that to each group of criteria (C1-C4), listed in Table 1, the experts assigned the respective rank 1, 2, 3, or 4, in accordance to their subjective estimation based on the knowledge in the field, experiences and intuition. The rank 1 belongs to the most serious set of barriers in tagging supply chains, while the rank 4 represents the set of the slightest problems.

Table 1. Challenges in tagging goods in supply chains

C1-Security & Privacy (S&P)
C11-Securing data safety and customer privacy
C12-Ownership transfer issues between seller and buyer
C13-Undesired sharing tagged items information between seller and buyer
C2-Technology issues (T)
C21-Tag reading errors
C22-Tag localizing errors
C23-Need for engaging external experts
C24-Need for outsourcing
C3-Costs (C)
C31-High investments while introducing this technology
C32-Returns on investment vagueness
C33-Difficulties in estimating opportunity costs and risk of obsolescence
C4-Standardization (S)
C41-Developing standards for ensuring interoperability at the global level
C42-Alleviating regulatory aspects differences among countries

The aggregate rank of the four selected criteria (C1-C4) over the respondents' estimations is determined by means of normalized average weight coefficients per criteria [24,25,26]. The idea of evaluating these weight coefficients is associated with the sum of ranks of each criterion, with respect to the assessments of the respondents (1):

$$c_q = \sum_{p=1}^{150} c_{qp}\ ,\ q = \overline{1,4} \tag{1}$$

Where,

c_q - is the sum of ranks of each criterion, while q is the number of criteria (4), and p is number of respondents (150); and,

c_{qp} - is rank of the q-th criteria estimated by the p-th respondent.

The average weight coefficient for each criterion is calculated by the following formulae (2):

$$\overline{w_q} = \left[c_q / \sum_{q=1}^{4} c_q \right]^{-1} \tag{2}$$

The normalized average weight coefficients are then calculated by formulae (3):

$$\overline{w_{qn}} = \overline{w_q} / \sum_{q=1}^{4} \overline{w_q} \tag{3}$$

The aggregate or final rank of analyzed criteria (C1-C4) according to their severity, assessed by the 150 selected respondents (R1-R150), is processed by the equations (1)-(3), while the results are presented in Table 2. The criteria with the highest $\overline{w_{qn}}$, has the highest rank. This logic is applied to the rest of the analyzed criteria. The calculus is realized in Excel by an Inter(R) Core™ i5 processor on 2.4 GHz (4GB RAM).

Tabela 2. Final rank of the considered challenges

R/C	C1	C2	C3	C4
R1	4	2	1	3
R2	4	1	2	3
R3	3	4	1	2
R4	4	3	1	2
R5	4	2	1	3
...	...	...	...	...
R150	4	3	1	2
c_q	2.69299821	3.75939849	7.38916256	4.39882698
$\overline{w_q}$	0.14763932	0.20610301	0.40509902	0.24115865
$\overline{w_{qn}}$	0.14763932	0.206103	0.405099	0.241159
Rank	**4**	**3**	**1**	**2**

In addition, the experts were asked to assess the complexity of the problems associated to the sub-criteria within the main criteria sets (C1-C4), with one mark on a scale of 1 to 5, where 1 represents the lowest and 5 the highest rating problem in accordance to their per-

ception, experiences and expertize in the domain. Then, the average score for each of the sub-criteria is calculated and the secondary level ranking of sub-problems or sub-criteria is made. The results are shown in Table 3. These calculations are realised in Excel, too.

Table 3. Final rank of the considered key and sub-challenges

Rank 1: C3-Costs (C)
Sub rank 1: C31-High investments while introducing this technology (avg. 3.627)
Sub rank 2: C32-Returns on investment vagueness (avg. 3.440)
Sub rank 3: C33-Difficulties in estimating opportunity costs and risk of obsolescence (avg. 2.507)
Rank 2: C4-Standardization (S)
Sub rank 1: C41-Developing standards for ensuring interoperability at the global level (avg. 2.560)
Sub rank 2: C42-Alleviating regulatory aspects differences among countries (avg. 2.327)
Rank 3: C2-Technology issues (T)
Sub rank 1: C23-Need for engaging external experts (avg. 3.467)
Sub rank 2: C24-Need for outsourcing (avg. 2.307)
Sub rank 3: C21-Tag reading errors (avg. 1.573)
Sub rank 4: C22-Tag localizing errors (avg. 1.500)
Rank 4: C1-Security & Privacy (S&P)
Sub rank 1: C12-Ownership transfer issues between seller and buyer (avg. 3.627)
Sub rank 2: C13-Undesired sharing tagged items information between seller and buyer (avg. 3.440)
Sub rank 3: C11-Securing data safety and customer privacy (avg. 2.507)

In accordance to the obtained final rank, the costs of implementation are seen as the biggest problem in adopting RFID in supply chains. Then, on the second position are the standardization problems. These standards are still developing [27,28], and we have to mention, once again, the lack of common RFID-WSN platform at physical and transmission layers, although there are several successful RFID-WSN applications of different kind. At the third place are technological issues like: needs for engaging external experts, outsourcing needs, tags reading and positioning errors, etc. The participants' security and privacy problems are rated as the lowest impediments. Albeit, it is to be pointed that this problem should not be neglected, on the contrary. As the number of deployed RFID devices grows, the number of possible attacks grows in parallel. This is in collision with the intention of tagging goods on the level of each single item, and it deserves further investigations. After ranking the challenges in the prospective implementation of the RFID in supply chains in considered transitional economies, the Spearman's bi-variant correlation coefficients are calculated by the formulae (4) for each pair of the considered criteria sets. The Spearman's rank correlation coefficient (r_s) is well-known, reliable and fairly simple method of testing both the strength and direction (positive or negative) of any correlation between two variables [23]. It is calculated by the formulae (4):

$$r_s = 1 - \left(\frac{6\sum_{i=1}^{n} d_i^2}{n^3 - n} \right) \tag{4}$$

Where,
r_s – is Spearman's rank correlation coefficient;
d – is the difference between two considered variables ranks; and,
n – is the number of pairs of criteria compared by the respondents (i.e., 150 per each pair of considered criteria). In all considered cases, Spearman's correlation coefficients, i.e., $\forall r_s > 0.99$, that means a strong positive correlation between the main sets of critical issues for employing RFID in supply chains in accordance to the experts' assessments (Table 4). These results have strong statistical significance ($\forall r_s^2 > 0.99$), too. The calculations are made like in the previous two cases in Excel. A sample of correlation coefficients calculus between pairs cost-technology issues (C,T) and technology issues-security & privacy (T,S&P) is given in Table 5. The correlation coefficients between other pairs of main criteria sets are calculated in the same way.

Table 4. Correlation coefficients between pairs of analyzed criteria

Correlation	Spearman coefficient (r_s)	Rank
(S) & (T)	0.999956331	1
(C) & (S&P)	0.999855006	2
(S) & (S&P)	0.999799349	3
(T) & (S&P)	0.999707975	4
(C) & (S)	0.999505805	5
(C) & (T)	0.999340057	6

Legend: (S) – standardization; (T) – technology; (C) – costs; (S&P) – security and privacy

Table 5. Calculating correlation coefficients between pairs (C,T) and (T,S&P)

No.	C	T	Rank (C)	Rank (T)	d	d^2	T	S&P	Rank (T)	Rank (S&P)	d	d^2
1.	3.333	2.250	113	56	1.08	1.17	2.250	3.333	56	20	-1.08	1.17
2.	3.667	2.000	55	82	1.67	2.78	2.000	3.000	82	91	-1.00	1.00
3.	3.333	2.750	113	1	0.58	0.34	2.750	3.333	1	20	-0.58	0.34
4.	3.667	1.750	55	121	1.92	3.67	1.750	3.000	121	91	-1.25	1.56
5.	4.000	1.750	1	121	2.25	5.06	1.750	2.667	121	133	-0.92	0.84
6.	4.000	2.000	1	82	2.00	4.00	2.000	3.333	82	20	-1.33	1.78
7.	3.667	2.250	55	56	1.42	2.01	2.250	3.333	56	20	-1.08	1.17
8.	4.000	2.500	1	22	1.50	2.25	2.500	3.000	22	91	-0.50	0.25
9.	3.667	2.500	55	22	1.17	1.36	2.500	3.333	22	20	-0.83	0.69
10.	3.333	2.750	113	1	0.58	0.34	2.750	3.333	1	20	-0.58	0.34
11.	4.000	1.750	1	121	2.25	5.06	1.750	2.333	121	141	-0.58	0.34
12.	3.667	2.000	55	82	1.67	2.78	2.000	3.667	82	6	-1.67	2.78
13.	4.000	2.000	1	82	2.00	4.00	2.000	4.000	82	1	-2.00	4.00
14.	3.333	2.500	113	22	0.83	0.69	2.500	3.667	22	6	-1.17	1.36
15.	3.333	2.750	113	1	0.58	0.34	2.750	3.333	1	20	-0.58	0.34
16.	3.667	1.750	55	121	1.92	3.67	1.750	3.000	121	91	-1.25	1.56
17.	3.667	2.000	55	82	1.67	2.78	2.000	3.000	82	91	-1.00	1.00
18.	4.000	1.750	1	121	2.25	5.06	1.750	2.333	121	141	-0.58	0.34
19.	4.000	2.500	1	22	1.50	2.25	2.500	3.000	22	91	-0.50	0.25
20.	3.333	2.250	113	56	1.08	1.17	2.250	3.333	56	20	-1.08	1.17
…	…	…	…	…	…	…	…	…	…	…	…	…
					$\sum d^2$	371.20					$\sum d^2$	164.26
r	0.999340057					r	0.999707975					
r^2	0.998680550					r^2	0.999416035					

Also, we would like to examine in some more detail correlation between groups of sub-criteria within main criteria sets, e.g., between technology issues (T: C21, C22, C23, C24) from one side, and costs (C: C31, C32, C33), standardization (S: C41, C42), and security and privacy (S&P: C11, C12, C13) from another side. These correlation coefficients are shown in Table 6, and they are obtained by calculus in SPSS (ver. 16.0).

Table 6. Correlation between groups of variables (T vs. C, S, S&P)

T vs. C, S, S&P		C13	C32	C33	C41	C42	C11	C12	C13
Spearman's rho	C21 correl. coeff.	.142	-.221**	-.263**	**.675****	-.031	.103	.588**	.232**
	Sig. (2-tailed)	.082	.007	.001	.000	.703	.209	.000	.004
	n	150	150	150	150	150	150	150	150
	C22 correl. coeff.	.110	-.110	-.244**	.134	-.100	**-.763****	.358**	.597**
	Sig. (2-tailed)	.179	.179	.003	.101	.226	.000	.000	.000
	n	150	150	150	150	150	150	150	150
	C23 correl. coeff.	.142	-.337**	-.405**	.479**	.118	-.161*	**.722****	.024
	Sig. (2-tailed)	.083	.000	.000	.000	.151	.050	.000	.768
	n	150	150	150	150	150	150	150	150
	C24 correl. coeff.	.005	**-.830****	**-.548****	**.357****	**.369****	.002	**.513****	.271**
	Sig. (2-tailed)	.950	.000	.000	.000	.000	.981	.000	.001
	n	150	150	150	150	150	150	150	150

**Correlation is significant at the 0.01 level (2-tailed)

Within this context, we are particularly interested in: How the need for outsourcing (C24) correlates with other considered sub-criteria? - On the basis of the results given in Table 6, the following can be observed:

- There is a strong positive correlation (0.513) between concerns about the need for outsourcing (C24) and the ownership transfer issues between seller and buyer (C12). In the next section, it will be shown that outsourcing in a cloud is the most convenient model for adopting and implementing RFID-enabled goods in supply chains in the transitional economies. Therefore, this problem should be the problem of designers and providers of cloud services, but not of the users. However, it is good that users are aware of this, since they should consider this issue in advance with potential providers of cloud services and regulate it through the contract;
- There is a medium positive correlation between the need for outsourcing (C24) and the standardization issues alleviating regulatory aspects differences among countries (C42), and developing standards for ensuring interoperability at the global level (C41). These correlation coefficients are respectively 0.369 and 0.357. Like in the previous case, within the conditions of outsourcing in a cloud, standardization is a concern of the designers and providers of cloud services, more than of the users;
- There is a strong negative correlation between the need for outsourcing and the returns on investment vagueness (C32), along with the difficulties in estimating opportunity costs and the risk of obsolescence (C33). These coefficients are respectively -0.830 and -0.548. It means that the need or the necessity of outsourcing in a cloud implies considerably less problems with these risks from the aspect of the users. These risks will be transferred, in the certain extent, from the user to the provider of cloud services.

It might also be worth to point out the high correlation coefficients between:

- The need for engaging external experts (C23) and ownership transfer issues between seller and buyer (C12), which is 0.722. It is a question of confidence between the user and external expert(s) and it can be regulated through the contact;
- Tag reading errors (C21) and concerns about standardization at the global level (C41) have a strong positive correlation (0.675). However, the problem of global standardization is currently on the road to be overcome by adopting the EPC Gen2 standard [27], and by implementing some white papers supported by China and EU countries [28]; if we abstract the absence of the unique RFID-WSN platform;
- Tag localizing errors (C22) and securing data safety and customer privacy (C11) have a large negative correlation (-0.763). Statistically it has a sense, but from the practical aspect it cannot be recommended as a way for providing customers' safety and privacy. The appropriate mechanisms of reducing tad localizing errors and uprising customers' safety and privacy are to be developed in parallel.

The relations between other considered sub-criteria with high positive or negative correlation coefficients, with the appropriate level of statistical significance, can be interpreted by analogy.

4. Concerning cloud perspective in adopting RFID in supply chains

On the basis of the overview of the pros and cons of implementing RFID in supply chains and the statistical analysis of the survey conducted among the professionals from academia and the logistics sector in Montenegro, Serbia, and Bosnia and Herzegovina, in this section we would like to propose a model for adopting this advanced technology through the cloud. In that regard, firstly we shall give a short review of cloud models, including the methodological framework for assessing users' commitment to a certain type of sourcing in the cloud (4.1). Then, we shall propose, at the logical level, a model for adopting cloud in the developing countries which function in the transitional circumstances (4.2).

4.1. Blending cloud and RFID technology

Cloud computing is a model in which any and all resources: application software, processing power, data storage, backup facilities, development tools, etc., are delivered as a set of services via the Internet (or Intranet). Since cloud computing is relatively new and growing rapidly, definitions and terminology are still in a state of flux [29,30,31]. Three basic models within the cloud concept are well-know and they are briefly described below:

- SaaS (software as a service): It is a delivery model for software in which the company, or other customers, pays for software on pay-per-use basis instead of buying the software outright;
- PaaS (platform as a service): It is a delivery model for software identical to SaaS with the additional features, as the ability to customize data entry forms, screens, reports, and as the access to software development tools to change the way in which the software works;
- IaaS (interface as a service): It is a delivery model in which the customer acquires all the technology needs: storage hardware, network equipment, application software, operating system, data backup facilities, processing capabilities, etc.

The possibilities of using cloud today are huge, whether it comes to the public (based on Internet), or private one (based on Intranet). The public cloud, as its name suggests, comprises cloud services that exist in the Internet offered to anyone and any business. On the other hand, a private cloud is a cloud computing service established and hosted by an organization on its internal network and available only to employees and departments with that organization. Thus, a private cloud doesn't exist in the Internet, but rather within a specific organization Intranet [29]. There are also possibilities of using community or hybrid cloud [32]. Relationships between partners in cloud (users, service operators, service designers, etc.) are regulated by SLA (Service Level Agreement). The SLA regulates user's requirements and operator's obligations in terms of time, privacy, security, availability, reliability and determined procedures for data recovery. It specifies the price and method of penalty payment if the contract is breached from some reason, etc.

Figure 2 shows the costs of implementing RFID in supply chains and the main cloud concepts: SaaS, PaaS, and IaaS. This scheme can give an insight to the managers and stakeholders in the logistics sector of the considered countries into the relations between tagging goods in supply chains and cloud services. Direct costs of hardware should be replaced by IaaS costs; software ones by SaaS and/or PaaS, while cost of engaging external experts for the needs of system integration running and maintenance should be replaced by SaaS, PaaS and/or IaaS including their combinations when it is necessary, depending on the individual needs and preferences. The initial costs of deploying SaaS, PaaS, and/or IaaS are in any case considerably lower that the costs of buying this technology and its "in-house" setting, running and maintenance.

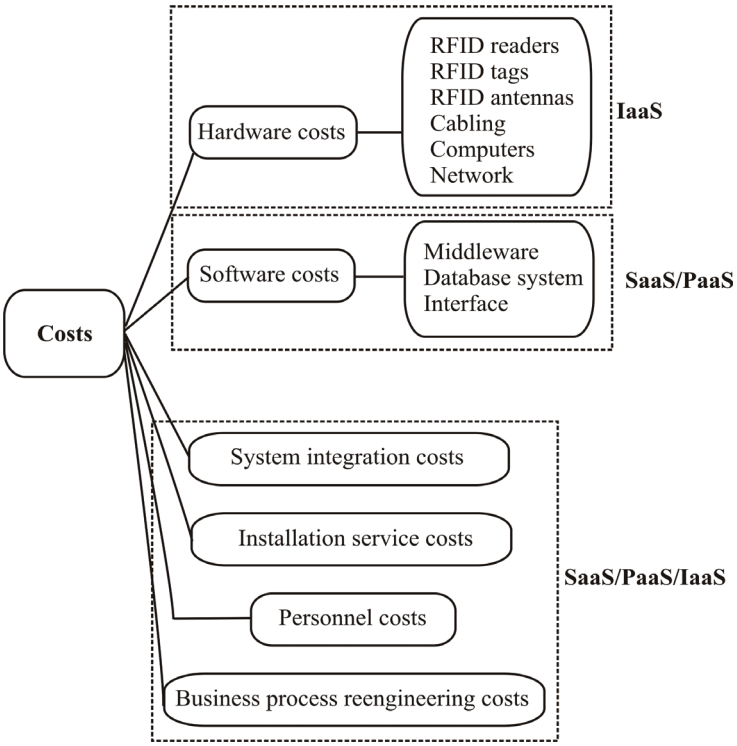

Fig. 2. RFID implementation costs tree and cloud modes
Source: adapted from [10, p. 91]

However, the question is: Which kind of sourcing in a cloud should be the most convenient in the case of the developing countries [33,34,35], like Montenegro, Serbia, and Bosnia and Herzegovina? - On the basis of the literature review of rather scarce available resources in the domain of outsourcing motives and decisions [36,37,38], it can be concluded that *outsourcing as a service* is the most suitable option for the considered transitional economies. On the second place might be placed *standardization of commodities* and *strategic partnership*, and on the third one – *insourcing* that seems presently unacceptable for the current needs of the analyzed countries (Figure 3). These statements are explained in some more detail within the next paragraph.

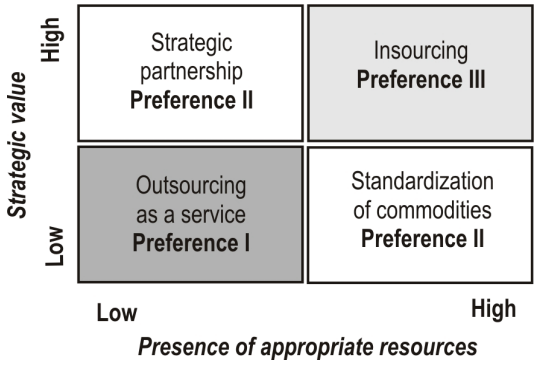

Fig. 3. The sourcing in a cloud motive framework for the transitional economies
Source: adapted from [38, p. 13]

Firstly, the models of "moving" logistics into cloud are shortly described as follows:

- Insourcing: It is the opposite of outsourcing. The activities of tagging and tracking goods in supply chains should be performed by the internal resources. Currently, insourcing seems inappropriate for the analyzed countries, without the staff capacity and other resources increasing;
- Standardization of commodities: It means that IT/IS is not seen as a source that provides sustainable competitive advantages for the company. As a consequence, the IT/IS can be freely shared with competitors without facing a competitive disadvantage or losing a competitive advantage;
- Strategic partnership: It aims at gaining access to complementary resources and capabilities that are not present internally. However, the company retains the ownership and the control over the IT/IS that is linked to its strategic needs;
- Outsourcing: It implies that the rights are owned by the supplier during the delivery process as it owns the required resources for the IT/IS development. The responsibility for delivery is exclusively on the part of the external supplier. This model seems the simplest and the most acceptable in the case of the considered Western Balkans countries.

