HUMAN FACTOR RISK MANAGEMENT FOR MARITIME PILOTAGE OPERATIONS

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ABSTRACT

In recent years, marine pilotage accidents occurring on a worldwide basis as a result of human error have not ceased to transpire, despite advances in technology and a significant set of international conventions, regulations, and recommendations to reduce them. Existing studies reveal that previous maritime risk and safety assessment findings provide valuable insights, but over the last decade, scarce information in terms of human factor studies specific to pilotage operations can be found. The risks and uncertainties in pilotage operations have yet to be fully explored. As a result, identifying, evaluating, and mitigating the human factor-related risks influencing the safety performance of pilotage operations is essential.

The aim of this research project is to investigate the effect of human factors on pilotage operations, and to evaluate the impact of these factors on operators' performance; this last in turn may affect current pilotage operations by ultimately proposing an effective risk management framework, based on a decision-making analysis methodology.

Firstly, human-related risk factors (HCFs) identification is conducted through a combination of primary and secondary sourced data. A comprehensive literature review was carried out, and a considerable number of real past case examples and maritime accident/incidents investigation reports have been reviewed. In order to validate the identified risk factors (HCFs) and to explore other contributory factors, survey questionnaires and semi-structured interviews with domain experts have been conducted. An initial structural hierarchy diagram for the identified risk factors (HCFs) has been developed and validated through experienced experts belonging to the maritime sector.

In order to assess the human causal factors (HCFs), a novel hybrid MCDM technique based on the combination of the Analytic Hierarchy Process (AHP) and Decision-Making Trial and Evaluation (DEMATEL) methods is applied. The AHP is firstly used to evaluate the weight and rank the importance of the identified human causal factors that affect pilotage operation safety, while the DEMATEL method is applied to determine whether there are relationships among the factors.

The key findings of the previous models assist the decision-making process by informing of appropriate measures for mitigating the risks influencing pilotage operations. Risk mitigation measures are identified through literature review, the implemented regulation, rules, and recommendations adopted by IMO and other organizations and via experts' perspectives, and then evaluated through the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

The results of this study are beneficial to the maritime industry, by means of identifying a new database on causal factors contributing to the occurrence of maritime pilotage disasters. In addition, the study provides an effective risk factors assessment tool, and offers a diagnostic instrument to help implement effective risk reduction strategies, in order to prevent or at least mitigate a human error incident/accident from occurring.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
ASEP	Accident Sequence Evaluation Program
ASME	American Society of Mechanical Engineers
AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
CREAM	Cognitive Reliability Error Analysis Method
CAMSS	Centre for Advancement of Maritime Safety and Security
DEMATEL	Decision Making Trial and Evaluation Laboratory
EMSA	European Maritime Safety Agency
ECDIS	Electronic Chart Display and Information System
ENC	Electronic navigational chart display
FSA	Formal safety assessment
G.A.M.E	German Association for Maritime English
GPS	Global Positioning System
HF	Human factor
HCFs	Human causal factors
HCR	Human Cognition Reliability
HEI	Human Error Identification
HEIST	Human Error Identification in Systems Tool
HFACS	Human Factors Analysis and Classification System
HELM	Human Element, Leadership and Management

HRA	Human Reliability Assessment
IG	International Group
IMO	International Maritime Organization
ISM	International Safety Management Code
Kts	Knots
MAIB	Marine accident investigation branch
MCDA	Multi-Criteria Decision Aid
MCDM	Multiple criteria decision-making
MLC	International Labour Organization
MLC	Maritime Labour Convention
MSC	Maritime Safety Committee
NIS	Negative ideal solution
NFPA	National Fire Protection Association
NTSB	National Transportation Safety Board
OOW	Officer of the Watch
P&I:	Protection and Indemnity
PIS	positive ideal solution
RCO	Risk-control options
RMM	Risk mitigation measures
SHERPA	Systematic Human Error Reduction and Prediction Approach
SMCP	Standard Marine Communication Phrases
SIRC	Seafarers International Research Centre
SLIM	Likelihood Index Methodology
SOLAS	International Convention of Safety of Life at Sea

STCW	Standards of Training, Certification and Watch keeping for Seafarers
THERP	Technique for Human Error Rate Prediction
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
TSB	Transportation Safety Board of Canada
UKMPA	United Kingdom Maritime Pilots' Association
UNCTAD	United Nations Conference on Trade and Development
VLCC	Very Large Crude Carrier

CHAPTER 1: INTRODUCTION

1.1. SUMMARY

This chapter presents an overview of this thesis. The first section provides the background and justification for conducting the study, followed by the discussion of the research aim, objectives, and questions. The fourth and fifth sections outline the research framework (methodology, and the scope of the thesis) and the structure of this thesis, respectively.

1.2. RESEARCH BACKGROUND

Over the past decades, the complicated nature of pilotage operations has challenged researchers in the maritime industry to research, design and develop models and mechanisms to improve maritime safety and to solve the complexity associated with maritime transportation related risks, in particular, pilotage maritime operations. In spite of the development of new technologies, the developments in the shipping industry, and the implementation of safety related regulations, the impact of maritime accidents has remained on average at about the same level (Corovic & Djurovic, 2013; Noroozi et al., 2014), and the safety level of various ship types has not significantly changed (Eliopoulou & Papanikolaou, 2016).

Most authorities concerned with safety at sea reported that human element factors have now become one of the major causes of accidents. And most of these accidents occur in narrow channels, and during berthing and unberthing manoeuvres (Uğurlu et al., 2015b), resulting in damage to the environment and property (Erol and Basar, 2015). There are many causes that can result in maritime accidents such as organisational, mechanical, and electrical problems, as well as external factors such as adverse weather conditions; however, studies estimate that around 80% of maritime accidents are attributable to human error (Uğurlu et al., 2015a). And according to Graziano et al (2016), 96.5 % of the errors have been performed on the Bridge where the main actor is involved.

Prominent international organizations involved in the maritime industry such as the IMO, ASME and NFPA, UNCTAD have been improving on maritime navigation safety through recommendation of rules and regulations aimed at addressing previous accidents. However, accidents still occur and will continue to happen if proactive risk assessment is not practised in pilotage operations. Therefore, the way pilotage operations' risk is assessed and managed should be in a proactive rather than reactive manner.

Over the past decade little has changed and cases of collisions and ship grounding are regularly reported, where numerous instances provide evidence that many incidents that occur during pilotage can be attributed to human error (Mercator, 2012; Uğurlu et al., 2015). Murdoch et al. (2012) stated that since 2000, the standard I&P club has seen the annual cost of dock damage claims increase from approximately $3 million to $19 million, and almost 70% of these claims came because of bad ship handling, errors due to ship control, fast speed, tug errors or pilot errors. According to Gill and Wahner (2012) captains of the ships, deck officers, and pilots have caused the major contributory factor for many maritime disasters. The complication and the difficulties that the mater represents today in the shipping industry in terms of structural adjustments, technological changes and operational requirements reveal the necessity for further research to address this issue.

In spite of the presence of marine pilots on board ships to avoid human error involved in marine accidents, and to ensure the safety of navigation of visiting ships, it is however, a fact that a considerable number of accidents still occur (Gard, 2014). Gard (2014) reported that, in recent years, the number of maritime accidents occurring worldwide has been increasing, involving significant contact damage to fixed objects by vessels manoeuvring in confined waters, mostly within port. Fixed objects include berths, docks, locks and shore side equipment such as cranes. The contact damage has resulted in some very large claims for the repair and/or loss of use of such objects. These accidents have raised questions on how risk/ safety is reviewed in pilotage operations.

Pilotage operations involve the management of high-risk situations that require intense concentration and high standard levels of competence and skills, Pilotage operations are categorised as one of the most complex tasks, which is predominantly performed under a dynamic and uncertain working environment, extreme weather conditions, and heavily congested areas. Pilotage operations are liable to diverse risks due to their interaction and interdependence, in addition, the multiplicity of the entities who are performing ships' berthing operations. It is conducted by multiple operators with different responsibilities including the pilot, ship's crewmembers, tugboats and mooring boat crews, VTC regulators and shoreline personnel, who are required to work cooperatively together as one team with the objective of guiding the ship safely to its berth (Murdoch et al. 2012).

It is worth mentioning that, during pilotage operations, high levels of operational uncertainties exist. Especially when a shipmaster is unfamiliar with the pilotage area or the master may be entering the port for the first time or the port pilot is not qualified. It is therefore essential that operators maintain a consistently high standard of human performance in order to maintain the ship's piloting safety, as any decrease in performance can potentially lead to a disaster (CAMSS, 2012). Pilotage safety performance at sea contributes to maritime safety and is of great importance to seafarers, the shipping industry and the international maritime organisations.

The quality of performance and safety of ship's operations during pilotage operations has a significant effect on productivity, safety, and reputation of the port. Therefore, a system evaluation that includes the early detection of risks is critical in avoiding performance degradation and damage to human life or properties. Furthermore, accidents or disasters that would endanger the pilotage operations will be avoided if a robust evaluation system forecasting mechanism is developed and effectively enforced.

Ships have changed over the years and ship handling has to evolve in line with these changes, e.g. ship sizes have increased whereas, ports have not always increased in size accordingly (Armstrong, 2007, p.1). Handling a large vessel in congested and restricted areas, such as straits, canals, and docks, is high-risk, making pilotage operations more challenging and complex (Uğurlu, et al., 2016). According to Xi et al. (2017), the technological innovations, developments in the shipping industry, and the emergence of complex systems and Very Large Crude Carrier (VLCC), makes the consequences of disasters more and more serious. The incredible growth of international trade and the introduction of new technologies mean that shipping industry risks are evolving. The issue is complex, and there is an imperative need to focus on this issue in more detail.

A large tanker ship entering a harbour may collide with a breakwater at the entrance of a port as a result of a pilot's error, which can cause an environmental disaster. An accident that may occur in areas, such as straits, or canals, or docks, may cause heavy traffic to slow down or even stop the transportation and shipping, and could causes high economic damage to the countries of the region (Erol and Başar, 2015). For instance, one serious accident caused by the grounding or collision of ships at sea or upon entering the port because of human error can endanger the port, crew, ships, cargoes, and damage the maritime environment, causing huge financial impact on coastal countries and companies (David, 2008). One such recent disaster was the collision of the M/V Cosco Busan with the San Francisco-Oakland Bay Bridge in 2007, an accident that cost the vessel's operator and insurers more than $60 million in clean-up costs and claims damages (NTSB, 2009).

In light of these considerations, and based on the above reasons, and the accidents described previously together with other disasters, the need for the maritime industry to improve its operations safety can be justified. It is now assumed that the assessment of the human related risk associated with pilotage operations, needs to be established in the maritime industry and threats to human performance must also be understood and mitigated to maintain pilotage operations safety, and achieve enhanced safety for international shipping and reduce consequent injuries, loss of life, and damage to the maritime environment and properties..

Since the marine casualties, most frequently occur when ships are piloting in narrowing waters, such as ports, and channels, investigating the major contributory causes to human error, which play a central role in the causal chain of maritime accidents, is critical to mitigate threats to the marine pilotage operations. Thus, determining the human factor influence on ship navigation safety is becoming more and more important (Gerigk and Hejmlic, 2015). The human factor should be dealt with proactively, and more research on this topic should be conducted to reduce the risks of pilotage accidents.

To tackle this issue, it is essential to understand what these risks are and how they influence the pilotage operations’ safety performance. The appropriate way to reduce the frequency and risk of maritime accidents is by identifying and mitigating the root causes of the accidents occurring in this region. In order to reach this aim, it is necessary to consider how operators may contribute to causing these accidents, and how they may act to mitigate and escape from any accidents that do occur. As Dekker (2006) stated, in order to find the cause of an accident it is important to identify where people made incorrect assessments and wrong decisions.

In this regard, the existing studies reveal that the findings of previous maritime risk/ safety assessments provide valuable insights. According to the literature review, there are a small number of studies specifically focused on the human factor risk assessment especially in pilotage operations. Nevertheless, the findings of the literature review reveals that the current human factor related risk analysing models are not capable of meeting challenges faced by maritime stakeholders.

The human related risks in the pilotage operations have yet to be fully explored. In addition, limited studies have examined the efficiency of the implemented mitigation measures in the maritime pilotage operations. Currently, the attention that is given to human related risk factors' measurement in this area is limited and needs further investigation. Therefore, the research applications on pilotage operations safety performance is becoming more and more important and should be emphasized to reduce the risks of accidents. The identification and mitigation of these risks is crucial as the successes or failures of the shipping industry can have far-reaching impacts on global trade and economy. Therefore, this research presents a risk measurements tool and has developed a performance improvement framework, and decision-making techniques that are capable of finding solutions that will ensure safety and efficient performance of pilotage operations.

1.2.1 Justification for conducting the research

Providing high quality and safe port service that meet the needs of customers lead to increase the port attractiveness to attract shipping carriers to berth at the port and enhance the port competitiveness (Ding et al., 2019). Therefore, the research applications on pilotage operations safety are becoming more and more important and should be emphasized to reduce the risks of accidents. As mentioned in the previous section, in the last decade the ships have not only become larger and faster, but there has also been a big increase in the numbers, resulting in more vessel traffic, particularly in ports and their vicinity (Hsu, 2012). Consequently, marine disasters are more likely in such waters causing loss of lives, damage to vessels and cargo, and damage to the maritime environment (Pak et al., 2015). Any of the aforementioned reasons would be sufficient to justify the need for the maritime industry to examine the impact of the human elements on maritime safety.

On the whole the above concerns indicate that pilotage operations safety at sea is of great importance to all the parties interested in the maritime industry and the research applications on the human factor are becoming more and more important and should be emphasized to reduce the risks of pilotage accidents. On the other hand, the problem facing maritime stakeholders who are professionals in assessing and managing human related risks regarding the pilotage operations is the lack of a model that approximates the risk management realities of the field and confusion over terminology, approaches and methods in the discipline. There is an imperative need to form a generic framework that can highlight the human errors and pilotage operations' safety issues facing marine professionals.

In recent years many research projects, regarding the maritime risk management issue have been conducted from several aspects, by using different methods in order to reduce the occurrence of maritime accidents in open sea areas, however it appears from a review of the literature that little research has been done in the maritime domain on issues related to the pilotage operation safety analysis issue, and until now, few studies have employed an appropriate evaluation method to examine how human factors contribute to the maritime pilotage accidents.

The incapability of traditional methods in addressing human-related risk factors in pilotage operations reveals a necessity for more practical research and a new approach in order to ensure proper implementation of the risk quantification and mitigation methods. There is a distinct need for a new human-related measurement tool not only to meet the need of port stakeholders but also to develop diagnostic instruments to port and pilotage systems capable of supporting decision-making in solving complex pilotage operations problems in an uncertain environment.

The problem with the previous studies is that they could conclude that all risks or challenges could be considered "critical" or "important", when the respondents were assessing each of them separately. Therefore, a ranking is missing to reflect the perceived degree of importance of risk factors in relation to each other. Without such ranking, stakeholders are not able to determine the relative importance of factors and will have difficulties in determining the right strategies to overcome them. Therefore, in order to solve this problem, and to produce more realistic and reliable results, this study aims at introducing a multi-criteria decision making (MCDM) method, to overcomes the shortcomings of the previous studies by introducing a new approach to identify the relative importance among accidents' human causal factors in maritime pilotage operations, by taking subjective judgments of decision makers into consideration.

Another limitation of the previous studies is that in recent years, international maritime authorities, scholars and practitioners have made a significant amount of effort to evaluate the human factor in order to identify root causes of human error and accident causations in the shipping transportation industry in order to improve safety at sea; however, most of these researches frequently neglected to evaluate the causal relationships among the human factors that contributed to the pilotage accidents, and few of these studies focused on analysing the interaction between accident causation factors using MCDM method. Therefore, in order to solve this problem this thesis presents a new method which has the capability of effectively quantifying the causal relationships and interdependence among factors. The method could also be used to estimate, and assimilate the relationships and interdependencies among human factor variables involved in other transportation systems and industrial fields.

At the substantive level, there exists a gap in knowledge about this issue. Similarly, at the academic level there is a need for more-practical research to find out the justification for the existence of the risk management and different methods for its proper implementation on this significant environment particularly with due regard to the potential requirements in the near future. This is a research gap that has not yet been intensely examined and needs to be addressed. This study, therefore, aims to propose a new comprehensive framework for identifying assessing, mitigating the human factors related risk affecting maritime pilotage operations safety, using a decision- making methods.

1.3. RESEARCH AIM AND OBJECTIVES

The aim of this research project is to propose a novel conceptual human-related risk management framework based on a decision-making analysis methodology for identifying, assessing, and mitigating the human factors affecting the maritime pilotage operations safety. The developed conceptual framework provides an integrated and effective human-related risk factors assessment tool and offers a diagnostic instrument to reduce human error, enhance the maritime pilotage safety performance and thus subsequently mitigating maritime accidents.

The aims specified above, can be addressed by achieving the following objectives:

• To carry out a literature search on human related risk factor associated within maritime pilotage operations.

• To develop a conceptual framework, to identify and develop a taxonomy for the human causal factors contributing to pilotage accidents

• To establish an innovative human causal factors quantification method to evaluate the weight and rank the human causal factors using Analytic Hierarchy Process (AHP).

• To develop an innovative method using a Decision Making Trial and Evaluation Laboratory (DEMATEL) technique to investigate the relationships between human causal factors

• To develop a model for the selection of the most ideal risk mitigation strategy, based on the technique for order preference by similarity to ideal situation (TOPSIS).

• To examine the proposed methods by the use of various case studies in some of the major ports and pilotage areas of the UK and Mediterranean.

This thesis, therefore, raises the following research questions and will answer them at the end of this research.

1.4. GENERAL RESEARCH QUESTIONS

Given the research background aforementioned, this study aims to provide an effective human factor quantification tool, and offer a diagnostic instrument to pilotage operations to satisfy the port stakeholders in a flexible manner. In this regard, in order to ensure that the research objectives are met and for providing a base for activities in this research, the following questions have been generated:

- RQ1.What are the risk factors (human element/ human factor) causing maritime pilotage accidents and how can they be identified and classified (develop a taxonomy)?

- RQ2. What are the most appropriate and useful methods to assess the most significant identified human related risk factors and how can they be used?
- RQ3. How can the identified human factors risk be prioritised and ranked?
- RQ4. What are relationships and interactions between human factors and how are these factors influencing each other?
- RQ5. How can the identified human related risk factors be mitigated and controlled? What are the risk mitigation measures (risk control options) that can be implemented to control and improve the performance of bridge staff involved in the execution of pilotage operations?

To answer the above questions, and based on the proposed conceptual framework, the three steps risk management process (i.e. human-related risk factors identification, assessment, and mitigation) as the main guideline to structure the research process is employed. This process is needed not just to meet the needs of interested stakeholders, but also to enrich the diagnostic tools available to support decision-making in complex pilotage operations in an uncertain maritime environment.

What are the human factor related risks causing maritime pilotage accidents and how can they be identified and classified (develop a taxonomy)?

“The human factor is a complex, multi-dimensional issue that affects maritime safety and marine environmental protection. It involves the entire spectrum of human activities performed by a ship's crew, shore-based management, regulatory bodies, recognised organisations, shipyards, legislators, and other relevant parties, all of whom need to cooperate to address human element issues effectively”(IMO, 2003). Human factors refer to human and individual characteristics, which influence behaviour at work in a way that can affect safety. In this study, much emphasis will be placed on operational aspects, including the human factor-related risks which have an impact on the operators who are responsible for executing pilotage operations. According to Berg et al (2013), the human factor plays a significant role in maritime safety. Therefore, managing the human factor that affects maritime safety is an important way to prevent accidents (Xuecai & Deyong, 2018).

The first objective of this study is to develop a comprehensive human factor related risks identification and classification methodology within the context of the maritime pilotage operations. The procedure for risk factors identification is one of the most significant steps in pilotage safety/risk assessment process. Risk identification enables decision makers to classify the contributory causal factors that can lead to maritime accidents during pilotage operations. Risk classification enables complexity to be simplified (Ugurlu et al., 2015). In addition, it facilitates the evaluation and helps risk managers to understand the events and the circumstances from which they arise (Pak et al., 2015).

There are different types of human factors that can contribute to maritime accidents during pilotage operations. Furthermore, there are different methods and techniques for their identification. The investigation should not be limited only to identify the causes already known. The investigation must be carried out for potential causes which may lead to accidents in future but have not happened yet. It must be ensured that all the human causal factors are identified. Taking into consideration the ones which have previously occurred. There are different tools and techniques to do this. This study adopts more than one method to collect data and provide extra evidence of the human factors affecting maritime pilotage operations safety.

In this research identifying the human causal factors contributing to pilotage accidents was accomplished through a combination of primary and secondary source data. Firstly, a comprehensive literature review related to the study was carried out. A detailed literature review is critical and extremely essential to research work, which must not only be comprehensive but also has to be up to date. The benefit of conducting this literature review is that it can assist to review previous relevant studies related to human factors and their impact on maritime accidents. It saves time and cost as the required data is previously searched and available (Saunders et al., 2007).

In addition, because obtaining primary data about an accident that has occurred in the past is practically impossible, using accident and incidents reports as a secondary source of data is unavoidable (Mazaheri et al., 2013; Mazaheri et al., 2015). In this research a considerable number of real past case examples and an analysis of the maritime accident investigations reports regarding pilotage operations events that occurred between 1995 and 2015 have been reviewed and examined. These reports were investigated by expert accident investigators and published by countries and relevant institutions and organisations such as, the Marine Accident Investigation Branch (MAIB) of the United Kingdom, the National Transportation Safety Board (NTSB) of the United States of America, and the Transportation Safety Board of Canada (TSB). Accident investigation reports are considered to be one of the most reliable sources of evidence to identify the root causes of the ships' accidents (Mazaheri et al., 2015). These issues will be further discussed in the literature review in Chapter two.

The main philosophy of reviewing and studying examples from past marine incident/accident, is to obtain an understanding of the concept of accidents, to figure out how they happen, to determine the causes and contributory factors which may negatively influence mooring operations safety and play a central role in the causal chain of maritime accidents. As Graziano et al. (2016) concluded "Accidents analysis provides important information on the root causes of marine accidents in specific locations and conditions". Learning reasons for accidents should assist others to learn lessons from them, what went wrong and how to avoid recurrence of similar accidents in the future. Thus, determining the root causes of the accidents is extremely important in mitigating the likelihood of their occurring in the future (Ugurlu et al., 2015).

The study is not all about the investigation of a particular previous accident. Revealing pilotage operations' associated risks, is not an easy task, especially when the process is proactively based. And due to the lack of data, the use of domain experts' knowledge is required to overcome this challenge. An empirical study has been conducted, interviews, and survey questionnaires with maritime experts were carried out through which it will be possible to explore and identify the other potential risk factors which may contribute to pilotage accidents in the future. After having identified the causal factors of the pilotage accidents, an initial structural hierarchy risk taxonomic diagram is developed, and then validated through experienced experts belonging to the maritime sector. Chapter 4 will be dedicated to developing an appropriate methodology framework to identify and classify the human causal factors contributing to pilotage accidents.

What are the most appropriate and useful methods to assess the identified human related risk factors and how can they be used?

