**BRANISLAV ĆOROVIĆ**, Ph.D.
E-mail: corovic@t-com.me
University of Montenegro, Faculty of Maritime Studies
Dobrota 36, 85330 Kotor, Montenegro
**PETAR DJUROVIĆ**, M.Sc. Candidate
E-mail: p.djurovic@abaco.co.me
Abaco Ltd.
Jovana Tomaševića Str. 35, 85000 Bar, Montenegro

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# RESEARCH OF MARINE ACCIDENTS THROUGH THE PRISM OF HUMAN FACTORS

***ABSTRACT***

*This paper focuses on the impact of human factors on marine accidents and their prediction developed by regression analysis. Despite the rapid technological development of ships and the presence of legislative framework for the control and safety at sea, this paper identifies the human factor as one of the weakest link in maritime safety system. First, we start from the literature review of human error existence in maritime transportation pointing out the psychological and organizational aspects. Then, regarding international maritime law we specify the regulations that consider the marine casualty statement. Descriptive statistics and review of number of ships and lives involved in accidents in the European Union (EU) waters present a starting point for applying the regression analysis to predict the number of accidents in the coming years. The obtained results indicate two directions. Firstly, the linear trend for the predicted number of accidents is mostly stable, while secondly, we state that this trend would not be stable in the case of number of lives lost because of the level of reliability which clearly indicates that the latter must be investigated by other different approaches in the future.*

***KEY WORDS***

*safety at sea, legislative framework, human error, marine accident, regression analysis*

## 1. INTRODUCTION

Marine accidents have been occurring ever since men started to set sail. The custom of the trade has been systematized over time, and later, by the middle of the 19th century, the navigational standards emerged primarily as regulations for preventing collisions at sea. Since the beginning of the last century, marine accidents have resulted in maritime industry efforts to improve ship construction, ship systems reliability and onboard operations organization aiming at reduction of marine accidents. Most of the literature applied in this paper which tackled this topic has come to the conclusion that modern shipping technologies are not essential for the safety at sea. However, in spite of this modernisation, marine accidents still occur nowadays. Over the last three decades different surveys have identified the fact that the human element is the major cause of marine accidents. It means that human factor is of paramount importance for the safety at sea. However, a few directions have been developed in this paper. First, we focus on statistical analysis of the accidents and casualties as well as the level of lives lost at sea. Then, we establish a linear trend that justifies our prediction for the coming years. Second, the human error factor as the most common cause of ship accidents is identified and also all the factors which contribute to human errors at sea are discussed afterwards.

Different aspects of human behaviour are treated in [1] and [2] where the authors showed that the pattern of behaviour, which can be quite unique and recognized is also integrated into risk models. The background that occurs between different modes of behaviour in humans is presented here. The conceptual Butterfly Flower Shower (BFS) Human Behaviour Model has been developed in [3]. This model describes human behaviour in each demanding, possible accidental situation and has been presented for a traffic situation. These references are very useful and represent a good starting point for applying and analyzing the psychological aspects for human errors in accidents.