Afore described sourcing models are to be placed in the matrix of the logistics company's strategic value, from one side, and presence of appropriate resources, from the other one. The lower the strategic value of the certain activity (i.e., RFID-enabling goods in supply chains) and the related expertise in the IT/IS development, the more the company is willing to outsource. When it comes to presence of appropriate resources, the less

the company's resources own appropriate experiences, the more it will seek to overcome the knowledge gap by accessing external, complementary resources and capacities. As they operate since decades in the transitional environment, Montenegro, Serbia, and Bosnia and Herzegovina have low levels of strategic value when it comes to enhancing supply chains through tagging goods as well as other necessary resources in terms of human, organizational and physical capital. Therefore, *outsourcing in a cloud* should be taken as an optimal solution in the initial stage of adopting RFID technology for providing seamless goods' stream and adherent activities.

4.2. A model for adopting RFID

In accordance to the results of the statistical analysis given in Section 3 and on the basis of the previously given short review of sourcing models, we have proposed here a model for adopting outsourcing in a cloud, while deploying RFID in supply chains within the context of the transitional economies (Figure 4). As a reference for our model we also used a similar one developed by Humphery et al. (2016) and examined in [39].

In the center of our model is *outsourcing in a cloud* as the most convenient sourcing model in the transitional conditions. This sourcing model can include SaaS, PaaS and/or IaaS services, within the frame of public, private, community, or hybrid cloud, while the relations between the users, providers and designers of the services are regulated by SLA (Service Level Agreement). The model is influenced by previously analyzed barriers for implementing RFID into supply chains, while there is a strong negative correlation between the need for outsourcing from one side, and the risks of returns of investments vagueness and technology obsolesces, from another one, as it has been shown in Section 3. Besides, adopting advanced RFID technology in supply chains should be motivated by the intent to adopt cloud. These intention is (in)directly influenced by the multidimensional nature of technology adoption and innovation diffusion (innovation factors) [40,41]. However, innovation diffusion and adoption must take into consideration existing economic and socio-cultural conditions of the adopter, i.e., the contextual factors. These innovation and contextual factors also affect indirectly the primer RFID adoption concerns (dashed lines in Figure 4). If these factors are on the lower level, greater will be their influence of the considered barriers in RFID adoption and vice versa.

By using positive deterministic paradigm, there is a positive correlation between innovation factors, like: relative advantage (in comparison to the existing technologies), trialability, observability, results demonstrable, usefulness and ease of use, and the user's intent to adopt new technology. On the other side, complexity of new technology is negatively correlated to the intent of its adoption. The strength of these correlations should be examined at the level of each individual adoption case. When it comes to the contextual factors, one has to be aware that potential users do not have available the same level of infrastructure, e.g., access to the infrastructure (Internet) is not the same in urban and rural areas, etc. Socio-cultural attributes considerably vary from area to area, and their influence to the attempt to adopt RFID-tagging through the outsourcing in a cloud should be examined also at the level of each particular case. The same is with the user's awareness about the need of adopting new technology, the level of her/his education, and her/his geographical location. According to some previous studies [39,42], greater level of education implies greater readiness to adopt new technological solutions, even there are still big differences in this respect between different geographical regions and within them.

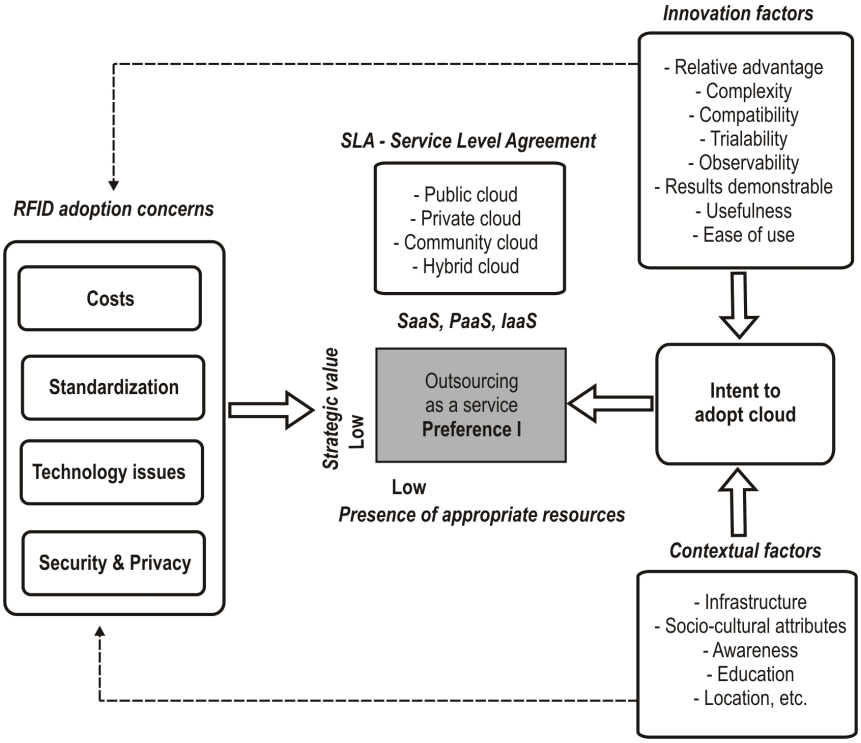

Fig. 4. A model of adopting RFID in supply chains

The contextual and innovation variables and their mutual cross-correlations with the RFID adoption concerns and the core outsourcing model in a cloud should be examined due to the individual needs and preferences of the potential user(s) and this may be the subject of another research study. Apart from that, the information about the RFID technology impediments and cloud sourcing models opportunities, can serve as a key point in opening a discussion about the adoption of these advanced technologies. Enhancing such discussion, starting from the research community, was in fact our primer goal. Therefore, this pilot study can be used as an instrument for uprising the awareness of the managers and stakeholders in the considered transitional economies about the necessity of the logistics innovation towards overcoming the existing technological gaps.

5. Conclusions

The paper gives the overview of pros and cons of adopting RFID technology in supply chains with a reference to the transitional economies at three Western Balkans countries (Montenegro, Serbia, and Bosnia and Herzegovina). Also, it proposes *outsourcing in a cloud* as a model which is theoretically most convenient for small and medium size enterprises in the developing economies. On the basis of the results of the survey conducted among the experts in logistics in aforementioned countries, and the survey of the sourcing models in a cloud, the following can be drawn:

– Considered barriers in implementation of RFID into supply chains, the experts are ranked as follows: (1st) costs, (2nd) standardization, (3rd) technological issues, and (4th) security & privacy concerns;

- There is a strong positive bi-variant correlation, with the statistical significance, between each pair of the considered sets of criteria (barriers) in the survey (Spearman's coefficients: $\forall r_s > 0.99$ and $\forall r_s^2 > 0.99$);
- There are strong negative cross-correlations between sub-criteria: the need for outsourcing, from one side, and the returns on investment vagueness (-0.830) and the difficulties in estimating opportunity costs and risk of obsolescence (-0.548), from another side. This means that these risks can be overcome by outsourcing. It strongly supports our hypothesis that tagging goods in supply chains in the considered developing countries should be moved into the cloud;
- The methodological framework for adopting different sourcing models is applied to the analyzed developing countries, and *outsourcing in a cloud* is proposed as the most suitable one, due to the scarcity of financial, technological and human resources in these countries;
- The advanced technology *adoption model* in developing countries is proposed at the logical level by taking into account previously analyzed barriers in implementing RFID in supply chains, along with some innovations and contextual factors. The *outsourcing in a cloud* is in the center of this model, while the intent of its adoption is influenced by users' individual needs and preferences including their economical and socio-cultural attributes.

Further research should include the in-depth interviews and discussions with managers and stakeholders in the transitional economies on this topic, besides the polls. Also, technology innovations and contextual factors that affect adopting cloud solutions should be assessed at the individual level(s). These analyses should also include comparing the objective initial costs of implementing the entire technology and cloud outsourcing model costs, on the concrete exemplars. The issues of stability and interoperability between the supply chain participants in both physical and cloud realms are to be taken into consideration, as well.

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Chapter 6:
Neuro-fuzzy modeling and some ship route optimization problems

6. Preface

This chapter includes three research works on neural networks and neuro-fuzzy modeling. In the first study, Hoppfield recurrent neural network was used to solve the Traveling Salesman Problem (TSP) in sea navigation. In determining the distance between the fourteen ports included in the simulation experiment were used the rules of spherical trigonometry and loxodrome navigation through orthodroma. Through programming were realized some accelerations in generating TSP zero-one matrix. However, it turned out that this neural algorithm requires a large computational time for the number of nodes (i.e. the ports), which is above fourteen. In order to achieve some improvements, in the second research work within this chapter was used the fast insertion heuristics. This method proved to be more efficient than using the neural network "itself".

The third research work is on neuro-fuzzy modeling. The idea was to provide support to a navigator in a situation when the computer based route selection does not function autonomously in the waypoint, which offers two optional sailing paths, but requires a navigator intervention. The model remained at the conceptual and simulation levels, due to the complexity and insufficient author's knowledge of the route selection function operations at the electronic chart system itself, but it can serve as a kind of starting point for further research. However, this would certainly require a more detailed introduction to the advanced automatic route optimization features of the modern navigation support systems.

6.1. Modeling ship's route by Hopfield -Tank TSP neural algorithm

This research work considers determining the optimal linear ship's route by the application of the Hopfield-Tank neural network algorithm adaptation for solving well known traveling salesman problem (TSP). In the work proposed mathematical approach to the Hopfield-Tank TSP neural algorithm realization is primarily based upon faster generating zero-one matrices of suboptimal solutions.

1. Introduction

It is known that the route planing is the beginning of all operations in marine shipping, particularly linear one. Since route of linear ship provides a cycle voyage, it is naturally compared with well-defined general traveling salesman problem (TSP) [1]. According to this problem, navigator has to complete a round trip of a set of ports, visiting each one only once in such a way as to minimize total sailing distance. This kind of problem is computationally very difficult and it is shown that the time to find a solution grows exponentially with number of visiting ports. The solution of the problem is in the *nutshell* and that is where the application of the artificial intelligence becomes interesting. Besides simulated annealing and genetic algorithms, Hopfield-Tank recurrent neural network application to the TSP is one of the most interesting methodologies. This solution may not be the best and the fastest obtained one, but undoubtedly gains insight to the marrow of the problem.

The remaining part of the paper is organized in the following manner:

(1) the second part is addressed to some basic remarks to the TSP formulation and chronology of its most important solutions;
(2) the third part describes TSP model adaptation to Hopfield recurrent neural network architecture;
(3) the fourth part considers the shortest sailing path between two distant ports on the Earth surface;
(4) the fifth part contains the original mathematical approach to the Hopfiel-Tank TSP neural algorithm implementation and the numerical results for TSP in the case of relatively large number of ports being arbitrary chosen, and finally
(5) the last one contains some conclusion remarks and further investigation directions.

2. TSP overview

The origins of the traveling salesman problem (TSP) are obscure. The mathematical problems related to it were treated firstly by the Irish mathematician William Rowan Hamilton and by British mathematician Thomas Penyngton Kirkman (1800's). The description of this early work of Hamilton and Kirkman can be found in [2]. The mathematician and economist Karl Menger publicized it among his colleagues in Vienna, in 1930's [3]. Later, the chronology of the most significant TSP solutions has been going as follows: Dantzing, Fulkerson and Johnson (1954) solved it for 49 nodes; Held and Karp (1971) for 64 nodes; Camerini, Fratta and Maffioli (1975) for 100 nodes; Grotschel (1977) for 120 nodes; Crowder and Padberg (1980) for 318 nodes; Padberg and Rinaldi (1987) for 532 nodes; Grotschel and Holland (1987) for 666 nodes; Padberg and Rinaldi during the same year for 2 392 nodes; Applegate, Bixby, Chvatal and Cook (1994) for 7 397 nodes, and four years later, for even 13 509 nodes, etc. In the recent years Applegate, Bixby, Chvatal and Cook (2001) have solved TSP for impressive number of 15 112

nodes. But nobody was able to come up with an algorithm for solving the traveling salesman problem (TSP) that does not show an exponential growth of run time with a growing number of nodes. There is a strong belief that there is no algorithm that will not show this behavior, but no one was able to prove it completely. But one was able to prove that the TSP is a kind of prototypical problem for a big class of nondeterministic polynomial (NP) time hardness problem and a lot of artificial intelligent methods have been developed in aim to solve it exactly or approximately. Hopfield (1986) has explored an innovative method to solve it by the electronic circuit that produces approximate solutions quite effectively. Later, Hopfield and Tank (1987) have improved this neural network based method for TSP implementation and its more efficiently solving.

Our intention here is the Hopfield-Tank TSP neural algorithm adaptation to the liner ship's routing problem, in a mathematical sense. But firstly, some remarks to the functional equivalence between Hopfield-Tank network energy function and TSP model are given. Then some elements of the shortest path estimation between a pair of ports on the Earth surface are examined, by the roles of sphere trigonometry. Finally, some remarks to the software realization of the Hopfield-Tank TSP neural algorithm are discussed. The results being obtained through the adequate example(s) are also presented, numerically and graphically.

3. Functional equivalence between Hopfield-Tank neural network and TSP model

Neural networks are very important in many scientific disciplines in solving previously *unsolvable* problems, like in a way the TSP of larger dimensions is. Among many neural network schemes that have been proposed and investigated, the Hopfield-type neural network remains an important one due its applicability in solving associative memory, pattern recognition, and optimization problems, with ease of VLSI implementation [4]. The first neural algorithm for combinatorial optimization was the simulated annealing method. In this algorithm one of the neurons is selected randomly and the state of the selected neuron is updated to reduce the energy of the network. Therefore the state transitions of the system must be operated serially though the network itself has parallel architecture. Hopfield and Tank used analog neurons and continuous dynamics for energy reduction. In this manner becomes possible to operate calculation in parallel. Although to simulate continuous dynamics with digital computers, many iterations are required before reaching low or minimum energy state [5].

Namely, the Hopfield-Tank neural network optimization algorithm is based on the fact that weights of the network are to be made so that the optimal solution is located in the lower energy area of the state space. In other words, the neural network optimization problem is based upon minimization of energy function given by (1):

$$E(x) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}x_i x_j + \sum_{i=1}^{N}\theta_i x_i \tag{1}$$

where x_i - state of the i-th neuron; θ_i - threshold of the i-th neuron and w_{ij} - weight of the connection from the j-th neuron to i-th neuron ($w_{ij} = w_{ji}$). A candidate of the solution is represented by one of the state vectors $x = (x_1, x_2, \ldots, x_N)$. The energy function (1) consists of two parts, cost (2) and penalty (3):

$$E_c(x) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}^{(c)} x_i x_j + \sum_{i=1}^{N} \theta_i^{(c)} x_i \tag{2}$$

$$E_p(x) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}^{(p)} x_i x_j + \sum_{i=1}^{N} \theta_i^{(p)} x_i \tag{3}$$

Both of them, in addition, are to be reduced as much as possible, according to the aim of $E(x)$ minimization. The second one is to be reduced to zero in the optimal solution. TSP could be formulated in a following way: the shortest round tour, which covers all P nodes (here ports) salesman (here navigator) is to visit, has to be found. The problem of P nodes may be coded into P-by-P network. Each row of the network corresponds to a node and the ordinal position of the node in the tour is given by the node at the place outputting a high value (i.e. one), while rest are all at very low values (i.e. zero). The nodes of the network are unipolar sigmoidal activation units where *ai*-th unit has output $x_{ai} = 1$, if, and only if, node *a* is visited *i*-th in the tour and output $x_{ai} = 0$, if *a* is not visited *i*-th in the tour [6.7]. The distance between nodes a and b is denoted as d_{ab} and the energy function, that is its cost part, takes the form (4):

$$E_c(x) = \frac{D}{2}\sum_{a}\sum_{b\neq a}\sum_{i} d_{ab} x_{ai}\left(x_{b,i+1} + x_{b,i-1}\right) \tag{4}$$

where indexes are cyclic, that is $P+1=1$, $1-1=P$, and D is positive constant. Constrains that must be satisfied are: only one node can be visited at the same time; each node is visited only once and every node must be visited in the tour. These constrains could be formulated in the following way (5):

$$E_p(x) = \frac{A}{2}\sum_{a}\sum_{i}\sum_{j\neq i} x_{ai}x_{aj} + \frac{B}{2}\sum_{i}\sum_{a}\sum_{b\neq a} x_{ai}x_{bi} + \frac{C}{2}\left(\sum_{a}\sum_{i} x_{ai} - P\right)^2 \tag{5}$$

where A, B and C are positive coefficients. From the energy function weight matrix can be obtained (6):

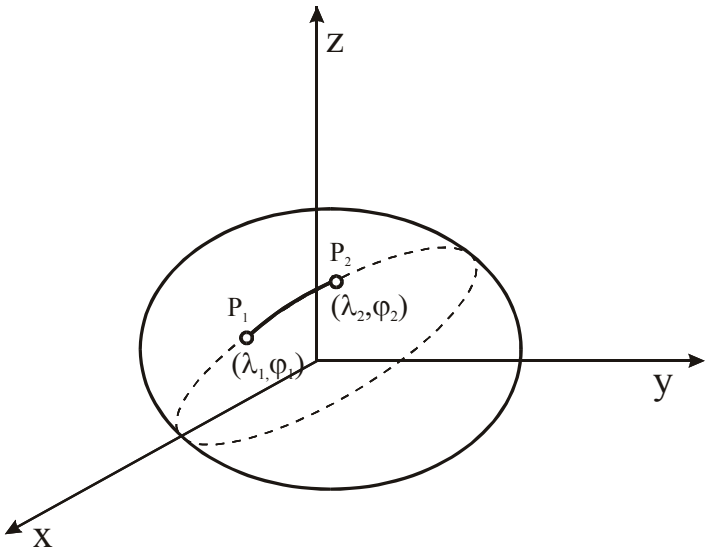
$$w_{aibj} = -A\delta_{ab}(1-\delta ij) - B\delta_{ij}(1-\delta_{ab}) - C - Dd_{ab}\left(\delta_{j,i+1} + \delta_{j,i-1}\right) \tag{6}$$

where $\delta_{i_1 i_2} = 1$, if $i_1 = i_2$ and $\delta_{i_1 i_2} = 0$, if $i_1 \neq i_2$. In accordance with original Hopfield and Tank adaptation [8] coefficients A, B, C and D take values 500, 500, 200 and 500, respectively. The neural network with the above weights has a tendency to give solutions that do not cover all P nodes (here ports). Kakeya [5] suggested certain improvements by introducing new parameters r and α into the original Hopfield and Tank recurrent neural network optimization model. Penalty term of energy function $(C/2)\left(\sum_a \sum_i x_{ai} - P\right)^2$ was replaced by $(C/2)\left(\sum_a \sum_i x_{ai} - \alpha P\right)^2$ where $\alpha > 1$, in order to increase firing rate of the neuron. While the weight vector takes new form $w^{(c)} = D(r - d_{ab})\left(\delta_{j,i+1} + \delta_{j,i-1}\right)$, where $r > 0$. By allowing the network to run un-

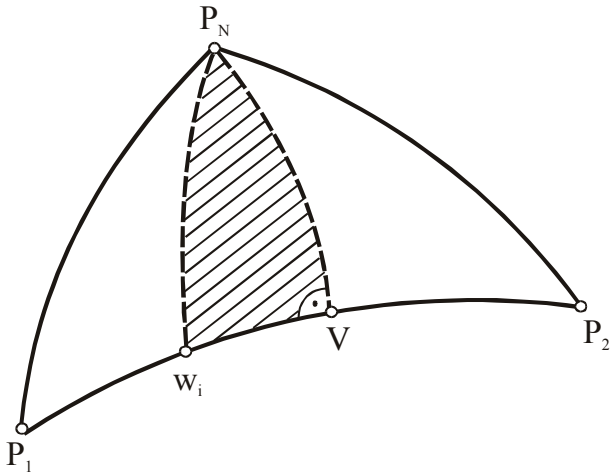
der its dynamics, the energy minimum is to be reached. This energy minimum corresponds to the solution of the problem. What is meant here under solution is to be qualified. Hopfield-Tank network is not guaranty to produce the shortest round tour, but only those that are close to the shortest one. The TSP requires large number of iterations because number of possible tours is equal to $(P-1)!$ when the problem is asymmetrical and $(P-1)!/2$ when it is symmetrical, that is when $d_{ab} = d_{ba}$. Besides subcycles are to be dismissed because the continual round tour has to be found as the optimal one. Thus, the computational complexity of the problem, particularly when the number of visiting ports is large, does not vanish so simply [8,9]. In aim to find the shortest linear ship's route, in the next sections we shall firstly give some remarks to the manner(s) of estimating the shortest path between each pair in the given set of ports on the Earth sphere surface. Then, we shall realize the software adaptation of the Hopfield-Tank TSP neural algorithm to the problem of the optimal linear ship's route modeling.