The objectives of the above questions rely on widely used decision-making techniques such as Analytic Hierarchy Process (AHP), Decision Making Trial and Evaluation Laboratory (DEMATEL), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). For the application of any specific risk-based model on the pilotage operations environment there will be a need to use expert judgements and to use knowledge-based decision support systems. The decisions are usually made on multiple uncertain attributes. As a result, this study needs to deal with the uncertainties of data which are mostly unavoidable in pilotage operational contexts. Furthermore, given the complexity of pilotage operations, knowledge of human factor influences is critical to understand and mitigate threats to performance. In addition, decision makers may require an essential understanding of the interdependence relationships among the identified risk factors and develop appropriate solutions to reduce their impact and improve pilotage operations' safety

The evaluations of human causal factors, their importance, relationships, and selection of an appropriate measures to ensure the pilotage operations safety is a crucial decision for many stakeholders including port managers, ship-owners, surveyors, and safety engineers. The determination process of human factors in maritime pilotage accident should have the technical ability of handling complex multidimensional factors with scientifically acceptable methodology. Therefore, identification, evaluating, and mitigation of maritime pilotage accident caused by human errors is a kind of multiple criteria decision-making (MCDM) problem and requires MCDM methods to solve it (Özdemir et al., 2015). Consequently, in this study, in order to handle the problem appropriately, MCDM methods, AHP, DEMATEL, and the TOPSIS are employed.

MCDM is considered one of the most significant types of decision making studies. MCDM is a procedure that facilitates decision making processes, such as choosing, ranking or sorting actions. Multi-Criteria Decision Making (MCDM) methods have been applied by many researchers and practitioners for evaluating, assessing and ranking alternatives across diverse industries (Behzadian et al., 2012). Consequently, in this study, in order to handle the problem appropriately, MCDM methods, AHP, DEMATEL, and TOPSIS are employed. The MCDM techniques have been used because the scope of this research is to select from a predetermined number of decision alternatives on a set of attributes for a defined objective

In such a process of complex group MCDM, ambiguous and incomplete data are usually presented in different quantitative and qualitative forms. According to Yoon and Gyutal (1989), MCDM is "technical decision aids for evaluating alternatives which are characterised by multiple attributes". The attributes represent the different dimensions from which the alternatives can be viewed. Most critical situations that use MCDM problems in engineering practice are characterised by both quantitative and qualitative attributes with various types of uncertainties. In many circumstances, the attributes, especially in qualitative forms may only be properly assessed by human judgment, which is subjective in nature and is inevitably associated with uncertainties.

From the above discussion, the quantification of human errors can be viewed as a typical multi-criteria decision making (MCDM) problem under uncertainty as it involves multiple criteria of both quantitative and qualitative features to solve multi-criteria and complicated problems. The aforementioned techniques are based on the principle of the higher the weights, the more desirable the alternatives. The weights/ratings assigned to criteria are mostly obtained through subjective judgments and the scores are synthesised as a single value for each alternative to select the best solution from the alternatives. However, MCDM problems can be often assessed imprecisely due to uncertain and incomplete data related to different quantitative and qualitative determinants.

In order to tackle the problem, a hybrid approach of two or more methodologies that are already proven to be successfully applicable for dealing with MCDM problems under uncertainty has shown more appropriate applications. In this research, a hybrid approach of AHP and TDEMATEL for solving MCDM problems under fuzzy environment was applied to address the choice of to human factors that affect pilotage operation safety. Using a combination of both subjective approaches of utilizing expert judgment to select appropriate criteria could reduce the effects of ambiguity that arose from using information from human judgment and preferences.

In this study AHP method has been used to compare the importance or rating of a criterion against that of other criteria at the same level in the hierarchy decision. The fundamental criteria scale for the expert judgment was used in the pairwise comparison matrices, because it is already in the fuzzy form (Saaty, 2008a). In this methodology, to deal with the uncertainty of human thoughts and expressions, linguistic terms has been used in making decisions and the assessment grades. Linguistic terms are expressed by fuzzy numbers. In addition, to confirm the consistency of the pairwise judgement (judgement reliability), the consistency verification is employed, which is considered as one of the most important tasks of the AHP approach. The application of the fuzzy theory was introduced by Zadeh (1965) to express the linguistic terms used in the decision-making process in order to determine the existence of uncertainty and subjectivity of human judgment. The fuzzy theory has been preferred to assist in the selection of appropriate criteria because the fuzzy approach allows for the uncertainty of expert judgment to be taken into consideration.

How can the identified related risk factors be prioritised and ranked? And what are the relationships and interactions between human factors and how are these risk factors an influence on each other?

This research adopts a mixed approach, it is uses an MCDM approach as a data analysis technique. In the MCDM applications, the evaluations of human causal factors and their importance are conducted. The causal relationships and potential interactions among the selected human factors are also investigated. Analytic Hierarchy Process (AHP) is applied to determine the relative weights and rank the importance of the selected human factors that affect pilotage operation safety, while the DEMATEL method is applied to identify whether there are relationships among these factors. A mixed approach that uses different techniques and data sources in the same study can offset weaknesses in each. The combination of various methods (i.e. a hybrid approach) can yield more powerful decision-making support tools in MCDM problems. Therefore, this research applying a mixed methodology (i.e. hybrid approach).

The aforementioned methodologies facilitate the decision-making process for identifying the most important risk factors influencing the safety of maritime pilotage operations, and provide a comprehensive illustration of relationships among the factors and offer insightful understanding of the mutual influence among the risk factors to be managed. The key findings of the previous methods assist the decision-making process for choosing appropriate measures in later stages for mitigating the risks influencing pilotage operations, and prevent the occurrence of a similar incident/accident to the one investigated from reoccurring. Chapters 5 will be dedicated to developing appropriate decision- making frameworks to evaluate the human causal factors contributing to pilotage accidents.

How can the identified human related risk factors be mitigated and controlled? What are the main risk mitigation measures to be considered?

After the pilotage related risks factors were identified and assessed in order to manage and control the risks, an appropriate decision-making method is employed to select the most ideal measures for their mitigation. The proposed risk mitigation model for pilotage operations enable us to choose optimal risk mitigation measures which are deemed to be an important and necessary step in pilotage operations' safety improvement, and mitigating maritime accidents. The list of implemented risk mitigation measures (RMMs) to improve the pilotage operations' safety is identified through a literature review, rules and regulations adopted by maritime authorities, and via marine experts' perspectives. Afterwards, in order to obtain feasible alternatives (mitigation/control options), the identified risk mitigation measures are prioritized and selected. The selection is addressed by the adoption of the TOPSIS model.

1.5 RESEARCH METHODOLOGY, AND SCOPE OF THE THESIS

The previous literature review indicated that there is lack of knowledge about how to control risks in the maritime pilotage operations. Specifically, there is a lack of human related risk management framework in pilotage operations as a guidance or foundation which would support decision makers in the achievement of efficient risk management. According to Harris (2000), the ultimate objective of managing the risks is the capability of identifying, assessing, and mitigating the risk factors in which any company or industry is involved. In view of this, the research methodology of this study aims to develop a comprehensive framework for identifying, assessing, and mitigating the human factors related risks in maritime pilotage operations.

The proposed framework offers valuable insight to find optimal solutions for effective risk control to improve the pilotage operations' performance, and ensure that safety measures can be taken to reduce the potential human errors that may occur during maritime pilotage operations in real-world practice, and thus subsequently preventing or at least mitigating maritime accidents in the future. The research framework of this thesis is shown in Figure 1.1.

Maritime risk and safety are very broad research topics. This research focuses only on the evaluation of the impact of the human factor related risk on the safety of pilotage operations. In addition, it examines the currently implemented risk mitigation measures in this uncertain environment. The research will begin by reviewing literature articles, official documentation and other published materials related with pilotage incidents/accidents from reliable organisations to establish the need for carrying out human errors related risk research in pilotage operations to prevent or mitigate maritime accidents.

In conducting research on the riskiness related to pilotage and pilotage safety performance, much emphasis will be placed on operational aspects, including the human factors which have an impact on the pilots, assistant parties, and ship's crewmembers' performance (personnel who are responsible for executing pilotage operations) which in turn may affect the normal pilotage operations, leaving other risk aspects influencing pilotage safety such as organizational, management, policy implications, and natural and political issues to be addressed in future work. The reason this research is focused on the human factor only is that it is evident from the literature review that the human element has proven to be a major contributory factor for many maritime accidents and the majority of these accidents have been caused by ship's captain, ship's crew members, pilots, and assistant parties' errors. Examples come from data from a number of sources (Tzannatos, 2010), (Murdoch et al. 2012), (Gill and Wahner, 2012), (Akhtar and Utne, 2014), (Gard, 2014) and (MAIB, 2015).

Relevant literature review is used as a base to identify the human factors contributing to pilotage maritime accidents (HCFs). The historical data that has been utilized for this study is the accident reports of the maritime accidents/ incidents investigations reports prepared by different maritime organisation. However, as a result of lack of data, and in order to validate the HCFs that were extracted from the existing resources, and to explore other contributory factors and potential causes which may contribute to accidents in future that have not been mentioned in the literature and other documentation, another source of data is used in the form of expert knowledge. The expert knowledge for this study is acquired as a primary source via survey questionnaire and interviews with domain experts.

This study adopts more than one method to collect data and provide extra evidence of the human factors affecting maritime pilotage operations' safety. Data was collected via survey questionnaire and semi-structured interviews with experienced experts from both academic and industrial fields. This step was employed to better understand the role of humans in accident causation and ensure that all the causal factors contributing to pilotage accidents are identified. Questionnaires were designed and tested with the results being used to modify the contents. Ethical approval was also obtained to further validate questionnaire contents and participant consent. The questionnaires were then distributed via either emails or offline with a cover letter and content form to the targeted experts. The final questionnaire is shown in appendix II.

After having identified the contributory factors of the pilotage accidents and based on previous maritime safety studies related with human factors and risk classification, with assistance of ship's masters and academic experts with education level PhD degree from an educational institution, staff who have more than 10 years teaching and researching experience and have a good understanding of marine operations risk research, a hierarchal structure as a taxonomy is initially constructed. Thereafter, in order to validate the developed hierarchy a series of email questionnaires were distributed and face-to-face interviews were conducted.

The geographical focus of the research within this thesis are a major ports and pilotage area located in the United Kingdom (UK), and Miditerraiian. Experienced experts were requested to participate and share their expertise in identifying and evaluating data for technical models in the research. In order to reduce the individual researcher bias (Oppermann, 2000), the participants of this study were selected from a variety of backgrounds and different geographical areas within the maritime industry. In order to obtain views on a wider scale and to get multiple points of view, the participants included ships' captains who had served long periods onboard different types of ships which are navigating and visiting worldwide sea ports, experienced senior marine pilots, and tug masters who had been working long periods in different ports companies.

Furthermore, senior marine risk consultants, and academics from maritime educational institution staff with rich knowledge and experience of risk assessment and questionnaire surveys, flag state administration officials, insurance and port company managers who are professionals in assessing and managing risks, and who could provide factual information and broader data regarding causes of human errors that might occur during pilotage operations, and technical information and opinions on the research topic. All the criteria mentioned above ensures that the professionals are sufficiently senior and knowledgeable to answer the questions and are able to provide a good insight and valuable comments to all aspects of the survey.

For the purpose of assessing the human related risk factors, it is essential to measure the human factors contribute to the maritime pilotage accidents by determining their priority weighting and evaluating their inter-relationships. Other questionnaire surveys (risk assessment survey) were conducted and analysed using a mixed methodology (i.e. hybrid approach) Analytic Hierarchy Process (AHP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL). AHP has been applied to rank and identify the importance of the HCF and DEMATEL has been utilised to evaluate the causal relationships among interdependent HCFs. This thesis presents decision making techniques that are capable of finding optimal solutions that will ensure safety of pilotage operations.

In order to identify the relevant risk mitigation measures with regard to the identified risk factors, the current implemented measures in the real-time context and the rules and regulations adopted by maritime organizations were reviewed. In order to explore other mitigation measures that have not been mentioned in the literature and other documentation further questionnaire surveys were conducted. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was then used to analyse the data and rank the relative importance of those risk mitigation measures. The safety improvement measures that can ensure optimal operations of the pilotage operations were selected.

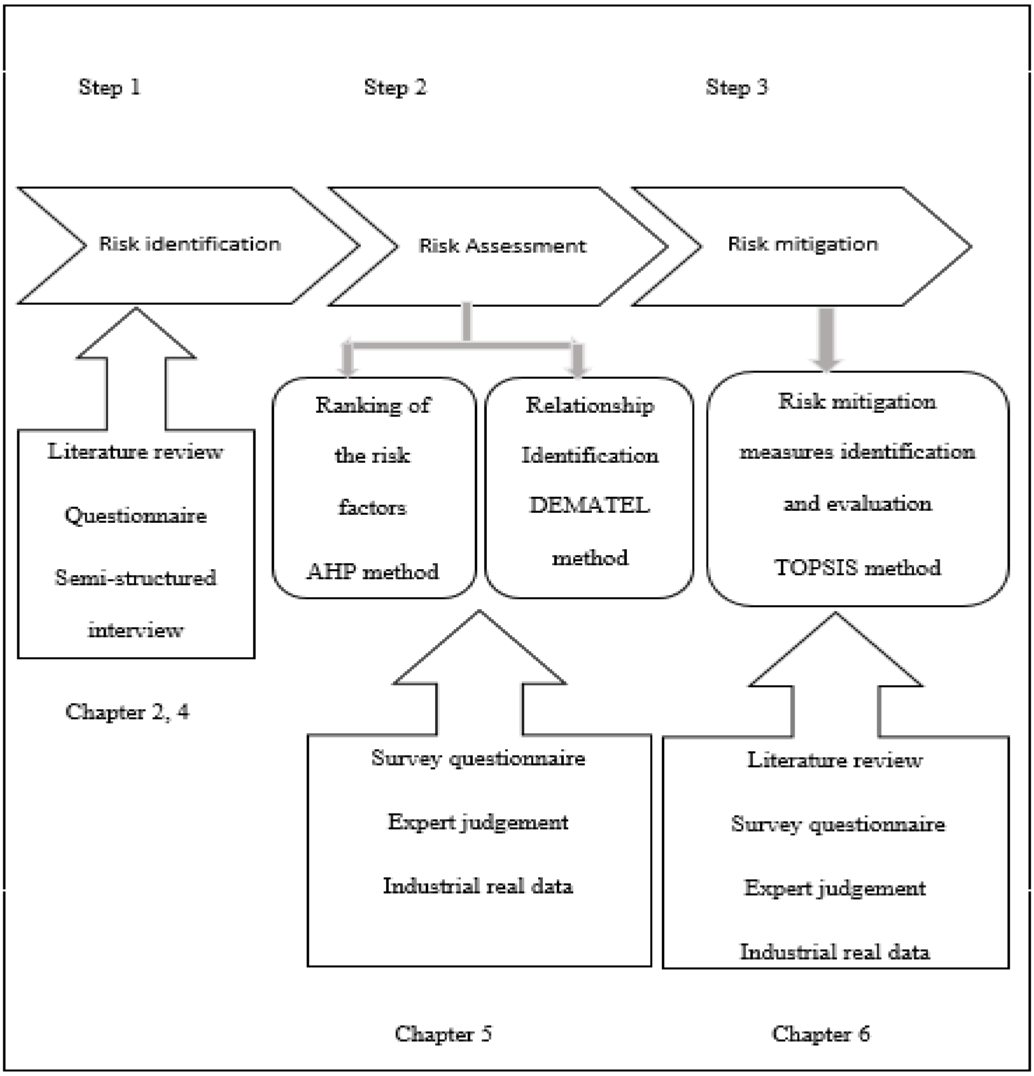


Figure 1.1 Research framework in this study

1.6. STRUCTURE OF THE THESIS

The thesis consists of seven chapters to achieve the major research objectives.

Chapter One – Introduction:

This chapter outlines a general overview of the research background and justification, aim, objectives, and the generated research questions, the scope of research, and methodological approach and structure of this thesis. It briefly reviews the requirement for this research and outlines how the research will be conducted.

Chapter Two – Literature review:

This chapter comprehensively reviews the literature on the concepts of safety in maritime transportation, intensive literature search on human related errors and main sources of risk factors (human related risk factors) and its effect on pilotage operations safety, the status of risk management in the maritime shipping operations context and their development as well as an analysis of the maritime accident investigations reports regarding pilotage operations events. This chapter discusses the current existing studies in association with human factors, and assesses the current knowledge on human factors and their effect on pilotage operations safety performance. The efficiency of currently implemented pilotage risk mitigation strategies in the maritime organizations. Eventually, some research gaps are found out, particularly concerning the pilotage operations human-related risks in the maritime sector.

Chapter Three – Research methodology: This chapter details the research methodology adopted, philosophy, approach, strategies and choices that established the fundamental for the research work. After defining the overall research design, the chapter looks to justify the methodological choices to meet the research objectives by outlining the application of data collection and analysis methods.

Chapter Four – causal factors contributing to pilotage accidents identification: This chapter presents the first step of the human factors related risk assessment process, i.e. the human factors affecting maritime pilotage operations safety identification. In order to expand the coverage of the risk factors identification and classify the unstructured risk factors, this chapter reviews relevant literature and other published materials involved with the human causal factors that contribute to maritime accidents, surveys, face-to-face and telephone interviews with professional experts belonging to various sectors of the maritime industry have been conducted. Based on the survey results, the hierarchical structure of identified risk factors is developed, modified and further validated through a serial of email and face-to-face interviews with the experts.

Chapter five – maritime pilotage operations risk assessment: This chapter introduces the second phase of the risk management framework. This chapter focuses on the assessment of identified human factors influencing the safety of maritime pilotage operations (HCFs), using a hybrid approach of two methodologies. It illustrates second and third-round questionnaire surveys conducted by empirical studies, where the data collected are analysed using AHP and DEMATEL methods. This is carried out to determine the relative weights of the risk factors identified and highlight the interrelationships between factors. First, the AHP (Analytic Hierarchy Process) is applied to determine the relative weights and rank the importance of the human factors that affect pilotage operation safety, and then the DEMATEL method is applied to identify whether there are relationships among the factors and which factors have influence on other factors.

Chapter Six – Identification and evaluation of risk mitigation measures: Instead of identifying the mitigation measures based just on the literature review, this research focuses on the current implemented measures and identifies them through the rules and regulations adopted by maritime organizations and via expert perspectives from both UK, Mediterranean, and other maritime industries. The significant levels of the identified risk mitigation measures are evaluated and ranked by using a TOPSIS method.

Chapter Seven – Conclusion: This chapter summarises the overall results and findings of this study. It also suggests the limitations of this thesis and provides the direction and recommendations for further research. Figure 1.2 illustrates the overall thesis structure.

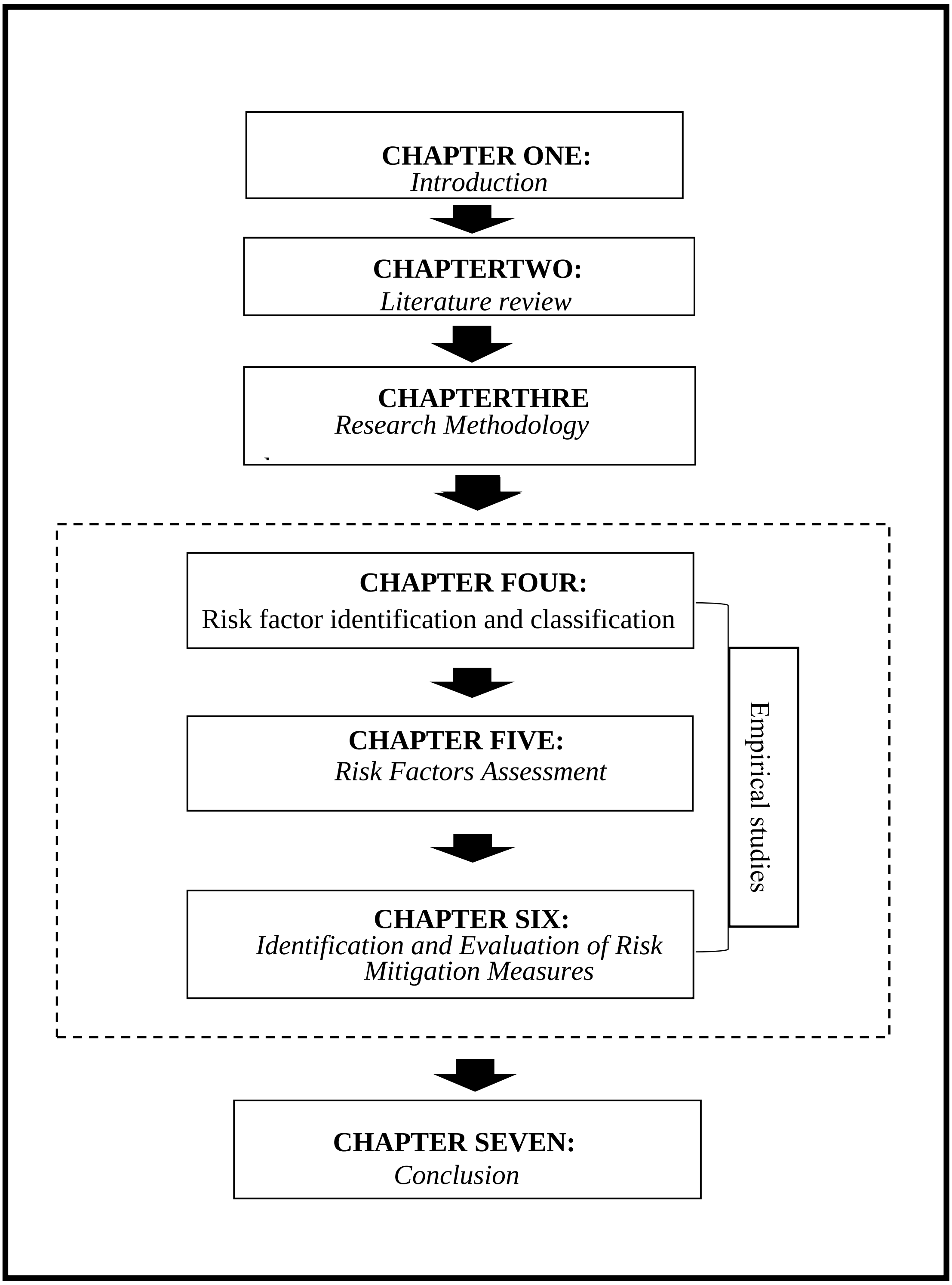


Figure 1.2: The structure of the thesis

CHAPTER 2 LITERATURE REVIEW

2.1 SUMMARY

In this chapter, to review previous relevant studies related to human factors and their impact on maritime accidents, a comprehensive and carful literature review was carried out. The literature was used to provide background information and an understanding of the field. This review of the literature will concentrate on the type of human factors that influence pilotage performance and contribute to accidents during pilotage operations. The significance of carrying out an analytical literature review is critical to the success of this study, as this helped the researcher to use new and appropriate methods to fill the gaps in this area and contribute to the development of better policies and more effective preventative measures to improve maritime pilotage safety.