There have been a lot of papers such as from [4] to [12] to consider and describe some human and organizational factors that were presented in marine accidents and which can be found in many of them over the years. A neural network applied in [4] has demonstrated its usefulness and accuracy in predicting the type of ship accidents that would occur under different combinations of navigating conditions on the lower Mississippi River. In [5] it was determined how accident investigators report the term of 'sleepiness' in Incident at Sea Reports and subsequently analyze the relationship between sleep, fatigue and accidents in these reports. Sea-state related parameters (i.e. meteorological centres' standard wave products) at the time of accidents were analyzed and compared to known ship characteristics in [6]. In [7] the severity of ship accidents from the standpoint of the crew was investigated, i.e. the determinants of the number of non-fatal crew injuries, fatal crew injuries and missing crew in ship accidents were investigated. The influence of the national culture on the performance of multicultural crews, focusing its analysis on both Greek-owned tramp shipping companies and Greek seafarers are examined in [8]. This study concluded that culture management can enhance crew team cohesion, upgrade communication at all levels, and, finally, improve the quality of the working environment, the safety of the workplace and the overall performance of the team. In order to reduce the number of marine accidents caused by human errors [9] has described that the effort will have to focus on reducing the latent error, mitigating the impact of psychological precursors, and improving the crisis management capability within marine community. This study also considered the dangerous situation of sea based on human factors and used a web-base simulator to develop applications in navigation and ship handling area with different grades of difficulty and risk. In [10] an analytical HFACS (Human Factors Analysis and Classification System) is proposed, a mechanism for identifying latent human errors in shipping accidents. This study reported the following contributions to the accident analysis and prevention literature such as improving the structure of the existing HFACS model, and extending the application of HFACS to shipping accidents. In [11] the significance of the human element in accidents involving Greek-flagged ships, during 1993–2006, worldwide has been analyzed. The human element as a general factor of accident initiation and most importantly its constituent component in the form of specific onboard duties (functions) and/or off-board (mainly ashore) entities has been presented and analyzed. An overview of the cultural issue impact on shipping crew thoughts that raises questions stemming is presented in [12]. The main point of the study was to examine how managing multicultural crews is related to the social responsibility of shipping companies and the industry. The output results show that managing multicultural human resources in a socially responsible manner requires socially acceptable behaviour towards seagoing labour from all the industrial actors. In [13] the result of modelling human error and human reliability emanating from the use of technology onboard ship navigation in coastal water area by using qualitative and quantitative tools is analyzed. The result presented here can contribute to rule making and safety management leading to the development of guidelines and standards for human reliability risk management for ship navigation. In [14] the extent to which the factors involved in the sinking of the Titanic is discussed, which can also be found in the Costa Concordia accident. This study considered some human and organizational factors that were present in the Costa Concordia accident as well as in the foundering of the Titanic a century ago, and which can be found in many other marine accidents over the years. Authors argue that these factors do not work in isolation but in combination and often together with other underlying factors. Also, critical reviews of the marine accident investigations and insinuations that these factors do not receive sufficient attention are studied in [14]. In [15] it is reported that most of the international studies have determined a strong connection between marine casualties and human error which are connected to the individual ship crew member's subjective approach for solving the problem. The authors determined the relationship between different subjective definitions of a near-miss in situations of immediate danger of collision for different categories of examinees.

After a comprehensive literature review about the presence of human factor in developing the marine accidents, the aim of this paper is to examine the influence and to analyze the significance of the human factor in accidents involving sea ships. This unique parallel analysis will contribute to the examination of the issue of human element and the accident in shipping by offering a more comprehensive approach of the matter. The legislative framework for the control and improving safety at sea is presented in Section 2. After establishing the content of this study, Section 3 defines the research hypothesis and underlines the object of the research framework, while the issue of marine accident review is discussed in Section 4. Section 5 applies a regression model to estimate the trend of marine accidents and casualties. Several observations and discussions of human error as cause of marine accident are elaborated in Section 6. Conclusions are offered in the last section.

## 2. LEGISLATIVE FRAMEWORK FOR THE CONTROL AND SAFETY AT SEA

After overall examination of the international regulations for marine accident (casualty or incident), it is obvious that almost every accident resulted in international regulations whose goal was to improve the safety at sea. There are different interpretations of marine accident, incident and casualty. Here we begin with the accident which comprehends a marine casualty, a very serious marine casualty, a serious marine casualty and a marine incident. The latter is defined as occurrences that cause damage to ships, facilities, or personnel, such as collisions, allisions, groundings, fires, explosions or foundering. Unlike accident which represents an unplanned event or sequence of events that result in undesirable consequences, incident is an event which occurs directly in connection with the operation of a ship, or could endanger the safety of a ship. On the other hand, a marine casualty is an event that can result in material damage to a ship and death or injury of a person onboard.

According to the International Maritime Organization (IMO) instruments of marine safety investigations and marine casualties and incidents, the Code of International Standards and Recommended Practices for Safety Investigation into Marine Casualty or Marine Incident (Casualty Investigation Code) is highlighted [16]. It was implemented in 2008 in the form of the MSC.255(84) Resolution whose most important part is Paragraph 14.1 of Chapter 14 of the mandatory Part II [16]. The code contains three parts, namely: *General provisions*, *Mandatory standards* and *Recommended practices*.