4. The shortest path on the Earth between each pair in the given set of ports

The navigation between two distant points (here ports) on the Earth is possibly done in three ways: orthodrome navigation, loxodrome navigation and combined navigation. The shortest way from departure to arrival position is a shorter section of the great circle arc, that is orthodrome. Such navigation is difficult to achieve since the orthodrome intersects the meridians at different angles, so it would require constant, precisely defined change of course. In the case when course is constant, that is easily achievable in practice, navigator follows a curve asymptotically approaching nearer pole. Such a curve on the surface of the Earth is called a loxodrome. In the case of combined navigation, a standard orthodrome is replaced by two orthodrome tangents to the boundary parallel and a loxodrome between them. The dangerous areas that could be reached by following strictly the orthodrome navigation are avoided by applying the technique of combined navigation [10].



a)



b)

Fig. 1. Orthodrome (a) and waypoint sphere triangle (b)

4.1. The orthodrome approximation by the loxodrome

The orthodrome is the shortest path between two distant points on the surface of the Earth (figure 1.a). Therefore, the aim of orthodrome navigation is the shortest path and the least traveling time, resulting invariably in cost effectiveness. Since strict orthodrome navigation is difficult to achieve in practice, it is divided into a finite number of waypoints between which loxodrome navigation is applied. Thus certain number of shorter loxodromes approximates the orthodrome, where the common positions are determined waypoints. For the purpose of waypoints coordinates calculation the right angle sphere triangle whose vertices are: the pole closer to the orthodrome vertex, the orthodrome vertex and the waypoint, is taken into consideration (figure 1.b). The labels of the sphere triangle in figure are: P_N - North Pole; P_1-departure port; P_2 - port of arrival; w_i -*i*-th waypoint ($i = \overline{1,N}$, where N is number of waypoints) and V - the orthodrome vertex. The waypoints (w_i) may be selected symmetrically to the orthodrome vertex, or by orthodrome division into finite number of equal sections. The orthodrome division is arbitrary and may be *1,2,3,…* degrees, depending on the orthodrome length. We suggest the second approach, since it is much more appropriate to computation. Upon the determination of waypoints number through adequate simulation process [10,11], waypoints geographical coordinates, the appropriate loxodrome courses and distances can be calculated by application of the adequate sphere trigonometry rules. The difference (*d*) between the sum of the loxodrome distances and orthodrome one, expressed in nautical miles, is to be reduced as much as possible (7):

$$min\, d = \sum_{j=1}^{n} d_{lox}(j) - d_{ort} \tag{7}$$

where d_{lox} is loxodrome distance for $j = \overline{1,n}$ ($n = N + 1$, N is number of waypoints) and d_{ort} is orthodrome distance between endpoints. Through the process of waypoints number optimization this could be achieved [10]. In case of orthodrome intersection with Equator or Greenwich (figure 2), first of all points of intersection are to be determined, then on each orthodrome segment, former meant procedure of waypoints number optimization is to be done.

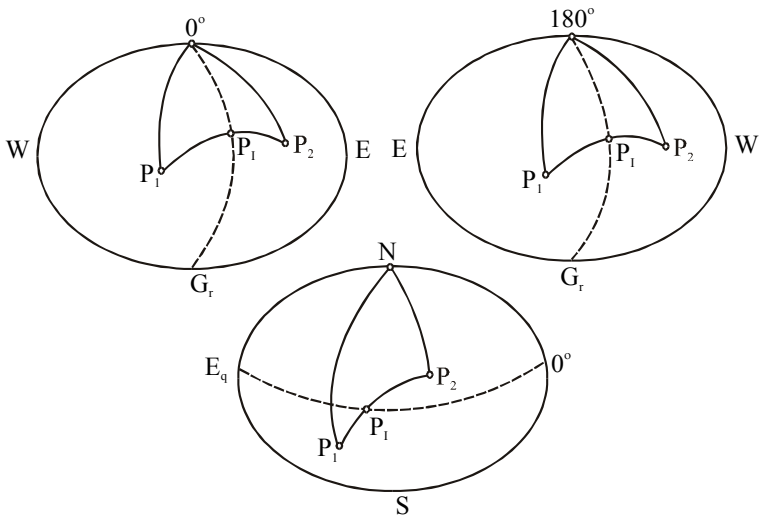


Fig. 2. The orthodrome and its intersection with Greenwich and Equator

In the paper has been assumed that the distances between each pair of ports are orthodrome, that is absolutely the shortest ones, but in the practical navigation, they should be replaced with the optimal number of the loxodrome, with the appropriate loxodrome courses. The deviations are also to be involved in aim to avoid obstacles and to enable the eventually predicted route tracking.

Now, let us introduce some mathematical adaptations of the Hopfield-Tank TSP neural algorithm applied to the process of linear ship's route modeling. It must be pointed out that through the detailed survey of ship routing and optimization problems given in [12] by Christiansen, Fagerholt and Ronen (2003), becomes obvious that nobody has treated linear ship's TSP routing problem and its proper modifications by means of neural networks. Namely, this problem has been mostly treated as integer that is binary programming one. Although this approach based upon neural networks is in a way more sophisticates, since it reduces number of boundaries and enables easier subcycles dismissing.

5. The mathematical approach to the Hopfield-Tank TSP neural algorithm

The traveling salesman problem (TSP) is a classic example of a nondeterministic polynomial (NP*)* complete problem. A problem is assigned to the NP class if it is verifiable in polynomial time by a nondeterministic *turing machine*. While, a nondeterministic *turing machine* is a "parallel" *turing machine* which can take many computational paths

simultaneously, with the restriction that the parallel *turing machines* cannot communicate. A problem is said to be NP hard if an algorithm for solving it can be translated into one for solving any other NP problem. It is much easier to show that a problem is NP than to show that it is NP hard. A problem which is both NP and NP hard is called a NP complete problem. Essentially, the only way known to solve NP complete problem, is to compute the costs (here distances) of all tours [13].

There are fiew assumptions in this paper:

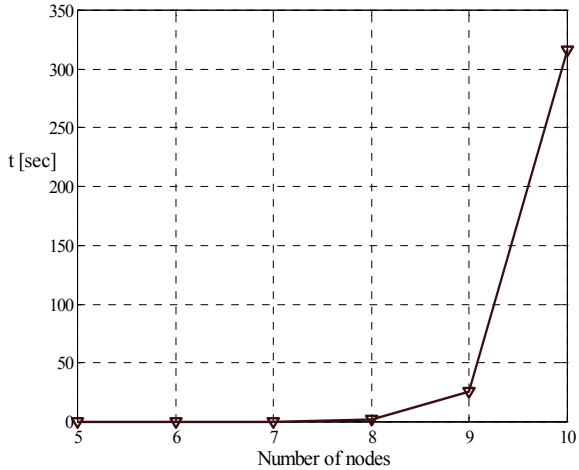
1. P represents the number of nodes, and mark the nodes with numbers $1,2,3,\ldots,P$;
2. We assume that the distances between P nodes are specified in a matrix of distances that specifies the non-negative orthodrome distances between any pair of ports and this matrix is symmetrical: for each pair $(i,j) \in P \times P$ distance between node *i* and node *j* is same as distance between node *j* and node *i*. All entries in the matrix have some distance and the distance on the main diagonal are set to zero.
3. Each port must be visited exactly once and no port can be skipped.

The tour is represented as 0 - 1 matrix with P rows and P columns. If number 1 is in matrix on positin (i,j), that means that the *i*-th node is on the *j*-th position in the tour. There is a variable named *minControl* representing a distance that is assossiated to the tour $1,2,3,\ldots,P$ which is propagated as the optimal one, in the first run. This is a first tour that is examinated with the algorithm and it is represented with matrix with ones on the main diagonal. After that, algorithm find a next tour, compute the distance, and compare it with a *minControl* that is find so far. If a new generated tour has a distance *d,* and *d* is a smaller distance then *minControl*, we will introduce d as a best tour and refresh *minControl* with this computed minimum distance. This proccess continues for all possible tours. If there are P ports, then there are $P!$ possible tours, so the number of tours to be checked grows very large and very quickly. Exploring all tours is called a "brute force" approach or exhaustive search. This algorithm generate a 0 - 1 matrix so that every row and every column has exactly one 1, and every generated matrix is treated as a subomptimal solution. This aproach is implemented within the next pseudo-code:

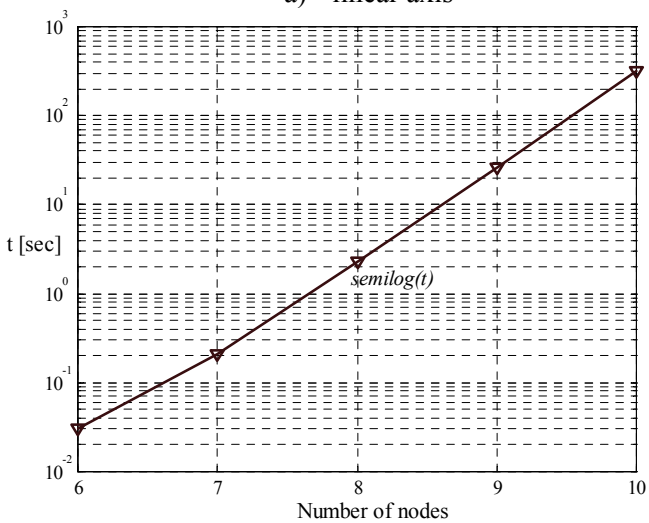
```
const
  MaxPortNumber = 9;
  D = 500;
  C = 200;
Type
  PortMatrix = array [1..MaxPortNumber, 1..MaxPortNumber] of integer;
  PortMatrixReal = array [1..MaxPortNumber, 1..MaxPortNumber] of real;
  order = array [1..MaxPortNumber] of integer;
var
  matrix : PortMatrix;
  distance : PortMatrixReal;
  tour : order;
  k, m, P: integer;
  s, min, Ec, w: real;

{mark that in the algorithm s represents a distance of courent tour, pre-
viously in the work labeld as d}

procedure Visit (var matrix : PortMatrix; row, col : integer);
```

```
var i, j : integer;
        help: order; {generated tour derived from 0-1 matrix}
begin
   if done one solution then
      begin
        for i := 1 to P do
          for j := 1 to P do
               if matrix[i,j]=1 then
                   help[i] := j;
        s := 0; {compute the curent cost}
        for i := 1 to P-1 do
              s := s + distance[help[i],help[i+1]];
        s := s + distance[help[1],help[n]];
        if s < minControl then
          begin
              min := s;
              best := help;
          end;
      end
   else
       repeat
             clear all colums after used column
             if Put (row, col) then
                begin
                matrix [row, col] := 1;
                Put (1, next column in matrix);
                end;
             go to next row in matrix
       until last row;
end;
```

$Put(i, j)$ is a function implemented to check if 1 can be in the 0 - 1 matrix on the (i, j) position. *Help* array is formed only for better understanding of the algorithm, since the total distance of tour can be computed from the *matrix*. In the main program we must specify P and input the distances into distance matrix. After that program will call the esential procedure *Visit* wich will find the best tour. The exponential search space can be seen in the figures 3, 4 and 5, for ten, twelve and fourteen nodes with linear and semilogarithm coordinate axis, respectively.



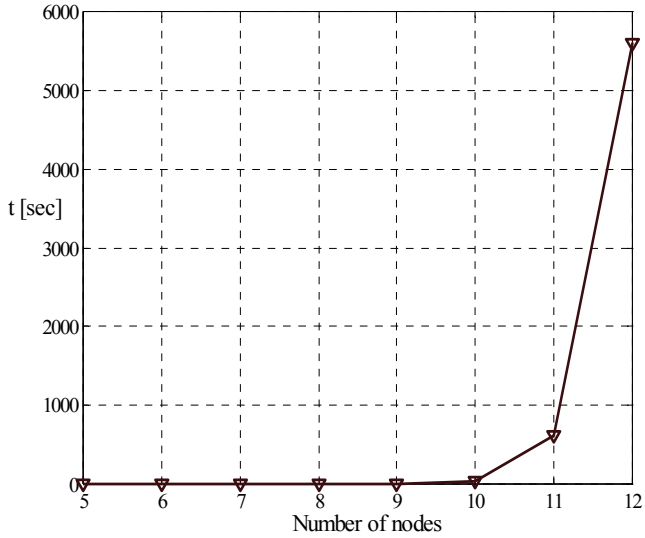
a) linear axis



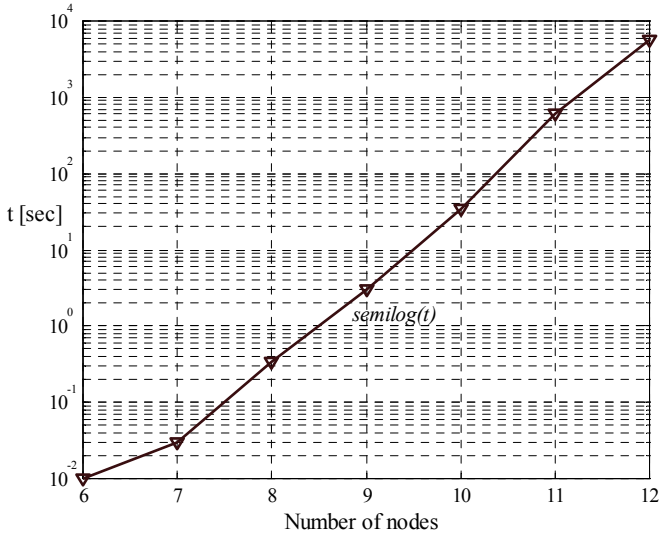
b) semilogarithm axis

Fig. 3. The exponential search space in the case of ten nodes

Lets remark that the 0 - 1 matrix represents a permutation of ports. It is not important which port will be the first one in the optimal tour, since we can rearrange the optimal tour to start from the desired one. If $P = 5$ and the optimal tour is e.g. 1 5 3 2 4, but if it is necessary to start from node 3, the rearranged tour is 3 2 4 1 5. Here, we will use only those tours that start from node 1. The goal is to find the sequence of ports that starts and ends with city 1 such that the overall passed distance of the tour is minimized. In this case, for P ports, it is enough to examine $(P-1)!$ suboptimal 0-1 matrices. Pseudo-cod for this improvement is same as the previous one because this is the case where the program generates all permutations for ports $2,3,4,\ldots,P$ and puts the port 1 on the first position in each permutation.



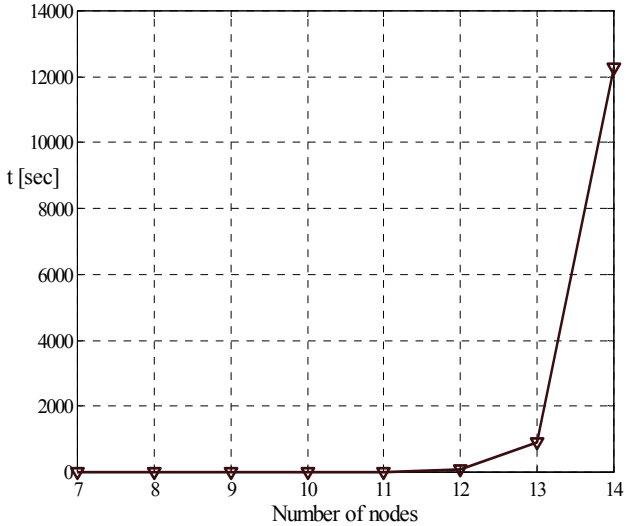
a) linear axis



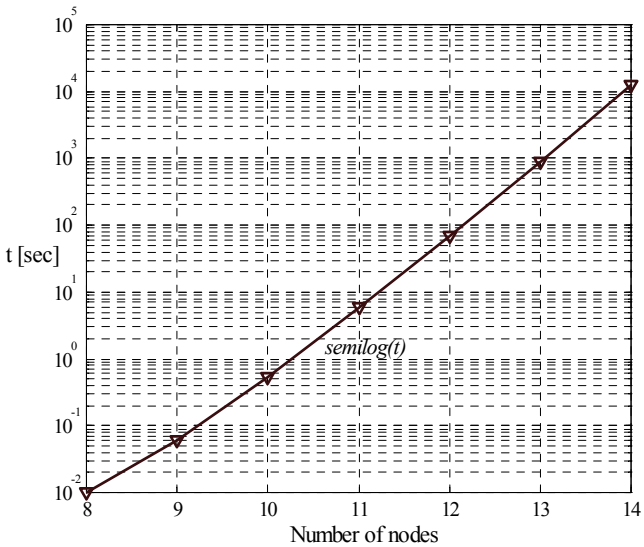
b) semilogarithm axis

Fig. 4. The exponential search space in the case of twelve nodes

Assume that we have to investigate problem of $P = 5$ ports, and that the total distance d_{total} is computed for the tour 1 2 3 4 5. In the symmetrical TSP case all tours with same adjacency of nodes in tour have the same distance d_{total}, so it is not necessary to compute the distance of the tour 1 5 4 3 2, since we know that the total distance of this tour is also d_{total}. This leads to improving the search space, since only $(P-1)!/2$ permutations have to be examined. It is convenient to generate all permutations in lexicographical order.



a) linear axis



b) semilogarithm axis

Fig. 5. The exponential search space in the case of fourteen nodes

There is still no algorithm, which can, in general, find the optimal solution for the TSP without suffering from exponentially growing complexity. Further researchers must examine efficient pruning methods for search tree, some kind of branch and bound method, or try to use fast algorithms for generating lexicographical permutations to cut a running time for TSP algorithm. If it is not so important to obtain a true minimal length tour, it is possible to investigate a different heuristic methods which will lead to tour that is near to the optimal one.

6. The numerical examples and simulation results

The problem being considered here is to find the exact shortest linear ship's round tour visiting fourteen arbitrary chosen ports on the Earth north-east hemisphere in accordance with previously proposed mathematical adaptation of Hopfield-Tank algorithm to the TSP. The observed ports geographical coordinates that is their latitudes and longitudes are given in degrees and minutes in table 1.

Table 1. The observed ports geographical coordinates

No.	Port	Latitude φ (° ′ N)	Longitude λ (° ′ E)
1.	P_1	45° 20′	14° 20′
2.	P_2	44° 05′	15° 05′
3.	P_3	43° 25′	16° 20′
4.	P_4	42° 45′	18° 05′
5.	P_5	42° 05′	19° 10′
6.	P_6	41° 10′	16° 50′
7.	P_7	42° 35′	14° 03′
8.	P_8	43° 35′	13° 20′
9.	P_9	43° 53′	12° 55′
10.	P_{10}	44° 03′	12° 45′
11.	P_{11}	43° 40′	15° 58′
12.	P_{12}	43° 30′	16° 18′
13.	P_{13}	41° 15′	16° 35′
14.	P_{14}	42° 00′	14° 58′

The distances between each pair of ports can be calculated as the orthodrome one by means of the sphere trigonometry rules, that is by the equation (8):

$$d_{ort}(i,j) = \arccos\left(\sin\varphi_i\varphi_j + \cos\varphi_i\varphi_j \cos\Delta\lambda_{i,j}\right) \text{ for } (i,j) \in P \tag{8}$$

where φ_i and φ_j are endpoints, i.e. endports, latitudes and $\Delta\lambda_{i,j}$ is an absolute value of the difference between endports longitudes. The problem has been treated as a symmetrical one. Namely, the distances between ports are the orthodrome in both directions while the initial orthodrome courses are different for the opposite directions. The matrix representation of the orthodrome distances between each pair in given set of ports is presented in table 2. The distances are given in nautical miles [Nm] and it is clear that it is not possible to sail from a certain port to itself, that is $d(i,j) = \infty$, if $i = j$. Since it is not possible to represent ∞ in a proper way within the algorithm, this has been achieved by replacing ∞ with zero values. Finally, by the application of in the paper proposed mathematical adaptation of the Hopfield-Tank neural algorithm, the exact optimal TSP solutions, for the cases when $1,2,\ldots,14$ ports are to be visit, have been found and given in table 3. It is to be pointed out that the number of possible combinations in the last case is even $(14-1)!/2 = 3113510400$.