2.2 INTRODUCTION

Maritime safety in the last few decades has become one of the most significant issues in the maritime industry. Since the known disaster of the passenger ship, Titanic, where there where 1,502 fatalities, the greatest challenge and the largest problems facing the maritime industry, according to reports, is human error (Corovic and Djurovic, 2013). The human errors are the basic and by far the major cause of maritime accidents, where 80% of all maritime accidents are caused by human error (IMO, 2011). As Graziano et al. (2016) stated, the human factor has been considered as contributing to most marine casualties. It is estimated that most of maritime accidents can be attributed to human error. Therefore, investigating of human factors and their contribution to accidents is essential.

In recent years many research projects regarding the maritime safety and maritime transportation-related risks have been conducted from a range of perspectives and several aspects including hundreds of articles and reports, however, few studies have examined how the human factors contribute to the maritime pilotage accidents, and until now, very few works of literature has been produced in the maritime domain on issues related to human factors and the pilotage operation safety issue. Therefore, safety management of pilotage operations needs urgent attention, in order to prevent catastrophic accidents.

Due to the lack of data regarding this area this literature review is restricted to researches that have investigated similar themes and applied similar methodologies which attempted to examine the effect of human factors on maritime safety, determine the main contributory factors of the accident, and to provide a solution for evaluating causes of accidents in the marine industry. The purpose of this literature review is to present previous studies that have been conducted related to the human factors in shipping operations, and their impact on maritime safety with a particular emphasis on pilotage operations. Understanding how the research area has developed in the past can help researchers to target the right directions for their research and assist with the formulation of new policies and practices to reduce future maritime accidents. (Luo and Shin, 2016).

The literature review provides significant data and information to this study and it is envisaged, "to provide a historical perspective of the respective research area and an in-depth account of independent research endeavours" (Colicchio and Strozzi, 2012). This chapter reviews the fundamental elements which make a valuable contribution to every step of the research pathway. It discloses, clarifies and exemplifies the structure of problems related to human factors and their effect on pilotage operations safety. The information has been sourced from academic journals, newspapers, books, and consultancy reports.

In this chapter, the literature related to the study is reviewed. The concept of pilotage operations and the human factor are described. The role of `human factor in maritime accidents at sea is outlined and past case examples of real pilotage accidents, including human errors, and unsafe acts caused by pilots and ship crew members and their impact on maritime safety is also discussed in this Chapter. The international rules, regulations, and the recommendations which have been adopted by the International Maritime Organization, and presented by other organizations, in order to ensure maritime pilotage safety are presented. Existing human factor and maritime accident-related methodology and various studies which have been conducted on the role of the human factor in the marine environment are discussed.

2.3 THE CONCEPT OF THE PILOTAGE OPERATIONS

Pilotage can be defined in number of ways relating to the nature of the pilotage act. For instance, harbour or port pilotage might refer to pilotage involving guiding a vessel into or out of a port. This can also be known as sea pilotage. Coastal-based pilotage is understood in some countries to be where a vessel is guided by pilot along the coast and not necessarily into or out of a port or harbour in that country. Deep-sea piloting is a pilotage that takes place in the North Sea, the English Channel, and Baltic Sea, and is subject to the requirements of IMO Resolution A.480v and A.486. UK pilotage is governed under the 1987 Pilotage Act as amended. According to UKMPA (2012), the English law, section 742 of the Merchant Shipping Act 1894 which still stands today under current legislation, a pilot is defined as "any person not belonging to a ship who has the conduct thereof".

Maritime pilotage is managing of high-risk situations and complex tasks that requires intense concentration and high skill levels (CAMSS, 2012). It is worth mentioning that, during pilotage operations, high levels of operational uncertainties exist, particularly when the weather is adverse or the ship is very large. Consequently, this will put pressure on the master at the peak and lead him to make his own assumptions on how the approach to the berth should be handled, especially when a shipmaster is unfamiliar with the area, or entering the port for the first time (Armstrong, 2007, p.8). Therefore, "Compulsory Pilotage in port areas is the principal risk mitigation measure available to ensure the safety of navigation of visiting ships; the safety of passengers and crews; the protection of the various environments: port, marine, riparian and littoral; the safety of other vessels navigating in the same waters and the overall efficiency and commercial success of the port" (UKMPA, 2012).

The importance of employing qualified pilots in approaches to ports and other areas where specialised local knowledge is required was formally recognized by IMO in 1968, when the organisation adopted the Assembly Resolution A.159 (ES.IV) recommendation on pilotage. The resolution recommends that governments organise pilotage services where they would be likely to prove more effective than other measures and to define the ships and classes of ships for which employment of a pilot would be mandatory. Qualified pilots are usually employed by the local port or maritime administration and provide their services to ships for a fee, calculated in relation to the ship's tonnage, draught or other criteria.

"Pilots with local knowledge have been employed onboard ships for centuries to guide vessels into or out of port safely or wherever navigation may be considered hazardous, particularly when a shipmaster is unfamiliar with the area" (IMO, 2016). In addition to local knowledge and expertise which reduces risks of navigating in constrained waterways, marine pilots are able to provide effective communication with the shore and tugs, often in the local language. Pilots should be experts and skilful ship handlers who guide ships through dangerous or congested waters, such as harbours or river mouths, give expert advice to the master concerning navigation, berthing and un-berthing conditions, and complete the berthing and un-berthing operation of the ships by controlling the ship's manoeuvrability directly and the tugs and shore linesmen through a radio. "The pilot is not simply a navigation adviser. In law the pilot has conduct of the navigation of the ship which involves a multitude of tasks and responsibilities" (UKMPA, 2012).

Maritime pilots play a critical role in ensuring the safe navigation of vessels (Hsu, 2012). Therefore, the pilot should ensure that he is adequately rested prior to an act of pilotage, in good physical and mental fitness and not under the effect of drugs or alcohol. The pilot and ship's master are responsible for the safety of navigation of the vessel piloting, as well as for other ships they may encounter, wharves, locks and docks. Indeed, the situation is that the ship master remains in charge of the ship and the pilot is in charge of handling the ship. A marine pilot assigned to that task has a responsibility to the state, the port authority and the ship's master, however, according to the IMO regulations, his presence onboard does not exempt the Master and the OOW from their duties and responsibilities for the ship's safety.

The relationship between ship's captain and pilot has always been a delicate one; it should be one of mutual trust and respect (Armstrong, 2007, p.8). There should be a sense of increased confidence when the pilot comes on board the vessel. Not only does the pilot bring local expertise that reduces the risk of navigation in confined waters. (CAMSS, 2012). But the pilot comes up on the bridge expecting to be a part of the bridge team. How the master and the pilot meet and greet each other is the key to how the rest of the passage and manoeuvring will be, it is very important that the chemistry between the pilot and ship's master is good. Otherwise it might lead to dangerous situations (Gard, 2007).

2.4 HUMAN FACTOR/HUMAN ERROR

A study on human factors to reduce human factor influencing the safety of operations of a complex system, was established in the 1950s (Subramaniam, 2010), however, the early work on the human-related risk assessment in maritime transport has been changed, and the scientists in the maritime field came to recognize that the old ways that have been used in past decades did not provide good system performance and are not capable of meeting challenges faced by maritime stakeholders. Furthermore, they also realized the need for new approaches for identification and quantification of human errors to verify various risks within a system, where the human factor has emerged as a major concern in maritime safety research and has become increasingly one of the most important maritime safety issues, as it has been widely acknowledged to be the most frequent cause that leads towards marine accidents.

As has been mentioned previously, "When discussing maritime safety, the term human element or human factor plays a crucial role" (Berg et al., 2013). There is no established international definition of the term, but according to IMO (2003), the human element is a complex, multi-dimensional issue that affects maritime safety and marine environmental protection. Human factor is considered as one of the most important contributors to the causation and avoidance of accidents (Subramaniam, 2010). Therefore, it is strategically important to carry out human factor evaluation in the shipping industry. Investigating human factors contributing to maritime accidents is of key importance for maritime policy and management, and highly required (Macrae, 2009). According to Özdemir and Guneroglu (2015), studying of the human factor and accident analysis has recently become a significant research topic among maritime professionals and scientists.

One of the ways to improve a human performance is by incorporating human elements, which can be achieved by carrying out human performance analyses and mitigating potential human errors within the system. According to Sanders and McCormick (1993), human error is an inappropriate or unacceptable human decision or action that degrades efficiency, safety or system performance. Safahani (2009) stated that, human error is a general term, which covers a variety of unsafe acts, omissions, behaviours, and unsafe conditions or a combination of these. Rothblum (2000) defined human error as incorrect decision, improperly performed action, or an improper lack of action.

(Rudan et al. (2012) describes human error as a product of the making of an incorrect decision or action. Reason (1990) describes the human error as unsafe acts that have various forms such as, violations or errors. Errors are divided into three sub-categories: decision based-errors, skill-based errors, and perceptual errors. Violations are behaviours that show disregard for the rules, and regulations (Shappell and Wiegmann, 2003).

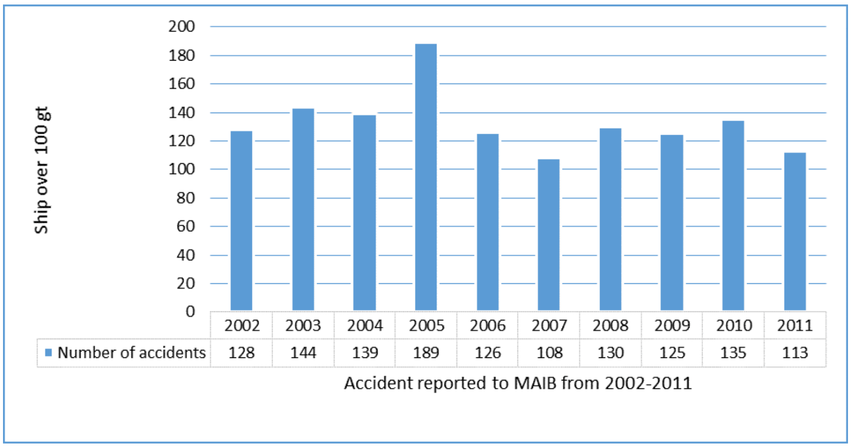
Human error associated with maritime pilotage operation accidents is an important issue in the shipping industry and to maritime stakeholders. The area of human error has continuously seen new publications and new findings over the past 30 years, signifying the complexity of human interactions with maritime operations (Luo and Shin, 2016). In order to mitigate potential human errors and improve the safety performance of the pilotage operations, it is of paramount importance that the aspect of human factor is incorporated in any effort of quantification of risk. Thus, the appropriate way to reduce the risk and the frequency of maritime accidents is by identifying the contributing human factors to human error and investigating methods which will either eliminate or mitigate these accidents (Celika and Cebib, 2009). Once that has been achieved, the human errors element contribution to marine accidents can be reduced. As Lu and Tsai (2008) pointed out, reducing accidents at sea depends upon implementing effective safety measures.

2.5 THE ROLE OF HUMAN FACTOR IN MARITME ACCIDENTS AT SEA

Over the past decades the greatest challenge faced by the maritime industry and the largest problems contributing to most maritime disasters has been the human factor. The international studies on maritime accidents show that the human error continues to be the primary cause in a considerable number of accidents at sea and these have not ceased to occur (Chauvin et al., 2013; Noroozi et al., 2014; Uğurlu et al., 2015; Othman, et al; and Graziano et al., 2016), despite advances in technology, and many studies being undertaken by many researchers and professionals (Akyuz and Celik, 2014), in addition, the rules and regulations that have been adopted by the International Maritime Organization in order to reduce them (Hetherington et al., 2006), resulting in the loss of life and damage to property and the environment (Hansen et al., 2002; Luo and Shin, 2016). Luo and Shin (2016) reported that, the overall number of maritime accidents over the past 36 years is 63,991, an average of 1.777 per year and human error has been identified as the main cause of these accidents.

UK Club reported that the percentage of the claims due to human error causes in maritime accidents increased, and the majority of these mistakes have been caused by deck officers, crew, shore persons and marine pilots (Goulielmos et al., 2012). In addition, less-skilled mooring parties CAMSS (2012). Mercator (2012) stated that over the past decade, cases of collisions and ships grounding are regularly reported, where numerous instances provide evidence that many incidents that occur during pilotage can be attributed to ineffective bridge team management, and it is often the case that the master and watchkeepers cease to monitor the navigation and position of the ship after the pilot has boarded.

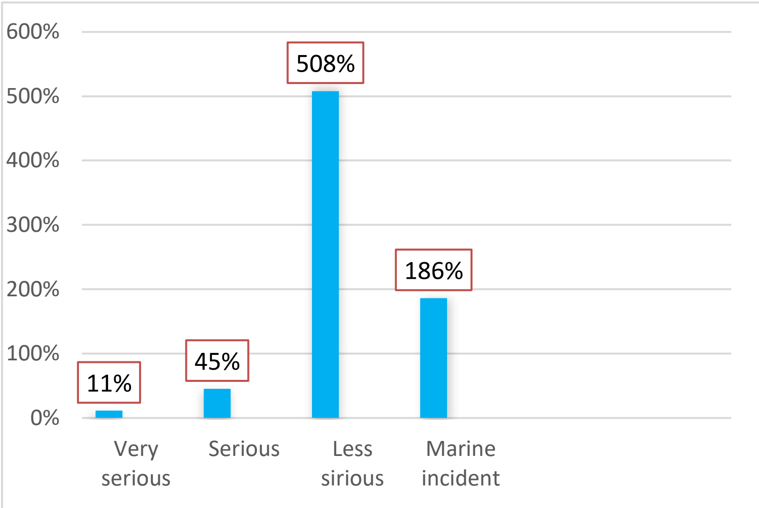
The data presented in Figure 2.1 highlights the statistics of the accidents reported to Marine Accident Investigation Branch (MAIB) from 2002 to 2011 to UK registered merchant vessels of 100 gross tons or more. Of 1337 accidents, 811 were caused as a result of human and technical factors, 555 accidents were due to human factor, 447 accidents had a technical factor, and 191 accidents were both human and technical factors (MAIB, 2011).



Source: MAIB, 2011. Graph author generated

Figure 2.1 the accidents reported to MAIB from 2002 to 2011

The data presented in Figure 2.2 highlights 1190 of the accidents (causalities and incidents reported to MAIB in 2016; these involved 1310 vessels. 42 of these accidents involved only non-commercial vessels, there were 687 accidents involving 750 commercial vessels that involved actual or potential casualties to vessels (MAIB, 2016)



Source: MAIB 2016

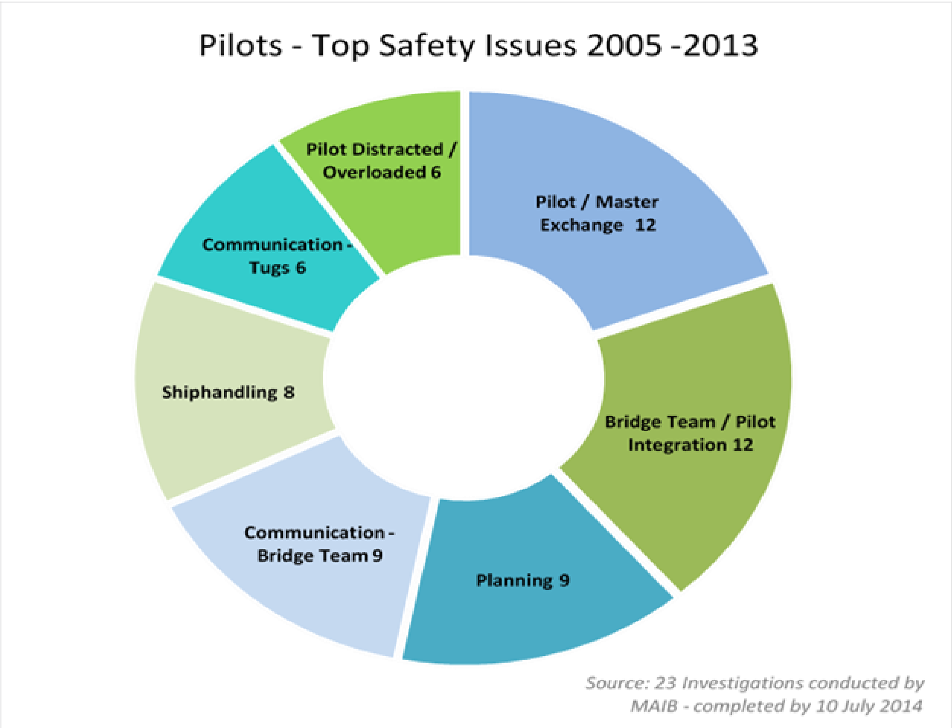
Figure 2.2: The accidents reported to MAIB in 2016

2.5.1. Past case examples of real marine accidents

In this study, in order to identify contributing factors to maritime accidents, investigation reports related to a number of occurring real worldwide maritime accidents during pilotage operations between the period 1995 and 2015 have been reviewed and examined. These reports were investigated and published by countries and relevant institutions and organisations such as, the Marine Accident Investigation Branch (MAIB) of the United Kingdom, National Transportation Safety Board (NTSB) of the United States of America, and the Transportation Safety Board of Canada (TSB).

As has been mentioned previously, determining the root causes of the accidents is extremely important in mitigating the possibility of their occurring in the future (Ugurlu et al., 2015), as many disasters have occurred because organizations have ignored the warning signs of past incidents or have failed to learn from the lessons of the past (Rohleder & Cooke, 2006). Therefore, one of the methods to reduce the number of maritime accidents, is to identify the types of human errors, by studying the past case examples from the real marine accidents and to review the investigation reports of marine accidents occurring worldwide, this last to determine how they happened (Chauvin et al., 2013). Moreover, ideally, learning the reasons behind accidents should help others to understand the causes and contributory factors which may negatively influence mooring operations safety, and to learn from them what went wrong and how to avoid similar incidents. By identifying and eliminating the causes, it is possible to prevent or mitigate the accidents in the future.

Investigations have been carried out by the MAIB in the UK. These investigations were into accidents that involved a UK vessel or occurred in UK 12-mile territorial waters during the period 2005 to 2013. In each case a pilot was onboard. The result of the analysis as demonstrated in Fig.2.3. showed that the major cause of the accidents which occurred was the human factor, and in the majority of cases reviewed the causes were one or more of the following: the pilot-master information exchange failure, poor bridge team-pilot integration, lack of communication, lack of planning, lack of ship handling skills, and pilot distracted/ overloaded (MAIB, 2015).



Source: MAIB 2015

Figure 2.3. Pilots- top safety issues 2005-2013

2.5.1.1 Team working and its influence on pilotage operations safety

Good teamwork plays a major role in safe and efficient navigation, as breakdowns in team work can lead to undesirable situation (Grech et al., 2008).The accident of the of container ship CMA CGM Centaurus is a case example of bridge team-pilot integration failure, when she had heavy contact with the quay and two shore cranes while under pilotage during her arrival at Jebel Ali, United Arab Emirates (Gard, 2006). The collision of bulk carrier Heloise with the tug Ocean Georgie Bain in the port of Montreal, is also one of the best accident examples of bridge team-pilot integration failure. The TSB (2013) investigation into this occurrence found that the pilot on the Heloise was not monitoring the Ocean Georgie Bain's position at the time of the collision, and the bridge crew on the Heloise had not been assisting the pilot by maintaining a lookout or using navigational equipment to advise the pilot of relevant traffic.

The lack of monitoring by the pilot and bridge team contributed to the collision between the two vessels. In this occurrence, when the pilot lost sight of the Ocean Georgie Bain while he was occupied with the task of locating the nearby pleasure craft, he did not request assistance from the bridge team, and the bridge team did not monitor the tug, maintain a lookout, or assist the pilot at that time. A significant factor in this situation was the language barrier that impeded communication. In addition, the master–pilot exchange was informal and minimal, and when the pilot made attempts to communicate with the officer of the watch (OOW) in English, his actions indicated that he had difficulty understanding the pilot's requests. The difficulties in communication among members of the bridge team while under way contributed to poor BRM and prevented the bridge team from serving as an effective backup for the pilot.

2.5.1.2. Communication and language problems and their effects on pilotage operations safety

Communication is very important for achieving the task goals, such as ship berthing operations. In a crisis situation good communication and language skills allow the deck officers to recognise a problem quickly and manage the situation and team safely and effectively (Saeed, 2015). Several studies have investigated coordination and communication between vessels, which showed that difficulties of communication (between two or more vessels or between members of the same crew) are the main causes of accidents.

According to NTSB (1981), inadequate communication between ship crew is a contributing factor to maritime accidents, and 70% of major marine collisions occurred while a pilot was directing one or both vessels. Study was conducted by the US Coast Guard (1995), they found that, the most important human factor challenges facing the maritime industry and the greatest problems which contributed to most of the casualties were: inadequate communication and coordination between pilot and bridge crew.

Additionally, the IMO has underlined the importance of effective communication in an International Seminar as a crucial issue for Marine Safety (Winbow, 2002). In addition, Hetherington et al (2006) pointed out that, communication is considered as one of the core skills central to effective and safe performance in all high-risk industries, it also influences team situation awareness as well as team working and effective decision-making, the language barrier is one of the main communication problems found on ships, and should be taken into account. Chauvin et al. (2013) also reported that, maritime accidents occurred due to problems of coordination and problems of communication between crewmembers.

One of the best examples of these accidents occurring as result of poor language which resulted in poor communication and insufficient master/ pilot information exchange was when the vessel Sichem Melbourne, made contact with mooring structures at Coryton Oil Refinery Terminal on the River Thames estuary near London on 25 February 2008. There was an inadequate exchange of information between the ship's master and pilot before commencing unmooring operations, as a result of poor interaction and communications. Much of the conversation between the crew was conducted in the Russian language and this made it difficult for the pilot to understand and recognise the master's actions and to be fully aware of situations, and effectively excluded the pilot from the bridge team (MAIB, 2008).

Failure of communication represents one third of maritime accidents caused by human factors, and lack of maritime English, and improper use of Standard Maritime Communication Phrases (SMCP) are the reasons why one third of the accidents are due to communication failures (Ziarati et al., 2011). Communication disintegration is listed as one among several significant factors which contributed to the maritime accidents (Psaraftis et al. 1998; Hanzu et al., 2008; Macrae, 2009; Chauvin et al., 2013; Ugurlu et al., (2015).

Problems are mainly related to ambiguities or misunderstandings or to an absence of relevant communication between two pilots or between pilot and ship's crewmember, or between pilots, and the vessel traffic service (VTS) (Chauvin et al., 2013). Low level English language skills of the ships' crews or pilots, results in ineffective communication and this ineffective communication affects negatively on the safety of the ship's manoeuvring.

Language barriers have been and will continue to be a challenge. Nowadays, in the maritime industry, employees of many cultures and nationalities work within the same environment. Multilingual and multi-national crew members on ships cause decisive problems for the shipping industry. Despite the positive impacts of multinational crews, communication was seen as the major problem. Ding & Liang (2005) stated that, multicultural crews and a possible lack of a common language have produced a rising concern about the competence of ship crews; proficiency in English is one clear example. According to Berg et al (2013) communication, and the language skills of a seafarer are the most important issues that contribute to maritime safety on the individual level.