The main purpose of the Casualty Investigation Code is to conduct marine safety investigations into marine casualties and marine incidents. Chapter 14 of the mandatory Part II, entitled *Marine safety investigation reports*, provides the steps for reporting the casualty or incident in relation to marine safety. It leads to the final version of marine safety investigation report which must be submitted to the IMO for every marine safety investigation conducted into a very serious marine casualty. In the case when a marine safety investigation is conducted into marine casualty or marine incident, other than a very serious marine casualty, a report should be provided for the IMO and this report must contain the information which can serve to prevent the seriousness of marine casualties or marine incidents in the future. The report shall take into account all the relevant safety issues that are included in order to obtain a safety investigation, and that safety action can be taken as necessary. Consequently, the final marine safety investigation report is to be available to the public and the shipping industry while all details of reports must be accessible [16].

In literature other regulations were reported that were based on some real accidents or incidents. For instance, the case of the Titanic in 1912 imposed the SOLAS Convention. Later on, the consequence of the accident of the passenger Ro-Ro ship the Herald of Free Enterprise in 1987 in which 193 lives were lost, resulted in the development of the International Safety Management Code - ISM Code. Also, this mandatory code was developed as result of 158 lives lost in a fire onboard Ro-Ro ship the Scandinavian Star in 1990. For this accident the blame was on the language barrier between the multinational crew, and therefore it was caused by the human factor. In 1989, a marine casualty involved the tanker Exxon Valdez in Alaska in 1989 and that was the reason for developing the Oil Pollution Act – OPA in 1990.

It should be noted that according to the IMO Casualty Investigation Code, a marine safety investigation means an investigation or inquiry into a marine casualty or marine incident conducted with the objective of preventing marine casualties and marine incidents in the future. The investigation includes the collection and analysis of the identification of causal factors and the making of safety recommendations as necessary.

## 3. HYPOTHESIS

The objective of this paper is to show the contribution of human factor which identifies the fact that human errors are mostly the causation for marine accidents. Therefore, in order to predict the number of marine accidents and discussing the human factor afterwards, it is necessary to establish and implement a regression analysis for obtaining trends of the accidents. This analysis represents the object of the hypothesis.

## 4. REVIEW OF MARINE ACCIDENTS

Marine accident, broadly speaking, implies each extraordinary and unwanted event which causes harmful consequences, endangering lives, property and environment. The extraordinary events are divided into those which did not cause harmful consequences, but could have caused, and accidents which indirectly or directly caused the loss of life, endangering health, material damage at sea or ashore, pollution, and other consequences. According to [9], about 75-96% of marine accidents are caused, at least in part, by some form of human error. They specified that human error contributes to 89-96% of collisions, 75% of explosions, 79% of groundings and 75% of allisions [9].

Perhaps the most distinct accidents that involved a big number of lives lost are sinking of the Titanic in 1912 when 1,502 people were killed and the foundering of the Costa Concordia in 2012 when 32 people lost their lives. In both cases, the cruise ships were involved. Despite the technological progress and ship modernization, there are still human and organizational reasons for the occurrence of accidents that should be precisely analyzed. Regarding accidents, the human error and organizational reason have played the main role [14]. Besides the cases of the sinking of the Titanic and the foundering of the Costa Concordia, in 2011 an accident happened with the riverboat Sergei Abramov Russian. The sources, namely, reported fire on a passenger ship moored at a Moscow river port. Four people onboard were injured and one crew member was missing. The reason for such an accident was that the fire might have been caused by defective electric wiring or fire-safety violations. The human factor also caused the incident that happened with the cruise ship Oriana P&O in 2011. The ship had a sizeable dent in the stern after finishing into a solid stone quay at her last port of call, Kristiansand in Norway. The incident resulted in the following consequences: a water pipe and an optical cable on the quay were damaged and the ship's stern was stoved in.

*Figure 1* presents the statistics of ships involved in marine accidents in the European Union (EU) waters from 2007 to 2010 [17]. Obviously, the number of sinkings, collisions and groundings was decreasing while accidents caused by fires/explosions and other types of accidents were reported to increase during 2010. The minimum number of accidents during the considered period was 28 in 2009 and related to sinking. In the case of EU waters and if comparing the number of lives lost in marine accidents from 2007 to 2010, in *Figure 2* the accidents are distributed according to the ship type [17]. Almost the largest number of lives lost was in 2007 when 49 people died on other types of ships. This represents around 18% of the total number of lives lost during the considered period. The statistics shows that 7% of the total number of people lost their lives on tankers, 1% on container ships, 28.9% on cargo ships, 9.7% on passenger ships, and finally, 53.4% on other types of ships.

