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Ship Engine Room Casualty Analysis by Using Decision Tree Method

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Abstract

Ships may encounter undesirable conditions during operations. In consequence of a casualty, fire, explosion, flooding, grounding, injury even death may occur. Besides, these results can be avoidable with precautions and preventive operating processes. In maritime transportation, casualties depend on various factors. These were listed as misuse of the engine equipment and tools, defective machinery or equipment, inadequacy of operational procedure and measure of safety and force majeure effects. Casualty reports which were published in Australia, New Zealand, United Kingdom, Canada and United States until 2015 were examined and the probable causes and consequences of casualties were determined with their occurrence percentages. In this study, 89 marine investigation reports regarding engine room casualties were analyzed. Casualty factors were analyzed with their frequency percentages and also their main causes were constructed. This study aims to investigate engine room based casualties, frequency of each casualty type and main causes by using decision tree method.

Keywords: *Decision Tree Analysis, Engine Room, Marine Casualties.*

Karar Ağacı Metodu ile Gemi Makine Dairesi Kazalarının Analizi

Öz

Gemiler, operasyonları sırasında istenmeyen koşullar ve kazalarla karşılaşabilirler. Kaza sonucu gemilerde yangın, patlama, su alma, karaya oturma, yaralanma ve diğer hasarlar meydana gelebilir. Ancak, önlemler ve önleyici işlemler ile bu sonuçlar engellenebilir. Deniz taşımacılığında kaza sonucu ortaya çıkan kayıplar çeşitli faktörlere bağlıdır. Kazaya sebep olan faktörler, makine ve teçhizatının yanlış kullanımı veya arızalı olması, operasyonel prosedürlerin ve emniyet tedbirlerinin yetersizliği ve önlenemeyen mücbir sebeplerin ortaya çıkması olarak kabul edilebilir. Bu çalışmada, 2015 yılına kadar Avustralya, Yeni Zelanda, Birleşik Krallık, Kanada ve Amerika Birleşik Devletleri'nde yayınlanan kaza raporları incelenmiş ve makine dairesi ile ilgili 89 adet kazayı oluşturan faktörler, kazaların oluşum sıklıkları ve kök sebepleri belirlenmiştir. Bu çalışmanın amacı, incelenen makine dairesi kazalarının, oluşum sıklıkları ve kök sebeplerini, Karar Ağacı yöntemi kullanarak değerlendirmek ve literatürdeki boşluğu doldurmaktır.

Anahtar Kelimeler: *Karar Ağacı Analizi, Makine Dairesi, Denizcilik Kazaları.*

1. Introduction

A marine casualty can occur due to an event or combination of some events. In the literature, marine casualties are separated into two categories; one is 'casualty with a ship' which is related to the ship, equipment or cargo and the other is 'occupational casualty' which is the result of human factors [1].

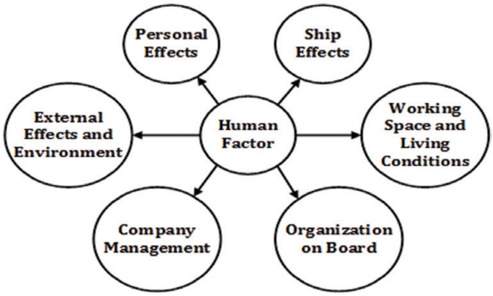

Figure 1. *Human Factor*
Source: *International Maritime Organization (IMO) [2]*

IMO classifies the human factors as personal effects, ship effects, working space and living conditions, organization on board, company management, external and environmental effects [2].

A considerable amount of literature has been published on investigation of maritime casualties. These studies were mainly based on one of the casualty types [3, 4, 5], main causes of any casualty types [6, 7, 8] or finding out the relationship between ship types or cargo types and casualty types [9, 10, 11]. For instance, Roberts et. al [12], investigated all casualty types in dry bulk ships, Chauvin et. al [13] studied human factors in maritime casualties, Pedersen [14] attempted to analyze grounding and collision casualties. Barnett [15] revealed main causes of maritime casualties and Akten [16] analyzed casualties in Istanbul Strait. In addition, several studies attempted to investigate risk concept in maritime industry and used various methodologies to make a risk assessment. There is a large volume of published literature on both investigating casualties and analyzing risk concept in maritime industry. However, there are very few studies that examine ship engine room casualties and its root causes. Yifenget et. al [17] analyzed fire and explosion casualties occurred in engine room of dual fuel ships by using fault tree analysis method and Adamkiewicz and Fydrych [18] studied risk analysis in maintenance of ship power system. Thus, there is not a great deal of previous research about ships' engine room casualty analysis. This study aims to fill a gap in the literature and to investigate engine room based casualties, frequency of each casualty type and root causes of each engine room casualty by using decision tree method.