Language barriers on foreign ships continue to be a serious obstacle to the safe navigation of these vessels in pilotage waters. Since effective information exchange is vital to safe navigation, safety is compromised on those vessels where the pilots are unable to communicate with the crew. Berg et al (2013) highlighted that, the lack of language skills may cause accidents as misunderstandings are inevitable in an environment where the crew shares no common language. These issues were discussed by Theotokas and Progoulaki (2007) who stated that 96% of marine accidents caused by the human factor came as a result of issues with the relationships among multilingual crews and sailors from different nationalities and cultures.

During pilotage operations, when skills in English are not good enough, it increases the risk of misunderstandings, which is a very dangerous activity and creates confusion on the bridge. Decisions based on wrong interpretations of complicated or ambiguous information as result of poor language or bad communication, might lead to undesirable situations. As a result, the majority of accidents could be prevented if the pilot and the bridge team had proper knowledge of a language and a common understanding of how the manoeuvring would be carried out (Gard, 2006)

2.5.1.3 Master/Pilot exchange information (MPX) and its effect on pilotage safety

The failure to exchange the information between pilot and ships master and failure to prepare passage plan properly before manoeuvring commences is a contributing factor to maritime accidents, and to ensure effective berthing operations, it is essential that the relevant information is exchanged between the master and the pilot before the commence of berthing operations (Wild and Constable, 2013). “The master-pilot exchange forms the basis for the pilot and bridge team to work cooperatively to monitor the vessel's progress” (TSB, 2014a).

In spite of Annex 2 of Resolution A.960 (23) and the IMO's Standards of Training and Certification of Watchkeeping (STCW) 2010 which obliged the ship’s master and the pilot to exchange information regarding navigation procedures, local conditions, and the ship's characteristic, investigations that have been conducted to analyses marine accidents, frequently reveal the root causes to be associated with the failure to exchange the information between pilot and ships master and failure to prepare a proper passage plan. The majority of cases investigated by Gard (2014) involving pilots showed that the major cause of accidents was due to failure to exchange the information between pilot and ship’s master, there had been insufficient time for the ship’s crew to familiarise themselves with the pilot’s intended passage plan because the pilot boarding ground was frequently closer to the harbour entrance compared with the charted boarding ground.

One of these events was on 25 July 2013, in a strong tidal flow, when the tanker Apollo left its intended track and made contact with the quayside at the Northfleet Hope container terminal on the River Thames near London, the vessel and the quayside both sustained significant damage as a result of the accident. One of the main causal factors for the accident was that the information regarding the vessel’s propulsion system was not readily available to the pilots, either through the port’s information data system or the vessel’s pilot card (MAIB, 2014).

The grounding of M/V Tundra, was another example that demonstrates how the failure to prepare a passage plan could contribute to the accidents, when the Tundra departed

Montreal, The Transportation Safety Board of Canada (TSB) investigation into this occurrence found that the pilot and other members of the bridge team had not been exchanging information pertaining to the navigation of the vessel. And passage plans for the voyage were not discussed and the bridge team was unaware of a planned course change. TSB found that fatigue and ineffective communication between the pilot and bridge team contributed to the grounding of the bulk carrier Tundra, near Sainte-Anne-de-Sorel, Quebec (TSB, 2014).

2.5.1.4 Situation awareness and its effect on pilotage safety

Analysis of a considerable number of pilotage accidents and several pieces of research has indicated that a lack of Situation Awareness (SA) is a high risk factor and one of the main contributory factors of a marine accidents. Hetherington et al (2006) stated that, Situation awareness is the "ability of an individual to possess a mental model of what is going on at any one time and also to make projections as to how the situation will develop". SA was defined by Grech et al (2008, p.48) as "extent of convergence between multiple crew members continuously evolving assessments of the state and future direction of a process".

Situation awareness (SA) is important for successful performance and necessary for the pilot and ship's master to select appropriate action during pilotage operations. Effective situational awareness is the most important factor that plays a major role in decision-making processes in pilotage operations. Saeed (2015) stated that, adequate Situation awareness (SA) is important for successful performance in maritime operations. He pointed out that inadequate or complete loss of SA can significantly affect performance and decision making in abnormal, time critical circumstances.

Decision making is the process of reaching a decision based on appropriate judgments, which depend on problem identification, recognition of solutions and options, assessing all solutions and options, understanding risks involved and finally reaching the best decision, and this cannot be done unless the individual obtains the quality of situation awareness (Safahani, 2015). Studies were conducted by Grech & Horberry, (2002) using a Leximancer tool in order to determine the extent to which SA is a relevant issue in merchant shipping operations, They found that SA is the most important factor that plays a major role in decision-making processes in the maritime domain.

Another study was carried out by Grech et al., (2002) in which they evaluated human error in maritime operations, based on the analysis of maritime accident reports involving 177 vessels, during the period 1987–2000 from eight different countries. Using Endsley's error taxonomy to define the three levels of situation awareness (situation perception, situation comprehension, and situation anticipation). They found that 71% of all human error types on ships are due to lack of situational awareness.

The collision of the M/V Cosco Busan with the San Francisco-Oakland Bay Bridge in 2007, is the best example which demonstrate the negative effects of losing situational awareness, on maritime safety. The Transportation Safety Board of Canada found that the cause of the collision was the failure to safely navigate the vessel in restricted visibility as a result of three primary errors that were made, which eventually led to losing of situation awareness: The absence of a comprehensive pre-departure master-pilot exchange; a lack of effective communication between the pilot and the master during the voyage, and thirdly, the master's ineffective oversight of the pilot's performance and the vessel's progress (NTSB, 2009).

2.5.1.5 Influence of Ship Technology on pilotage operation safety

Unfamiliarity with the electronic navigation equipment is considered a high risk and plays a significant role in the occurrence of maritime accidents (Hetherington, 2006). It can result in being fully unaware of the position of the ship and leading to loss of the whole situation awareness, particularly when the vessels navigate through narrow canals or while underway, inbound/outbound from/to ports and channels in the dark or under poor visibility conditions. For example, the case of the grounding of the chemical tanker Ovit in the Dover Straits in 2013, when the watch keepers failed to use an electronic chart display and information system (ECDIS) properly, due to the lack of on-board familiarisation training in the use of ECDIS (MAIB, 2015a).

Advanced maritime technology and the novel electronic navigational systems have significant safety and efficiency benefits. The potential effect of automation on the performance of the shipboard tasks and the role of advanced technology systems can reduce the risk of maritime accidents. However, poor knowledge in the use of navigational aids such as automated identification system (AIS), radar, GPS, and ECDIS can have a negative effect on pilotage operation safety. Lützhöft and Dekker

(2002), pointed out that, automation creates new human weaknesses and plays a significant role in the success and failure of navigation today.

Although new maritime technology can be viewed as beneficial in terms of being able to process more data, one of the consequences of the increasing level of technology is a loss of situation awareness, which significantly affects performance in abnormal, time-critical situations, potentially leading to an accident (Grech et al., 2008, p.125). An MAIB (2004) report, based on the analysis of 33 collisions involving 41 vessels during the period 1994–2003, showed that the poor use of radar is one of the biggest contributory factors in collisions, since it appeared in 73% of the cases being investigated. This conclusion is supported by Rios, and Baniela, (2013) and Chauvin et al. (2013), who emphasised the ratio of errors causing collisions and grounding, as result of mariners' lack of knowledge in using technology. This indicates that the standard of training and the seafarer's familiarity with electronic navigation equipment is inadequate and limited.

According to the US Coast Guard studies (1995), a lack of technical knowledge and failure to use the available navigational tools (particularly radar), on the bridge is one of the most important human factors which challenges seafarers, and contributes to maritime casualties. One case example was the near-collision between the cruise ship "Statendam", and the Tug/barge Unit "Belleisli Sond"/"Radium 622" on passage from Sitka, Alaska, to Vancouver, British Columbia, on the evening of 11 August 1996. The TSB (1996) investigated the occurrence of the near-collision, they found that the biggest contributing causes to the incident were: the reduced visibility in fog and darkness and the pilot's lack of familiarity with the navigational systems of the "Statendam".

The Maritime Accident and Investigation Board (MAIB) (2009), presented the following examples of where ECDIS had been the cause of, or contributed to an accident. In their report on the Pride of Canterbury, (2009) they report that despite an ECDIS system being onboard, none of the 8 officers was able to use it and it had been incorrectly configured. Navigation was conducted by eye and by reference to an electronic navigational chart display (ENC). None of the bridge team had been trained in the use of ENC, and the settings were inappropriate such that key dangers would not have been displayed. This case highlights that the greatest technology is only as good as the knowledge an officer possesses in respect of it.

On 15 November 2012 the bulk carrier Amber made contact with moored craft and grounded on the south shore of the River Thames, England shortly after departing from Tilbury power station. The vessel's bridge team lost situational awareness in dense fog as the vessel manoeuvred from the berth on the north shore, before grounding on the opposite side of the river. The MAIB (2013) investigation found that the accident was caused by the bridge team's loss of situational awareness as the vessel left the berth in restricted visibility. The roles and responsibilities of the bridge team had not been confirmed before departure, no continuous radar watch was kept and the vessel's position, course and speed were not effectively monitored during the manoeuvre. The collective loss of situational awareness, and poor standard of communications within the bridge team, led to the vessel making contact with moored barges and grounding. The pilot's attempt to establish the vessel's position and speed using the radar was unsuccessful as he was not familiar with the set. In addition, the radar display would have been cluttered by the trails of all targets, which would have moved relative to the vessel because there was no speed input to the set.

Following the investigation into the bulk carrier Amber incident, recommendations were issued in the MAIB annual report 2013. They recommended that the bridge teams must be familiar with all navigational and communications equipment onboard and understand the need to ensure that radars are set at optimum range scales and performance monitoring is used. (MAIB, 2013).

2.5.1.6. Fatigue and its effect on pilotage operations safety

Fatigue is considered a contributing factor to human errors which eventually lead to maritime casualties (Phillips; 2000; Hetherington et al., 2006; Ferguson, et al. 2008; Akhtar, and Utne, 2014). The seafarers International Research Centre's definition contends that fatigue is a result of continuously high or prolonged levels of information load which involves subjective feelings of tiredness or a disinclination to work (Cardiff University, 1996, p. 5). The marine Accident Investigation Branch (MAIB) (2004, p.3) conducted a study of vessel bridge watchkeeping to determine the extent to which fatigue, among other issues, affected marine safety. The study examined all collisions, groundings, contacts, and near collisions that had occurred in the United

Kingdom between 1995 and 2003. It concluded that, the current provision of STCW 95 in respect of safe manning, hours of work and lookout are not effective. In addition, Investigators found that a third of all the groundings involved a fatigued officer alone on the bridge at night.

Two of the most recent accidents caused by the fatigue factor, are the cases of the collision of the tanker ship Eagle Otome the Sabine-Neches Canal, Port Arthur, Texas, in 2011(NTSB, 2011), and the grounding of dry cargo vessel Beaumont at Cabo Negro on the north Spanish coast in 2012 (MAIB, 2013a). Both of these cases had as a common feature a fatigued navigator on watch operation. While in the Eagle Otome case two different sources of fatigue that adversely affected the pilot's cognitive performance as a result of his untreated obstructive sleep apnea and his work schedule in the days preceding the accident would have disrupted his circadian sleep pattern, in the dry cargo vessel Beaumont case the watch keeping chief officer fell asleep while on watch and alone on the bridge.

The case of the grounding of the bulk carrier Raven Arrow" in the Johnstone Strait, British Columbia on September 24, 1997 also was another notable example of the influence of fatigue on pilot's performance. The bulk carrier Raven Arrow grounded in fog when the pilot lost situational awareness and prematurely altered course to enter Blackney Passage after having elected to conduct the navigation of the vessel without assistance from the ship's complement. (Increasing his workload). The Pilot lost situational awareness and prematurely altered course.

Contributing to the occurrence were the following factors: the pilot was probably fatigued (at the time of the occurrence the pilot had been awake for over 19.5 hours); sound navigational principles were not implemented by the bridge team, the exchange of information between the pilot and officer of the watch was minimal (the officer of the watch had some doubts with respect to course alteration but did not challenge the pilot's decision, this report goes beyond the individual pilot and fatigue, and addresses fatigue from the perspective of management by examining pilot scheduling and fatigue management (TSB, 1997). Due to reduced manning levels in the maritime industry there is now an emphasis on automation. The increase in automation and decrease in manning levels has changed the role of the seafarer, resulting in faster ships which are almost always sailing, with minimum time spent in ports and minimum rest periods for the crew, leading them to either physical or mental fatigue.

The feedback from maritime accident investigation reports shows enormous challenges in preventing shipping accidents. Human fatigue is difficult to measure and even more difficult to state as a cause of an accident, therefore, accident investigation reports are often reluctantly to assign any great importance to human fatigue (Grech et al., 2008 p.59). As mentioned in the preceding section, the IMO adopted several actions, regulations, and guidelines in order to ensure maritime safety and to either eliminate or mitigate mistakes caused by human factors that contribute to marine accidents during maritime operations. For example, Maritime Labour Convention 2006 (MLC 2006), and IMO (2001) Guidance on Fatigue, have developed practical guidance to assist interested parties to better understand and manage the issue of "fatigue." However, the lack of an effective response to lessons learned from marine accident reports has threatened precautions already taken towards system safety

2.5.1.7. Workload and its effect on pilotage safety

Mental work load is a significant issue to consider when assessing the demand placed on an operator by changes in the marine task. Nowadays maritime Pilots and the ship's crew perform many more tasks than before because of reduced numbers of staff. There has been a cultural shift in the maritime industry toward increased levels of automation in tasks, particularly with regard to navigation systems (Grech & Horberry, 2002). In addition, the impact of technology in the shipping industry has also caused a much larger number of tasks and a larger amount of stress to ships' operators (Bielic and Zec, 2003). These two factors lead to mental fatigue, which lead to impaired information processing and reaction time, increasing the probability of errors and ultimately leading to ship accidents (Hetherington et al., 2006).

In the event of the collision of the bulk carrier Heloise with the tug Ocean Georgie Bain, the difficulties in communication among members of the bridge team while under way contributed to poor BRM and prevented the bridge team from serving as an effective backup for the pilot. Furthermore, in communicating only minimally with the crew and perceiving that the bridge crew was not available to assist him, the pilot essentially assumed all navigational responsibilities, including that of lookout. This situation led to an increase in the pilot's mental workload, which led him to narrow, or limit, his focus of attention to the pleasure craft at the expense of monitoring the Ocean Georgie Bain (TSB, 2013).

Diehl (1991) reported that, may some people debate that it may be as result of the presence of the advanced instruments through which operators obtain more and quick data and they can make timely decisions. At the same time it can be argued that due to advanced instruments, operators are overloaded with information and will not be able to reach the second level of SA to make the proper decision. Grech et al., 2008, p.123) stated that too high a workload could lead to demands exceeding an operator's capacity to cope. The mariner's high mental workload due to the use of technology and long-time monitoring navigational aids equipment can lead to memory loss and misperception of data. Therefore, controlling work load is a key factor with new technology, training and other forms of procedural guidance needed in order to make seafarers aware of the capabilities and limitations of new technologies.

2.5.1.8. Distraction during the time of berthing operations and its impact on safety

Grech et al (2008) concluded that the electronic equipment such as ECDIS, AIS, and electronic navigational chart display (ENC) are considered significant factors that overload, confuse, and distract operators, rather than assisting them. Therefore, the advanced instruments and technical innovations require greater knowledge and extensive training. In recent years, the use of personal communication devices has been also linked to numerous accidents across transportation modes worldwide (TSB, 2012). The National Transportation Safety Board (NTSB) (2011a) reported that many accidents occurred due to failure of the ship's operators to maintain a proper lookout due to distraction and inattentiveness, which resulted from repeated personal use of a cell phone and laptop computer while they were navigating the vessel.

The use of personal communication devices (such as cellular telephones) may reduce situational awareness. "Cell phone calls from the pilot's family are threats to ships' safety" (Gard, 2007). On Wednesday, July 7, 2010, the empty 250-foot-long sludge barge, being towed alongside the 78.9-foot-long tugboat Caribbean Sea, collided with the anchored 33-foot-long amphibious passenger vehicle DUKW 34 in the Delaware River at Philadelphia, Pennsylvania. The National Transportation Safety Board determined that the potential cause of this accident was the failure of the crew officer of the Caribbean Sea to maintain a proper lookout due to distraction and inattentiveness as a result of his repeated personal use of his cell phone and company laptop computer while he was solely responsible for navigating the vessel. (NTSB, 2011a)

According to the Marine Accident Investigation Branch (MAIB) (2005) report into the grounding of the ATTILIO IEVOLI in the Western Solent, off the south coast of England in June 2004, the mobile phone use on the bridge for the majority of the time between the pilot disembarking and the vessel grounding was the main contributing cause for the accident. Furthermore, they stated that it was known that the Master made some, if not all, of the calls during this period. With the remainder of the bridge team unclear of their relative responsibilities for navigation, and the master distracted on the telephone, no one appeared to have been concentrating on the safety of the vessel.

2.5.1.9. The excessive speed and its effect on mooring operations safety

Many accidents have happened due to excessive speed during berthing operations as the one described below (Gard, 2014). Case of collision with terminal dolphin is one of the best example of breaching the rules when the vessel entered the breakwater at 8.5 knots even though the maximum permitted speed was only 5 knots. Although the Master observed that they were exceeding the maximum speed, the Master did not attempt to bring this to the attention of the pilots. Four tugs were requisitioned to assist the vessel in berthing at the terminal. Due to the excessive speed of the vessel, the tugs had difficulty maintaining speed to keep up with the vessel as she made her way to the terminal. Extensive damage was caused both to the ship and to the mooring dolphin. The following causes contributed to this incident: (1) the vessel's speed was excessive when trying to connect to the tugs. (2) There was a lack of communication between the pilot and the master at many stages while transiting the channel. There was little or no information exchanged regarding the docking plan and how the 4 tugs were to be put to use and coordinated. (3) The Master did not insist that the pilot did not exceed the maximum allowable speed as it entered the breakwater. (4) The pilot, when communicating with the tugs, was speaking a language that was not understood by the Master. This made it difficult for the Master to have a proper situational awareness. (5) The Master was over-confident as to the abilities of the pilot (Gard, 2014).

2.5.1.10. Pilot boarding and disembarking close to the breakwater and its influence on berthing safety

A considerable number of research works showed that numerous maritime accidents occurred due to boarding and disembarking of the pilot close to the port entrance (P&I Club, 2012). Pilot disembarking early before the ship leaves the port entrance or embarking the ship at the breakwater, is a high risk procedure which influences negatively on the pilotage operations safety, as it will leave insufficient time for the captain of the vessel to exchange information with the pilot, and to arrange the passage plan which is considered as one of the most significant factors to achieving safe ship berthing. According to Gard (2007), Captain Erik Blom Master of the M/V BLACK WATCH, reported that, "I have experienced pilots embarking at the breakwater, not giving us time to meet and greet at all, and forcing me more or less to disregard the pilot as there is no time to discuss or exchange information. This is very often the case in Mediterranean ports. This is a very unsatisfactory situation as the pilot is not integrated with the bridge team and sometimes just creates clutter to the organization".

One of the best examples of these incidents, has been reported by P&I Club (2012), when the bulk carrier with an experienced master was leaving a port to which he had been to many times before. The ship left the berth behind schedule during the late afternoon and in good weather, when the pilot told the master that he wanted to disembark before the designated pilot station. This request turned out later to be for the pilot's personal reasons. The pilot did not leave the master with information of what courses to take, what dangers to avoid and/or any information about incoming or outgoing traffic. The watchkeeper had accompanied the pilot to the main deck to disembark and, during this period, the master was alone on the bridge. No positions were maintained on the chart and the master was navigating by 'eye'. For reasons that can only be explained as human error, the master steered the ship the wrong side of a navigational mark and it ran onto submerged rocks, which ripped out the double bottom tanks. The wreck removal and oil pollution costs were significant.

Even though the resolution A.960 (23) adopted by IMO, which recommends that the boarding position for pilots should be located, where practical, at a great enough distance from the port, still pilots breach the rules and making such errors, which lead to maritime disasters and injuries for humans, and damage to the environment and properties. It can be seen from the above discussion that embarking and disembarking of a pilot close to the breakwater is high risk, it influences the safety of the pilotage operation and contributes to maritime accidents, as it will not give the ship's captain and crew members the chance for the exchange of information with the pilot at all, and might force the ship's master more or less to disregard the pilot, as there is no time to discuss or exchange information.

2.5.2 Human factors and maritime accident research

Over the past decades, maritime authorities have been continuously challenged to improve maritime operations performance and safety. The increased numbers of maritime accidents during the last few decades have forced the maritime professionals and scientists to conduct a numerous studies to identify risk factors and to analyse their impact on maritime safety (Özdemir and Güneroğlu, 2015). Maritime safety practitioners attempted to find appropriate solutions to minimize human error and enhance safety in maritime transportation. For example, the Transportation Safety Board of Canada TSB (1995) in a study of operational relationships between shipmasters/watchkeeping officers and marine pilots, reported that the inadequate interpersonal communications among the bridge team, lack of adequate information exchange, incomplete understanding of the intended manoeuvres, loss of situational awareness, absence of monitoring of the ship's progress were the most contributory factors to maritime accidents.

Likewise, Psaraftis et al. (1998) conducted extensive studies, in order to present a comprehensive analysis of the human element as a factor in marine accidents. They investigated all accidents involving Greek-flagged ships, over the period of 1984 to 1994, regardless of the accident's geographical location. Moreover, all events that occurred in Greek territorial waters were similarly investigated, irrespective of the flag of the ship involved. As a result of the analysis, it was found that the major cause of all accidents was the human factor, and in the majority of cases reviewed, the incidents were due to one or more of the following: poor crew competence, lack of communication, lack of proper maintenance, and lack of application of safety.

Moreover, a comprehensive review of literature was conducted by Hetherington et al. (2006) to identify the relative contributions of individual and organizational factors in shipping accidents. They found that fatigue, stress, health, situation awareness, teamwork, decision-making, communication, automation, and safety culture is the most frequent contributing factors to maritime accidents. (MAIB) (2004) conducted a study of vessel bridge watch keeping to determine the extent to which fatigue, among other issues, affected marine safety. The study examined all collisions, groundings, contacts, and near collisions that had occurred in the United Kingdom between 1995 and 2003. It concluded that "the current provision of STCW 95 in respect of safe manning, hours of work and lookout are not effective. In addition, Investigators found that "a third of all the groundings involved a fatigued officer alone on the bridge at night.

Similar studies regarding this matter have shown that the duration between 00:00 and 06:00 hours is the most dangerous period for ships accidents (Great Britain, Department of Transportation, 2004). The same period of time is supposed to be most dangerous for maritime accidents as a result of the biological clock within the human organism which makes a person subject to heavy sleep during that period of time (Fatigue: IMO guidance, 2006). Also Ferguson, et al. (2008) examined the impact of brief, unscheduled naps during work periods on alertness and vigilance in coastal pilots along the Great Barrier Reef, as the duration of the work period can extend well beyond 24 hours. Seventeen coastal pilots were volunteered for the study, they found that a pilot's work environment, irregular and lengthy working hours without a decent nap, working at night without rest period, and travelling to and from their jobs impact on the alertness of marine pilots and can significantly contribute to fatigue.