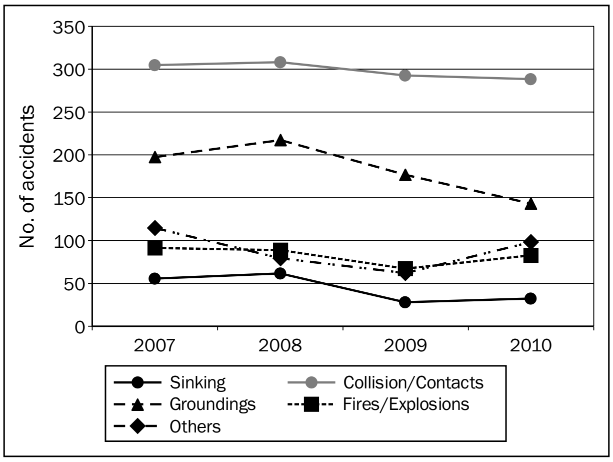
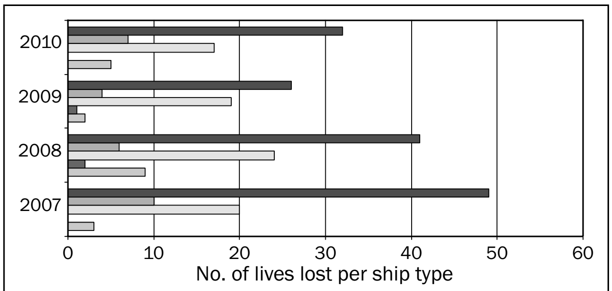



*Figure 1 - The number of ships involved in marine accidents in EU waters from 2007 to 2010 [17]*

More specifically, if analyzing the human error involved in marine accidents, some examples have to be highlighted. The first example is the collision between the ships Santa Cruz II and USCG Cutter Cuyahoga. The accident occurred at the moment when Cuyahoga passed close to the Santa Cruz II. The collision was inevitable and 11 people lost their lives. The second example was the grounding of the Torrey Canyon. It




| | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| Others | 49 | 41 | 26 | 32 |
| Passenger ship | 10 | 6 | 4 | 7 |
| Cargo ship | 20 | 24 | 19 | 17 |
| Container ship | 0 | 2 | 1 | 0 |
| Tanker | 3 | 9 | 2 | 5 |

*Figure 2 - Number of lives lost per ship types from 2007 to 2010 in EU waters [17]*

happened in the English Channel. The ship spilled 100,000 tons of oil. Considering both accidents, the only cause was related to human error [19].

The number of accidents features a steady growth in maritime shipping. However, some situations in cruise shipping are defined as incidents. In the period from 1979 to 2012 there were 45 incidents of ship sinking while some of them were treated as accidents [20]. In 2007 and 2011 the biggest number of five incidents per observed years was reached. Considering the ships grounding from 1972 to 2011, there were 118 incidents reported while some of them were accidents. In 2008, there were 14 incidents [20]. From 1990 to 2011 there were in total 398 incidents of collisions, fires and propulsion problems and some resulted in accidents while the biggest number of 58 occurred incidents was in 2010 [20].

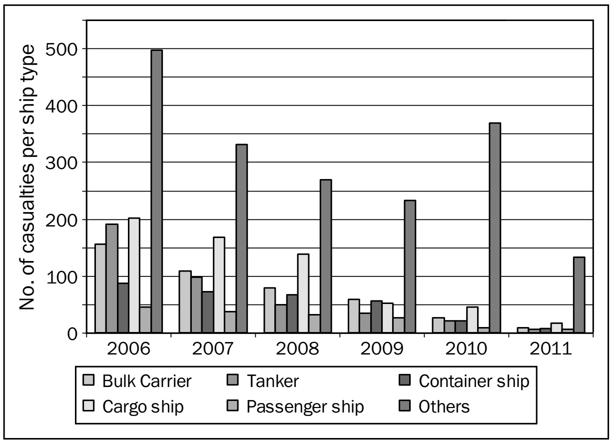



*Figure 3 - Number of casualties per ship types from 2006 to 2011 [19]*

Unlike accident and incident, a marine casualty is defined as an event that resulted in death or injury of a person onboard, their loss from a ship, the material damage to a ship and its involvement in a collision, etc. [21]. *Figure 3* presents the number of casualties per ship types from 2006 to 2011 [18]. The largest number of 202 casualties was achieved by cargo ships after the category other types of ships.