EMSA statistics also[1] give additional data about ship casualties' location around the world. The coast of the United Kingdom is the area where most ship casualties occurred in Europe and the USA's and Canada's are the Americas', and Australia's and New Zealand's are the Australia Continent's most casualty happening areas.

For this purpose, this study was divided into four parts. The first part deals with general information about maritime casualties, previous studies about both maritime and specifically engine room casualties and originality of the study. The second part details sample selection and describes the methods of analyzing the casualty investigation reports. The third part gives results and findings according to the analysis of reports. Finally, the fourth and last part indicates the analyses that are discussed in the conclusion.

2. Data Collection Process and Methodology

Engine room (E.R) is a crucial area for ship operations since propulsion, power generation, fuel, lubricating oil, cooling & heating systems, exhaust gas, starting, bilge and ballast, ventilation, cargo (for

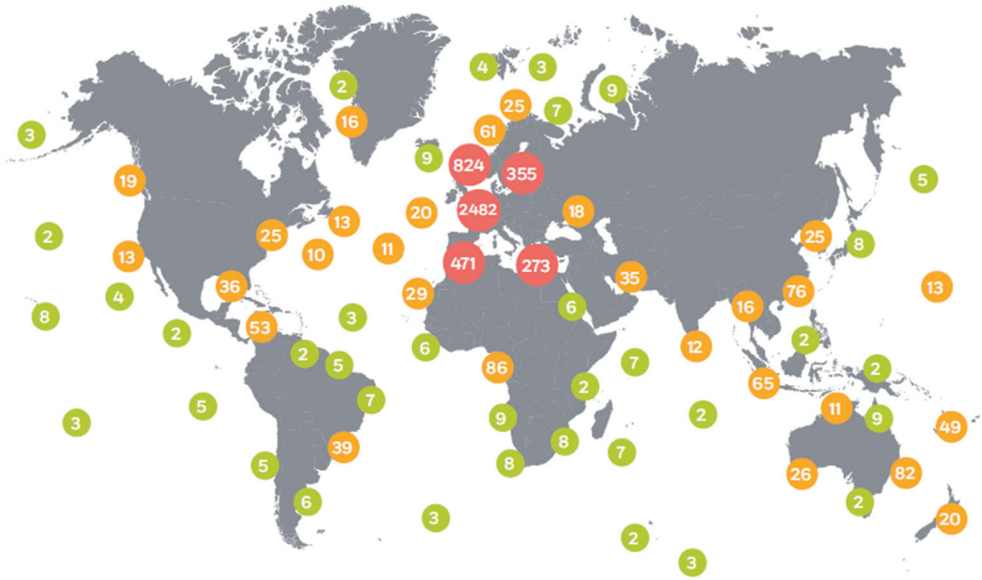

Figure 2. *Global Distribution of Casualty Location Between 2011-2013*

Source: *European Maritime Safety Agency (EMSA) [1]*

liquid cargo) and domestic (fresh water / sea water / waste) systems are located in the engine room [19]. One or more system malfunctions may end in catastrophic consequences.

The Marine Casualty Investigators' International Forum (MAIIF) is an international non-profit organization dedicated to the advancement of maritime safety and the prevention of marine pollution through the exchange of ideas, experiences and information acquired in marine casualty investigation [20]. Ship casualty reports were reached from MAIIF [21] database and Global Integrated Shipping Information System (GISIS) [22]. Then, the reports which were related to engine room and consisted "engine room" as phrase in full text of reports were filtered. The engine room casualty reports selection was finalized with the help of Mendeley. That is a very common data analysis program for content classification. In consequence of the selection of the ship E.R casualty criterion in Mendeley, the top five countries which have the most E.R casualty quantities were defined as the United States, the United Kingdom, New Zealand, Australia and Canada. These selected engine room reports were examined in terms of causes, consequences and frequencies. There were not any constraints on ship type casualties of all ships' E.R reported by the United States (17 reports) the United Kingdom (16 reports), New Zealand (13 reports), Australia (26 reports) and Canada (17 reports) and they were analyzed with their results. Table 1 indicates the number of casualty reports published online and the number of reports related to engine room of selected countries. In addition, due to the fact that all published reports are not adequately detailed, only the reports which detail the casualty and consequences clearly are considered. Thus, the rate of engine room casualty reports to the all casualty reports may not be accurate.