Another study has been carried out by Akhtar and Utne (2014), they constructed a Bayesian network (BN) using data from 93 accident investigation reports. It was found that a fatigued operator raises the probability of grounding for a large ship in long transit by 16 %. Moreover, the probability of a watchkeeper being fatigued was found to be 23 %. According to Akhtar and Utne (2014), alcohol misuse is a problem in maritime transport, and it also amplifies human fatigue levels, even low alcohol exposure significantly impairs the performance of navigators, and contributes to accidents at sea. Xhelilaj and Lapa (2010) reported that, quality, quantity and duration of sleep can play a significant role in a mariner's performance. Moreover, ingested chemicals such as alcohol, drugs and caffeine which are used very often among seafarers to overcome sleep and boredom can also limit a pilot's opportunity to obtain restorative sleep and can significantly contribute to fatigue (Fatigue: IMO guidance, 2006).

Macrae (2009) has also carried out accident analysis in two types of shipping accidents: groundings and collisions between 1995 and 2000. 30 detailed marine accident reports written by the Australian Transport Safety Bureau (ATSB) were reviewed. The study revealed that, 76% of shipping accidents caused by human error which occurred on the bridge. In addition, the analysis indicated that the most common causes of the accidents were due to a lack of communication among the bridge team, failure of position fixing, errors in determining the speed, failure to keep adequate watch, passage plan errors, and poor judgment of the situation. Moreover, the study showed that around 80% of marine accidents which occurred because of human error, had traditionally been viewed as a by-product of individual cognitive behaviour or occasionally moral issues caused merely by carelessness or ignorance.

Similar research was carried out by Tzannatos and Kokotos (2009), where all accidents involving Greek-flagged ships during the period 1993-2006, accidents were examined according to the vessel type, cargo, and location. The findings showed that 63.9% of the pre-ISM accidents were due to human error, as opposed to the 51.7% during the post-ISM period. As an indication of human source analysis, Tzannatos and Kokotos (2009) stated that the captains of the ships were found to be responsible for 41% of all accidents and for 72% of all human-induced accidents. In addition, the results of the analysis reported that 83% of tanker accidents were caused by the human factor, and 67% of accidents occurred in restricted areas as a result of human error.

Tzannatos (2010) conducted similar studies on different incidents of Greek-flagged ships during the period of 1993 to 2006. The research provided an analysis of various accidents based upon the findings of formal enquiries conducted by the Hellenic Coast Guard. According to the investigation, 57.1% of ship accidents were attributed to the human element. Furthermore, it was discovered that the captains of the ships were responsible for almost all of the frequently encountered groundings and collisions, and were involved in 80.4% of the accidents. On the other hand, the engine officers were responsible for 8.1% of the incidents, and the bridge officers and crew were responsible for 6.8% and 4.7%, respectively. Furthermore, the studies found that the incidence of human error had arisen due to of the manning policies being carried out by shipping company managers.

Furthermore, studies were conducted by Ćorović and Djurovic (2013), they investigated the human factor and its impact on maritime safety from psychological and organisational aspects. They reported that, health is considered one of the most important factors that influence the professional efficiency of seafarers and correlated to psychophysical strength, duration of resting, seafarers' job satisfaction, internal relationships and stressful situations. They also found that, psychological problems such as impatience, dissatisfaction, and lack of motivation may stimulate intolerance between crewmembers, which could also be a result of cultural and religious differences. In addition, they pointed out that working and living on a ship with employees of an array of nationalities and backgrounds could lead to misunderstanding, and operational problems which will have a negative effect on crew performance. And consequently, influence vessel safety.

Another paper was introduced by Chauvin et al. (2013), utilising the Human Factor Analysis and Classification System (HFACS) to determine the contributing factors in ship collisions, and jointly used the Multiple Correspondence Analysis (MCA) and hierarchical clustering methods to analyse the human factors and organizational factors in the ship collisions. This tool has been used to classify and analyse factors that are mentioned in accidents reports, for 39 vessels involved in 27 collisions that occurred between 1998 and 2012. 11 of those were under the conduct of a pilot. The results of the study show that most collision accidents occurring in restricted waters and involving pilot-carrying vessels are due to decision errors. They concluded that problems are mainly related to the inter-ship communications problems such as, ambiguities or misunderstandings or to an absence of relevant communication between two pilots or between pilot and ship's crewmember, or between pilots, and the vessel traffic service (VTS), and bridge resource management (BRM) deficiencies.

Another study concerning the human error during ship manoeuvring in restricted waters was presented by Gerigk and Hejmlic (2015) in order to find out how stress and stressing factors influence the decision-making process of ship's masters and marine pilots during ship manoeuvring in restricted area. They found twenty-four difficult situations at sea which are the main stressors influencing the decision-making process and the performance consequently the potential for human error during ship manoeuvring in restricted areas. They also found that knowledge of port area, experience, number of years of employment as ship master and pilot are significant factors affecting the manoeuvring performance in restricted waters.

A new approach was presented by Özdemir and Güneroğlu (2015), using a novel hybrid accident analysis method to analyse marine accident causes which occur in complex social and technical reasons. The hybrid method involves the decision-making trial and evaluation laboratory (DEMATEL) and Analytic Network Process (ANP) method in order to evaluate the importance level of the human factors in maritime casualties, and provide a solution for evaluating causes of accidents the in marine industry. As result of this study, the most important factors were found to be ability, skills, knowledge, physical condition and weather sea condition.

Ugurlu et al. (2015) reviewed maritime accident reports issued for grounded ships between 1993 and 2011, in order to determine the causes of the collisions by using the Analytic Hierarchy Process (AHP). They concluded that, the lack of communication and coordination in Bridge Resource Management, position-fixing application errors, lookout errors, interpretation errors, use of improper charts, inefficient use of bridge navigation equipment, and fatigue, were the most common factors behind collisions. In order to reduce the accidents, they suggested to providing more education and training opportunities to seafarers, and improving seafarers' working hours and rest breaks.

A similar study was carried out by Uğurlu et al. (2015a). In this study, collision and grounding data registered in GISIS (Global Integrated Shipping Information System) were investigated. The database includes the information of the collision and grounding accidents during the period between 1998 and 2010 for oil tankers. The risk assessments were carried out using the fault tree analysis (FTA) method. They found that the main reasons for the accidents originating from human error are as follows: for collision accidents, Convention on the International Regulations for Preventing Collisions at Sea (COLREG) violation and the lack of communication between vessels; and for grounding accidents, the interpretation failure of the officer on watch and lack of communication in the bridge resource management.

Likewise, Erol and Basar (2015) have examined 1,247 marine accidents occurring in the Turkish search and rescue area in the period between 2001 and 2009 by using the Decision Tree method. They concluded that 60% of marine accidents happening in the Turkish search and rescue area are caused by human error, and the main causes of the human error are navigational, manoeuvring failure, and carelessness. Technical failure and weather conditions followed human error as 18% and 15%, respectively.

Recently, study was carried out by Uğurlu (2016), in this study questionnaires and interviews with 71 pilots, were conducted in order to investigate the pilots' profile and structure of existing pilotage organisations in Turkey, to create an effective pilotage organisation model. They found that the commercial–political pressures and low salaries negatively affect maritime pilot performance. They concluded that the structural deficiencies in pilotage organisations caused commercial pressure on pilots, which has negative impact on task management and should be reduced. Moreover, they found that dense and irregular working conditions reduced job satisfaction and caused physical and social problems, they also found that the working schedule or job rotation is one of the most important factors affecting fatigue management, and maritime pilot performance.

2.6 HUMAN FACTOR RISK/ SAFETY ASSESSMENT METHODS

Over the past view decades, maritime risk and safety assessment researches have undergone many essential changes, and a considerable number of new approaches have been developed to facilitate risk quantification in order to improve maritime safety. The early studies in maritime accident research usually adopted very basic methods such as statistical and descriptive reviews, case studies and probability calculations, while recent studies often used multi-disciplinary approaches, comprehensive risk analysis, and system-width viewpoints (Luo and Shin, 2016).

In recent years, the most frequently used method for risk analysis and safety assessment was the Human Factors Analysis and Classification System (HFACS) method. It was proposed by Wiegmann and Shappell (2003) to investigate and analyse accident causes in the aviation industry, and the fundamental framework of the HFACS method was tailored from the Swiss cheese method which was initially introduced by Reason (1990) to provide researchers with a tool to identify the latent or active failures. The main aim of the method is to provide a schematic framework to assist safety practitioners in investigating and analysing human factor in accidents. HFACS is a schematic powerful tool to investigate human contributions to marine accidents. Recently the HFACS method was successfully extended by (Akyuz et al., 2016), introducing a comprehensive schematic framework consisting of four schematic levels: organisational influences; unsafe supervision; pre-conditions for unsafe acts, and the actual unsafe acts in order to analyse the role of the human error in accidents.

In the past decade many different approaches have been developed to address the maritime safety problems. Maritime accident research based on accident statistics has had significant effects on safety management practices in the industry. However, they are, on their own, unable to manage the uncertainty in data, failing to look at the overall picture of maritime safety analysis, as a result, a considerable number of developed approaches and different techniques have been used to quantify the risks in maritime transportation including fuzzy logic, Bayesian networks (BNs) evidential reasoning, Monte Carlo simulation, Markov chains and genetic algorithm to model risks in this dynamic and data-scarce application area have been put forward (Yang et al., 2013).

Yang et al. (2013) concluded that the formal safety assessment (FSA) provided by IMO is the primary method that is currently being utilised for the analysis of maritime safety, which provides a reasonable and integrated framework to facilitate maritime safety analysis, including the development of new risk-modelling and decision-making methods to address uncertainty in data as well as new cost–benefit analysis approaches to facilitate the implementation of maritime regulations. Furthermore, research on design for safety, risk-based inspection, traffic safety evaluation, evacuation and rescue simulation, fire risk estimation and human reliability analysis (HRA) has been also applied in the last decades.

2.6.1 Human Reliability Assessment (HRA) methods

The way of identifying and quantifying human error related risks in the maritime industry has undergone a transformation in the past decades. In recent research, there are many approaches that have been used for facilitating human error identification and human reliability analysis. HRA techniques have been an essential research issue in safety critical systems in the new century, it has been widely conducted to tackle specific difficulties in challenging maritime safety (Yang et al., 2013a). “HRA is a tool used to evaluate human reliability as well as the uncertainty of data concerning human factors and the complexity of the human behaviours” (Zhou et al., 2018). It is regarded as one of the most important methods that have been used to improve human performance and to describe the human contribution to risk, which includes a series of methods to identify sources of human errors and to predict the likelihood of their occurrence (Boring, 2008).

HRA has been employed since the early 1980s. It has become notable after the Three Mile Island accident in 1979, from which the method has become familiar to the nuclear industry, and has been utilised in many different industries (Kirwan et al., 2008). The HRA aims to assess and provides a good collection, interpretation and application approach to human failure data, resulting in enhancing human performance, and mitigating potential human errors within the system, including in the maritime industry, in a shipping company or onboard a ship (Cepin, 2008). It involves the use of qualitative and quantitative methods to assess the human contribution to risk (Holroyd & Bill, 2009), where quantitatively it facilitates to obtain HEPs, and qualitatively it identifies potential human errors in an incident/accident investigation (Subramaniam, 2010). The following subsections provide a summary of some of those tools identified as being of potential use to human factor identification and quantification.

2.6.1.1 First Generation Methods

Some of the methods developed and used were a well-known first generation HRA techniques, including, Technique for Human Error Rate Prediction (THERP) (Swain and Guttmann, 1983), Success Likelihood Index Methodology (SLIM) (Embrey, 1983), (ASEP), and Human Cognition Reliability (HCR) model, (Hannaman et al., 1984), etc. (Holroyd & Holroyd, 2009). These tools were the first to be developed to assist risk assessors predict and quantify the likelihood of human error. The first generation HRA techniques utilized a simple error taxonomy and "fits/doesn't fit" dichotomy to correspond error state to error identification and quantification (Boring, 2005). These approaches tend to be atomistic in nature; they encourage the assessor to break a task into component parts and then consider the potential impact of modifying factors such as time pressure, equipment design and stress. By combining these elements the assessor can determine a nominal human error potential (HEP).

First generation methods focus on the skill and rule base level of human action and are often criticised for failing to consider such things as the impact of context, organisational factors and errors of commission (Subramaniam, 2010). Despite these criticisms they are useful and many are in regular use for quantitative risk assessments. The first generation of the HRA methods are proposed based on the premise that inherent deficiencies lead to humans failing to perform tasks just like mechanical, electrical or structural components do (Marseguerra et al., 2007). This generation is represented by the THERP method (Zhou et al., 2018), etc. (Kim and Bishu, 2006).

One of the first HRA methods developed and used was the Technique for Human Error Rate Prediction (THERP), in 1961. The first meeting to discuss HRA was held in 1964. The first large scale application of HRA was carried out in 1972, when THERP was used to assess the impact of estimated human errors in a probabilistic risk assessment (PRA) of two nuclear power plants, referred to as the WASH-1400 reactor safety study. The method has been extensively used in the USA and in the UK nuclear industry, it has been also been successfully applied in many industries including nuclear, chemical, aviation, rail, medical and maritime to the other sectors such as offshore and medical sectors for assessing human reliability that deals with task analyses error identification and representation, as well as the quantification of HEPs (Kirwan, 1994). Kirwan et al (1997) conducted validation to an independent validation of THERP along with two other methods (HEART and JHEDI). They found that no one technique out performed the others, and all three achieved a reasonable level of accuracy.

The advantages of using the THERP method, are that designed to be a quick and simple method for quantifying the risk of human error. It is a general method that is applicable to any situation or industry where human reliability is important. In addition, it is a flexible, quick, and easy human reliability calculation method, which allows the user suggestions on error reduction, it requires relatively limited resources to complete an assessment, and it can also be easily integrated with fault tree reliability methodologies.

The disadvantages of the THERP method, are that the error dependency modelling is not included, it requires an enormous effort to obtain reliable HEPs and greater clarity of description to assist users when discriminating between generic tasks and their associated Error Producing Conditions (EPCs); there is potential for two assessors to calculate very different human error reliability (HEPS) for the same task, also the method lacks information about the extent to which tasks should be decomposed for analysis.

Success Likelihood Index Method (SLIM) tool is an expert judgement method which was first developed by Embrey (1983) for the US Nuclear Regulatory Commission and has become popular in the mid-1980s and remains so, particularly in less safety critical environments than major hazard industries. SLIM is an approach utilized to assess human error probabilities using structured expert judgment. The SLIM provides a quick tool to predict human error and evaluate human error probability (HEP) that occurs during the completion of a specific task. This tool provides a structured means for experts to consider how likely an error is in a particular scenario (Embry et al, 1984). However, the method, like other expert judgement tools, does have shortcomings, the weakness of this method is the subjectivity in the process of experts' judgments causing difficulties in ensuring consistency (Akyuz, 2016). To remedy this problem, Park and Lee (2008) developed a method where an Analytic Hierarchy Process (AHP) method was used to estimate HEP, known as AHP-SLIM, which quantifies the subjective judgement and confirms the consistency of collected data". Also, study was conducted by Akyuz (2016), using a fuzzy based SLIM technique which provides more accurate estimation during human error quantification. In the proposed approach, while the SLIM is utilized to estimate HEP, the fuzzy sets deal with the vagueness of expert judgments and expression in decision-making during the weighting process of performance shaping factors (PSFs).

The method, like other expert judgement tools, does have users and has been evolved to address the early problems that were identified with the method. According to Holroyd & Bill (2009), SLIM is a flexible tool and appropriate for application in major hazard sectors. It facilitates gross cost benefit evaluations to take place. It is found that the main criticisms of SLIM are that it requires an expert panel to perform an assessment, its methods are poorly structured resulting in various results for different analysts, it is resource intensive, and there is a lack of theoretical foundation on its quantification procedures. The mixed reviews of SLIM suggest that if the method is rigorously employed and the experts are sufficiently observed to reduce bias, then it can be beneficial.

In general, the disadvantages of the first generation HRA methods can be described as follows: they have generally recognised shortcomings in a scarcity of data, insufficient treatment of performance shaping factors (PSFs), inadequate proof of accuracy, inadequate psychological realism, lack of consistency in treating error of commission, inadequate treatment of dynamic situations, a mechanical view of human, high level of uncertainty, lack of systematic task analysis structure and inadequate error reduction strategies (Hollnagel, 1998, Kristiansen, 2005, Kim and Bishu, 2006). Second generation HRA methods have therefore been developed to overcome such difficulties by appropriately taking into account the contextual influence of a task and by being equipped with the more powerful ability of incorporating expert judgments to deliver quantitative human failure analysis results. Although attractive, these methods have still exposed some shortcomings in their practical application (Yang et al., 2013a).

2.6.1.2. Second Generation Methods

The development of ‘second generation’ tools began in the 1990s and is on-going, including, Cognitive Reliability and Error Analysis Method (CREAM) (Hollnagel, 1998), and A Technique for Human Error Analysis (ATHEANA) (Cooper et al., 1996), Human Error Assessment and Reduction Technique (HEART) (Williams, 1988), SHERPA (Embrey, 1986), and Simplified Plant Analysis Risk Human Reliability Assessment (SPAR-H) (Gertman et al., 2004), and there are also other methods (Holroyd & Bill, 2009).

The second generation approaches consider the context as the most crucial factor affecting human performance failure and hence focus on the relationship between context and associated human error probability (HEP). The literature shows that second generation methods are generally considered to be still under development but that in their current form they can provide beneficial insight into human reliability issues (Holroyd & Bill, 2009). Kirwan et al. (2008) reports that the most prominent of the second generation tools are the ATHEANA, and CREAM methods. The ATHEANA approach is defined as a method for obtaining qualitative and quantitative HRA results. It is the assessment method for the performance of safety operation (Holroyd & Bill, 2009).

ATHEANA was developed to assess the performance of safety operations, particularly for the probabilistic safety assessment of reactors in nuclear power plants, however the approach is suitable for application in other industries. It uses error forcing contexts (EFCs), which are defined as a compositions of working conditions and other influences that make an operator error more likely, to obtain qualitative and quantitative HRA results. It utilizes psychology, human factors, engineering knowledge and probabilistic risk assessment for retrospective and prospective analyses. It takes into account ergonomics, psychology and accidentology in modelling management system behaviour and safe system failure in the operation of nuclear power plants. It utilizes consistent configurations/orientations (CICA) of the system (Holroyd & Bill, 2009).

The benefits of using ATHEANA are that it is capable of estimating HEPs for various conditions of events and that it allows for a focused approach in predicting specific error and significant factors influencing that specific error. ATHEANA is an approach, which attempts to solve the problem of including EOC [errors of commission] in PSA in an extensive way. If the method is properly applied, the methods that comprise ATHEANA should be able to yield significantly more insight into the nature of human actions. ATHEANA can be used to develop detailed qualitative insights into conditions that may cause problems. It provides a systematic way of exploring how action failures can occur (Holroyd & Bill, 2009).

Meanwhile, the disadvantages of applying ATHEANA are that there are a limited number of ATHEANA applications and rigorous methods are applied in identifying the influencing factors used for quantification purposes (Forester et al., 2004). The ATHENA method is difficult to use and very costly. The guidance is too complex and depends too much on subject matter experts. The measurement method is weak, and the quantitative results are not proven. The quantification is extremely dependent on expert judgement, thus properly has low reliability as a method.

Hollnagel (1993) developed CREAM and the method is still under development. CREAM was first proposed for nuclear power plant applications (Jung et al., 2001, Tang et al., 2014) and was adopted by the National Aeronautics and Space Administration (NASA) in the early 1990s to predict human error (Calhoun et al. 2014). It is based on a set of principles for cognitive modelling with detailed classification of erroneous actions. Hollnagel (1998) provides comprehensive details on the principles of CREAM, classification and the methods of assessment, both retrospective and prospective.

The main advantages of CREAM are that it provides a well-structured systematic approach for identifying and quantifying human error, CREAM can be used retrospectively to analyse and quantify error, and prospectively to identify potential human error for an incident/accident that is possibly encountered. In recent years the method has become one of the most common methods and widely applied in many industries. In particular, for the maritime sector, researchers have applied the method to examine human reliability in maritime activities (Akyuz and Celik, 2015).

In order to overcome some of the shortcomings of the human reliability analysis methods, a new approach has been developed, it is the use of combined methods and coupled analysis. For example, an advanced CREAM and a human reliability quantification model was proposed by Subramaniam (2010) in order to address some of the shortcomings of the generic HRA and FSA methodologies that exist independently in the management of oil tankers to prevent oil spills. In this study a DEMATEL model, which allows for an inclusive understanding of relationships and interdependencies among the Common Performance Conditions (CPCs), and an integrated AHP and fuzzy TOPSIS model for determining the selection of appropriate risk control options are integrated into CREAM.

Yang and Wang (2012) also conducted a study in order to develop a generic method by modifying the CREAM methodology. In the paper, fuzzy evidential reasoning and Bayesian inference logic are integrated into the CREAM methodology to facilitate the quantification of human failure in the marine industry. Likewise, a similar study was introduced by Yang et al. (2013a) to extend the traditional CREAM approach by incorporating fuzzy evidential reasoning and Bayesian network techniques to facilitate human reliability quantification in marine engineering. In addition, an application of the CREAM method into the cargo loading processes of LPG tankers has been implemented by Akyuz and Celik. (2015). In the paper, the main focus of this research is to predict human error potential for identified tasks and to determine required safety control levels on board LPG ships. As a result, Akyuz (2015) has recently introduced an approach to measure human error probability in the gas inerting process of crude oil tankers. The paper provides a CREAM quantification approach on the case of a critical shipboard operation.

Furthermore, later, for making human error probability quantification in CREAM rational, and to quantify human error probability in maritime domain, a modified CREAM methodology based on an Evidential Reasoning (ER) approach and a Decision Making Trial and Evaluation Laboratory (DEMATEL) technique was proposed by Xi et al. (2017). This was the first time the method addressed the data incompleteness in HEP, given that the previous relevant studies mainly focused on the fuzziness in data. The findings provided useful insights for quantitative assessment of seafarers' errors to reduce maritime risks due to human errors.

2.6.2 Multi-Criteria Decision Making (MCDM)

Most of the aforementioned approaches and the traditional approaches such as FTA, ETA, Failure Mode, FMECA and Bow-Tie have been frequently used in human reliability analysis of critical systems and have widely enriched the risk analysis literature. However, due to their incapability in addressing human-related risk factors associated with the system operation, multi-criteria decision making (MCDM) methods such as the AHP and other assessment methods are nowadays widely used in many industrial sectors to overcome the previously mentioned drawbacks (John et al., 2014). The MCDM is a procedure that facilitates decision making processes, such as choosing, ranking or sorting actions. It is considered as one of the most significant types of decision-making studies.

The development of 'MCDM' was officially established in the 1970s, as a conference on MCDM was held by Cochrane and Zeleny at Columbia University in South Carolina in 1972 (Figueira et al., 2005). There are two main techniques to the MCDM method: Multi-attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM). The MODM analyses decision problems where the decision field is continuous, such as mathematical programming problems with multiple objective functions. While the MADM, concentrates on problems with discrete decision fields where the decision alternatives have been predetermined.