## 5. REGRESSION MODEL APPLICATION

The regression model is a statistical model which has the advantages of analyzing the relationship between one or several dependent variables and several independent variables exactly, and identifying which factors have stronger impact on the trend of the number of ships and lives involved in marine accidents, and of exploring the forms of these relationships [22].

The regression model is used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. More specifically, it helps us understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. In restricted circumstances, the regression model can be used to infer causal relationships between the independent and dependent variables. On the other hand, it is widely used for predicting and forecasting [22]. This study includes two methods which are presented in *Figure 4* - Enter and Backward which is selected as the best method for the results. First, it is necessary to estimate the model with all the predictors. Second, this research method follows the inputs of all the selected variables, and then estimates all the predictors by Enter method and Backward elimination method. The elimination method is used with the settings at a sufficient significance level. If all the regression coefficients are significant, the procedure stops. Otherwise, the ones with the smallest significance are eliminated from the model. Then the procedure stops when all the regression coefficients are significant.

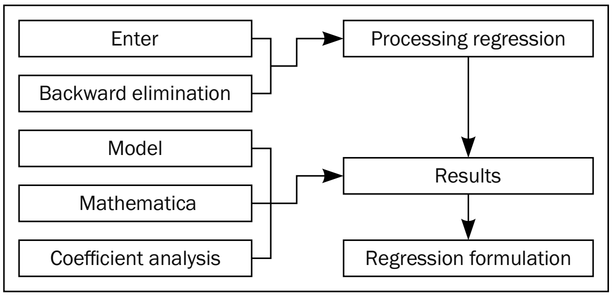



*Figure 4 - Regression model application*

In this study, a single linear regression analysis is applied to establish the trend of the number of ships involved in accidents in the EU waters (using data from 2007 to 2010) [17]. The model is based on a particular case of the multivariable regression analysis involving vector $\beta = (\beta_0, \beta_1, \dots, \beta_{r-1})$ with $r$ unknown parameters $\beta_0, \beta_1, \dots, \beta_{r-1}$, vector $X = (x_1, \dots, x_k)$ of independent variables and vector $Y = (y_1, \dots, y_n)$ of dependent variables. This model relates $Y$ to a function of $X$ and $\beta$, that is, $Y \approx f(X, \beta)$. If $r = 2$ (i.e., $\beta = (\beta_0, \beta_1)$), $k = n$, and it holds

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i, \text{ for all } i = 1, 2, \dots, n, \tag{1}$$

then such a regression is called a simple linear regression model. Here, the attention is focused on the previous model with $k = n = 1$, that is, on the linear regression model of the form $y = \beta_0 + \beta_1 x$.

According to data from *Figure 1* (Section 4), it is found that the majority of the ships involved in accidents in the EU waters during the considered period were involved in collisions and contacts, that is, around 40% per year. In the period from 2007 to 2010 the number of marine accidents decreased by 15.48%, which is, of course, a satisfactory trend. By using the data from *Figure 1* in Section 4, and by means of software *Mathematica* 8 to apply the linear regression method, the following linear trend function is obtained (in this function, the year 2007 is assumed as $x = 0$, 2008 as $x = 1$, etc.):

$$y = -48.2\,x + 768.8. \tag{2}$$

The results for forecasting are presented as a linear trend function of predicted ships involved in marine accidents in the EU waters from 2011 to 2014 defined by (2) and presented in *Figure 5*. *Figure 5* infers that the number of ships involved in marine accidents is going to retain a decreasing trend until 2014. In particular, by (2) we immediately find that the expected number of ships involved in marine accidents would be 576, 528, 480 and 432, in the years 2011, 2012, 2013 and 2014, respectively. *Figure 5* shows that $R^2 = 0.9633$ is very high which affirms our analysis that this linear trend is to be applicable regarding the input data.