Table 2. The distances between ports [Nm] – symmetrical problem

[Nm]	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
P_1	∞	81.53	143.45	223.97	286.20	272.79	165.45	133.39	105.97	102.41	122.00	138.56	263.94	201.87
P_2	81.53	∞	67.34	153.26	215.40	191.28	100.66	81.46	94.30	100.61	45.65	63.25	182.41	125.10
P_3	143.45	67.34	∞	86.49	148.25	136.81	111.97	130.94	150.94	159.91	21.89	5.20	130.47	104.18
P_4	223.97	153.26	86.49	∞	62.47	110.15	178.20	213.76	235.52	245.18	107.66	90.12	112.12	145.27
P_5	286.20	215.40	148.25	62.47	∞	118.21	228.88	271.91	294.72	304.90	169.75	152.15	126.11	187.19
P_6	272.79	191.28	136.81	110.15	118.21	∞	150.61	212.31	237.77	249.82	154.83	141.98	12.34	97.55
P_7	165.45	100.66	111.97	178.20	228.88	150.61	∞	67.72	92.40	104.70	106.15	112.95	138.52	53.66
P_8	133.39	81.46	130.94	213.76	271.91	212.31	67.72	∞	25.50	37.70	114.47	129.11	200.77	119.14
P_9	105.97	94.30	150.94	235.52	294.72	237.77	92.40	25.50	∞	12.32	132.76	148.56	226.26	144.47
P_{10}	102.41	100.61	159.91	245.18	304.90	249.82	104.70	37.70	12.32	∞	141.04	157.28	238.36	156.77
P_{11}	122.00	45.65	21.89	107.66	169.75	154.83	106.15	114.47	132.76	141.04	∞	17.60	147.54	109.24
P_{12}	138.56	63.25	5.20	90.12	152.15	141.98	112.95	129.11	148.56	157.28	17.60	∞	135.58	107.47
P_{13}	263.94	182.41	130.47	112.12	126.11	12.34	138.52	200.77	226.26	238.36	147.54	135.58	∞	85.33
P_{14}	201.87	125.10	104.18	145.27	187.19	97.55	53.66	119.14	144.47	156.77	109.24	107.47	85.33	∞

The obtained results have been presented through the optimal round tour, its total length and required time for its determination and given in table 3. While in the figure 6 are given the Hopfield-Tank neural network outputs in the case of optimal solution for fourteen ports, as well as, the scheme of linear ship's optimal route for the given ports arrangement. It is to be mentioned that all results are obtained by running executable Free Pascal programs on a 600 MHz Pentium 2 machine with 192 MB of RAM operating under Windows 2000 system. By the obtained optimal TSP results it becomes possible to calculate Hopfield-Tank recurrent neural network energy minimum and related weight vector (table 4). This is of great importance since it allows the Hopfield-Tank neural network usage in finding the approximately optimal solutions for the similar distances between each pair of ports to those in the given example. Thus, we are in position to use this neural network for solving almost the same problem, with satisfying accuracy, when deviations and other corrections are involved in the calculations of the distances between ports.

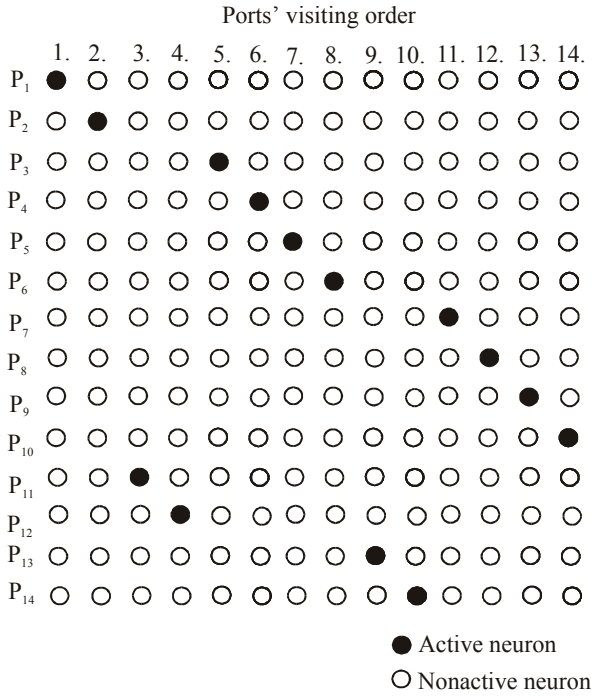
On the basis of the proposed method for solving TSP we are in position to solve successfully linear ship's routing problem. But it must be pointed out that it is still only one of many much more complex problems that must be solved previously, as well. Among these problems the most important are scheduling problems, supply and demand requirements, the optimal speed and weather routing, the optimal loading (unloading) problems, etc. Solving some of these problems separately or in combination undoubtedly requires the appropriate modifications of Hopfield-Tank TSP model. These modifications might be realized by adding for example some benefit, risk or cost coefficients to the route legs' distances in aim to emphasize how a certain route legline is convenient or not. After the proper modifications have been realized, it can be possible to apply here proposed TSP method, in the same or very similar manner, at the final stage of solving real, much more complex linear shipping problems.

Table 3. The optimal round tours and required time for their determination

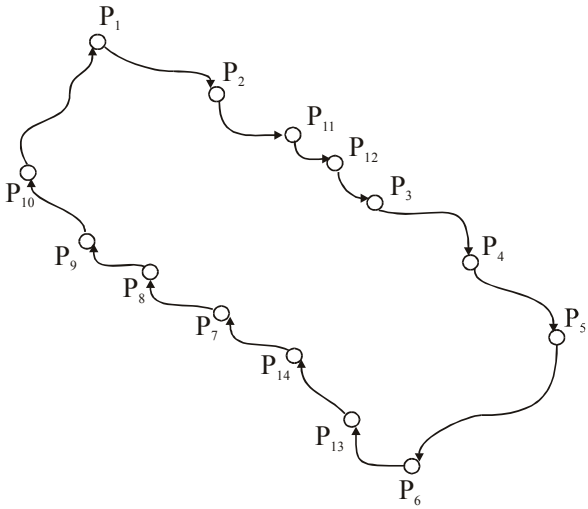
Number of ports	The optimal tour	Total distance [Nm]	Required time [sec]
1	-	-	-
2	1-2	81.533	0.000
3	1-2-3	148.875	0.000
4	1-4-3-2	459.335	0.000
5	1-2-3-5-4	583.572	0.000
6	1-2-6-5-4-3	683.448	0.010
7	1-2-3-4-5-6-7	732.117	0.000
8	1-2-3-4-5-6-7-8	767.781	0.010
9	1-2-3-4-5-6-7-8-9	765.859	0.060
10	1-2-3-4-5-6-7-8-9-10	774.625	0.540
11	1-2-11-3-4-5-6-7-8-9-10	774.833	5.880
12	1-2-11-12-3-4-5-6-7-8-9-10	775.750	70.620
13	1-2-11-12-3-4-5-6-13-7-8-9-10	776.010	896.130
14	1-2-11-12-3-4-5-6-13-14-7-8-9-10	776.485	12 289.430

Table 4. The Hopfield-Tank network energy minimum and the optimal weight vector in the case of fourteen ports

Number of ports		14	
Energy minimum		-194121.25	
Weight vector			
w [1,2]	-40966.50	w [6,13]	-6371.50
w [2,11]	-23028.50	w [13,14]	-42867.50
w [11,12]	-9002.00	w [14,7]	-27034.00
w [12,3]	-2803.00	w [7,8]	-34061.00
w [3,4]	-43445.00	w [8,9]	-12950.50
w [4,5]	-31435.50	w [9,10]	-6360.50
w [5,6]	-59308.50	w [10,1]	-51408.50



a) The layout of the Hopfield-Tank neurons' outputs



b) The scheme of the linear ship's optimal route

Fig. 6. The TSP optimal solution in the case of fourteen ports arbitrary chosen on the Earth north-east hemisphere

7. Conclusions

The adaptation of the Hopfield-Tank TSP neural network algorithm to the linear ship's route modeling problem, in the mathematical sense, has been examined in some details. The main differences between classical and here presented TSP are that nodes of the network are given in sphere coordinates (by longitude and latitude) and that distances

between them are not linear but nonlinear (orthodrome). The numerical results for the optimal linear ship's round tour, the energy minimum of the Hopfield-Tank neural network and the appropriate weight vector have been given for the case of enough large number of arbitrary chosen ports on the Earth north-east hemisphere. Once trained Hopfield-Tank network for a certain number of nodes, can be used for successful determination of the nearest solution to the optimal one or those that are very near to the optimal one for distances between ports being changed for the values of deviation or some other route corrections.

Although this approach is rather theoretical than practical in nature, it could be undoubtedly useful one in some kind of combination with the restrictions like demand between port pairs, weather and speed conditions are, even in the practical linear ship's route modeling. Namely, some route legs might have a certain priority over the others from some reasons. By adding to the each route legline some benefit, risk or cost coefficients, in aim to emphasize how they are convenient or not, it becomes possible to modify properly the proposed ship's routing model based upon Hopfield-Tank TSP neural algorithm.

It must be concluded, as well, that there is yet no algorithm capable of finding the optimal solution for the TSP without suffering from exponentially growing complexity. Thus, the further research work in this field, in general, independently of linear ship's route modeling, should be oriented toward efficient pruning methods for search tree, that is to some kind of branch and bound method, or to the usage of fast algorithms for generating lexicographical permutations to cut a running time for TSP algorithm.

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6.2. Modifying Hopfield -Tank TSP neural algorithm by a heuristic method

This research work considers determining the round tour that is near to the optimal one, by application of the Hopfield-Tank neural network algorithm adaptation for solving well-known traveling salesman problem (TSP). The mathematical approach to the Hopfield-Tank TSP neural algorithm realisation and exploitation proposed in the study is primarily based upon the fast insertion heuristics. This will help in finding the order of the visiting points in the tour that is near to the optimal, or in the best case, the optimal one.

1. Introduction

The traveling salesman problem (TSP) involves a person who must visit a number of points determined beforehand and then return to the starting point. At the same time, the traveling distance must be as minimal as possible. This problem is known as non deterministic (NP) -hard [1] and lots of effort is done due to its simplicity, that is, not to find the shortest tour but a tour that is reasonably short [2]. The TSP arises in distribution management, in scheduling, in routing and in manufacturing. In most cases, it occurs as a sub problem for the vehicle's and the linear ship's routing problem [3, 4, 5]. In this paper, we will reduce this problem to the Euclidian symmetric TSP, where the points are represented with the appropriate coordinates in the 2D plane.

The Hopfield-Tank recurrent neural network application to the TSP is undoubtedly an interesting methodology for solving this problem. It must be pointed out that the TSP approach based upon neural networks is in a way more sophisticated than binary programming, e.g., since it reduces the number of boundaries, that is enables easier sub cycles dismissing. Thus, hereinafter we shall consider the possibility of the fast heuristic strategy implementation into the Hopfield-Tank neural network approach to solving TSP.

2. The TSP heuristics: An overview

The term heuristics is commonly used for algorithms which find solutions among all possible ones. However, usage of heuristic does not guarantee that the best solution will be found; therefore this algorithm may be considered as approximate and not completely accurate one. The heuristic algorithms usually find a solution close to the best one and they find it fast and easily. Sometimes they can be accurate, i.e. they actually find the best solution, but the algorithm is still treated as heuristic until the best solution is proven to be the best [6]. Among available heuristics we can distinguish construction heuristics, nearest neighbor heuristic, insertion heuristics, saving heuristic, etc. The insertion heuristic will be applied here. It means that the starting tour has three points, in the case of symmetrical TSP, while a new insertion point is usually inserted into the tour at the place that causes the minimal increase in the length of the tour. This recipe will be followed in the example presented in the paper.

3. The proposed heuristic strategy

The heuristic strategy is a method of solving difficult optimization problems. In the paper we observe a problem that is easy to understand. However, it is almost impossible for computer algorithm to locate the optimal solution, since number of possible solutions to investigate is enormous. Accordingly, it is convenient to use a strategy that will reduce the number of possibilities to examine.

Let us suppose that we have a tour formed of k points and that this tour has the optimal total length. If we remove a point marked as k - th, we will produce a tour with $k-1$ points, but a total traveling distance of this tour is not necessarily the optimal. Generally it

is just near to the optimal one. In this paper we do thing backwards, from tour with $k-1$ points we generate a tour with k points, by inserting a point k - th in previous tour, but using one restriction: point k - th must be inserted only before or after $(k-1)$ - th point*. The rule for distance calculation if a point k is inserted between points i and j is: increase a total tour length formed previously by the value $D(i,k) + D(k,j) - D(i,j)$.
Table 1 offers a symmetric distance matrix obtained for 5 arbitrary chosen points in 2D plane aiming to explain the heuristic approach that will be used in the paper.

Table 1. The distance matrix for 5 sample points

	1	**2**	**3**	**4**	**5**
1	0.000	0.854	1.421	1.803	1.676
2	0.854	0.000	0.806	0.990	0.825
3	1.421	0.806	0.000	0.608	0.922
4	1.803	0.990	0.608	0.000	0.510
5	1.676	0.825	0.922	0.510	0.000

Let's suppose that points 2 and 3 are adjacent in the tour. Then we should read a matrix entry at position (2, 3) with distance 0.806 and involve it in calculation of total tour distance. Then suppose that a starting tour was 1, 2,3,4,5. In that case a total distance was 0.854 + 0.806 + 0.608 + 0.510 + 1.676 = 4.454. We will now show that the proposed heuristic will reduce a total tour distance. So, let us explain a heuristic that will form another tour with reduced total length. Firstly, the tour 1, 2, 3 is created with total distance 3.081. Point number 4 must be added to the tour. It can be done by inserting it next to point 1, point 2, or point 3. Suppose that we attempt to do an insertion between points 2 and 3. In this case a graph of this insertion is shown in Figure 1.

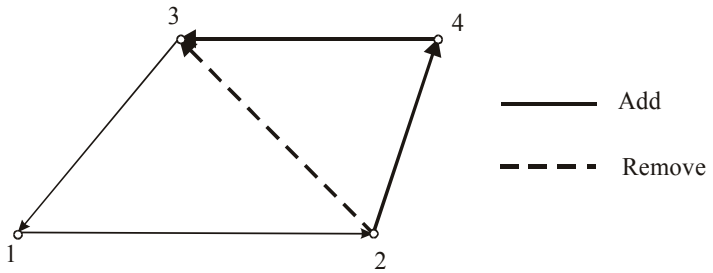


Fig. 1. The point 4 insertion and manipulation with distances

It is obvious that we must remove edge between points 2 and 3 (or precisely, subtract a distance D(2,3) from total tour distance) and add edges between points 2 and 4, as well as, between points 4 and 3 (that means that the distances D(2,4) and D(4,3) must be added to the total distance of so far formed tour), as we described above in formula for distance manipulation when point is inserted in the tour. We can calculate the distances of three possibilities being mentioned before, by adding the new distances as shown in Figure 1 and by subtracting the old ones, in the following way:

$$D(1, 4, 2) = 1.803 + 0.990 - 0.854 = 1.939$$

$$D(2, 4, 3) = 0.990 + 0.608 - 0.806 = 0.792$$

$$D(3, 4, 1) = 0.608 + 1.803 - 1.421 = 0.990$$

Since, point 4 is adjacent to point 1 in two cases with distances 1.939 and 0.990 (as well as, it is adjacent to points 2 and 3 in two cases with different distances), we will produce an insertion cost matrix with minimal value of these two calculated values, though we try to minimize the total distance function. Previously, for three points, total distance was 3.081, so it must be added to calculated minimums, as it has been shown in Table 2.

Table 2. The insertion costs for point 4 insertions at different positions

	4
1	4.071
2	3.873
3	3.873

Thus, until now, all the cases, in which points 1, 2, 3 and 4 are used, have been considered and the results for tours lengths when point 4 is adjacent to points 1, 2 and 3 are given in table 2. According to this, we can obtain a tour with point 5 insertion, since it has to be next to point 4, as the previously mentioned rule, marked by *, described. Let's calculate, now, the cost of point 5 insertions:

$$D(1, 5, 4) = 1.676 + 0.510 - 1.803 = 0.383$$

$$D(2, 5, 4) = 0.825 + 0.510 - 0.990 = 0.345$$

$$D(3, 5, 4) = 0.922 + 0.510 - 0.608 = 0.824$$

Here is a new table - Table 3, formed by insertion of point 5.

Table 3. The calculated distances after point 5 insertion

	4	**5**
1	4.071	4.454
2	3.873	4.218
3	3.873	4.697
		4.218

Evidently (Table 3), the shortest tour in which city 2 is adjacent to city 5, is formed by inserting city 5 into the shortest tour where city 4 is adjacent to city 2. The entry 4.218 is obtained by adding total distance 3.873 to calculated value D (2, 5, 4) which is equal to 0.345. The shortest tour produced so far, has 5 points and has length equal to minimum value in the last column of Table 3 and it is located in last entry of this column, too. In the algorithm we must memorize this entry index, thus the aim is to generate the tour itself after finishing the whole heuristic process. In our example the index is 2, since minimal value is in second row of the last column. Now, we can generate the tour itself, using backtracking. To generate a tour, examine the memorized index, which was 2, so the point 5 must be inserted between points 2 and 4, which implies that in previous step point 4 must be next to point 2. To determine what is an exact position of this point we will

compare distances D(1,4,2) and D(2,4,3) and observe that second one is smaller, since it is 0.792, so the conclusion is that point 4 must be put between point 2 and point 3. So, the final tour is now 1, 2,5,4,3 with total distance: 0.854 + 0.825 + 0.510 + 0.608 + 1.421 = 4.218, as it is pointed out in the last entry of Table 3.

Let's summarize the described algorithm, in a more formal way:

1. Randomize the point order in a starting tour, and calculate the total distance;
2. Form a tour from first tree points;
3. Run a heuristic on the formed tour;
4. If a new produced tour has smaller length then starting tour from step 1, go to step 3 and run a heuristic with this new tour, otherwise go to step 5;
5. Go back to step 3 but use the next point from a starting tour as a starting point for heuristic and
6. If there is no improvement after running a heuristic with all points from starting tour as a starting point, then note the current tour as a possible optimum.

It is to be pointed out, that the here proposed heuristic approach to TSP, shall be implemented into Hopfield-Tank neural network. In 1980's, Hopfield and Tank showed how the TSP can be solved by recurrent neural network. The first step was to map the problem onto the network so that solutions correspond to states of the network. Thus, the problem for P points may be coded into a P by P network as follows: each row of the net corresponds to a point, and the ordinal position of the point in the tour is given by the point at that place outputting a high value (nominally 1) while the rest are all at very low values (nominally 0) [7]. In accordance with previously considered tour length of 5 points, the layout of the Hopfield-Tank neurons' outputs in the case of the optimal solution is shown in Figure 2.

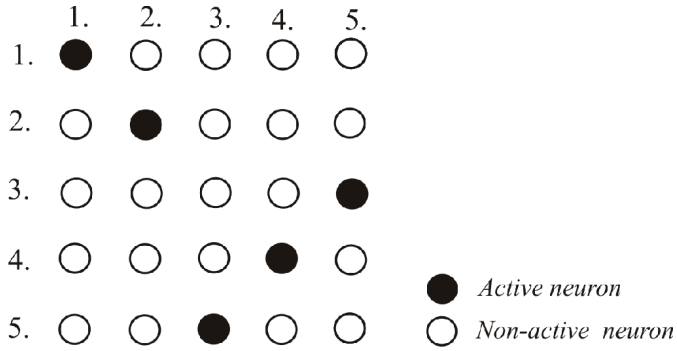


Fig. 2. The Hopfield-Tank neural network outputs' for the working example

By mapping the insertion heuristic solution onto the scheme of Hopfield-Tank neurons output state, the network optimal weights and energy minimum shall be easily calculated. Thus, the network with the same or similar weights can be used efficiently later as a solver for the TSP with similar distances between points.

4. The algorithmic approach to the Hopfield-Tank network TSP adaptation

The traveling salesman problem (TSP) is a classic example of a non deterministic polynomial (NP*)* complete problem, as previously mentioned. A problem is assigned to the NP class in case it is verifiable in polynomial time by a non deterministic *turing machine*. A problem is said to be NP hard if an algorithm for solving it can be translated into one for solving any other NP problem. A problem, which is both NP and NP hard, is called a NP complete problem. Essentially, the only way known to solve NP complete problem, is to compute the costs (here distances) of all tours [8].

So, there are a few assumptions in this paper:

1. P represents the number of points, and mark the points with numbers $1,2,3,\ldots,P$. Points (or nodes) are represented as coordinates in the 2D plane;
2. We calculate the distances between *P* points according to formula $d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$ where (x_i, y_i) and (x_j, y_j) represent coordinates of two points marked with i and j, with calculated distance d_{ij}. The distances d_{ij} are stored in a matrix of distances that specify the non-negative distances between any pair of points. This matrix is symmetrical: for each pair $(i, j) \in P \times P$ distance between point i and point j is the same as the distance between point j and point i. All entries in the matrix have the same distance and the distances on the main diagonal are set to zero.
3. Each point must be visited once and no point can be skipped.
4. The goal is to find a tour t that minimizes the expression $d(t) = \sum_{i=1}^{P-1} d(t_i, t_{i+1}) + d(t_1, t_P)$.
5. It is not important which point will be the first one in the resulting tour, since we can rearrange the optimal tour to start from the desired one. If $P = 5$ and the optimal tour is e.g. 1 5 3 2 4, then if it is necessary to start from node 3, the rearranged tour is 3 2 4 1 5.
6. It is clear that it is not possible to visit a certain point from itself, so that is $d(i, j) = \infty$, if $i = j$. Since it is not possible to represent ∞ in a proper way within the algorithm, this has been achieved by replacing ∞ with zero values.