The causes of the engine room casualties determined by filtering the causes which may be related to engine room were among

Table 1. Casualty Report Analysis of Selected Countries

Country	Institution	Website	Casualty Reports	Casualty Reports about Engine Room
Australia	Australian Transport Safety Bureau	http://www.atsb.gov.au/ [23]	213	26
Canada	Transportation Safety Board of Canada	http://www.tsb.gc.ca/ [24]	368	17
New Zealand	New Zealand Transport Casualty Investigation Commission	http://www.taic.org.nz/ [25]	207	13
United Kingdom	Marine Casualty Investigation Branch	https://www.gov.uk/maib-reports [26]	529	16
United States of America	National Transportation Safety Board US Coastguard	http://www.ntsb.gov/ [27] https://www.uscg.mil/ [28]	269	17

Source: *Gathered by authors*

the findings of Baker and Seah study [29] in which main causes were classified according to the United Kingdom Marine Casualty Investigation Branch (MAIB) [30], Transportation Safety Board Canada (TSB Canada) [31] and Australian Transportation Safety Board [32] casualty investigation reports. Therefore, determined reasons of engine room casualties are given in Figure 3. The Figure 3 was drawn in Microsoft Visio 2013 which is a commonly used diagram drawing software. There are some acronyms to reduce the size of this figure. These are M/E is for main engine, A/E stands for auxiliary engine and L/O is for lubrication oil. Furthermore, particular data of the ships were collected from reports in order to categorize vessels according to the casualty type of the ship, classification society, flag state, IMO number, deadweight tonnage (DWT)and built year information which gave us statistical findings about 89 casualties surveyed.

In consideration of grouping engine room casualty reasons, a decision tree was generated. Decision tree is a technique to make decisions [33] and representations of a decision procedure for determining the group of each possibility. Decision trees are a well-known algorithm for classification problems [34] and this method is used to analyze reasons of casualty frequencies. Each step of a decision tree specifies a subgroup [35]. It is also a common method to determine the relationship between observed and quantified data to build a mathematical model [36]. In this paper a decision tree is generated to analyze and group reasons of ships' engine room casualties.

3. Results and Discussion

The data, collected from Casualty Investigation Reports, were organized and counted. Moreover, statistics of these data were sorted, and report number per country, report date, flag state, ship type, build year, ship classification society and DWT range distributions were obtained. Besides, the decision tree analysis was organized according to the results of the reports.

Table 2 demonstrates the date distribution of casualties. Dates are categorized as before and after 01/01/2002, since 2002 is the ISM (International Safety Management) Code, which is related to standardization of marine safe management, operation and pollution and entry into force date. 43.82% of casualties are before 01/01/2002 and 56.18% of them are after 01/01/2002.

In the Table 3, distribution of classification societies was demonstrated. According to this table, there are twenty nine (32.58%) Lloyd's Register classed ships which had engine room casualty. However, twenty seven (30.34%) of vessels' classification society were not remarked in casualty investigation reports. Canadian and Australian authorities did not record ship classification society information properly.

Table 4 illustrates the flag state distribution of ships. The number of American flagged ships is sixteen (17.98%), Canadian flagged ships' number is fifteen (16.85%), and Australian flagged ships'

Figure 3. *Categories of Engine Room Casualties*
Source: *Gathered by authors from [29-32]*

Table 2. *Date Distribution*

Casualties reported	Quantity	%
Before 01 January 2002	39	43.82
After 01 January 2002	50	56.18

Source: *Gathered by authors from [23-28]* number is thirteen (14.61%). These three countries are the top flag states.

Table 3. *Classification Society Distribution*

Ship Classification Society	Quantity	%
LR (Lloyd's Register)	29	32.58
GL (Germanischer Lloyd)	3	3.37
DNV (Det Norske Veritas)	10	11.24
ABS (American Bureau of Shipping)	10	11.24
Nippon Kaiji (Japan Lloyd)	2	2.25
BV (Bureau Veritas)	5	5.62
Polish Register	1	1.12
TCMSS (Transport Canada Marine Safety and Security)	1	1.12
TC (Type Certification)	1	1.12
N/A	27	30.34
Total examined report number	89	100

Source: *Gathered by authors from [23-28]*

Table 4. *Flag State Distribution*

Ship flag state distribution	Quantity	%
Antigua & Barbuda	2	2.25
Australia	13	14.61
Bahamas	4	4.49
Barbados	1	1.12
Canada	15	16.85
Cyprus	2	2.25
France	1	1.12
Hong Kong	3	3.37
Liberia	2	2.25
Marshall Islands	1	1.12
Netherlands	2	2.25
New Zealand	9	10.11
Panama	4	4.49