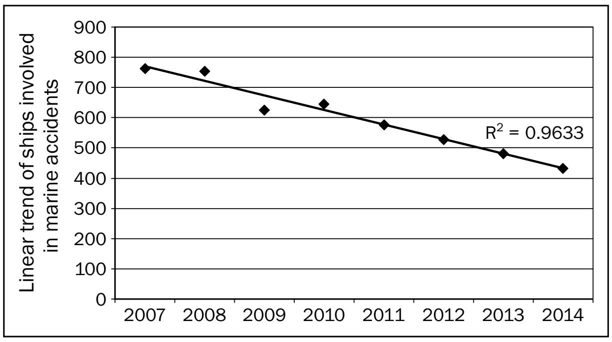



*Figure 5 - Linear trend of predicted ships involved in marine accidents in the EU waters from 2011 to 2014*

Considering the data from *Figure 2* (Section 4) in respect to lives lost in marine accidents by the ship type in the EU waters for the period from 2007 to 2010, also a regression analysis was performed to forecast the number of lives lost up to 2014. The linear regression method was applied and the following linear trend function was obtained (as above, in this function the year 2007 is also assumed as $x = 0$, 2008 as $x = 1$, etc.):

$$y = -9.3\, x + 83.2 \quad (3)$$

The results for forecasting the number of lives lost in marine accidents in the EU waters from 2011 to 2014 defined by (3) are presented in *Figure 6*. This figure shows that the number of lives lost is going to decrease in the future. In particular, by (3) it immediately yields that the expected number of lives lost is 46, 37, 28 and 18, in the years 2011, 2012, 2013 and 2014, respectively. *Figure 6* shows that $R^2 = 0.933$ which is very high and this suggests that the linear trend analysis may be useful, but unfortunately, the marine accident involving the ship Costa Concordia in 2012 proves that the numerical results obtained by the linear trend function (3) are not always in accordance with the reality.

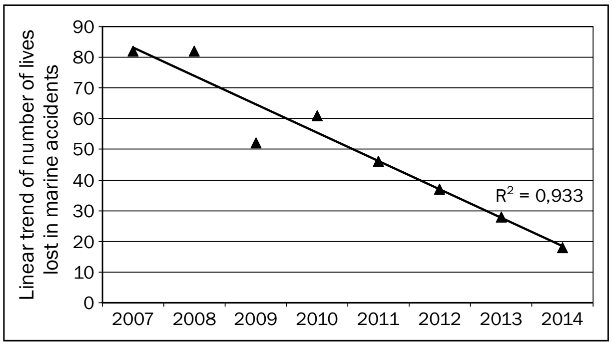



*Figure 6 - Linear trend of predicted number of lives lost involved in marine accidents in the EU waters from 2011 to 2014*

*Remarks*. As shown in *Figure 1* presented in [23], the trend of shipping accidents over the decade 1991-2000 categorized in the Marine Safety Management System (MSMS) was also decreasing (from around 900 accidents in 1991 to around 430 accidents in 2000).

Formula (3) also indicates the decreasing trend of lives lost. However, in view of possible/potential marine accident(s) with 'numerous' lives lost, numerical results obtained by the trend function (3) should not always be approximately equal to the related real data. For example, by the trend function (3) the expected number of lives lost in marine accidents in 2012 would be equal to 37, but in the marine accident involving the ship Costa Concordia in 2012 the number of lives lost was equal to 32.

Moreover, for studying human factors in marine risk modelling, it can be of interest to study different types of trends attributable to human errors in the considered periods. However, since the total number of accidents attributable to all causes varied each year, it follows that the related indicated trends attributable to human errors will be often/probably unstable (see *Figure 5* presented in [23]). Accordingly, we believe that for these investigations, the applications of multivariable nonlinear regression, time series analysis, Bayesian analysis etc. may be useful.

## 6. HUMAN ERROR AS CAUSE OF MARINE ACCIDENT

In the case of reducing marine accidents, it is important to concentrate on the type of human factors that cause casualties. It is necessary also to study the incidents to figure out how they happen [24]. These events are not usually caused by a single failure or mistake; more specifically, they represent a sum of errors. Human error is a product of incorrectly made decision or action. Some of the most investigated human factors that cause errors are: fatigue, inadequate communications both between crew members and general technical knowledge, decisions based on inadequate information, psychological and physical factors, etc. [9]. Therefore, marine accidents do not occur due to one human error. Usually, there are a lot of small mistakes that accumulate and may produce large-scale consequences.