If there are *P* points, then there are *(P-1)! /2* possible tours, so the number of tours to be checked grows very large and very quickly. The process of exploring all tours is called a "brute force" approach or exhaustive search. The number of algorithm runs is enormous, even for small P, so it is convenient to use an approach that will reduce the searching time. Some implementation notes used in the program follow:

1. The tour and the best tour found so far (*BestTour*) will be represented as 0 - 1 matrix with *P* rows and *P* columns. If number 1 is in matrix on position (i, j), that means that the i-th point is on the j-th position in the tour. Since, the tour is as a mater of fact a permutation of points it is obvious that the tour matrix has a number 1 entry exactly once in every column and every row. Function *TourLength* returns a total tour length of tour defined as function argument.
2. Procedure *CalcDistance* calls for x and y coordinates of all examined points, and then calculates all distances in *DistanceMatrix* according to input coordinates. *DistanceMatrix* contains Euclidian distances between points and it is symmetrical. After

that, when the program is called to store the points, *Tour* is defined with natural order of points, which means, that the first visited point is a point whose coordinates are read firstly.

3. Procedure *RandomizeOrder* is used to randomize starting order of points.
4. Procedure *Shift* execute a left cycle shift by one position of the points in the current tour, so the second entry in the tour becomes the first, the third becomes the second…, and the first entry becomes the last one. In this way, algorithm will examine current tour by starting from the next point. If someone assume that the current tour is 1,2,3,4,5, e. g., *Shift* procedure will produce tour 2,3,4,5,1.

From the main program we have to call the *CalcDistance* procedure to input coordinate values and calculate the *DistanceMatrix*. After that it is important to randomize the order of the inserted points with the *RandomizeOrder* procedure. In that way, we produce a new starting tour, and by the variable *Min* we will store its total cost, that is, its total length. The new generated tour will be used to check if it is better than the one found by the algorithm. It is clear that we assume that the tour is "better" if it has a smaller total length.

The algorithm is running itself recursively appropriate number of times, until the satisfied accuracy is not achieved. It is to be mentioned that the number of the algorithm running times depends rather on points starting order.

5. The numerical example and the simulation results

The problem being considered here is to find the round tour visiting 120 arbitrary chosen points in the 2D plane in accordance with the previously proposed heuristic and its implementation to the Hopfield-Tank TSP neural algorithm. The problem has been treated as a symmetrical one. The number of possible solutions is extremely large, thus, firstly we must test the proposed insertion heuristic on smaller number of points. Since, we have the exact solution for an example of fourteen points obtained by the "brute force" algorithm [9]; we take it as a test problem for the proposed heuristic method. The distance matrix used in the test example is shown in Table 4.

Table 4. The distance matrix for 14 points

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	∞	81.53	143.45	223.97	286.20	272.79	165.45	133.39	105.97	102.41	122.00	138.56	263.94	201.87
2	81.53	∞	67.34	153.26	215.40	191.28	100.66	81.46	94.30	100.61	45.65	63.25	182.41	125.10
3	143.45	67.34	∞	86.49	148.25	136.81	111.97	130.94	150.94	159.91	21.89	5.20	130.47	104.18
4	223.97	153.26	86.49	∞	62.47	110.15	178.20	213.76	235.52	245.18	107.66	90.12	112.12	145.27
5	286.20	215.40	148.25	62.47	∞	118.21	228.88	271.91	294.72	304.90	169.75	152.15	126.11	187.19
6	272.79	191.28	136.81	110.15	118.21	∞	150.61	212.31	237.77	249.82	154.83	141.98	12.34	97.55
7	165.45	100.66	111.97	178.20	228.88	150.61	∞	67.72	92.40	104.70	106.15	112.95	138.52	53.66
8	133.39	81.46	130.94	213.76	271.91	212.31	67.72	∞	25.50	37.70	114.47	129.11	200.77	119.14
9	105.97	94.30	150.94	235.52	294.72	237.77	92.40	25.50	∞	12.32	132.76	148.56	226.26	144.47
10	102.41	100.61	159.91	245.18	304.90	249.82	104.70	37.70	12.32	∞	141.04	157.28	238.36	156.77
11	122.00	45.65	21.89	107.66	169.75	154.83	106.15	114.47	132.76	141.04	∞	17.60	147.54	109.24
12	138.56	63.25	5.20	90.12	152.15	141.98	112.95	129.11	148.56	157.28	17.60	∞	135.58	107.47
13	263.94	182.41	130.47	112.12	126.11	12.34	138.52	200.77	226.26	238.36	147.54	135.58	∞	85.33
14	201.87	125.10	104.18	145.27	187.19	97.55	53.66	119.14	144.47	156.77	109.24	107.47	85.33	∞

The algorithm has been tested for 5000 different starting tours randomly selected from (14-1)!, i.e. 3 113 510 400 possible tours. The obtained results are extremely good: the optimal tour length of 776.485, with points visiting order: 1, 2, 11, 12, 3, 4, 5, 6, 13, 14, 7, 8, 9, 10 (obtained by the "brute-force" algorithm, after 12 289.430 sec) is found in over 3 651 cases, which is 73.02% of all tested cases . The worst found tour was 4, 6, 5, 13, 14, 7, 1, 9, 8, 10, 2, 11, 12, 3 of 1078.269 total length and it was achieved in only one case when starting tour was: 7, 3, 13, 5, 12, 2, 10, 14, 11, 1, 4, 9, 6, 8. The promising fact is that only in 69 cases tour length is out of 10% range from the optimal one.

As obvious, the heuristic algorithm gives good results for small number of visiting points, thus, we can assume that it will give good results for larger number of points, as well. But it is still rather an assumption than a guarantee.

Now, let's take into consideration our primary problem of finding the best tour for 120 points. The distribution of points in the 2D plane used as an example and test problem for the proposed insertion heuristic algorithm is shown in Figure 3.

If we examine the natural tour, formed by connecting points in order as they are marked, in Figure 3, it can be calculated that the total distance of the tour is 91.19. It is to be pointed out that the number of possible combinations in the case of 120 points is (120-1)! /2, if "brute-force" algorithm is used, and that in the paper presented heuristic reduces this number significantly. Namely, two cases have been tested for these 120 points: - when the algorithm starts from natural order of points, that is when points are visited in the order as they arise, and - when the algorithm starts from randomized order of points.

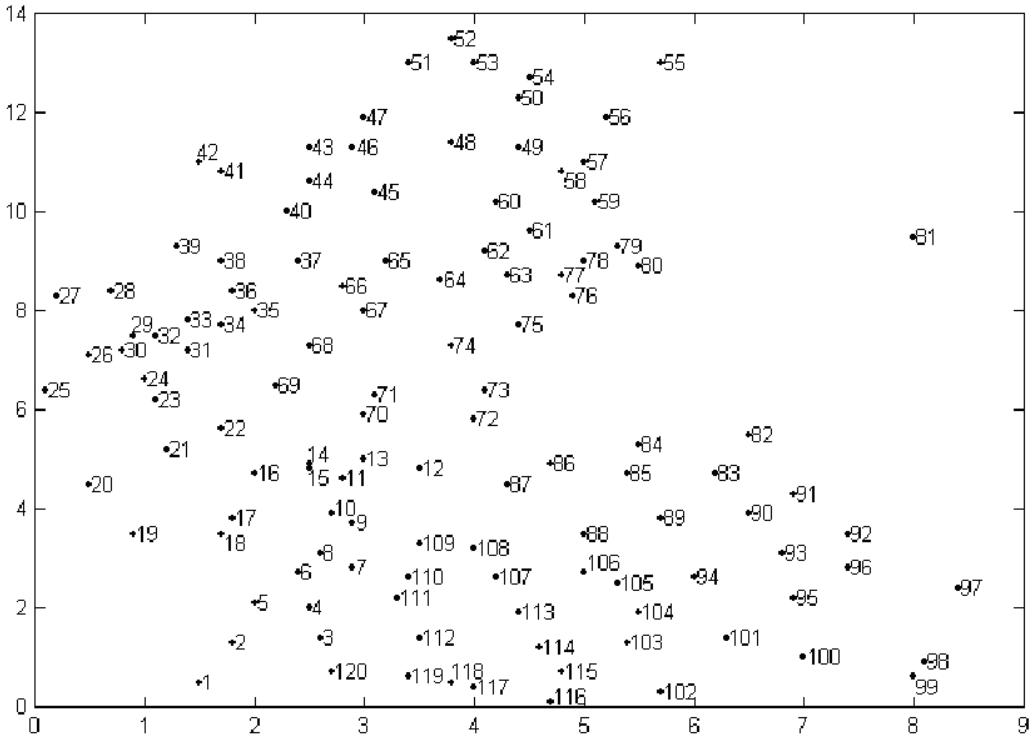
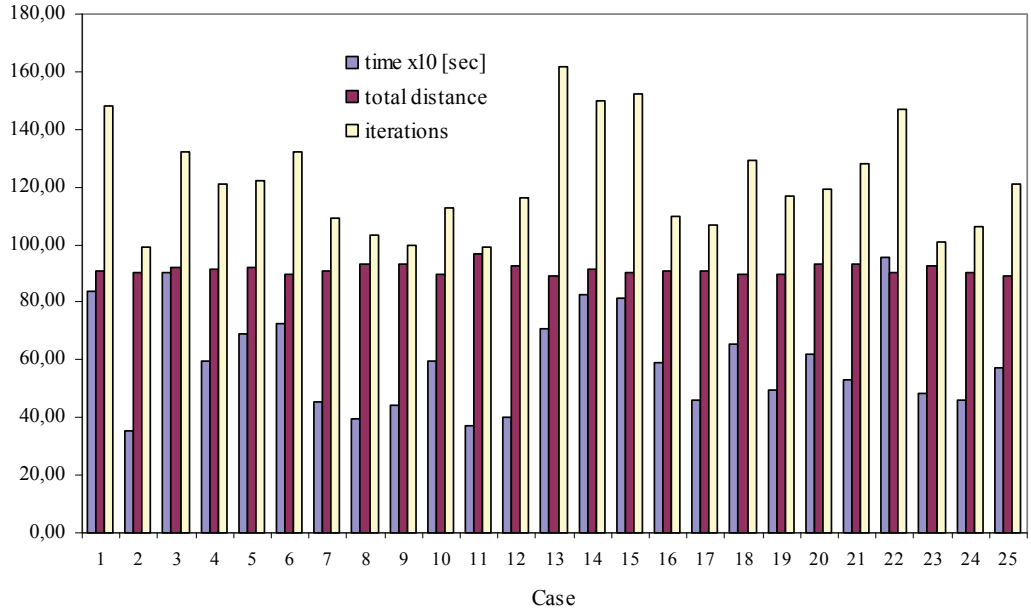
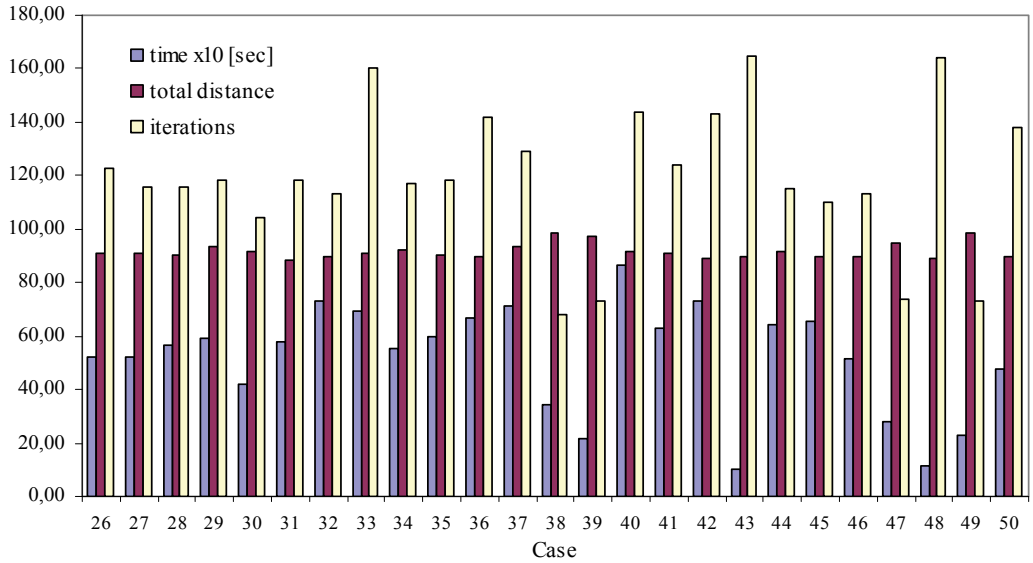


Fig. 3. The points are numbered in order as they are inputted in the algorithm

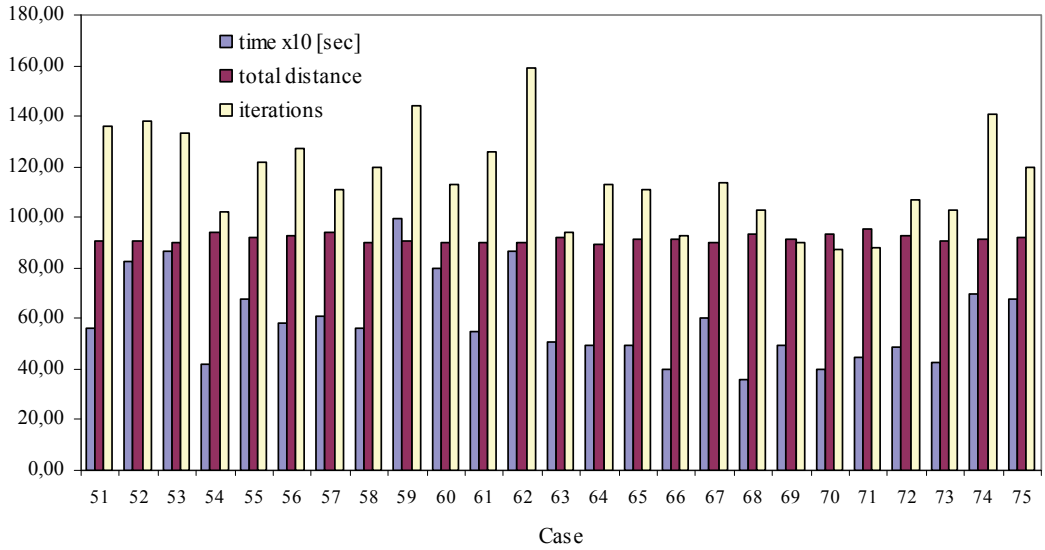
We have presented here graphically the algorithm efficiency through 100 different cases when the algorithm starts from randomized order of points. In each of them 120 previously defined points were used. Our intention was to determine numerical values for running time, number of improvements produced by the algorithm and the total length calculated for the tour that is propagated by the algorithm as "the best tour". These numerical values for all 100 examined cases are given in Figure 4 (4.a, 4.b, 4.c and 4.d).



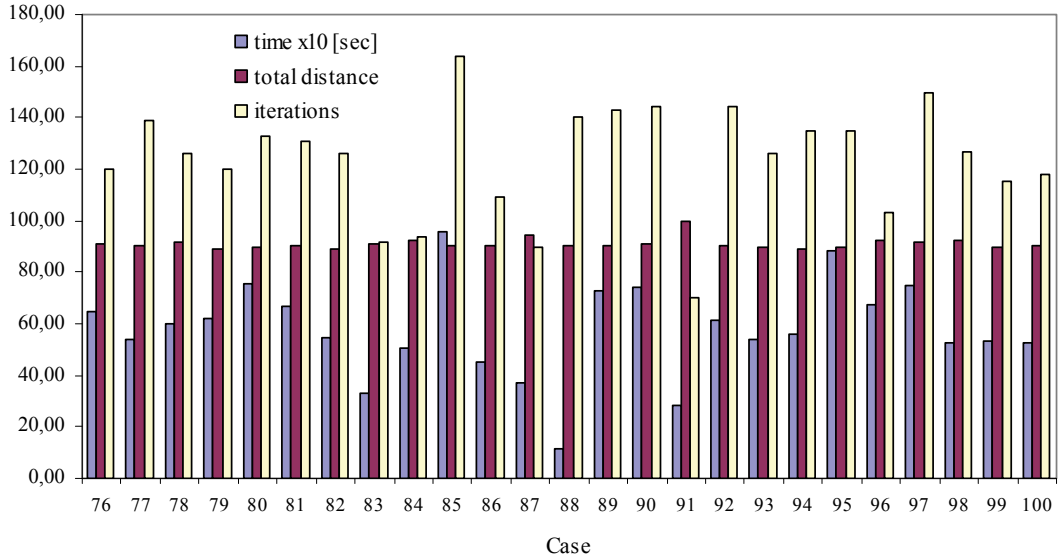
4.a) Cases 1-25



4.b) Cases 26-50



4.c) Cases 51-75



4.d) Cases 76-100

Fig. 4. The results for 120 points in 100 different cases for starting tour

The analysis of the obtained results has been presented through: the average total length of the best found round tours, the average required time for their determination and the average number of improvements being determined by the algorithm and given in Table 5.

Table 5. The numerical results produced by the algorithm for 100 different starting tours

Randomized starting order of 120 points	
Average tour length	91.416
Average time used	6.016 sec.
Average number of improvements	120

Graphically presented solution for the shortest round tour in Figure 5.a), as a scheme of the tour for the given points arrangement, found by running previously discussed algorithm in the case of natural arrangement of points in starting tour. This tour is represented by the characteristic numerical values as given in Table 6.a). Analogically the best found route results for randomized starting tour are represented in Figure 5.b) and Table 6.b).

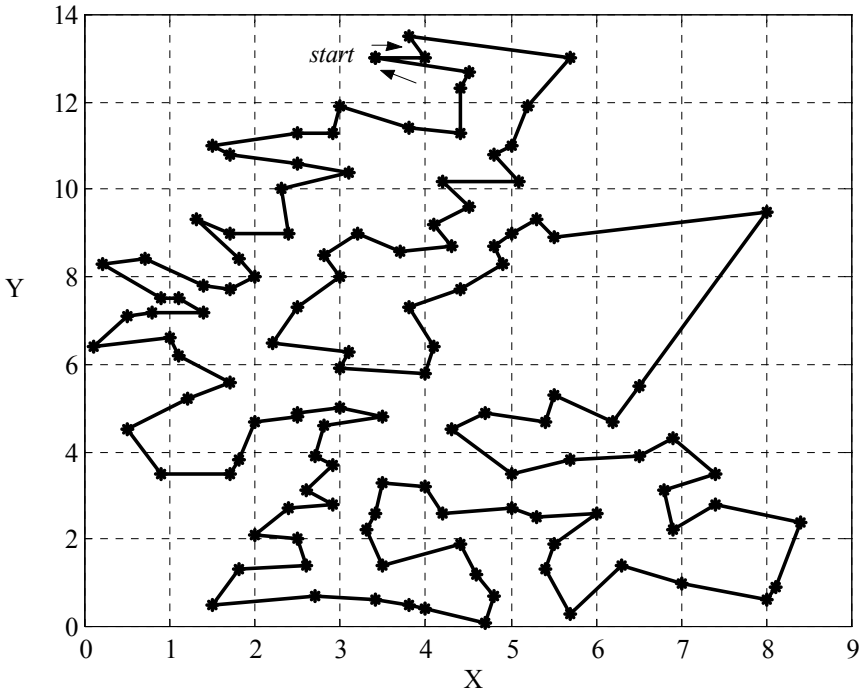


Fig. 5.a) Schematically presented tour generated by the algorithm when natural order is considered: The best tour if a starting tour has natural order of 120 points

Table 6.a) The numeric values for the tour obtained from "natural tour"

Tour length	90.040
Running time	3.260 sec.
Number of improvements	23

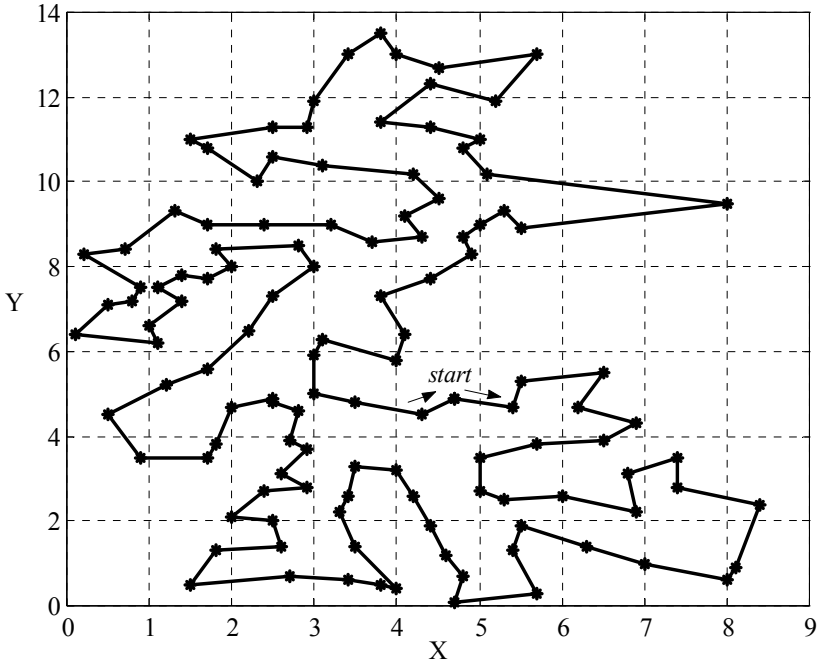


Fig. 5.b) Schematically represented tour produced by algorithm when randomized order is considered: The best tour if a starting tour has randomized order of 120 points

Table 6.b) The numeric values for the best "randomized tour"

Tour length	88.414
Running time	6.210 sec.
Number of improvements	118

The 91st examined case by the algorithm has the longest distance equal to 100.101, and the 59th case has the longest running time with 9.95 sec. The longest distance is about 14% greater then the optimal one. The best tour is found in the 31st analyzed case. This tour is obtained after 118 improvements of starting tour and after 6.210 sec. Total tour length is 88.414. Now, since we have shown experimentally the efficiency of proposed heuristic in finding the optimal tour, or the tour that is very close to the optimal one, within the next section we shall implement, in this way obtained, the best tour to the Hopfield-Tank neural network. Namely, according to the best obtained points visiting arrangement, the network weight coefficients are to be calculated, as well as, the network energy minimum.