MCDM is one of the most recognised branches of decision making studies (Triantaphyllou, 2000). The MCDM can be categorized depending on the type of data used such as deterministic, stochastic, fuzzy and combined MCDM approaches.

Another method of categorising MCDM methods is according to the number of decision makers involved in the decision process, including a single decision maker and a group of decision makers MCDM methods.

In general, the advantages of using MCDM methods is that the choice of objectives and criteria that a decision maker made initially can be further reviewed and modified if they are felt to be inappropriate. Another advantage of MCDM is that it facilitates the assessing process of the MCDM method used for administration purposes (Dodgson et al., 2009). The difficulties of applying MCDM method is the conflicts among criteria, where different criteria represent different dimensions of the alternatives and incommensurable units, where different criteria could be associated with different units of measurement (Triantaphyllou, 2000).

There are many various MCDM techniques developed to tackle real-world complex issues involving multiple criteria decision (MCDM) problems and these differences do not mean that one method is a better or worse methods, however each method has its own characteristics, advantages and disadvantages and some techniques are more appropriate to solve particular decision problems than others (Mohagheghi et al., 2017). An appropriate MCDM method to solve a decision making problem can only be selected once all the elements relating to the concerned problem have been designed in detail (Bufardi et al., 2004). There are some commonly known methods which use the MCDM approach to make decisions, which are briefly described in the following subsections.

2.6.2.1. Analytic Hierarchy Process (AHP)

The AHP technique is first introduced by Saaty (1980) in order to solve multiple criteria decision problems. It utilised a pairwise comparison technique to obtain relative weights of criteria base upon a hierarchical structure. Analytic hierarchy process (AHP) was recognized as the major method of decision making in the field of management engineering after the 1980's since professor Saaty of University of Pittsburgh developed the AHP method in the 1980's (Lee and Kim, 2013). The Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method which is rigorously concerned with the scaling problem and what sort of numbers to use and how to correctly combine the priorities resulting from them (Saaty, 1990). The main aim of the method is to calculate the importance-weight of the criteria, and to obtain relative performance measures of the alternatives (Saaty, 1980).

The AHP technique is suitable for dealing with complex systems that require making a choice from among several criteria, which provides a comparison of the considered options. One of the main advantages of this the method is the relative ease with which it handles multiple criteria. In addition to this, the AHP approach is easier to understand and it can effectively handle both qualitative and quantitative data. Moreover, it also has the capability to check and minimise inconsistencies in expert judgements, by computing a Consistency Ratio (CR) (Riahi et al., 2012). It is worth mentioning that a number of studies have been conducted by utilising the AHP method (Saaty, 2003). This method has been proven to be a powerful supporting tool for solving a wide variety of complex decision problems in different domains. Therefore, AHP method will be applied in this study to evaluate the relative importance of the human (HCFs) and more detail will be discussed in the later chapter (chapter 5).

2.6.2.2 Decision-making trial and evaluation laboratory (DEMATEL)

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was developed by the Geneva Research Centre of the Battelle Memorial Institute (Fontela and Gabus, 1976; Gabus and Fontela, 1973). It's introduced to build the network of relationships map for illustrating the interrelations among factors/criteria (Liou et al., 2007). Recently this method has proven to be a more successful tool for measuring and illustrating the causal relationships among interdependent factors (Özdemir, 2015), it has been widely used to display the cause and effect groups of a system (or subsystem) by applying matrices and digraphs to visualize the structure of complicated causal relationships (Tzeng et al., 2007; Lin and Wu, 2008; Jeng et al., 2012; Elham et al., 2013). This method will be used in this study and more detail will be discussed in the chapter (chapter 5).

2.6.2.3. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

The technique for order preference by similarity to ideal solution (TOPSIS), is one of the well-known ranking methods for MCDM that has been commonly used in solving decision-making problems (Ding, 2011). It was initially proposed by Hwang and Yoon (1981) to help in selecting the best alternative, and with a limited number of criteria as a simple ranking method in conception and application. The primary concept of the

TOPSIS method is that the preferred alternative should not only have the shortest distance from the positive ideal solution (PIS), but also have the farthest distance from the negative ideal solution (NIS) (Hung and Chen, 2009). The positive ideal solution comprises all best values obtained of criteria, while the negative ideal solution comprise for the all worst values attained of criteria (Wang, and Chang, 2007). It is worth mentioning that numerous research study have been conducted by using (TOPSIS) to solve decision-making problem in various fields. This method is simple and less complex to use compared to other methods. Such advantages make this technique an appropriate method to be used in this research, in addition, it will assist the decision makers to choose the best countermeasures for mitigating human errors, and, preventing accidents from happening again. Thus, it will be presented as beneficial to the maritime industry.

It is worth mentioning that there are many other techniques available for decision-making methods such as the Analytic Networks Processes (ANP), Evidential Reasoning (ER), and so on. Nevertheless, given the strength of the three aforementioned methods (AHP, TOPSIS, and DEMATEL) in tackling complex problems and their ability to effectively evaluate the human factor that contributes to the occurrence of maritime accidents during pilotage operations, these techniques have therefore been utilized in this research. Such powerful methods have been fully utilised in this research and will be discussed in more detail in forthcoming chapters (chapters 5, and 6).

2.7 LITERATURE GAPS IDENTIFIED

In the literature, a gap still exists with regard to the studies on human factors and maritime pilotage accidents. It was limited attention given to human related risk factors in the pilotage operations area. In recent years many research projects, regarding the maritime risk management issue have been conducted from several aspects, by using different methods in order to reduce the occurrence of maritime accidents in open sea areas, however it appears from a review of the literature that little research has been done in the maritime domain on issues related to the pilotage operation safety analysis issue, and until now, few studies have employed an appropriate evaluation method to examine how human factors contribute to the maritime pilotage accidents.

- The primary research gap was the lack of the comprehensive framework to evaluate (e.g., human related risk factors identification, assessment, and mitigation) safety performance in the pilotage operations. Currently, the attention that is given to human related risk factors' measurement in this area is limited and needs further investigation. There is a distinct need for a new human-related measurement tool not only to meet the need of port stakeholders but also to develop diagnostic instruments to port and pilotage systems capable of supporting decision-making in solving complex pilotage operations problems in an uncertain environment.
- The second research gap was related to the need for using a decision-making methods to overcome the shortcomings of the previous studies by introducing a new approach to identify the relative importance among accidents' human causal factors in maritime pilotage operations, by taking subjective judgments of decision-makers into consideration. In spite of quantifying accidents' human causal factors in maritime pilotage operations being type of multi-criteria decision making (MCDM) problem, there is a limited (MCDM) study which focused on this kind of problem.
- The third research gap identified was the lack of studies to examine the causal relationships and interdependencies among the human factors contributed to the pilotage accidents. Most of the previous research studies frequently ignored to evaluate the causal relationships among the human factors which contributed to the pilotage accidents, and few of these studies focused on analysing the interaction between accident causation factors using MCDM method.
- The forth research gap identified was the lack of studies examining the risk mitigation measures in the pilotage operations environment using a decision-making methods. In addition, limited studies have examined the efficiency of the current implemented mitigation measures in the maritime pilotage operations.

Within this context, this study will identify the human causal factors that affect maritime safety, with a particular emphasis on the pilotage operations. Moreover, this research will address the lack of appropriate measurement methods addressing the pilotage human error-related risk by proposing an integrated AHP and DEMATEL method, which allows for an inclusive understanding of independency relationships and interdependencies among the human factors contribute to the maritime pilotage accidents. Finally, the research will be concluded with an integrated AHP and TOPSIS method for determining the selection of appropriate risk mitigation measures to improve the safety and efficiency of maritime pilotage operations performance.

2.8 CONCLUSION

In this chapter, the concept of the maritime pilotage operations is described. This is followed by a brief description of human factors being a part of the human error element. Various studies that have been conducted related to human factors are also reviewed in this research. The role of the human factor in maritime pilotage accidents and detailed analysis of past pilotage incidents/accidents from 1995 to 2014 are presented in order to learn lessons from these past accidents and to learn from them what went wrong and how to avoid similar incidents. Brief descriptions of risk/safety assessment methods are provided. Finally, the research gap which will be addressed in this research is determined.

CHAPTER THREE - RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter aims to describe research methods that can adequately address the research questions in the previous chapter based on the research gaps found in the literature review. Thus, this chapter makes a link between the previous chapters 2 (literature review) and the following chapter 4 (pilotage human factor related risk identification) and then chapter 5 (causal factors assessment) and 6 (risk mitigation measures for pilotage performance improvement). As the interests of this research comprises all three steps of the safety/risk assessment processes, namely risk factors identification, risk assessment and risk mitigation, one research method is not able to sufficiently cover the entire topic of finding optimal solutions that will ensure safety performance of maritime pilotage operations and reduce the human related risk . Rather, selection of appropriate research methods for each step will be more desirable, which eventually leads to Chapters four, five and six which are at the core of this thesis.

Meanwhile, this chapter also helps for the selection of the appropriate methodology to validate and further develop the proposed model of this research. According to Blaikie (1993), “research methodology is a study which is discusses how theories are generated, and how particular theoretical perspectives can be related to particular research problems" This chapter mainly deals with the whole issue of the research design, including research strategy and design, research methods, sampling selection, data collection and analysis techniques. Figure 3.1 provides an illustrative view of a methodological framework for the purpose of this research upon which the research methodology will be directed.

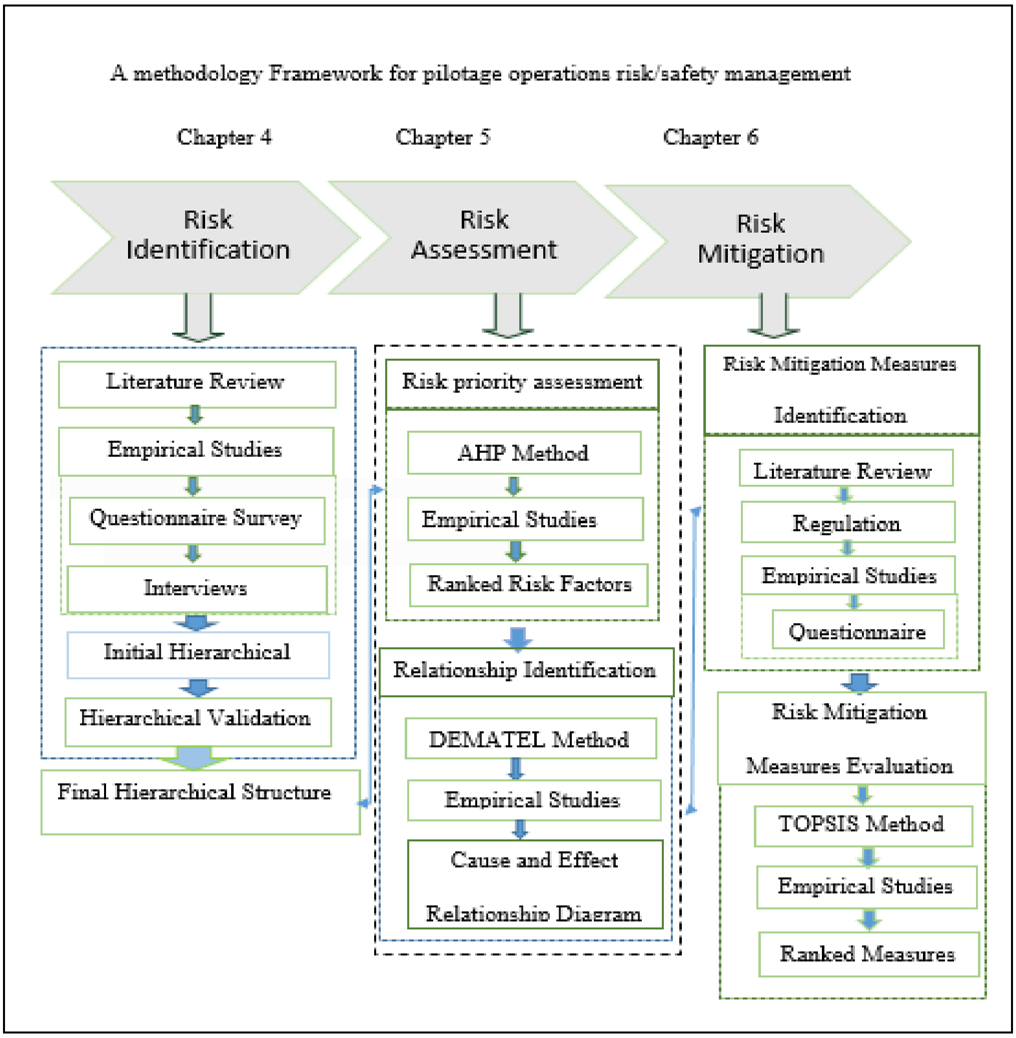


Figure 3.1: Proposed methodology of pilotage operation safety performance improvement

3.2 RESEARCH STRATEGY AND DESIGN

Research design can be described as the basic research plan or method, which aims at responding to research questions and to seek the validity and viability of the research (Lewis et al., 2007). In this research, the researcher applied a hybrid research approach, comprised of qualitative and quantitative approaches in a sequential exploratory approach to elicit the key factors that are considered a significant and influencing the safety performance of pilotage operations. In this study in order to satisfy the purposes of this research and meet the objectives of the researcher, both qualitative and quantitative methods are employed to identify, assess and mitigate human related risks in the pilotage operations environment. This thesis partially adopts more than one method to collect data, such as interviews, questionnaires, and documents, more than one data sources and more than one method to analyse the data.

In this research, the causal factors contributing to pilotage accidents were ascertained through a combination of primary and secondary source data. Primary data collection involves collecting new data, whereas secondary data collection concerns the collection of existing data. In this thesis in order to identify the human error related risk associated with the pilotage operations, literature review, questionnaire surveys, and interviews are adopted. To verify the comprehensiveness and validation of the identified risk factors as well as to examine the appropriateness of the risk classification method, questionnaire surveys have been conducted with experienced experts belonging to maritime industries of different geographical area from both the UK, and the Mediterranean.

Another questionnaire survey was used for the data collection in risk assessment and mitigation stages. The data collection method applied in this thesis is mainly based on expert judgements. The obtained risk data are used as inputs of the proposed conceptual decision making framework to understand the priority of risks and evaluation of currently implemented risk mitigation measures. From the discussion, human factor measurement can be viewed as a typical multicriteria decision making (MCDM) problem under uncertainty as it involves multiple criteria of both quantitative and qualitative features to solve multi-dimensional and complicated problems. This study uses an MCDM approach as a data analysis technique such as analytic hierarchy process (AHP), DEMATEL, and technique for order preference by similarity to ideal solution (TOPSIS). Full details about research methods and research techniques will be discussed in the subsequent sections.

3.3 METHODOLOGY FOR DATA COLLECTION AND ANALYSIS

This section presents a detailed explanation of the data collection and analysis methods used in the research. For the purpose of systematically identifying and understanding the relevant risk factors, it is necessary to employ an approach involving the use of both qualitative and quantitative methods to obtain and examine the risks along with justification. The first sub section describes the data collection method in each pilotage safety/risk assessment process. More specifically, the first phase of questionnaire surveys and interviews covering the key concepts of the identified risk factors will be conducted to validate the identified risk factors (HCFs) that were extracted from the existing resources, and to explore other contributory factors and potential causes which may contribute to accidents as well as the validation of the proposed classification method.

The second and third phase of the questionnaire survey will be conducted to quantify the level of importance and interrelationships of the identified risks factors. The current implemented measures in the real-time context and the rules and regulations adopted by maritime organizations were reviewed, and empirical study (questionnaire surveys) were conducted to extract identified pilotage risk mitigation measures for further evaluation. Moreover, the last questionnaire survey is designed to acquire the priority ratings of identified measures for mitigating pilotage risks. The forthcoming sub-section presents the data analysis methods in each risk management phase. Table 3.1 describes the methodologies for data collection and data analysis, which involves the three main risk management steps, and the related approaches and purposes of these approaches.

Table 3.1: Summaries of the research methods for data collection and analysis

Steps	Approaches	Purpose
Risk factors identification	Literature review (previous studies and maritime accident investigations reports regarding pilotage operations events)	To identify the existing risks causal factors contributing to pilotage accidents (HCFs)
	Empirical studies Questionnaire survey, telephone and face to face semi-structured interview	To investigate validation of identified risk factors and explore if there are more risk factors that are not mentioned in previous studies.
	Questionnaire survey, interviews	To investigate the reliability and validation of risk classification method, and further explore the appropriateness of the developed hierarchy model
Risk assessment	Empirical studies (AHP questionnaire survey) Analytic Hierarchy Process (AHP) method	To determine the relative weights and rank the importance of the human factors that affect pilotage operation safety

	Empirical studies (DEMATEL questionnaire survey) Decision Making Trial and Evaluation Laboratory (DEMATEL) method.	to identify the relationships among factors
Risk mitigation measures identification	To review the existing articles, the rules and regulations adopted by maritime organizations	To identify the current implemented risk mitigation measures
	Empirical studies (questionnaire survey)	To validate the identified risk mitigation measures and explore the current implemented risk mitigation measures via maritime experts
Risk mitigation measures evaluation	Empirical studies (TOPSIS questionnaire survey) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method	to rank and select the most ideal risk mitigation measures for pilotage

3.3.1. Data collection method

This study conducts three types of data collection methods: online/offline documentation (secondary data collection), questionnaire surveys (primary data collection) and interviews (primary data collection). Secondary data collection concerns the collection of existing data, whereas primary data collection involves collecting new data. Due to the lack of the research done in this area, and to understand the research problem it is required to use an approach involving the use of multiple methods. In order to identify and understand the human factors that influence the pilotage safety performance, it is necessary to conduct an approach involving the use of both qualitative and quantitative methods to collect and investigate the risk source along with justification due to the limitation of the existing research in this field.

In this thesis, empirical studies have been conducted to gain an understanding of human related risk factors that lead to accidents in the maritime pilotage operations area, and to identify the currently implemented risk mitigation measures. Empirical studies were conducted separately for chapters four, five, and six, respectively. This study employs different types of structured questionnaire surveys for data collection (i.e. qualitative HCFs data collection, AHP questionnaire for HCFs weight, DEMATEL questionnaires for HCFs interdependency, TOPSIS questionnaire).

The first sub-section introduces the data collection methods in the risk factors identification phase. In this stage questionnaire surveys and semi-structured interviews are conducted to identify risk factors as well as to construct an initial hierarchal structure as a taxonomy and test the validity of the appropriateness of the risk classification model. The second subsection discusses the data collection methods in the risk assessment phase. This step proposed another two questionnaire surveys B and C to evaluate the weight and assign the priority and relationships among the human related risk factors. The third subsection describes the data collection methods of risk mitigation measures identification, validation, and evaluation. Some sources of evidence i.e., careful literature review, rules and regulations adopted by maritime authorities, and questionnaire surveys with experts from maritime industries are utilized in order to identify the current implemented risk mitigation measures (RMMs). Then the questionnaire survey was conducted to analyse those identified measures by ranking their priority.

This study employs a questionnaire survey because, questionnaire surveys can be considered as one of the main tools for collecting data to quantify the opinion and behaviour of individuals (Bryman and Bell, 2011). A questionnaire as an efficient tool to collect data is composed of structured questions that become data and can be statistically analysed. This study employs different types of structured questionnaire surveys for data collection (i.e. qualitative HCFs data collection, AHP questionnaire for HCFs weight, DEMATEL questionnaires for HCFs interdependency, TOPSIS questionnaire).

The advantages of a surveys and questionnaires is that data collection does not require a skilled interviewer to be present. The research questionnaire method is useful for quantitative and qualitative data collection because it reaches a wide variety of respondents through electronic media with less time spent to complete the survey and less cost (Saunders et al., 2012). In contrast, there are drawbacks of the questionnaire surveys: they cannot ask more questions that are not prominent to respondents, there is a risk of missing data, and they cannot gather further data (Bryman and Bell, 2011). In order to avoid these drawbacks, questionnaires need to be short and easy to answer (closed questions) (Bryman and Bell, 2011).

For the purpose of this research as data required is qualitative and would require using an exploratory technique to probe for information clarification, a semi-structured qualitative interview method with marine experts was conducted. Qualitative interviews such as semi-structured interviews are an appropriate method for an exploratory study to seek what is taking place and to find out new insights (Saunders et al., 2012). Therefore, a semi-structured interview is the most appropriate method for this type of research (exploratory study), and has many advantages. It is reliable and efficient to extract maximum information from the interviewee and suitable to create a huge amount of data. In a semi-structured interview there is more flexibility for the interviewer to investigate the issues that arise during the interview and questions can be adapted. These advantages were presented by Saunders, (2009). This was further confirmed by Saunders et al, (2012) and Creswell and Creswell, (2017).

3.3.1.1 Data collection methods in risk factors identification and classification

To conduct the risk factors identification, the research continues with the empirical studies including the key definitions of (risk sources) the human factors that affect the operators who are performing ships' berthing operations (HCFs). Chapter four presents a detailed description of data analysis and taxonomic diagram validation in the risk factors identification phase. Many methods can be utilised for identifying risk factors such as, interviews, relevant document review, group meetings, and historical data collection (Water, 2007). A literature review has also been used by researchers to identify the risks in the maritime sector (Moreton, 2000; Subramaniam, 2010; Saeed, 2015; and Xi et al., 2017). This research first reviewed the relevant literature including the official documentation, historical data of the human factor in maritime pilotage accidents, and other published materials related to pilotage incidents/accidents from reliable organisations in order to identify the human factors related risk associated with ship operations in the pilotage environment and marine ports in the form of qualitative data. As has been mentioned in Chapter 2 and based on Saunders et al, (2009), the advantage of the literature review is that it saves time since it has already been collected, and it is also less expensive than other methods. It is also likely to be of higher-quality, and the data can be used in conjunction with the data collected through other qualitative methods such as experts' judgements.

In this thesis through conducting a literature review in Chapter 2 human factors were identified in the first phase of the qualitative data collection. After this, to validate the identified risk factors and explore other potential contributory causal factors that play a major role in maritime accidents during pilotage operations a questionnaire survey and interviews involving 25 professional captains who have served long periods onboard a variety of vessels have been conducted. Thereafter, a panel of experienced experts belonging to maritime fields were invited to take part in order to develop and validate a structural hierarchy risk taxonomic diagram.

In a survey research, a sample of the people is significant because the success of this type of study is dependent on the representativeness of the sample with respect to a target population of interest to the researcher (Bryman and Bell, 2011). Saunders (2009) suggested different techniques for the sampling design such as a probability sampling method (simple random, systemic, stratified random and multi-stage cluster samplings) and a non-probability sampling method (convenience, purposive, snowball and quota samplings). The non-probability sampling method is using a sample that has not been selected using a random selection method (Bryman and Bell, 2007). This type of sampling is more suitable for in-depth qualitative research (Saunders et al., 2012).