Safety and profitability of a shipping company depend on human factors. Creating a good relationship among crew is very important. Compliance with international and national regulations is also implied by the mentioned legislative framework [24]. In the last few decades, the main goal of maritime industry has been to increase the productivity and prevent marine accidents. Besides modern technologies and safety systems onboard, the accidents still occur. Here different human factors are presented and discussed, that can cause errors and are available in literature. Obviously, there are many but we will pay attention to some of them.

Following the hierarchical aspect, first we start with communication barriers that occur between seafarers and are presented in all types of ships, especially when there is a multinational crew. For example, this can cause misunderstandings between the pilot and the ship's master. There were situations in which due to the weather conditions and imprecisely given information about it, a marine accident was caused. Also, the mistakes and insufficient information about the ship's environment resulted in sinking.

Health is one of the factors that influence professional efficiency of seafarers. It is directly connected to psycho-physical strength, resting periods, seafarers' satisfaction with the job, internal relationships and stressful situations, etc. In some circumstances, psychological problems such as impatience, dissatisfaction and lack of motivation may provoke intolerance between crew members which mostly results in cultural and religion differences. In these circumstances, the master of the ship has to use their management skills to acknowledge these differences and to provide good behaviour of the crew. The results from investigations of predominant problems in the case of multicultural crew are rooted in cultural and linguistic incompatibility and also in inadequate and inappropriate training [8]. To avoid these kinds of problems, the crew members must improve their management practices and behaviour more like participating leaders. In this manner, the company should not be proud of them because even though there are different nationalities onboard, the cultural diversity is not registered as a problem. Working and living under the conditions among different nationalities examined how multicultural crews management is related to the shipping companies' and the industry's social responsibility. The ship's master must learn how to manage multiculturalism. This guarantees a long-term stability in relationships among crew members [12]. On the other hand, physical factors also cause human errors, and the most representative example is the period just before the dawn when surveys showed that many collisions occurred in that period of time. Thus, the visibility aspects represent also the reasons for collisions.

The deck officers comprising the master and the first and second mate are responsible for watchkeeping. Beside that, they are responsible for mooring and unmooring operations and cargo handling as well as for commanding the ship and for the crew safety. The results of the accident may be found in sleepiness which is connected with fatigue [5]. On the other hand, some authors proposed an analytical foundation for human factors analysis and classification system where they characterized the role of human errors. Their results yield the following conclusion: the skill-based errors are on the first level for causing the accidents. It comprises the incompetence of engine room personnel; followed by the lack of preconditions such as coordination, communication and planning, disorganization and maintenance [10].

To define the level of 'nearest' the accident, it understands human errors and violations [9]. There are three error types and two forms of violations. The error types include the decision errors which are the action or in-action of an individual who does not have the knowledge and makes wrong choices. The second is skill-based error described as operating skill that occurs with little conscious thought. The latter is perceptual error when the individual perception is different from reality. This results in illusions and spatial disorientation. On the other hand, violations consist of routine/infractions that consider routine violations, optimizing violations, and situational violations. From the psychological aspects, the preconditions for the level of 'nearest' the accident are also treated in two directions. The first is the substandard condition of humans (crew members) which considers adverse mental state of a member, followed by the adverse psychological state and physical/mental limitations. The second is a substandard practice of crew member categorized as crew resource mismanagement and personal readiness [9].

The accidents still occur regardless of the impact of modern technology. Moreover, one hundred years after the foundering of the Titanic there was foundering of the Costa Concordia in January 2012 and it shows that human and organizational factors (latent conditions) still exist [14]. The latent errors are reported to be much more investigated in the future [13]. Following some literature, physical factors were not causes of accidents but organizational ones are changeable due to increased horizontal and vertical integration as consequence of ubiquitous information technology [14].

Being a seafarer and taking part in a crew immediately suggests that this is one of the most responsible and toughest jobs in the world. It also implies the need for constant improvement and knowledge check. These parameters are in relation to personal education of each crew member [24]. They encounter many risks which affect their safety so they must work as a team or group. However, all these mentioned factors that contribute to human errors must be reduced and solved on time because otherwise the worst scenario that could happen is the loss of lives at sea. However, beside these factors that imply human errors, the seafarers must pay attention to recognize the latent errors and reduce them. These errors are based on the mitigation of the impact of psychological factors.