6. The proposed heuristic implementation to the Hopfield-Tank neural network

The neural networks are very important in many scientific disciplines in solving previously *unsolvable* problems, as the TSP of larger dimensions is. Among many neural network schemes that have been proposed and investigated, the Hopfield-type neural network remains an important one due to its applicability in solving associative memory,

pattern recognition, and optimization problems, with ease of integration technology implementation [10].

Namely, the Hopfield-Tank neural network optimization algorithm is based on the fact that weights of the network are to be made so that the optimal solution is located in the lower energy area of the state space. In other words, the neural network optimization problem is based upon minimization of energy function given by (1):

$$E(x) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}x_i x_j + \sum_{i=1}^{N}\theta_i x_i \tag{1}$$

where x_i - state of the *i*-th neuron; θ_i - threshold of the *i*-th neuron and w_{ij} - weight of the connection from the *j*-th neuron to *i*-th neuron ($w_{ij} = w_{ji}$). A candidate of the solution is represented by one of the state vectors $x = (x_1, x_2, \ldots, x_N)$. The energy function (1) consists of two parts, cost (2) and penalty (3):

$$E_c(x) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}^{(c)}x_i x_j + \sum_{i=1}^{N}\theta_i^{(c)}x_i \tag{2}$$

$$E_p(x) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}^{(p)}x_i x_j + \sum_{i=1}^{N}\theta_i^{(p)}x_i \tag{3}$$

Both of them, in addition, are to be reduced as much as possible, according to the aim of $E(x)$ minimization. The second one is to be reduced to zero in the optimal solution. The TSP of P points may be coded into P-by-P network. Each row of the network corresponds to a point and the ordinal position of the point in the tour is given by the node at the place outputting a high value (i.e. one), while the rest are all at very low values (i.e. zero). The nodes of the network are unipolar sigmoidal activation units where *ai*-th unit has output $x_{ai} = 1$, if, and only if, node *a* is visited *i*-th in the tour and output $x_{ai} = 0$, if *a* is not visited *i*-th in the tour [6,7]. The distance between nodes (or, points) a and b is denoted as d_{ab} and the energy function, that is its cost part, takes the form (4):

$$E_c(x) = \frac{D}{2}\sum_{a}\sum_{b\neq a}\sum_{i} d_{ab}x_{ai}\left(x_{b,i+1} + x_{b,i-1}\right) \tag{4}$$

where indexes are cyclic, that is $P+1=1$, $1-1=P$, and D is positive constant. Constrains that must be satisfied are: only one node can be visited at the same time; each node is visited only once and every node must be visited in the tour. These constrains could be formulated in the following way (5):

$$E_p(x) = \frac{A}{2}\sum_{a}\sum_{i}\sum_{j\neq i} x_{ai}x_{aj} + \frac{B}{2}\sum_{i}\sum_{a}\sum_{b\neq a} x_{ai}x_{bi} + \frac{C}{2}\left(\sum_{a}\sum_{i} x_{ai} - P\right)^2 \tag{5}$$

where A, B and C are positive coefficients. From the energy function weight matrix can be obtained (6):

$$w_{aibj} = -A\delta_{ab}(1-\delta ij) - B\delta_{ij}(1-\delta_{ab}) - C - Dd_{ab}(\delta_{j,i+1} + \delta_{j,i-1}) \qquad (6)$$

where $\delta_{i_1 i_2} = 1$, if $i_1 = i_2$ and $\delta_{i_1 i_2} = 0$, if $i_1 \neq i_2$. In accordance with original Hopfield and Tank adaptation coefficients A, B, C and D take values 500, 500, 200 and 500, respectively. The energy minimum corresponds to the solution of the problem. Thus, by the obtained TSP results within the previous section, that is by the optimal obtained related zero-one matrix on the basis of the proposed insertion heuristic, it becomes possible to calculate easily Hopfield-Tank recurrent neural network energy minimum and related weight vector [9, 10]. The results for the network energy minimum and weight coefficients, in the case of the best order of visiting points being found in the 31st iteration of 100 analyzed cases for 120 points, are given in Table 7. More precisely, the best obtained TSP solution by the proposed heuristic corresponds to the optimal Hopfield-Tank neural network outputs, that is, to the optimal scheme of active and non-active neurons in $P \times P$ neural network layout.

Table 7. The Hopfield-Tank network energy minimum and the optimal weight vector in the case of 120 points

Number of points	120		
Energy minimum	-22103.54		
Weight vector			
w[86,85]	-564.0	w[5,6]	-560.6
w[85,84]	-504.1	w[6,7]	-455.0
w[84,82]	-709.9	w[7,8]	-412.1
w[82,83]	-627.2	w[8,9]	-535.4
w[83,91]	-603.1	w[9,10]	-341.4
w[91,90]	-482.8	w[10,11]	-553.6
w[90,89]	-603.1	w[11,15]	-380.3
w[89,88]	-580.8	w[15,14]	-250.0
w[88,106]	-600.0	w[14,16]	-469.3
w[106,105]	-380.3	w[16,17]	-661.0
w[105,94]	-553.6	w[17,18]	-358.1
w[94,95]	-692.4	w[18,19]	-600.0
w[95,93]	-652.8	w[19,20]	-738.5
w[93,92]	-560.6	w[20,21]	-695.0
w[92,96]	-550.0	w[21,22]	-520.2
w[96,97]	-738.5	w[22,69]	-714.8
w[97,98]	-964.9	w[69,68]	-627.2
w[98,99]	-358.1	w[68,67]	-630.1
w[99,100]	-738.5	w[67,66]	-469.3
w[100,101]	-603.1	w[66,36]	-702.5
w[101,104]	-671.7	w[36,35]	-423.6
w[104,103]	-504.1	w[35,34]	-412.1
w[103,102]	-722.0	w[34,33]	-358.1
w[102,116]	-709.9	w[33,32]	-412.1
w[116,115]	-504.1	w[32,31]	-412.1

w[115,114]	-469.3	w[31,24]	-560.6
w[114,113]	-564.0	w[24,23]	-406.2
w[113,107]	-564.0	w[23,25]	-709.9
w[107,108]	-516.2	w[25,26]	-603.1
w[108,109]	-455.0	w[26,30]	-358.1
w[109,110]	-553.6	w[30,29]	-358.1
w[110,111]	-406.2	w[29,27]	-731.5
w[111,112]	-612.3	w[27,28]	-455.0
w[112,117]	-759.0	w[28,39]	-740.8
w[117,118]	-311.8	w[39,38]	-450.0
w[118,119]	-406.2	w[38,37]	-550.0
w[119,120]	-553.6	w[37,65]	-600.0
w[120,1]	-808.3	w[65,64]	-520.2
w[1,2]	-627.2	w[64,63]	-504.1
w[2,3]	-603.1	w[63,62]	-469.3
w[3,4]	-504.1	w[62,61]	-482.8
w[4,5]	-455.0	w[61,60]	-535.4
w[60,45]	-759.0	w[57,58]	-341.4
w[45,44]	-516.2	w[58,59]	-535.4
w[44,40]	-516.2	w[59,81]	-1691.6
w[40,41]	-700.0	w[81,80]	-1485.5
w[41,42]	-341.4	w[80,79]	-423.6
w[42,43]	-722.0	w[79,78]	-412.1
w[43,46]	-400.0	w[78,77]	-380.3
w[46,47]	-504.1	w[77,76]	-406.2
w[47,51]	-785.2	w[76,75]	-590.5
w[51,52]	-520.2	w[75,74]	-560.6
w[52,53]	-469.3	w[74,73]	-674.3
w[53,54]	-491.5	w[73,72]	-504.1
w[54,55]	-818.5	w[72,71]	-714.8
w[55,56]	-804.2	w[71,70]	-406.2
w[56,50]	-647.2	w[70,13]	-650.0
w[50,48]	-740.8	w[13,12]	-469.3
w[48,49]	-504.1	w[12,87]	-627.2
w[49,57]	-535.4	w[87,86]	-482.8

The question is what will be the accuracy of the solutions obtained by the Hopfield-Tank network with these weights for small changes of distances between points in the input distance matrix?

Aiming to show the efficiency of the described heuristic implementation to the Hopfield-Tank neural network approach to the TSP, we make some changes in the input distances matrix in manner that we have changed some randomly chosen points' coordinates. A graphical presentation of the total tour distances distribution (between 88.00 and 100.00 length units) obtained from 100 tested cases with randomized starting order of 120 points set, in which some points' coordinates have been previously randomly changed, is given in Figure 6.

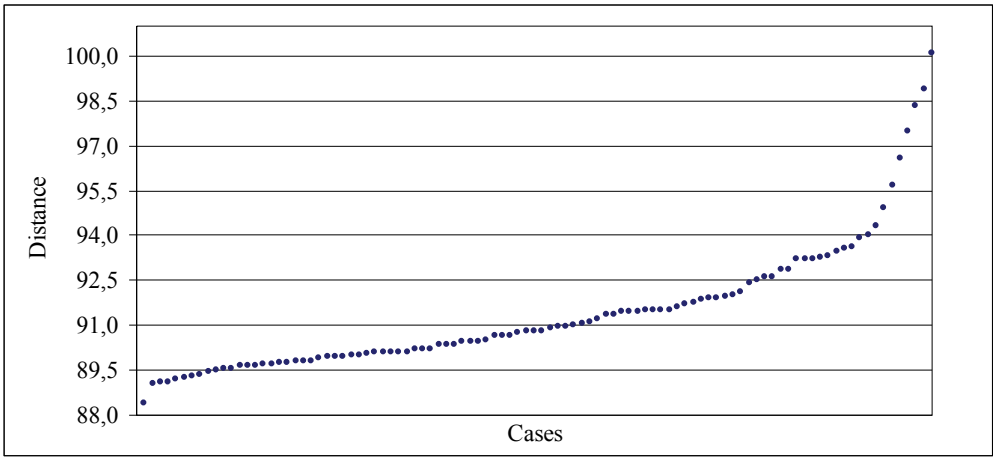


Fig. 6. The distances distribution in 100 different points arrangements

It has been concluded that the most number of distances are distributed in interval 2.9% greater than the optimal one, but less than 4.6% greater than the best tour distance. According to the previously determined optimal tour the intervals are defined in the following way: the lower and upper bound of each interval will be obtained by increasing the distances of the optimal tour by specified percentage. Table 8 shows the number of tours which total lengths are within the given interval, that is, it is showing their deviation from the best tour distance.

The 90% of tours have the distance which is shorter than the tour distance obtained when the best tour distance is increased by 6%. This is of great importance, since, if the algorithm does not find an optimal tour, the best found tour is with great probability near to the optimal one. This fact is exceptionally significant if large number of points is examined when the number of all possible tours is huge and can not be checked on nowadays computers.

Since, the proposed heuristic is here the constitute part of the network, we shall scan the characteristics of the network parameters behavior, when some changes in the input matrix have been done. Commonly, the network behavior can be described in the most suitable manner by its energy and weight. Here, we shall focus our examination on tracking changes in the energy minimum. The obtained results are given in Table 9.

Table 8. The exact number of tours which total lengths are within the intervals with bounds proportionally greater than the shortest distance

Interval	Number of tours
[0%,1%]	7
(1%,2%]	27
(2%,3%]	22
(3%,4%]	17
(4%,5%]	7
(5%,6%]	10
(6%,7%]	3

(7%,8%]	1
(8%,9%]	1
(9%,10%]	1
(10%,11%]	1
(11%,12%]	2
(12%,13%]	0
(13%,14%]	1

Table 9. Changes in energy minimum and total tour length for small changes of some points' coordinates values

Increasing points coordinates values	Randomly chosen points	The absolute values of coordinates changes		The new values of energy minimum	The total tour length
		X	Y		
1%	47	0.030	0.119	- 2.210363194404018E+004	88.41
2%	47	0.060	0.238	- 2.210379539045983E+004	88.42
3%	104	0.165	0.057	- 2.210389745208290E+004	88.42
4%	38	0.068	0.360	- 2.210333261288417E+004	88.41
5%	2	0.090	0.065	- 2.210331254722040E+004	88.41

By changing some points coordinates for small values of 1%, 2%, …, 5%, the network energy minimum stays unchanged or changes for negligible small values. Consequently, the total tour length stays almost unchanged. This makes things much easier since by once generated the optimal Hopfield-Tank network output state, through insertion heuristics, we can calculate faster and in more sophisticate way the optimal tour than by running the proposed heuristic algorithm from its beginning.

7. Conclusions

In the paper has been analyzed the fast heuristic for solving TSP problem and its implementation to the Hopfild-Tank neural network as TSP optimization tool. The combination of this algorithm and constraint solving has an open range of applicability. This algorithm can be effectively used since it generates a worth solution even when it is not the optimal one.

According to the obtained numerical results represented in the paper and produced in aim to analyze the algorithm quality, it can be concluded that algorithm has very good features in case of relatively small number of points. The satisfying results are also obtained for relatively large number of points. A good thing is that great percentage of calculated tour distances is located in small interval around the total length of the best possible tour.

As it has been shown through presented numerical results, it is obvious that the running time of this algorithm depends on starting tour, so different sorting methods of input points can be considered. If it is not so important to obtain a true minimal length tour, it is possible to investigate different heuristic methods which will lead to a tour that is near to the optimal one. The proposed heuristic can be implemented into Hopfield-Tank network, that is, it can be used in obtaining zero-one matrix representing the network optimal outputs layout. On the basis of once obtained the optimal zero-one matrix, the appropriate network weight vector can be calculated and used later for solving TSP with the similar distance matrix.

It is to be concluded, as well, that there is still no algorithm, which can, in general, find the optimal solution for the TSP without suffering from the exponentially growing complexity. Thus, the further research work in this field should be oriented toward efficient pruning methods for search tree. The heuristic strategy is generally much better then the optimization methods, like e.g. branch and bound algorithm is, for the reason that the running time is normally shorter. This is one of the leading motivations to use the heuristic for itself or in combination with the Hopfield-Tank neural network as a particular tool for solving problems with many sub optimal solutions, as in the paper it has been done with TSP.

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6.3. An ANFIS based optimal route selection approach in sea navigation

This research study considers developing the adaptive neuro-fuzzy inference system (ANFIS) based upon functional equivalence between the two-input first-order Takagi-Sugeno-Kang (TSK) fuzzy inference system and radial basis network (RBN). The input values are the linguistic qualifications related to the criteria: the wind strength and the traveling distance, in the long-ocean sailing zone, treated here since they are of up-most importance from the aspects of the traveling safety and efficiency. The output value is the degree of particular traveling direction preference. In the paper considered, hybrid neuro-fuzzy system could be used as a theoretical support for developing the system with power of assistance in preferential sailing direction selection in long-ocean navigation.

1. Introduction

The input data in most of real world selection processes are not always precise. The same is in the case of preferential sailing direction selection in long-ocean navigation. Let's suppose that the mariner needs to navigate the vessel from one port to another one, and that he has a few different sailing directions from which he must choose one. His choice will depend of a large number of parameters, such as the wind strength, the total traveling distance, the traffic density, the fuel consumption, the demand for transport, etc. In aim to simplify this problem, since our work is attended to be rather theoretical then practical, we will be interested only in two criteria: the wind strength and the traveling distance. The parameters related to these two criteria will be in fact the input values for the hybrid neuro-fuzzy system, while the desired output is a numerical value that corresponds to the degree of considered sailing direction preference.

The first step is to define the decision selection rules based on inputs, using experts' knowledge for a certain sailing zone. Here are the two most important rules:

- If the wind strength and the traveling distance are small, than the decision selection will have high value, and
- If the wind strength and the traveling distance are high, than the decision selection will have small value.

Then, an ANFIS is to be designed and trained, in aim to simulate experts' knowledge in the observed sailing area. Finally, the adequate example with numerical and graphical results will be given.

2. The motivation

The question is: Where the motivation for the problem previously defined can actually be found? - An explanation could be the following: now-a-day in order to navigate the vessel from one to another point, in the most efficient way, the mariner uses the actual digital technology of the electronic chart in the same manner as the traditional paper chart. The elements of route planning in electronic chart technology are waypoints and the line legs, which connect the waypoints. While waypoints may stand alone or may be connected to legs, legs are always bounded by waypoints. The leg lines can be constructed for a preplanned speed, while waypoints can carry information about the turning radius of the course change, etc. The leg lines and the waypoints are created in the electronic chart-planning mode. The alternate routes are connected to waypoints to form a network of leg lines that represent all the routes a vessel could use on her voyage. After the alternate routes are planned, the actual route, that is the route which the vessel will use, must be selected. The electronic chart supports this operation with its auto selection

function. If the way through the possible routes net is unambiguous, this function will trace the preferential route automatically. But, if more than one leg departs from a waypoint (Figure 1), then electronic chart's auto selection function asks for the mariner's decision. That is why various decision support methods in preferential sailing direction selection are required and are to be conceived, developed and implemented into up-to-date navigational equipment. This was in a way the motivation for developing the TSK and RBN based ANFIS devoted to the route, that is, its segments preference estimation [1,2,3].

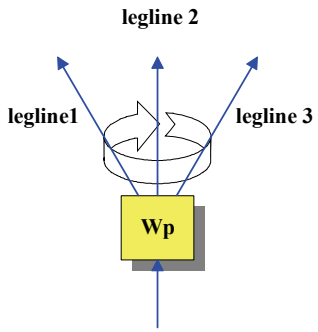

Fig. 1. The case when more then one leg line departure a waypoint

3. Linguistic variables and membership functions

In the cases similar to the previously mentioned one, we often relay on qualitative features, since it is not convenient to consider numerical values in the system input segment. Namely, in such cases the input numerical data are not sufficiently precise. The main problem appears because of the different system users' estimations: someone will characterize the wind as a strength one with number 6 in Beaufort's scale, but someone else will characterize the same wind with number 7 in Beaufort's scale. In aim to resolve this problem and avoid numerical values at the system input part, the linguistics variables are to be introduced into the neuro-fuzzy modeling process.

Thus, the words or the sentences in natural or artificial languages are values of linguistic variables. According to the basic fuzzy rules mentioned in the section one, it is obvious that the inputs should be characterized with at least two linguistic constants: *small* and *high*, but we will incorporate *very small, medium and very high* as new categories in aim to increase the system precision. Each linguistics constant has its own membership function.

Let X be a set of objects, called the universe, whose elements are denoted as x. The membership in a subset A of X is the membership function μ_A from X to the real interval $[0,1]$. The universe consists of various elements which will be of concern in the particular context. A is called a fuzzy set and is a subset of X that has no sharp boundary. The function μ_A is the grade of membership x in A. The closer the value of μ_A is to 1, the more x belongs to A. The total allowable universe of values is called the domain of the fuzzy set. The domain is a set of real numbers, increasing monotonically from left to right where the values can be both positive and negative. A is completely charac-

terized by the set of pairs $A = \{(x, \mu_A(x)), x \in X\}$. The degree of membership is known as the membership or truth function since it establishes a one-to-one correspondence between an element in the domain and a truth value indicating its degree of membership in the set. It takes the form $\mu_A(x) \longleftarrow f(x \in A)$ [4]. There are few commonly used membership functions. In this work we prefer that each input has five membership functions (MF) represented by Gaussian functions given in the following form:

$$f(x) = e^{\frac{-(x-\mu)^2}{\sigma^2}} \tag{1}$$

where μ is the location parameter and represents a MF center and σ is the scale parameter which determines the MF width. The function (1) has maximum equal to one and minimum equal to zero.