This research uses purposive sampling and snowball sampling. In purposive or judgmental sampling the method enables researchers to use their judgement to select cases that will best enable them to answer research question(s) and meet their objectives and, in snowball sampling, a researcher makes initial contact with a small group of people who are relevant to the research topic and then uses these to establish contacts with others (Saunders et al. 2007). This study targets the maritime industry as the population.

In order to obtain reliable views on a wider scale and to obtain multiple points of view, the participants of this study were selected from a variety of backgrounds and different geographical areas within the maritime domain. The respondents were chosen based on the following criteria: The first criterion for the selection of the (experts) participants was that they must hold a master mariner certificate of competency (an unlimited master licence). The second criterion, experts must be professionals who belong to the maritime industry including; professional ships' captains who had served long periods on board a variety of vessels in shipping companies; experienced senior marine pilots and tug masters who had been working long periods in different ports companies. They were selected as the study focuses on pilotage operations and they are the main operators who are performing and play a significant role in achieving safe and successful piloting and berthing operations. Thus, they are key for avoiding marine accidents, so they could provide views on their performance through their long practical experience and observations during maritime pilotage operations, as well as giving significant information regarding the human element factors contributing to maritime accidents. Additionally, they can judge their associated pilotage operations performance, if they had faced any abnormality or difficulties during their tasks, and they can explain regarding the situation and the actions that were taken to handle the situation during the performed pilotage

In addition, the participants included maritime educational institution staff who have a good understanding of marine operations risk research. Moreover, insurance and port company managers who are professionals in assessing and managing risks, and who could provide factual information and broader data regarding human errors and causes of maritime accident that might occur during pilotage operations. The main factor in selecting these experts was based on their expertise that they have contributed in the fields related to the human risk factors. The criteria ensure that the professionals are sufficiently senior and knowledgeable to answer the questions and are able to provide reliable technical information and opinions on the research topic. Thus, their responses will give robustness to the study and can be relied upon in explaining the study objectives.

In this research structured questionnaire was developed with the purpose of investigating the effect of human factors on the safety of pilotage operations, and identifying the accidents' causal factors in pilotage operations from the experts' perspective. Initially a draft version of the questionnaire was designed in line with research questions and the relevant studies to be completed in 30 minutes. The questionnaire designed for this stage of study used closed-ended questions including 12 items, to validate the existing factors and opened-ended questions to explore other potential contributory causal factors that might influence safety performance of maritime pilotage operations.

In order to investigate the feasibility, content validity of the developed risk factors and consent of its design, the proposed questionnaire was first examined by three ships' captains with education level PhD degree who have a good understanding of marine operations risk research and are highly knowledgeable of human related risk associated with pilotage operations. They were asked to test the context and investigate the precision of questions in order to establish suitable questions to reach the final questionnaire. Based on their feedback, the final draft of the questionnaire was developed for data collection. Ethical approval was also obtained to further validate the questionnaire content and participant consent. A sample copy of this questionnaire is shown in Appendix II.

Questionnaire surveys were conducted with twenty-five experienced seafarers to verify the extent to which any of the risk factors (HCFs) might impact on pilotage performance and contribute to maritime accidents. The number of responses was deemed acceptable for this study, as Saaty (2001) reported that just a small sampling size is required if the data collected are gathered from the experienced experts. This is due to that fact that experts should share consistent beliefs and thus reduce the necessity for a large sample size. The detailed information on the experts and sample selection process are described in chapter 4. For further information, please refer to chapter 4.

12 Statements were made and participants were asked to answer each statement using the following 5-point Likert scale: strongly disagree; disagree; neither agree nor disagree; agree; and strongly agree. This, as advocated by Saunders et al. (2012), can allow the participants to clearly express their perceptions with an adequate level of agreement with the statements given. The five-point Likert scale as a common measurement tool is considered the most widely used technique for scaling data in questionnaires, providing the respondent with a number of possible options from which to make a selection (Field, 2013). This method has been employed because, it is much easier for the researcher to analyse the data and for the potential participants to stay focused on the statements given and carefully respond to the questions. Based on the Likert measurement, the quantitative data generated from the questionnaire has been analysed using the basic descriptive statistics. As pointed out by Woo et al., (2011), descriptive statistics is one of the statistical analysis methods for describing attributes in seaport research.

In order to investigate the human factors that can affect pilotage operations' safety, and to collect broader data regarding contributing factors to maritime accidents, a number of interviews were also carried out with experts belonging to different maritime sectors. For the purpose of this research as data required is qualitative and would require using an exploratory technique to probe for information clarification (Saunders et al, 2012), the method used in this study was a semi-structured qualitative interview method. Initially the requests for conducting interviews were sent, to 10 professional experts with more than 10 years' working experience from a variety of backgrounds and different geographical areas within the maritime domain, by letter/email depending on which addresses were known. However, 6 professionals among them replied positively to interview requests. Interviews were held face-to-face or telephonically. Of the six interviews, three interviews were conducted by telephone because of distance constraints. The details of the interview plan, sampling, related questions and interview administration are explained in chapter 4. For further information, please refer to chapter 4.

Finally, and based on the obtained results, twenty-five factors have been identified and then summarized into a final hierarchy structure, which provides a comprehensive risk database to risk/safety pilotage operations research.

Behind doing this, and after having identified the contributory factors of the pilotage accidents (HCFs) and before conducting the further larger-scale risk assessment survey (to measure their weight priority and inter-relationships), these risk factors (HCFs) are designed in a hierarchal order forming the contributory factors of the pilotage accidents (HCFs). Questionnaires were conducted and distributed to the "validation team" by email to ensure the applicability and appropriateness of the hierarchy structure.

In this important step and based on previous maritime safety studies related with human factors and risk classification model, with assistance of two experienced ship's captains a hierarchal structure as a taxonomy is initially constructed, those experts were academic with education level PhD degree from an educational institution, staff who have more than 10 years teaching and researching experience and have a good understanding of marine operations risk research. They had also served long periods on board a variety of vessels which are navigating and visiting sea ports worldwide.

First of all, the two experts were invited to construct the preliminary taxonomy and provide their opinion with respect to the level of each factor. They were asked to help in categorising and placing the accident causal factors in the correct position in the taxonomy. They were asked to classify twenty-five factors which can represent their associated main factors (categories) and sub factors and if necessary, modification, removal, division and combination are allowable. Through the iterations and feedbacks, some factors (HCFs) were modified, removed, and combined. Instead of twenty-five factors identified, the experts selected only twenty-one factors and classified the factors into five main group factors, each group was then divided into several sub-factors (see chapter 4).

Thereafter, to assure the validity and confirm the reliability of the developed hierarchy diagram, a panel consisting of six experienced experts belonging to the maritime sector were consulted. Emails distributed questionnaire and face-to-face and telephone interviews with the validation team were subsequently conducted. The experts were all experienced ship masters who have been working in shipping and port industries for more than 10 years. They were asked to review and validate the effectiveness of the developed taxonomy and to confirm if the identified factors were grouped in accordance with their characteristics and grouped factors were presented in a hierarchy properly. Finally, experts agreed and the developed hierarchy diagram was accepted without any modification. The identified risk factors are summarized into a final hierarchy structure, which would be followed by the analytical hierarchy process (AHP) for ranking the set of criteria raised. The details of the identification and classification process, are explained in chapter 4. For further information, please refer to chapter 4.

3.3.1.2 Data collection methods in risk assessment stage

Following the questionnaire development procedures described in the previous section, the questionnaire surveys B and C in respect of risk assessment stage are constructed to elicit expert opinion on the pilotage operations human risk factors regarding their weight priority and inter-relationships. Draft copies of the suggested questionnaires, AHP questionnaire for HCFs weight, and DEMATEL questionnaires for HCFs interdependency were sent to the supervisory team to be approved. Based on the comments of the supervisory team, the questionnaires were adjusted and then the final versions were completed. In this study, the developed questionnaires were sent via email to the experienced experts from the maritime field with more than 10 years working experience. The participants of this study were selected from different geographical areas within the maritime domain. Full explanations and discussion in respect of those two questionnaire survey procedures are presented in Chapter five.

3.3.1.3 Data collection methods in risk mitigation measures identification and analysis

The current implemented risk mitigation measures will firstly be identified, validated, and finally evaluated. Based on the results obtained from the risk assessment phase of this thesis, in order to identify the risk mitigation measures in the pilotage operation, firstly the most relevant studies that can reflect the latest information about the current situation of the last implemented risk mitigation measures in maritime pilotage are reviewed. Followed by reviewing the recommendations, regulations and rules adopted by maritime authorities for maritime pilotage safety performance improvement, and questionnaire surveys with marine experts are conducted.

In order to identify the relevant risk mitigation measures with regard to the identified risk factors, the current implemented measures in the real-time context and the rules and regulations adopted by maritime organizations were reviewed. In order to explore mitigation measures that have not been mentioned in the literature and other documentation, a further questionnaire survey was conducted.

Following the same procedure of developing the questionnaire survey above, questionnaire surveys have been conducted to validate and identify more risk mitigation measures. The developed questionnaires D were sent to the experienced experts with more than 10 years' working experience from a variety of backgrounds and different geographical areas within the maritime domain, from both the UK, and the Mediterranean maritime industries. The implemented risk mitigation measures were introduced to the experts, and they were asked to decide whether the identified measures are relevant or not and to identify more risk mitigation measures. In addition, these experts were asked if they would be willing to accept the invitation to view the survey in advance to evaluate these identified measures. In the last phase, depending on the results obtained from above questionnaire, another questionnaire survey was conducted with experts aiming to evaluate the efficiency of the identified risk mitigation measures with relation to each risk factor. The finalised questionnaire D is attached in Appendix IIII. Full explanations and discussion in respect of those two questionnaire survey procedures are presented in Chapter 6.

3.3.2 Data analysis methods

Data analysis is considered one of the most important steps in any research study because it investigates and clarifies the data collected through the research process so that conclusions can be reached. As Yin (2009) stated, some specific methodologies and techniques are required to analyse collected data in order to produce high quality results. In this sense, to reduce potential analytical difficulties, as Yin (2014) pointed out, researchers should organise a clear strategy for data analysis to ensure using appropriate analytical tools that serve the ultimate research aims. For this study, as discussed earlier, a mixed methods strategy was chosen as an appropriate method in this research. As a result, the process of analysis commenced firstly with the use of AHP and DEMATEL methods to analyse the survey results from questionnaire B and C respectively and further TOPSIS has been utilized to analyse the survey results from questionnaire D. For the purpose of ensuring the reliability and consistency of the gathered data, a series of tests (e.g. consistency check) should be conducted prior to carrying out the evaluation of risk factors and mitigation strategic research. The procedure of applying each model and producing a high-quality data analysis will be presented in Chapter five and Chapter six.

3.4 CONCLUSION

This chapter has explained and introduced the various research designs in an effort to lay down the basics for the research. It has presented the main philosophical views behind the research methodologies. Different research perspectives, research types, data collection methods, data collection techniques and data sources were described. The chapter explains in detail the reasons behind the selection of research methods and techniques for the present study. In this chapter, various research methodologies were reviewed based on the previous studies. Based on the literature study, the appropriate methodologies for this research were identified and outlined. The techniques for the data collection and analysis by conducting the empirical studies have been described in this chapter.

There are three main parts of the data collection methods, which are: (1) data collection methods in risk factors identification, validation, and classification (2) data collection methods in the risk assessment phase, and (3) data collection methods in risk mitigation measures identification, validation and evaluation. In the first part, the risk factors are identified through literature review, the historical data of the accident reports of the maritime accident/ incidents investigations reports and then the validation, exploration, and categorization of the identified risks are done through questionnaire survey and interview with both industrial and academic experts. Next, another two questionnaire surveys are conducted for the assessment of risk factors. In the last part, the implemented risk mitigation measures are identified and validated by conducting the empirical studies (e.g. questionnaire survey).

In order to evaluate the identified risk mitigation strategies, a mitigation-measures questionnaire survey is conducted. This enables the researcher to select the most efficient risk mitigation measures. The techniques for the analysis of data are based on the employment of combined AHP, DEMATEL and TOPSIS for the risk assessment and mitigation strategy evaluation. In the next chapter the significant contributory factors of the pilotage accidents (HCFs) are identified and a preliminary model with a hierarchal structure as a taxonomy for causal factors contributing to maritime accidents in pilotage operations (HCFs) is developed.

CHAPTER FOUR: RISK FACTORS IDENTIFICATION AND CLASSIFICATION

4.1 SUMMARY

The objective of this chapter is to develop a comprehensive risk factors identification model within the context of the maritime pilotage operations. This chapter describes the methods and techniques used to identify and classify the human factor related risks influencing the maritime pilotage operations safety. In this research, the identifying of the human causal factors that contribute to pilotage accidents (HCFs) was accomplished through a combination of primary and secondary source data. After having identified the causal factors of pilotage accidents, a taxonomy is then developed and validated.

4.2 INTRODUCTION

The extensive review of the literature in Chapter 2 provides an outline for critical insight into the maritime related risks factors. Additionally, the literature review of maritime accidents and safety/risk analysis and their use in the marine and other safety critical industries, in addition to the experts' perspectives, has provided a valuable input, as it indicates the type of human casual factors (HCFs) that need to be addressed.

The visibility of the human factor related risks is one of the most challenging aspects of pilotage operations risk/safety management, it is therefore, essential to comprehensively identify human related risk factors existing in this area. Identifying the major causes of accidents and taking proper measures to mitigate further potential accidents are necessary for controlling the risks threatening the safety of pilotage operations. Within this research the term 'HCFs' is used to describe the human causal factors contributing to pilotage accidents which are not directly related to the risk factors applying to the a ship navigating in the open sea areas. Nevertheless, the same has been applied to address this problem.

Firstly, to build a new organized classification model in the context of pilotage operations, the identification of potential human causal factors (HCFs) is conducted. Initially, based on a literature review including the previous related studies and marine accident investigation reports, then a questionnaire survey and interviews with marine experts were carried out. The procedure for human factor related risks identification and classification is one of the most significant steps in the pilotage risk/safety assessment process.

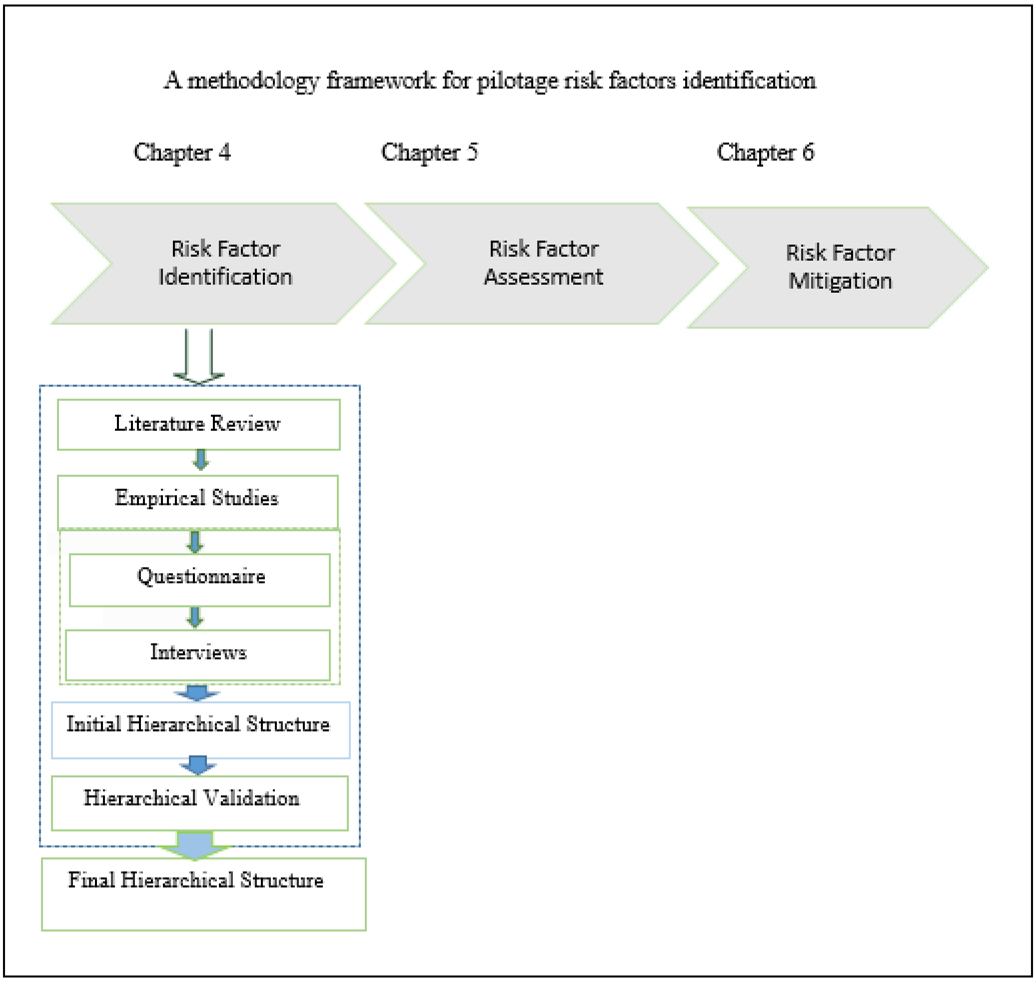


Figure 4-1: Proposed methodology for pilotage human risk factors identification

4.3. THE ACCIDENTS HUMAN CAUSAL FACTORS (HCFs) IDENTIFICATION AND CLASSIFICATION PROCESS

This chapter presents the first step of the risk assessment process, i.e. human factors contributing to the maritime pilotage accidents identification and classification. Identification of the relevant pilotage operations human related risk factors is the vital step for employing efficient risk management in the maritime industry. This study consisted of three main steps as shown in Fig. 4.1. Firstly, this research started with identifying the human relate risk factors that have been addressed in the relevant works of literature (shown in Chapter two), in addition, as mentioned previously, this study reviewed the previous relevant studies which have been conducted related to human factors and maritime accidents and other published materials such as analysis of various reports of investigations into real world maritime incidents relating to vessels under pilotage operations during the period 1995 and 2015.

The main philosophy behind it is to obtain an understanding of the concept of accidents, and to determine the causes and contributory factors which may negatively influence mooring operations' safety and play a central role in the causal chain of maritime accidents. As determining the root causes of the accidents is extremely important in improving the maritime safety and mitigating the possibility of its occurring in future (Ugurlu et al., 2015). Consequently, this step enables the decision maker to provide extra and reliable evidence regarding the human factors contributing to pilotage accidents.

To ensure that all the causal factors contributing to pilotage accidents (HCFs) are identified, survey questionnaire and semi-structured interviews with experienced marine experts were carried out in this study, attempting to validate and test the feasibility of the selected factors, as well as to explore new potential causes that may affect pilotage performance. This step leads up to in a composite the human causal factors affecting (HCFs) safety performance in the marine pilotage environment. After having identified the 25 risk factors (HCFs) and based on previous maritime safety studies related to human factors with assistance of maritime experts, a preliminary hierarchical structure for these factors (HCFs) was developed. The developed hierarchical structure of the identified risk factors is then modified and further validated through experienced marine experts.

4.3.1 Empirical study for risk factors (HCFs) identification

Identification of critical risks for pilotage operations is a challenging problem, due to insufficient availability of data and the limitation of information. It is also very difficult to investigate the risks that influence ship masters and marine pilots' personality characteristics on their attitudes towards risk, and the probability of error in maritime pilotage operations, due to the lack of evidence. Therefore, identifying the risk factors that might influence on human performance can be studied by using expert methods. As Long (2014) has explained the benefit of empirical studies is to verify current existing or newly proposed collected evidence about research on the basis of empirical data.

In this research in order to identify the human causal factors that impair the efficiency of pilotage performers, the primary research method was conducted in two phases. The first phase dealt with data collection by means of a survey, the second stage consisted of activities related to face-to-face and telephone interviews with professionals experts belonging to various sectors of the maritime industry. The researcher tried to combine, integrate and apply mixed methods to benefit from the advantages of each method and obtain accurate and reliable results.

4.3.1.1. Questionnaire survey

4.3.1.1.1 Procedure for developing questionnaire survey and sample selections

In this research a structured questionnaire was designed with the purpose of investigating and identifying the human factors influencing the safety performance of pilotage operations, and identifying the accidents' causal factors in pilotage operations from the experts' perspective. The data was obtained and content validity was performed to improve the clarity of the developed questionnaire. At first and based on secondary source data, a draft version of questionnaire was designed to be completed in 30 minutes. In order to investigate the feasibility, content validity of the developed risk factors and consent of its design, the proposed questionnaire was first examined by three ships' captains with education level PhD degree who have a good understanding of marine operations risk research and are highly knowledgeable of human related risk associated with pilotage operations. They were asked to test the context and investigate the precision of questions in order to establish suitable questions to reach to the final questionnaire. Based on their feedback, the final draft of the questionnaire was developed for data collection. Ethical approval was also obtained to further validate the questionnaire content and participant consent. A sample copy of this questionnaire is shown in Appendix II.1.

Once the questionnaire was developed initially it was sent to professionals to be completed electronically through an online survey tool as well as distributed by e-mails. However, because of the difficulty of finding experts in this field, this study used purposive sampling and the snowball sampling method for the sampling processes. In purposive sampling, it is assumed that a researcher depends on his or her own knowledge when selecting members of the population to be included in the sample (Saunders et al. 2007). The Snowball sampling method is a non-probability sampling technique (Black, 2010), in which a researcher begins with a small population of known members and extends the sample by asking those initial participants to identify others that should participate in the study. Snowball sampling is commonly used when it is hard to identify individuals of the required population (Saunders et al., 2007), and the experts are difficult to reach (Yang et al, 2016).

In this study at first one ship's master and two experienced senior marine pilots from different geographical areas within the maritime industry (UK, and Mediterranean) who were known and available were located for the questionnaire survey. They were asked to distribute the questionnaire and provide a named list of experts in this working environment for more questionnaire surveys. The respondents were requested to complete an item survey with responses collated anonymously. Finally, only 25 survey responses were completed and returned. The number of responses was deemed acceptable for this study, as Saaty (2001) reported that just a small sampling size is required if the data collected are gathered from experienced experts. This is due to that fact that experts should share consistent belief and thus reduce the necessity for a large sample size. The detailed information of the experts is described in Figure 4.2 and 4.3.

4.3.1.1.2 Sample Characteristics

In order to obtain reliable views on a wider scale and to obtain multiple points of view, the participants of this study were selected from a variety of backgrounds and different geographical areas within the maritime industry. The respondents were chosen based on the following criteria: The first criterion for the selection of the (experts) participants was that they must hold a master mariner certificate of competency (an unlimited master license). The second criterion, experts must be professionals who belong to the maritime industry including; professional ships' captains who had served long periods onboard a variety of vessels; experienced senior marine pilots and tug masters who had been working long periods in ports and performed pilotage operations.

In addition, maritime educational institution staff who have a good understanding of marine operations risk research. Moreover, insurance and port company managers who are professionals in assessing and managing risks, and who could provide factual information and broader data regarding human errors and causes of maritime accident that might occur during pilotage operations.

The main factor in selecting these experts was based on their expertise that they have contributed in the fields related to the human risk factors as illustrated in Figure 4.2 and 4.3. The criteria ensures that the professionals are sufficiently senior and knowledgeable to answer the questions and are able to provide reliable technical information and opinions on the research topic. Thus their responses will gives robustness to the study and can be relied upon in explaining the study objectives.