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Table 4. *Flag State Distribution (Cont')*

Saudi Arabia	1	1.12
St Vincent	1	1.12
UK	11	12.36
USA	16	17.98
N/A	1	1.12
Total examined report number	89	100

Source: *Gathered by authors from [23-28]*

According to the literature review which was done in the subject of marine casualties, causes of engine room casualties were classified and their percentages were deduced as a result of the analysis on casualty investigation reports of selected countries. 89 engine room casualties were examined and their reasons were obtained. According to this examination, the rate of each category was designated, organized and shown in a decision tree which was drawn by using Microsoft Visio 2013. Decision tree provides an alternative tool for designation and illustration of the causes of engine room casualties. There are two ratios near subheadings. The ratio between parentheses (before the subheading) represents the rate of the subtitle in its group. The other ratio shown at the right side of the subheading is the rate of the title in all casualties. In Figure 4, the decision tree analysis is illustrated.

Inadequacy of Operational Procedure and Measure of Safety' are the leading heading with 65.283%. Among the subheadings, 'Carelessness/Neglect' has the highest ratio (19.565%). Besides, 12.183% of all casualties are caused by carelessness and neglect. Moreover, 'Failure of implying preventive maintenance', 'Failure of complying rules and regulations', 'Inadequate Safety Measures' and 'Lack of training' are the following subheadings in this part. As you can see, the last four subheadings are about following the procedures established by companies, surveys or maritime institutions. As a result of these ratios, it can be said that preventing omission and following rules have a high impact on avoiding engine room casualties. (32.812% of the group). The most common example of this cause is fuel leakages which cause fires frequently. It can be said that the ship crew should be trained to handle pressurized pipes and fittings to reduce

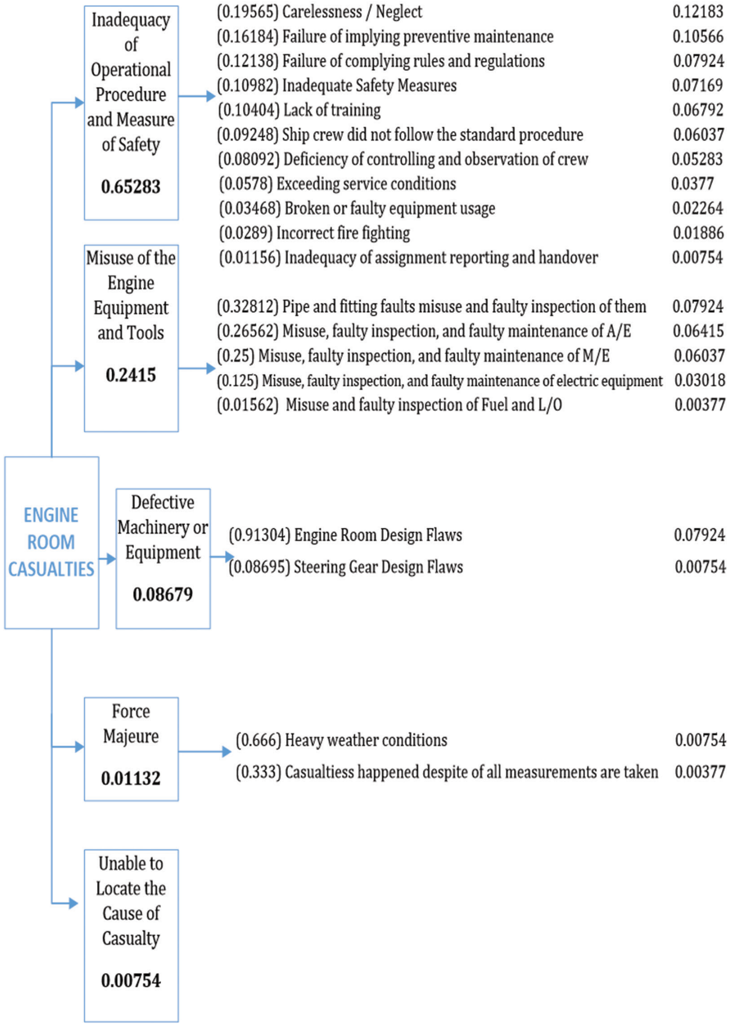

Figure 4. *Decision Tree Analysis of Engine Room Casualties*
Source: *Gathered by authors from [23-32]*