4. Fuzzy inference system

The concept of a fuzzy set has been proposed by L. A. Zadeh (1965). Namely, the fuzzy sets were introduced as a generalization of conventional set theory. The fuzzy logic, based upon the fuzzy sets, implements human experiences and preferences via membership functions and fuzzy rules. The fuzzy sets are functions that map a value that might be a member of the set to a number between zero and one indicating its actual degree of membership. A degree of zero means that the value is not in the set, while a degree of one means that the value is completely representative of the set. This produces a curve across the members of the set. The fuzzy models manipulate linguistic variables. A linguistic variable is the representation of a fuzzy space which is essentially a fuzzy set derived from the evaluation of the linguistic variable. It encapsulates the properties of approximate or imprecise concepts in a systematic and computationally useful way. Although a linguistic variable may consist of many separate terms, it is considered as a single entity in the fuzzy proposition. The fuzzy if-then rules or the fuzzy conditional statements are expressions of the form IF A THEN B, where A and B are labels of fuzzy sets characterized by appropriate membership functions [10]. The if-then rules determine the system behavior. A knowledge base, decision making unit, fuzzification interface and a defuzzification interface construct a fuzzy inference system. The knowledge base comprises if-then rules and the appropriate MF associated to the linguistic constants. A decision-making unit performs the inference operations on the rules. The fuzzification interface determines the membership degree of crisp inputs to the linguistic constants, while defuzzification interface transforms the out coming fuzzy result into the crisp output. The basic structure of a fuzzy inference system is presented schematically in Figure 2.

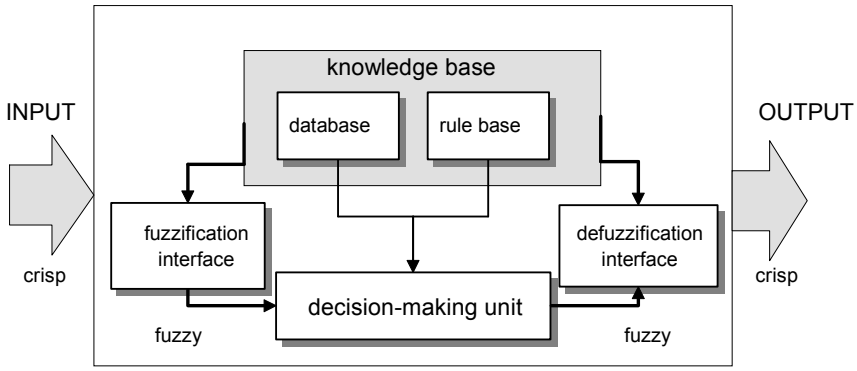

Fig. 2. Fuzzy inference system

The fuzzy inference system performs a fuzzy reasoning (inference operations upon fuzzy if-then rules) through next steps:

1. comparing the input variables with the membership functions on the premise part to obtain the membership values of each linguistic label;
2. combining through a specific T-norm the membership values on the premise part to get firing strength (weight) of each rule;
3. generating the qualified consequent of each rule depending on the firing strength and
4. aggregating the qualified consequents to produce a crisp output.

Several types of fuzzy reasoning have been proposed in the literature [6, 7]. A mathematical model which in some way uses fuzzy sets is called a fuzzy model. Here, we shall use Takagi–Sugeno model with incorporates fuzzy if-then rules where the output of each rule is a linear combination of input variables plus a constant term, and the final output is the weighted average of each rule's output [9]. The first order TSK fuzzy model is outlined in the Figure 3.

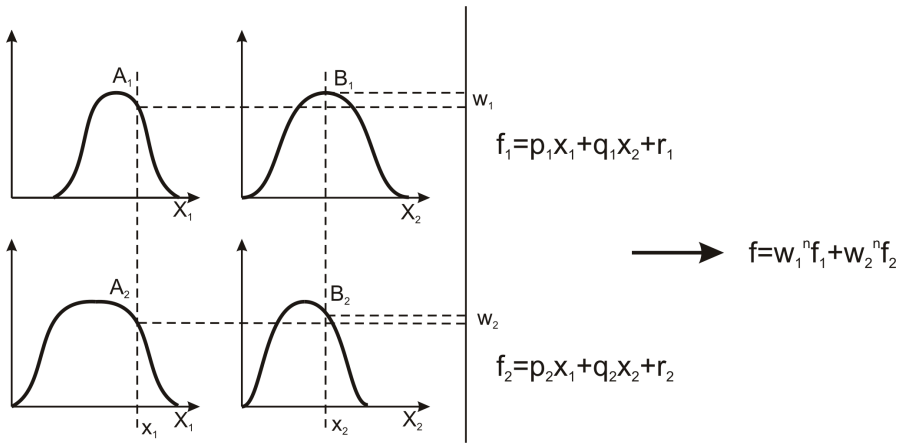

Fig. 3. The Takagi-Sugeno-Kang (TSK) fuzzy inference system

5. The adaptive neuro-fuzzy inference system (ANFIS)

An adaptive network is a multi-layer, feed-forward network in which each node performs a particular node function based on incoming signals, as well as, on the set of parameters related to this node. Namely, each node function depends on the set of parameters which are associated to it. In the training process these parameters are being corrected in the aim of overall error minimization at the output of the network.

The ANFIS is the hybrid neural-fuzzy system. It has the capability of simulating the expert knowledge in the domain for which it has been constructed, on the basis of the expert knowledge represented by the if-then rules, and after the hybrid learning procedure has been realized. Thus, if an unknown input has been represented to the ANFIS, after the hybrid learning process, it can successfully predict the adequate output for the given input.

Now, let's consider our primer problem of route, or its part, preference estimation, and mark the wind strength with x_1, the traveling distance with x_2, and MFs attached to inputs with A_i and B_i respectively, where $i = 1,2,3,4,5$. Our ANFIS is based on Takagi-Sugeno fuzzy inference system [5] and employs fuzzy rules of the next kind: if x_1 is A_i and x_2 is B_i then $f_i = p_i x_1 + q_i x_2 + r_i$, where p, q and r is parameter set of function f. The number of these rules is 25. The ANFIS has five layers where all nodes from one layer have the same functions and its structure is represented in Figure 4.

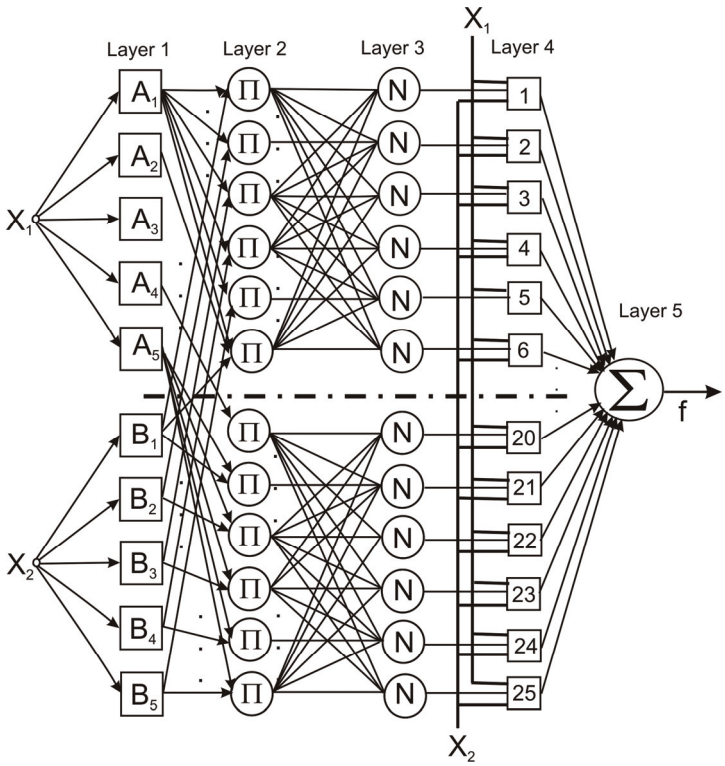

Fig. 4. The ANFIS structure, here used as a navigation decision support tool

Each node represented with a square has a parameter (adaptive nodes), while nodes represented with a ring are fixed (fixed nodes). The parameters related to the adaptive nodes are presented by the set of training data in the learning process.

- Layer 1: The inputs to this layer are crisp values x_1 and x_2. The nodes are implemented as MFs and will determine the degree in which the inputs satisfy the MF. Each Gaussian function depends on its center and spread constant and these parameters are referred to as *premise parameters*.
- Layer 2: The number of the nodes is determined with the number of the fuzzy rules: with 2 inputs and 5 MFs, this layer consists of 25 nodes. The overall output of the nodes is the product of all incoming signals. Any T-norm operator can be used as fuzzy AND operator in this layer.
- Layer 3: The number of nodes in this layer is 25, too. Every node is a fix node and calculates the ratio of the j - th fuzzy rule firing strength (RFS) to the sum of RFS according to formula:

$$\overline{w_j} = \frac{w_j}{\sum_{i=1}^{25} w_i}, \text{ where } j = 1,2,...,25 \tag{2}$$

- Layer 4: Every node in this layer is adaptive node with node function:

$$\overline{w_i} f_i = \overline{w_i}(p_i x_1 + q_i x_2 + r_i), \text{ where } i = 1,2,...,25 \tag{3}$$

and p_i, q_i, r_i are parameters named *consequent parameters*.

- Layer 5: There is only one node that computes the output f of the ANFIS as the sum of incoming signals:

$$f = \sum_{i=1}^{25} \overline{w_i} f_i \tag{4}$$

The premise part of a rule defines a fuzzy region, while the consequent part determines the output within this region. The total number of these regions in case of here considered ANFIS is 25 (Figure 5).

6. The hybrid learning algorithm

The gradient method can identify a parameter in an adaptive network, but its disadvantages are slowness and huge possibility to be troubled in local minimum. This is the main reason why the hybrid learning method, which combines gradient descent and least squares estimate (LSE) methods, has been exploited here.

The ANFIS uses back propagation to learn the premise parameters and least mean square estimation to determine the consequent parameters. In batch learning mode, which we have used in this paper, backward pass and premise parameters update, take place after the whole training data set has been presented to the ANFIS. Namely, premise parameters have been tuned after each epoch.

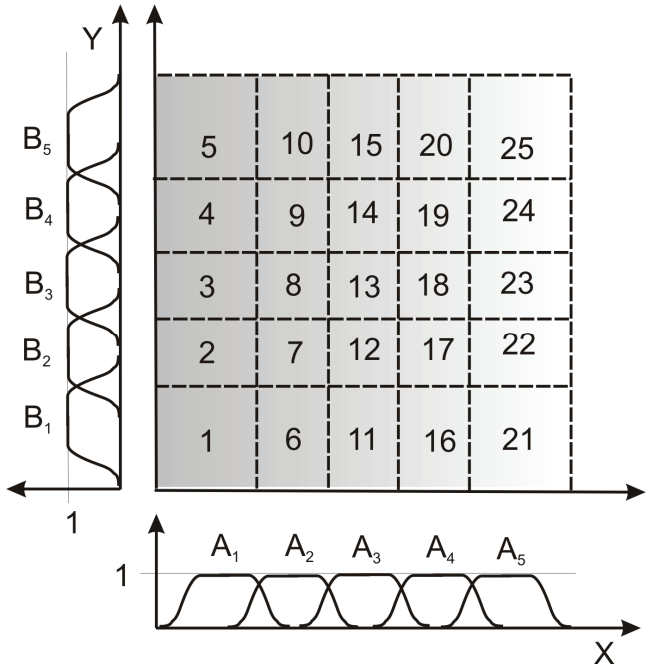

Fig. 5. The partition of the input space into 25 fuzzy regions

Generally, the hybrid learning algorithm in each epoch is developed through two phases: forward pass and backward pass, as it is summarized in the Table 1.

Table 1. The hybrid learning procedure

	Forward pass	**Backward pass**
Premise parameters	Fixed	Gradient descent
Consequent parameters	LSE	Fixed
Signals	Node output	Error rate

In the forward pass a set of training data formed from input values and desired corresponding output value is presented to the system. Layer by layer, every node output is calculated. According to described ANFIS structure, the overall output from the ANFIS can be represented as:

$$f = \sum_{i=1}^{25} \overline{w_i} f_i = \left(\overline{w_1} x_1\right) p_1 + \left(\overline{w_1} x_2\right) q_1 + \left(\overline{w_1}\right) r_1 + \ldots + \left(\overline{w_{25}} x_1\right) p_{25} + \left(\overline{w_{25}} x_2\right) q_{25} + \left(\overline{w_{25}}\right) r_{25} \quad (5)$$

This means that the output is a function of the input variables and the set of parameters. More formally, output can be rewritten as:

$$f = F(I, S) \quad (6)$$

where I is the vector of input variables and S is the set of parameters. This set of parameters can be decomposed in two subsets from the perspective of output: linear parameters and nonlinear parameters. From equation (5) it is obvious that the output is linear in the consequent parameters $\{p_i, q_i, r_i\}$ $i = 1,2,\ldots,25$, so we can apply least squares

method to identify these parameters. Also, after presenting a set of training data to the system, the ANFIS output can be described as matrix equation $A\theta = B$, where θ is an unknown vector whose elements are consequent parameters. The best values for these parameters can be calculated by the least-squares estimator $\theta^* = (A^T A)^{-1} A^T B$ where A^T is the transpose matrix of A. This method can be used if $A^T A$ is nonsingular matrix.

In the backward pass, all consequent parameters are fixed, since their best values are identified in the forward pass, and the error is calculated for each training pair. Let's assume that there are P training data pairs and that the ANFIS has L layers. With $N(L)$ we denoted the number of nodes in the layer L. The node in the i-th position of the k-th layer, as well as this node output, is symbolized with O_i^k. For the p-th training data, where $1 \le p \le P$, we can define the error, as a sum of the squared errors:

$$E_p = \sum_{m=1}^{N(L)} \left(T_{m,p} - O_{m,p}^L\right)^2 \tag{7}$$

where $T_{m,p}$ is the m-th component of p-th target output vector, and $O_{m,p}^L$ is the m-th component of actual output vector obtained by the presentation of the p-th input vector to the network. The overall error measure is:

$$E = \sum_{p=1}^{P} E_p \tag{8}$$

and needs to be minimized. Now, the error rate $\frac{\partial E_p}{\partial O}$ for p-th training data and for all node output O has to be calculated. According to the formula (7) the error rate for the output node in the i-th position is

$$\frac{\partial E_p}{\partial O_{i,p}^L} = -2\left(T_{i,p} - O_{i,p}^L\right) \tag{9}$$

while the error rate for the node in the i-th position of the k-th layer, where $1 \le k \le L-1$, can be derived by the chain rule:

$$\frac{\partial E_p}{\partial O_{i,p}^k} = \sum_{m=1}^{N(k+1)} \frac{\partial E_p}{\partial O_{m,p}^{k+1}} \frac{\partial O_{m,p}^{k+1}}{\partial O_{i,p}^k} \tag{10}$$

The equation (10) means that the error rate for the node from k-th layer can be calculated as a linear combination of the error rates of the nodes in the $(k+1)$-th layer. Consequently, the formula (9) needs to be applied first. After that, backward layer by layer, the formula (10) can be applied, until all error rates are calculated. The error signals propagate from the output to the input end, so this learning paradigm is called the *back-propagation* [8]. We need to apply the chain rule again, to find the *gradient vector*. Gradient vector is the derivative of the error measure with respect to each parameter. If q is a parameter of the network, we have:

$$\frac{\partial E}{\partial q} = \sum_{p=1}^{P} \frac{\partial E_p}{\partial q} = \sum_{p=1}^{P} \sum_{O^* \in S} \frac{\partial E_p}{\partial O^*} \frac{\partial O^*}{\partial q} \tag{11}$$

where S is the set of nodes containing q as a parameter. The update formula for the generic parameter q is:

$$\Delta q = -\eta \frac{\partial E}{\partial q} \tag{12}$$

in which η is a learning rate which can be expressed as:

$$\eta = \frac{k}{\sqrt{\sum_q \left(\frac{\partial E}{\partial q} \right)^2}} \tag{13}$$

where k is the step size. In the batch learning, the update formula for parameter q is (11), since update action occurs after each epoch, i. e. when all training data are presented to the network. At the end of the backward pass all the premise (nonlinear) parameters are updated by the gradient descent.

6.1. The hybrid learning algorithm

This subsection contains the applied pseudo-code for the hybrid learning method and its technical explanation in some more details.

The values necessary for creating the ANFIS are defined in the main program. The procedures ***Set*** set the value of the variable being denoted as the first argument to the numerical value representing the second argument of the procedure. Here are given the concrete numerical values being used in the paper. The first one ***for statement*** determines the initial values for MF, that is its centers and σ values. This has been achieved in a way that for each input – Gaussian functions are uniformly distributed in the given range of inputs. After entering the data being used for the network training, the set of rules is to be formed and the procedure of training can start through ***Learning*** procedure. In aim to test in this manner trained network, the appropriate testing procedure is to be realized by the procedure ***Testing***.

```
Set (NumberOfInputs,2);
Set (NumberOfOutputs,1);
Set (NumberOfMF,5);
For input := 1 to NumberOfInputs do
      Begin
        Read(minValue[input], maxValue[input]);
        EvenlyAllocateMFs(maxValue[input]-minValue[input], NumberOfMF);
        For k:= 1 to NumberOfMF do
                Remember(Center[input,k], Sigma[input,k])
      end;
Read(TrainingData);
Determine(TrainingDataNumber);
Calculate(NumberOfRules);
CreateRules;
Set (EpochNumber,100);
Learning;
Testing;
```

The procedure ***Learning***, as we shall see later, calls the procedure ***UpdateStepSize*** to realize possible correction of the variable ***StepSize*** values. The correction of this variable is to be done after each fourth epoch, counting from the epoch in which the previous correction has been done. It is realized on the base of the rules listed below:

1. If the error undergoes four reductions, then increase ***StepSize*** by 10%. This condition is checked with the function ***Increase***.
2. If the error goes through combination of increase and decrease, then decrease ***StepSize*** by 10%. This condition is confirmed with the function ***Decrease***.

The variable ***Epoch*** contains the index of the current epoch, while the variable ***lastChanged*** stores the index of the epoch in which the variable ***StepSize*** has been changed previously.

```
procedure UpdateStepSize(var lastChanged : integer; epoch : integer;
                              var StepSize : integer;)
begin
        if Decrease(lastChanged,epoch) then
                DecreaseStepSize(StepSize, 10);
        if Increase(lastChanged, epoch) then
                IncreaseStepSize(StepSize, 10);
        lastChanged := epoch;
end;
```

The pseudo-code for the key procedure ***Learning*** containing all the theoretical statements from the section 6, follows:

```
procedure Learning;
        var epoch, lastChanged, i, j, k, ErrorMeasure : integer;
            y, grad : real;
begin
        set MinError to huge value;
        lastChanged := 1;
        for epoch := 1 to EpochNumber do
           begin
                ErrorMeasure := 0;
                for j := 1 to TrainingDataNumber do
                begin
                        for k := 1 to NumberOfInputs do
                                ReadInputValue(TrainingData[j]);
                                DesiredOutput[j]:= exstract last value from
                                                        TrainingData[j];
                        { forward pass for all layers }
                        for i := 1 to NumberOfNodes do
                                Calculate Node[i] output based on InputValues;
                        LSE;
                        { calculate error measure }
                        ErrorMeasure := ErrorMeasure +
                                sqr(DesiredOutput[j] - ObtainedOutput[j]);
                        OutputNode.de_do := -2*(DesiredOutput[j]-
                                                obtainedOutput[j]);

                        Perform backward calculation for all inner layers;

                        y := exp(-sqr((x-c)/sigma)/2);
                        for i := FirstNodeFromLayer1 to LastNodeFromLayer1 do
                                for j := 1 to 2 do
                                   begin
                                        do_dp[1] :=
                                                y*sqr(x-c)/(sqr(sigma)*sigma);
                                        do_dp[2] := y*(x-c)/sqr(sigma);
```

```
                                node[i].de_dp[j] := node[i].de_dp[j] +
                                node[i].de_do*do_dp[j];
                            end;
            end;
            Calculate (Error[epoch]);
            if Error[epoch] < MinError then
                    begin
                            MinError = Error[epoch];
                            remember all current parameters as best
                                                                parameters;
                    end;

            { update parameters: sigma and center }
            grad := 0;
            for i := FirstNodeFromLayer1 to LastNodeFromLayer1 do
                    for j : = 1 to 2 do
                            grad := grad + sqr(node[i].de_dp[j]);
            grad := sqrt(grad);
            for i := FirstNodeFromLayer1 to LastNodeFromLayer1 do
                    for j : = 1 to 2 do
                            node[i].para[j] := node[i].para[j] - Step-
                            Size*node[i].de_dp[j]/grad;
            UpdateStepSize(lastChanged,epoch,StepSize);
        end
end;
```

The ending of this procedure, means that the network has been trained. The last phase in ANFIS creation process is its testing. This procedure has been realized upon the set of test data, by the procedure ***Testing***, and after the testing, we have clear picture of the network efficiency.

```
procedure Testing;
var   i :  integer;
       TestingError : real;
begin
       Read(TestingData);
       Determine(TestingDataNumber);
       for i:= 1 to TestingDataNumber do
              Determine(inputs[i], DesiredOutput[i]);
       for i:= 1 to TestingDataNumber do
              begin
                     ObtainedOutput[i] := CalculateOutput(inputs[i]);
                     Error[i]:= DesiredOutput[i]-ObtainedOutput[i];
              end;
       TestingError := 0;
       for i := 1 to TestingDataNumber do
              TestingError := TestingError + Error[i];
       TestingError := TestingError/ TestingDataNumber
end;
```

This is the summarized presentation of the original code in Pascal being applied for the appropriated calculations in the paper, but it contains all cardinal elements of the proposed methodology for creating, training and testing the ANFIS based upon TSK and RFN functional equivalence. The obtained results, which will be presented within the next section, confirm its applicability in solving the real problem, as well as, its validity.