## 7. CONCLUSION

Despite the fact that the human error is probably the main cause of majority of marine accidents, a continuous improvement of safety culture and knowledge of crew members can minimize the number of marine accidents caused by human errors. Therefore, this survey primarily covers the facts that cause human errors. We have also elaborated the psychological and organizational (latent) factor pointing out the communication barriers, multicultural difference, psycho-physical strength of seafarers, the impact of sleepiness and watchkeeping, skill-based errors, etc.

Beside this theoretical analysis of human factors that cause errors, a regression analysis has been provided in order to predict the number of ships and lives lost in marine accidents in the EU waters for the period from 2011 to 2014. From the statistical analysis it is evident that in the period from 2007 to 2010 the number of ships and lives lost involved in marine accidents decreased. We wanted to find out if this decreasing trend was going to continue in the future. Therefore, the linear regression method for expressing the number of ships involved in accidents as well as for estimating the number of lives lost in marine accidents in the EU waters has been applied. The decreasing trend (although globally not applicable here) has proven the good purpose of the analysis especially in the case of predicted number of ships involved in marine accidents. The level of $R^2$ indicates the reduction of the number of ships involved in accidents and this is a very real result. On the other hand, this cannot be confirmed in the case of the number of lives lost because in cases involving passenger/cruise ship in some accidents these may lead to enormous losses of lives. In such circumstances, for solving this problem, some other methodological approaches must be used, such as multivariable nonlinear regression, time series analysis, Bayesian analysis and so on. This may represent the direction for the future investigations.

Generally speaking, there are many aspects not covered in this paper. For example, unlike road transport, this study does not cover some details about punishment policy in marine transportation which is a very interesting point of view because it is not known that any master has ever taken real responsibility for the caused marine accident, but this may change with the Costa Concordia example. Perhaps, the penalty should be much more accessible and adequate for the situations of large-scale consequences such as lives lost. On the other hand, we are aware that today, concepts and procedures in marine accident investigations are changing faster than at any time before.

Dr. **BRANISLAV ĆOROVIĆ**
E-mail: corovic@t-com.me
Univerzitet Crne Gore, Fakultet za pomorstvo
Dobrota 36, 85330 Kotor, Crna Gora
**PETAR DJUROVIĆ**, magistrand
E-mail: p.djurovic@abaco.co.me
Abaco Ltd
Jovana Tomaševića 35, 85000 Bar, Crna Gora

## *SAŽETAK*

## *ISTRAŽIVANJE POMORSKIH NEZGODA SA OSVRTOM NA LJUDSKI FAKTOR*

*Ovaj rad je baziran na uticaju ljudskog faktora kod pomorskih nezgoda i prognoze koja je data uz pomoć regresione analize. Uprkos brzom tehnološkom razvoju brodova i pravnom okviru za kontrolu i sigurnost na moru, rad identifikuje ljudske faktore kao jedne od najslabijih tačaka u pomorskom sigurnosnom sistemu. Prvo, predstavljen je pregled literature koja se odnosi na postojanje ljudskih grešaka u pomorskom transportu koncentrišući se na psihološke i organizacione aspekte. Zatim, kada je u pitanju međunarodno pomorsko pravo, specificirani su pravilnici koji se odnose na utvrđivanje nezgoda na moru. Statistički podaci broja brodova i života koji su učestvovali u nezgodama u vodama Evropske Unije (EU) predstavljaju početnu tačku za primjenu regresione analize koja daje prognozu za broj mogućih nezgoda u narednim godinama. Dobijeni rezultati su analizirani sa dva aspekta. Prvo, utvrđeno je da je linearni trend nezgoda stabilan dok se za broj izgubljenih života na moru ovaj trend ne može smatrati stabilnim. Prema tome, za analiziranje trenda izgubljenih života na moru neophodno je koristiti neke druge istraživačke pristupe.*

*KLJUČNE RIJEČI*

*sigurnost na moru, pravni okvir, ljudska greška, pomorska nezgoda, regresiona analiza*

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