The second heading is 'Misuse of the Engine Equipment and Tools' with 24.15%. 'Pipe and fitting faults misuse and faulty inspection of them' has the highest rate these types of casualties. 'Misuse, faulty inspection, and faulty maintenance A/E' and 'Misuse, faulty inspection, and faulty maintenance M/E' have near ratios. Main causes of these types of casualties are mostly because of inexperienced ship staff and the solution is education of the staff more accurately. The first and the second headings cover the human errors and its total rate is 90.433% which is remarkably a high value. The importance of education was mentioned above. In addition to high human error factor, other crucial main causes are fatigue and excessive workload. Hence, crew's working hours are journalized and these results show that it is crucial to supervise these records more strictly.

The third heading is 'Defective Machinery or Equipment' with 8.679% and "Engine Room Design Flaws" has the rate of 91.304% in this group. The other subheading is "Design Flaws of the Steering Gear" with 8.679%. These results show us the importance of the ship design process. Designers should consider the operating conditions at the design phase to ease the operation and to avoid casualties. Moreover, it is seen that manufacturers are obligated to provide understandable and adequate instruction books for their equipment. Besides, approximately eight percent of casualties in this group occurred due to steering gear breakdowns. Especially, it is seen that collision and grounding casualties could have been prevented with better maintenance and design of steering gear.

In this analysis, 'Force Majeure' heading takes the fourth place with 1.132% and the last one is 'Unable to Locate the Cause of Casualty' heading with 0.754%. There are only three casualties under the 'Force Majeure' heading and two of them occurred because of the heavy weather conditions. Even the voyage plans of ships included weather conditions, in these two casualties, ships experienced unexpected heavy weather conditions. Hence, they lived through engine room casualties. In the other casualty in this group, it is reported that, all measurements were taken yet the casualty occurred. There are also two casualties whose reasons could not be identified.

4. Conclusion

The present study was designed to determine main causes of ship engine room casualties by using decision tree analysis method. For this purpose, casualty investigation reports of engine room casualties were categorized and five selected countries' reports were investigated to determine the causes of engine room accidents. Finally, a decision tree was generated to analyze and group reasons of ships' engine room accidents. Occurrence frequencies of main causes of accidents showed all rates and rankings of headings and subheadings. This analysis demonstrated some significant outputs for further studies about frequency.

The most obvious finding to emerge from this study is that human factor is crucial for safety of engine room operation. According to the findings, 90.433% of all engine room accidents were caused due to human error. Main causes of human errors were mainly lack of training and experience, fatigue and excessive workload. The second major finding was high percentage of accidents occurred because of design and manufacturing defects. Also, the importance of adequate instruction books can be seen in the finding.

These findings have significant implications for the understanding of why engine room casualties occur. A key strength of the present study was to contribute to the literature which is missing in examination of ship engine room casualties. The method used to analyze engine room casualties in this study may be applied to other maritime casualty investigation analysis studies. Although the current study is based on a small sample of casualty investigation reports, the findings can be used to explain other engine room accidents.

Despite the fact that a large number of

marine casualties occur all over the world, only a low percentage of these casualties was reported and published online. Thus, a small amount of casualty investigation reports published online could be analyzed. Therefore, it is the major limitation of this study. On the other hand, due to the fact that published reports were not adequately detailed, only the reports which detail the casualty and consequences clearly were considered. In addition, five countries which have the greatest number of published reports available online on their official websites were selected to investigate. Because of all these limitations, only 89 reports from 5 countries were investigated in the study.

In further studies, research which consists of more casualty investigation reports from different countries may be conducted. This situation can help us with testing and correcting the results of the study. In addition, the method used in the study can be developed via using an algorithm, and a full decision making mechanism can be established.

The findings of this study have a number of important implications for future practice. There are a number of important improvements which need to be made to decrease casualty occurrence in ships' engine room. For instance, once the results of the study were examined, it was seen that the majority of the problems arising from human error was based on fatigue and excessive work intensity. Thus, the audits on the working hours of human resources working in the maritime industry need to be tightened. Another reason for casualties caused by human error is due to lack of education and failure to comply with the regulations. In order to find a solution to this situation, it is necessary to make the trainings more disciplined and to impose safety culture on the ships' crew. Finally, it is seen that a considerable amount of engine room casualties are caused by design flaws. In order to solve this problem, the ideas of the operators should be taken into consideration in the design phase and the design process should be followed in a more systematic way.

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