7. The simulation results

According to the problem formulation in section 2, we have to determine the preference of the route in long-ocean navigation, or even the preference of its segment, upon two criteria: the wind strength and the traveling distance in the sailing zone. Only two criteria have been considered in aim to simplify the problem, though the very similar procedure based on TSK and RFN equivalence could be applied to more complex problems of this kind with three, four or more criteria relevant for the degree of the route preference estimation.

Let's us suppose that we have the elementary fuzzy rules, formed on the base of expert knowledge related to the wind strength and the traffic density (which usually implies traveling distance between departure and arrival port, or between two waypoints) for the observed sailing zone (table 2).

Table 2. The basic fuzzy rules for the sailing zone

Rule	Traveling distance		Wind strength		Preference
No.	Linguistics value (fuzzy)	Num. value, e. g. (crisp)	Linguistics value (fuzzy)	Num. value, e. g. (crisp)	Value (crisp)
1	very small	500	very small	0.20	1.00
2	very small	500	small	2.70	0.75
3	very small	750	medium	4.00	0.50
4	very small	550	high	6.00	0.25
5	very small	500	very high	7.60	0.00
6	small	1550	very small	0.00	0.75
7	small	1630	small	2.75	0.75
8	small	1600	medium	4.75	0.50
9	small	1630	high	5.75	0.25
10	small	1500	very high	8.00	0.00
11	medium	2750	very small	0.60	0.75
12	medium	2100	small	2.00	0.75
13	medium	2700	medium	4.50	0.50
14	medium	2500	high	6.00	0.25
15	medium	2750	very high	7.80	0.00
16	high	4100	very small	0.00	0.25
17	high	4250	small	2.00	0.25
18	high	4000	medium	4.00	0.25
19	high	4100	high	6.10	0.25
20	high	3600	very high	7.90	0.00
21	very high	4900	very small	0.10	0.25
22	very high	4600	small	1.80	0.25
23	very high	5000	medium	4.75	0.00
24	very high	4900	high	5.50	0.00
25	very high	4900	very high	7.60	0.00

The exact numerical values in Table 2 (columns: 3rd and 5th) are given as some "crisp samples" for linguistics values *small*, *medium*, *high*, etc. These are the basic or "rough" fuzzy rules used for defining training and testing sets. Namely, the example being considered here is based upon the MFs of the wind strength and the traveling distance presented in figures 6 and 7. The wind strength in the sailing area is usually between numbers 0 and 8 of Beaufort scale, while traveling distance is a number from the interval between 500 Nm (nautical mile) and 5000 Nm.

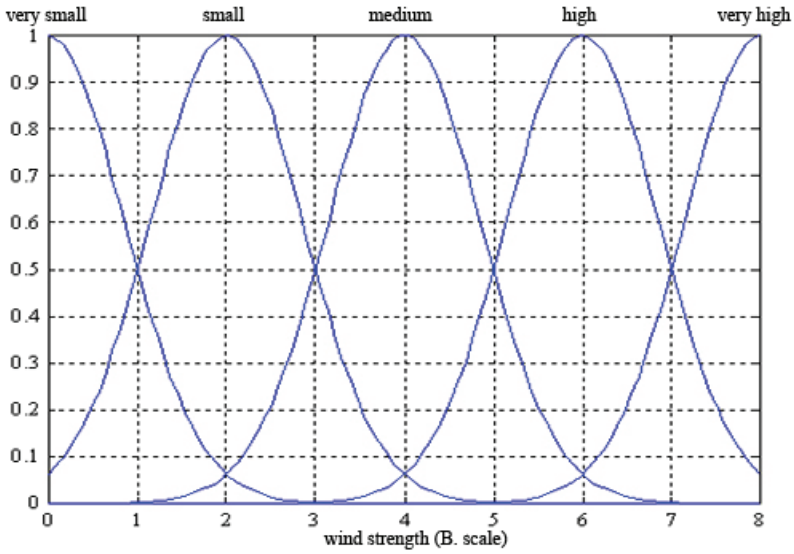

Fig. 6. The MF of the wind strength

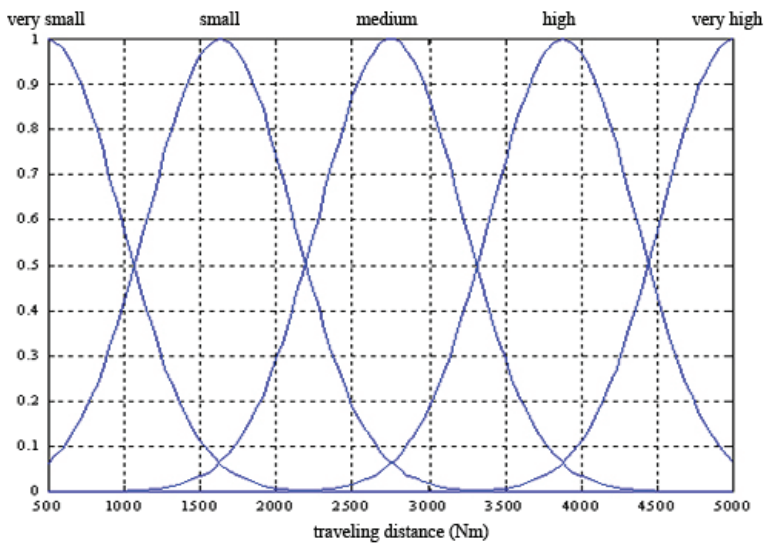

Fig. 7. The MF of the traveling distance

The values of the MFs centers and spread constants can be easily read from the presentation given above. The shapes of the wind strength MF before learning procedure are given in figure 6, while the case after parameter regularization produced with hybrid learning algorithm (section 5) is presented below, in figure 8. It is obvious that the centers of MFs have been shifted in a way, i.e. they have been tuned properly in aim to reduce errors between obtained and target outputs (the degrees of the route preference). Thus, this MFs tuning implies the least level of the output error in the model.

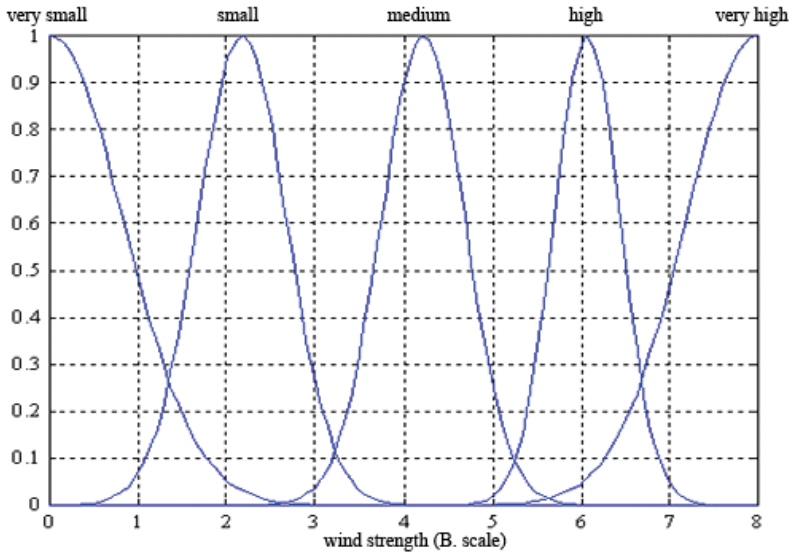

Fig. 8. The wind strength MFs' tuning (the MFs after learning)

It is to be summarized that the total number of nodes in the ANFIS is 75. Though, the applied ANFIS model has 25 fuzzy rules, 25 linear and 20 nonlinear parameters. The 436 data pairs have been used in its training process. The average error after training process was $E = 0.038793$. The training error minimization, which is a result of the described hybrid learning completed after 100 epochs, is presented in the Figure 9. Obviously, the error curve decreases permanently and approaches to its minimal obtained value.

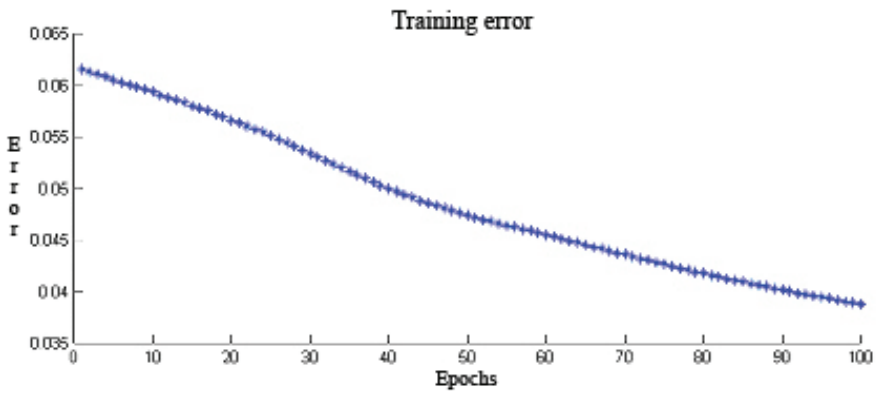

Fig. 9. The error curve for the ANFIS

The route preference surface produced on the base of the 25 fuzzy rules previously defined and the corresponding outputs within corresponding fuzzy regions are presented graphically in 3D space in figure 10.

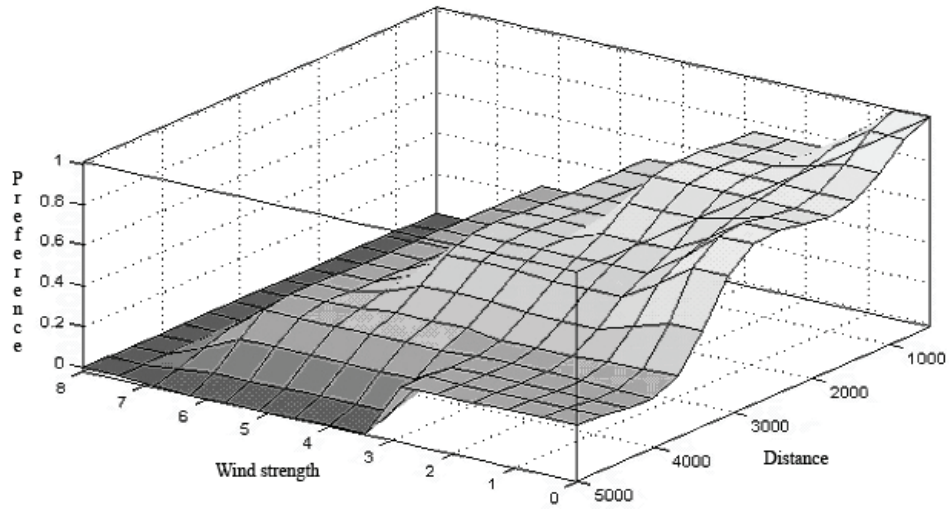

Fig. 10. The output regions and the corresponding output values

Within the ANFIS creation procedure, the testing phase follows after the training process. We used 50 data pairs as testing data to calculate the ANFIS output. The proposed ANFIS efficiency has been presented in figure 11. Here, 50 training data pairs have been used and the system output has been shown with "*", while the expected value has been represented with "·". (figure 11). The average testing error was 0.014781. It is clear that in the most cases they are at the same position or next to each other. This confirms validity of the proposed ANFIS and the applied hybrid learning procedure.

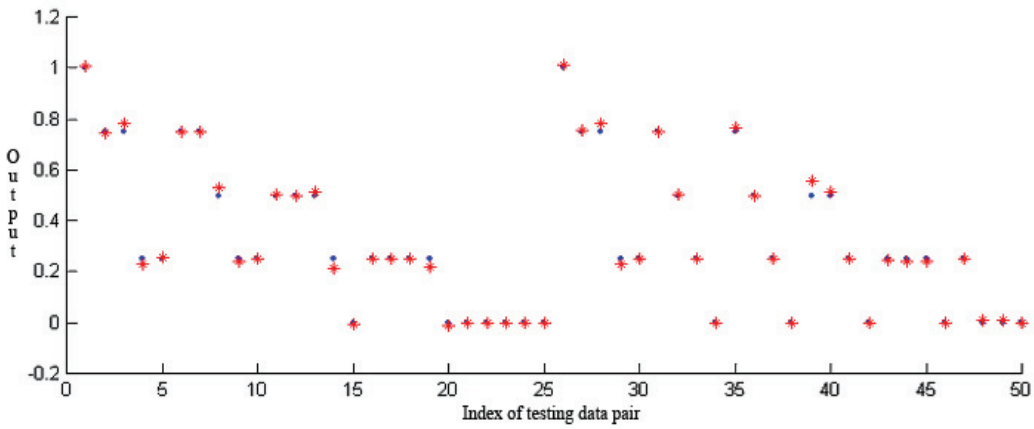

Fig. 11. The desired outputs judging against the obtained ones

Some of the illustrational samples, chosen from these 50 tested cases, are given in table 3. On the base of the numerical data given in table 3, it is obvious that the error is of E-02 or E-03 order, which is satisfying accuracy for a decision support method, like this of route preference degree estimation in long-ocean navigation.

Table 3. The calculated data for some sample testing data

Inputs		Outputs		Error
Wind strength [B. scale]	Traveling distance [Nm]	Desired output	Obtained output	
1.00	555	1.00	0.9919	0.0080968
0.30	510	1.00	0.9863	0.0136330
0.10	1500	0.75	0.7573	0.0073257
0.90	1700	0.75	0.7582	0.0082239
4.00	1728	0.50	0.4988	0.0012556
3.90	2500	0.50	0.5075	0.0075517
5.80	1500	0.25	0.2501	0.0001391
3.00	4128	0.25	0.2485	0.0014879
4.00	4921	0.00	0.0076	0.0076976
7.50	4800	0.00	0.0083	0.0083899

How this model can be practically used in navigation? - It could be used in the following manner: mariner gives the inputs to the computer, i.e. its own estimations for the wind strength and the traveling distance, and according to that how do they "fit" into the expert knowledge base – the degree of the route preference (or its segment) will be obtained automatically by the computer. This could be, in a way, a great help in ship maneuvering, particularly when larger number of criteria is to be considered and when it is not so easy to estimate a certain route (or its segment) preference. Surely, this is still more theoretical then practical approach to the optimal long-ocean route selection, but it can be, undoubtedly, used when the appropriate knowledge base for some sailing zones become available.

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About the author

Prof. Dr. Sanja Bauk was born in Kotor (Montenegro) in 1972. As an excellent student, she won the "Luca I" prize in elementary and high school. She graduated in 1997 at the Maritime Faculty in Kotor, University of Montenegro. As one of the best students she received the University Plaque.

In 2001 she earned her master degree studies at the Faculty of Traffic and Transportation Engineering, University of Belgrade (Serbia), defending the Master Thesis: „Information and Communication Technologies in Optimizing the Ship Navigation“. In 2005 she finished her PhD studies at the same Faculty, defending the doctoral dissertation: „Intelligent Information Systems in Route Optimization in Maritime and Port Transport“. In 2013 she completed the post-doctoral studies in the field of didactic informatics at the Academy for New Media in Knowledge Transfer at the University of Graz (Austria).

Prof. Dr. Sanja Bauk has received several international academic awards as a visiting researcher and lecturer at Universities of: Coimbra (Portugal), Barcelona (Spain), Pittsburgh (Pennsylvania, USA), Odessa (Ukraine), Graz (Austria), Lund (Sweden) Aachen (Germany), London (UK) and others.

The field of her research interest is multiple. It is partly in the domain of quantitative optimization method, and partly in the domain of information and communication technologies (ICT). In the field of quantitative optimization, she has analyzed some of the optimization problems of transport, logistics, maintenance, market positioning, assessment of the customer satisfaction level, etc. In the field of informatics, she studied the properties of various ICT applications, mainly in maritime affairs, as well as didactic informatics and post-production tools. Currently, her interest is focused on the evolution of web, the Internet of Things, virtually smart environments, and the human dimension in technological development.

Prof. Dr. Sanja Bauk is the author of two scientific monographs, and one university textbook. As an author and co-author, she has published a significant number of papers in scientific journals indexing in reference databases (around 30), and in other international scientific journals (about 100). She has published a large number of articles in the proceedings of international scientific-professional conferences. She is a member of editorial board and a reviewer in several international scientific journals. Also, she is a member of scientific boards of several international maritime conferences. She has actively participated in the realization of numerous research projects.

Since 1998, Prof. Dr. Sanja Bauk has worked at the Faculty of Maritime Studies, University of Montenegro, and since 2013 she has been an associate professor, teaching the Operations Researches and Information Technologies in Maritime Affairs at undergraduate and postgraduate studies. Currently she is also an adjunct professor at the Durban University of Technology (South Africa).

In addition to her native Serbo-Croatian, she fluently speaks English, and knows elementary German.

Excerpts from reviews

This is an up-to-date, high-quality, high-expertise, research scientific monograph, which will enrich literature of the complex area of digitization in maritime sector that has been insufficientlly analyzed. I was especially impressed by the brave (and successful) attempt of the author to combine the management and techical aspects (skills) in the text.

I find this work a lighthouse in the persistent and difficult struggle of reference authors for the affirmation of consciousness and truth about the dominant importance of monographic research publications as the highest form of scientific activity.

In an experienced and proven scientist manner, Prof. Dr. *Sanja Bauk* has managed to to integrate contemporary theoretical and practical topics and aspects of key information and communication systems in maritime navigation, business, and education, in a technical, functional and conceptual sense. Her international experience in projects and pedadogy is on the high level, which she brilliantly applied it in the considered text. That is why she deserves the highest praise, and recognition (necessary and deserved) from the scientific and social community. It would be the best way of confirming the above stated objective and sincere review findings.

The evaluation of this scientific monograph deserves repeating my previous statement that every new book represents a great contribution to the publishing industry, and it is my great honor to participate as a reviewer in this important project. Especially because of the fact that the author managed to provide new insights, as well as new answers to some old questions. "*Ex astris scientia*"!

dr Veselin Draskovic, Full Professor
University of Montenegro, Maritime Faculty
Kotor, Montenegro

On over three hundred pages of high quality scientific text, enriched with many schemes, images, tables, and depictions, Prof. Dr *Sanja Bauk* has managed to successfully analyze an interesting, contemporary, and complex topic in information and communication area, which is extremely important for the scientific and practical (maritime) activity. The considered scientific monograph is logically structured in six chapters, which are functionally interwoven and supplemented. In this respect, this book will be useful and inspirational to all future researchers of the above mentioned area, as well as to practitioners and students.

An additional quality of this valuable scientific monograph is its technical processing, and the author's great effort to present the most of the schemes and images in colour drawings. This makes it easier to understand the basic text and all the analysis for the future readers and users. The same applies to a number of practical applications.

The text is concisely and originally conceived, written in clear, precise, and simple language and style. It abounds with numerous data, statements, interpretations, and explanations. That's why the readers will find it interesting, especially the part about numerous models. Obiously, the author's long-time diligent and professional work on the subject matter has helped her to create a specific and original symbiosis of theory and practice in the field. Methodologically viewed, the text is perfectly adapted to world standards.

I sincerely recommend this valuable scientific monograph to all students, interested readers, and appreciated publishers, because it is written extremely professionally.

dr Radislav Jovovic, Full Professor
University Mediterranean
Podgorica, Montenegro

Monograph by Prof. Dr *Sanja Bauk* deals with one of the most important practical issues of maritime economic activity, whose trend will directly impact the future social and economic sustainable development of maritime countries. The author has concieved the text in a professional, creative and very stylish manner. It contains a large number of scientific analyzes, data, statements, and technical forms. In this sense, this book really inspires many aspects in the future scientific research.

The text is concise and concentrated, intended mainly for professionals - theoretical and practical - because understanding some segments of this monograph requires a good knowledge of matter.

It contains a large number of scientific studies by the author, combined with various textbooks and materials. Functionally and technically it is formatted in a very appealing way, and methodologically is adapted to the structure of this valuable text.

The author has invested a great creative effort and energy to write this book, which will be published in a time that, according to the distinguished reviewer Prof. Dr Veselin Draskovic - is not favorable to the book nor the scientific work, due to the deformed value criteria, preferences, needs, and motivation, caused by the general crisis. However, it only increases the significance of this scientific work, and the contribution of the reference author. Her fundamental and studious analysis of the discussed issues from many important aspects will be extremely useful for all readers and professionals, to whom this scientific monograph is intended.

I use this opportunity to recommend the publication of this valuable and thematically rare scientific and pedagogical text.

dr Borut Jereb, Associate Professor
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