4.3.1.1.3 Questionnaire structure

The research question that formed the basis for this study was: How does the human factor contribute to maritime accidents. The questionnaire consisted of three parts, closed and open-ended questions as following:

Part A. Feedback and professional background

This section contained a set of questions intended to obtain information about the respondents' background, to define the position held by the respondents and practical experience. The figure. 4.2, and 4.3 show the distribution of respondent's occupation and work experience.

Part B. Validation of pilotage operations related risk factors (HCFs)

As has been discussed previously, the previous studies and the analysis of the past marine accident investigation reports showed that the main cause of the accidents which occurred was the human factor, and in the majority of cases reviewed this was due to human error. For this reason, the questionnaire survey is conducted with the experienced seafarers to verify the extent to which any of the existing risk factors (HCFs) might impact on pilotage performance and contribute to maritime accidents. 12 Statements were made and participants were asked to answer each statement using the following 5- points Likert scale: strongly disagree; disagree; neither agree nor disagree; agree; and strongly agree. This, as stated by Saunders et al. (2012), can allow the participants to clearly express their perceptions with an adequate level of agreement with the statements given. This method has been employed because, it is much easier for the researcher to analyse the data and for the potential participants to stay focused on the statements given and carefully respond to the questions which would be followed by the Analytic hierarchy Process (AHP) for ranking the set of criteria raised.

Part C. Exploration of additional risk factors (HCFs) from the participants' view point

In this part of the questionnaire, in order to explore if any other remaining factors were yet to be determined, participants were asked their opinion to add any other factors that may affect pilotage operations' safety performance. The question was as follows: From your experience do you know any additional risk factors (HFCs) that might negatively affect pilotage operations' safety performance? , Have you had any issues or incidents in the past affecting the safety of the ship piloting? These particular questions were asked in order to provide the participants of the survey the opportunity to give their views through their observations and long practical experience during pilotage operations about the influential human factors and causes which might contribute to maritime accidents. Each participant was able to add any comment they felt necessary.

4.3.1.2 Interviews

In order to investigate the human factors that can affect pilotage operations safety, and to collect broader data regarding contributing factors to maritime accidents, a number of interviews were carried out with experts belonging to different maritime sectors. Initially the requests for conducting interviews were sent to 10 professionals by letter/email whichever addresses were known. However, 6 professionals among them replied positively to interview requests. Interviews were held face-to-face or telephonically. Of the six interviews, three interviews were conducted by telephone because of distance constraints.

In this approach the interviewer requires a fair degree of understanding about the subject area to be able to know when to probe further, what to ask and to understand clearly the answers provided (Fletcher et al., 2003; Saunders et al., 2012). In this study the interviews were conducted by the author himself and were done individually and there was no obligation to take part. It is worth mentioning that the author has worked as a senior pilot in one of the biggest commercial ports in the Mediterranean Sea and held a first-class category licence which allows him to piloting all types of ships and unlimited tonnage, for almost 12 years in the period 2000-2012. The writer has gained long-term experience and sufficient practical knowledge related to pilotage operation issues. As a result, it was possible during the interview to adjust questions and to ask supplementary questions to follow up the themes and statements from the respondents.

The questions in the interview do not have to be asked in the same order as in the interview guide. The interview method was flexible and gave the interviewer more options to add any comment felt necessary during the interview. It also provided an opportunity to correct misunderstandings. Respondents also had considerable freedom to formulate answers in their own way. Each interview started with a brief introduction by the interviewer, explaining to the respondents the main purpose and usefulness of the discussion. This was to gain the interviewees' trust while making them feel comfortable at the same time, so as to achieve their honest and significant contribution.

The main question that formed the basis for this study was, how does the human factor influence pilotage operations' safety performance? The interview is divided into three parts: 1) the interviewee is asked to think of the human factor he considers to be the risk factor that might influence negatively on pilotage operations performance, the interviewee is asked to describe a real case from his own experience that was particularly challenging, 2) the interviewee was also asked to validate the factors that are presented in the developed questionnaire and suggest additional factors, 3) issues related with risk mitigation measures were also discussed in the interviews. Each interview was conducted for approximately 60 to 90 minutes. Notes were taken during the interview since it was considered the best way to document the results. Lastly, confidentiality and data privacy was ensured and safeguarded at all times.

4.3.1.2.1 The interviewee's background

The telephone interviews were held with two senior pilots, and one tug master who had been working in one of the biggest ports in the Mediterranean for more than 20 years. One telephone interview was held with the Director of Loss Prevention Standard P&I Club who has served 9 years onboard a variety of vessels, and sailed as master on gas tankers. Subsequently, he worked as marine superintendent for an oil/gas/chemical ship Management Company, followed by a spell as an external independent surveyor. For the last five years he has worked as internal surveyor for Standard P&I Club and took over as Director of Loss Prevention in 2013.

A face to face interview was conducted with an experienced senior pilot who has been working in shipping and port industries more than 25 years. He has served long periods onboard a variety of ships, four years as ship master, two years as marine operations and safety manager, and 20 years as a marine senior pilot in the port of Liverpool and currently working as a lecturer at Liverpool John Moores University. In addition, a face to face interview was also held with a master mariner who has vast experience as a director in the maritime sector, he worked for a long period of time as a marine pilot in one of the most significant ports in the Middle East. In addition, he has held many positions such as: harbour master, director of maritime affairs, assistant chairman of port, and acting chairman of port management. All the professionals experts mentioned above are sufficiently senior and knowledgeable to answer the questions, and are able to provide reliable technical information and opinions on the research topic

4.3.1.3 The survey results

Twenty-five survey responses were received. In this section, feedback and results from questionnaire responses were analysed and presented in this section. This section will be structured into three sub-sections, the first relating to professional background, the second and the third section relating to human factor influencing the safety of maritime pilotage operations.

4.3.1.3.1 The survey professional background

The first part of the questionnaire question was addressed in order to obtain information about the respondents' background, to define the position held by the respondents, and the period of their practical experience.

The survey respondents' position

The pie chart shown in fig 4.2 illustrates the position held by the survey respondents. It is highlighted that the survey participants belonged to various sectors of the maritime industry, 40% of respondents were pilots, 32% were ship masters, whereas 8% were tug masters, and the rest were managers or insurers or academics. The majority of the respondents were ship masters and pilots who have the overall responsibility of ship berthing.

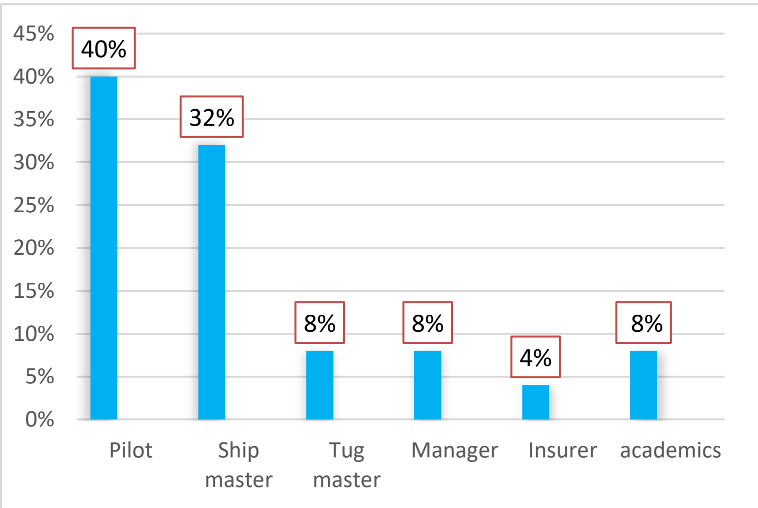


Fig. 4.2 The survey respondent's profession and position

The survey respondent's experience

The survey respondents were asked to provide information about their background and to outline a bit about the time period they have spent at sea so far. The intention for the question was to uncover the respondents' experience in years. The results show that almost half of the respondent had between 8 and 12 years of experience, whilst 16% had between 13 and 20 years of experience, and only 4% of the respondents had

7 years of experience. Meanwhile, 32% of respondents had over 20 years experience in the maritime field (Figure. 4.3).

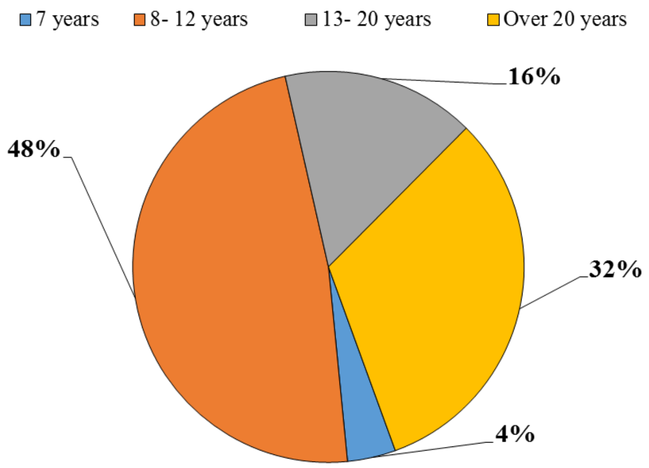


Figure 4.3 The experience period of the respondents.

This study utilised a questionnaire containing three parts, A, B and C. Part B consists of twelve items related to the identified risk factors (HCFs), closed ended questions were designed to verify the extent to which any of the identified risk factors (HCFs) affect performance and contribute to maritime accidents. For the purpose of this research, 12 Statements were made and 25 participants were asked to answer each statement using the following 5 point Likert scale. This method was adopted to capture the degree of importance of the identified risk factors (HCFs). This, as stated by Saunders et al. (2012), can allow the participants to clearly express their perceptions with an adequate level of agreement with the statements given. Sekaran, (2000) has also pointed out that ‘a Likert’ scale is a widely accepted technique to reflect the amount of agreement of disagreement with a variety of statements about some beliefs, attitudes, person or objects.

Based on the Likert measurement, the quantitative data generated from the questionnaire has been analysed using the basic descriptive statistics. As described by Shannon (2000) and Saunders et al. (2007), descriptive statistics is a statistical analysis method for describing attributes. According to Saunders *et al*. (2012), in research, the three most frequently used tools of statistical measurement are median, mean and standard deviation. Therefore, the data collected from the questionnaire survey was analysed employing a variety of statistics, including; Cronbach's Alpha, frequencies, value of mean, standard deviation, value of median, and Cronbach's Alpha. Cronbach's alpha tests to see if multiple-question Likert scale surveys are reliable.

Cronbach's Alpha

Cronbach's alpha, α (or coefficient alpha), developed by Lee Cronbach in 1951, is the first process used in statistical analysis and the most common measure of 'internal consistency' (reliability). It is most commonly used when you have multiple Likert questions in a survey/questionnaire that form a scale and you wish to determine if the scale is reliable (Yin, 2014). Cronbach's alpha will tell you if the test you have designed is accurately measuring the variable of interest. It should be mentioned that the reliability of the questionnaire survey is closely associated with its validity. A questionnaire survey cannot be valid unless it is reliable. Accordingly, 'internal consistency' (reliability) test was carried out to test whether the study measures the required items and the reliability of the received responses.

Cronbach's Alpha can be calculated by using the formula:

$$\alpha = \frac{N.\bar{c}}{\bar{v}+(N-1).\bar{c}}$$

Where: N = the number of items,

$\bar{c}$ = average covariance between item-pairs.

$\bar{v}$ = average variance.

While it's good to know the formula behind the concept, however, in this study, the reliability of the obtained results was evaluated by using the Cronbach's Alpha (α) method (Sijtsma, 2009) by employing the SPSS Statistics. It is most widely used because the method is much easier to use in comparison with other estimates as it only requires one test administration (Sijtsma, 2009).

Cronbach's Alpha ranges from 0 to 1, and the measurement instrument is considered to be more rigorous as long as this indicator is closer to 1 (Chomeya, 2010; Field, 2013). The overall Cronbach's Alpha coefficient for the data set in this study is 0.961, which indicates that the chosen item is consistent and reliable (see table 4.1). It can be concluded that the survey obtains a high level of internal consistency (reliability).

Table 4.1 the reliability test for the questionnaire survey

Cronbach's Alpha	No of Items
.961	12

Table 4.2: Likert Scale Interpretation

Scale	Interpretation	Interpretation
1	Very low	Do not influence
2	Low	Slightly influence
3	Moderate	Moderately influence
4	High	Significant influence
5	Very high	Extremely influence

Table 4.3 shows the frequency and percentage of the survey participant's response

Risk factors (HCFs)	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree	Total	Percent
Lack of effective communication and language barriers (HCF1)	0	0	0	60%	40%	25	100.0
Lack of team work (HCF2)	4%	4%	4%	40%	48%	25	100.0
Failure to exchange the information (HCF3)	0	0	0	88%	12%	25	100.0
Failure to establish a proper manoeuvring plan (HCF4)	0	0	8%	64%	28%	25	100.0
Distraction (HCF5)	0	0	4%	52%	44%	25	100.0
Lack of situation awareness (HCF6)	0	0	0	84%	16%	25	100.0
Lack of familiarity with the electronic navigational equipment knowledge (HCF7)	0	0	0	60%	40%	25	100.0
Failure to proceed with safe speed as stipulated in COLREG (HCF8)	0	0	8%	64%	28%	25	100.0
Pilot boarding and disembarking too close to breakwater (HCF9)	0	0	8%	56%	36%	25	100.0
Mental and physical work load (HCF10)	0	0	12%	48%	40%	25	100.0
Stress (HCF11)	0	0	8%	72%	20%	25	100.0
Fatigue (HCF12)	0	0	8%	68%	24%	25	100.0

Table 4.4 shows descriptive statistics for the risk factors (HCFs)

Risk factors (HCFs)	Sum	Mean	Midian	SD
Lack of effective communication and language barriers (HCF1)	25	4.60	5	0.500
Lack of team work (HCF2)	25	4.24	4	1.012
Failure to exchange the information (HCF3)	25	4.88	5	0.332
Failure to establish a proper manoeuvring plan (HCF4)	25	4.56	5	0.651
Distraction (HCF5)	25	4.48	5	0.586
Lack of situation awareness (HCF6)	25	4.84	5	0.374
Lack of familiarity with the electronic navigational equipment knowledge (HCF7)	25	4.60	5	0.500
Failure to proceed with safe speed as stipulated in COLREG (HCF8)	25	4.56	5	0.651
Pilot boarding and disembarking too close to breakwater (HCF9)	25	4.48	5	0.653
Mental and physical work load (HCF10)	25	4.36	4	0.700
Stress (HCF11)	25	4.64	5	0.638
Fatigue (HCF12)	25	4.60	5	0.645

Tables 4.4 illustrates the Sum, weighted Average and Standard Deviation (S.D.), and the ranking of the identified human related risk factors on the basis of expert judgements. In the questionnaire survey, the experts were asked to answer at which point they would mark to agree with or disagree with the given statements using a five-point Likert scale (i.e. 1= strongly disagree, 2= disagree, 3= neither agree nor disagree, 4= agree and 5= strongly agree).

The average of the Likert scale will be 3 which can be calculated by (1+2+3+4+5)/5), therefore, where the mean average above 3 will show an agreement (extremely influence, strongly satisfied) with the statements meanwhile the mean average below 3 will indicate overall disagreement (do not influence, strongly dissatisfied) with the statements (Table 4.2). Though the mean average is most frequently applied as a measure of central tendency compared to other measurements such as median, however, applying the mean alone will not be sufficient to describe and to give clear information and a frequency distribution about the data. Therefore, one of the important points that must be considered is measuring the standard deviation which is considered as a much more accurate and detailed estimate of dispersion or variation. Moreover, the small value of standard deviation indicates the tendency of data to similarity and homogeneity. The mean for each of these questions is above 4 which indicates that respondents 'mostly agree' and also what makes it more important is the fact that the standard deviation is far below 1 which shows that participants share the same belief and there is not any polarisation of their views.

In this study the significance of each identified risk factor is ranked to suggest the significant and influential factors to pilotage operations. The results analysis according to the statistical means demonstrated that the weighted average values of the 12 risk factors are almost very high which clearly demonstrates agreement among the participants that the aforementioned risk factors are significant and contributing factors to maritime accidents. Nevertheless, although the invited participants consisting of experts from different academic and industry fields and countries, the results reflect the consensus of their opinion. This implies that the experts have similar perspectives on the determined causal factors (HCFs) and their effects on the safety performance of the pilotage operations.

4.3.1.4 Findings from the survey and interviews

The second part of the questionnaire was to know to what extent the human factors affects maritime pilotage safety performance. The finding of the survey and interviews in the current study show that most of the participants share common beliefs and agreed that the abovementioned risk factors influence the safety performance of pilotage operations (table 4.3 and 4.4). In this section, data collected from the survey responses were collected and presented in the following sections:

4.3.1.4.1. Lack of effective communication and language barriers and their effects on pilotage operations

The participants of the survey were asked to express their views on language problems and poor communication and their impact on pilotage operations safety. This item in the survey assessed the respondent's views on whether or not they felt that accidents occurred during pilotage operations because of lack of effective communication and misunderstanding between the pilots, and the ship's crewmember as result of language problems. Data from the survey shows that most of the participants agreed with the statement that the lack of effective communication due to poor language of crew members or pilot is a significant cause which negatively affects the safety of pilotage operations.

The same questions were asked to the interviewees. The responses collected from the interview participants strongly support the statement, and the sweeping majority of the interviewees agreed that the low-level English language skills of the operators resulting in ineffective communication and this ineffective communication negatively affects the safety of the pilotage operations. The interview participants confirmed that the proper knowledge of English clearly facilitates communication and leads to fewer accidents.

One interviewee reported that when English language skills are insufficient, this will lead to an increase of misunderstandings and lack of communication between the pilot and ship crew members, the language barrier is a significant risk factor which impedes communication among members of the bridge team. He stressed the fact that English has conquered seas worldwide and has become necessary to communicate onboard every vessel. Therefore, all seafarers should have a sufficient understanding of the English language.

Most of the interviewees confirmed that efficient pilotage is mainly dependent upon the effectiveness and understanding of the communications between the pilot and the bridge team members, between master and crewmembers as well as between pilot and assistant parties such as shore staff, mooring boats and tugs when manoeuvring. It was further stated that, during ship berthing when crewmembers, ship's captain and pilot onboard ships do not speak the same language, and English language communication ability is insufficient, this increases the risk of misunderstandings, and can cause undesirable situations which will negatively affect the safety of ship berthing.

One of the interviewees who is working as a senior pilot, when he illustrated his experience with an Asian captain, stated that during the manoeuvring whilst on board a ship he was unable to communicate with the captain because of the language barrier, the captain consistently said "Yes Mr. pilot" whilst he did not understand. This resulted in an undesirable situation for the captain and he was very disturbed because the cadet on board the ship had to translate the pilot's instructions to him.

An important point raised by the senior pilot was that, "I find with some of the crews that if they are not really good at English they have to translate into their own language before they can interpret and then they respond having translated back to English. That translation take a lot of the time, creates misinterpretation, doesn't create the required response, does not create the required action, and that can induce errors. Language is always the cause, it's causation for sure in incidents". The senior pilot went on to state "how do I manoeuvre and conduct the safe navigation and berthing of the vessel if I do not have a line of communication with the prime member of the bridge team".

One expert mentioned that, you can't expect every tug master and the other assistant parties in every port to be able to speak in the English language, as that will simply not be the case and consequently, during ship berthing the port pilot will communicate with the port/tugs in a different language that the ship's staff will not understand, making it difficult for the ship's master and crew members to recognise the pilot's actions and to monitor any subsequent actions taken by those external parties, as well as to be fully aware of the situation. As a result, the safety of the ship's manoeuvring will be negatively affected.

A study has been carried out by Hsu (2012) showed that when a pilot is communicating to external parties, such as vessel traffic services (VTS), tugs or linesmen with a language that cannot be understood by the ship's master on the bridge, the pilot should, as soon as practicable, explain what was said to enable the ship's master and bridge personnel to understand and monitor any subsequent actions taken by those assistant parties. However, in this study during the interview one expert senior pilot presented an alternative view to the previous respondent and mentioned that "bridge team need to be informed of the action of the pilot/ tugs, how the vessel is going to be manoeuvred, they need that information, the ship's master needs to know continuously about what's happening with his vessel. That won't happen, if the pilot and tug master are talking in their common language, the pilot in a lot of situations will not have the opportunity and the time to tell the master in advance what he is going to tell the tug master. During manoeuvring you don't want that distraction, so if the pilot is talking to tug master and watching the vessel and the tug, the last thing he wants to do is to be distracted and have explain to the master what action he is going to do".

One of the interviewees who is working as Director of Loss Prevention Standard P&I Club, stated that, "many accidents occur during the ship berthing because of the communication between pilots and assisting tugs with a language not understood by the ship master, and ship masters often have too much confidence and trust in the pilot's abilities. However, the pilot is a human being and can make mistakes. As result, in order to avoid the risk of collision, the master must ensure that he is familiar with all commands and expected actions during the manoeuvring. He went on to state that, "I think, certainly having a common language helps, whether it's English, French or any other language. Speaking a common language is undoubtedly the greatest facilitator of communication on board a ship and contributes considerably to pilotage safety". Therefore, a common working language during pilotage maneuvering should be used.

This issue was confirmed by results obtained in the TSB study of operational relationships between ship masters/watch keeping officers and marine pilots (TSB, 1995). This study showed that the lack of a common working language is often a problem, in various ports, the pilot will communicate with the port tugs in a different language which the crew will not understand, and hence they may not be aware of what is being agreed/planned.

4.3.1.4.2. Lack of team work and its effect on pilotage operations safety

The finding of the survey in the current study (table 4.3 and 4.4) show that most of the participants share common beliefs and agreed to the statement that the lack of team work is a contributory causal factor for pilotage accidents.

The participants of the interviews were also asked to express their views on the above statement. Most of the experts interviewed confirmed that failure of pilot, ship's staff, and assisting parties (tugs masters, VTS, and shore personnel) to work with each other cooperatively, or failure to create an effective relationship on the bridge of a ship between pilot and ship's captain can cause undesirable situations during ship berthing, which will negatively effect on the safety of the pilotage operations.

It was further confirmed that, efficient teamwork is mainly dependent upon interactive co-operation, co-ordination and effectiveness of the communication between the pilot and the ship's crewmembers and between pilot and assistant parties. These three factors are considered as very significant for achieving effective and safe mooring operations, which rely heavily on effective team working.

4.3.1.4.3: Master/Pilot exchange information (MPX) and its effects on pilotage operations safety

The previous marine accidents investigation reports show that a considerable number of accidents occurred due to the failure to exchange the information between pilot and master before manoeuvring commences. The marine experts were asked to verify and confirm the above statement made in the literature review. The finding show that all of the participants share common beliefs and agreed with the statement, as the results show that the majority of the respondents believe that the exchange of information between pilot and master is significant for ensuring an effective berthing operation. While 88% of the respondents strongly agreed, and 12% agreed with this statement (Table 4.4).

When the interviewees were asked to express their views on the master-pilot exchange of information, they confirmed that failure to exchange the information prior to the commencement of a manoeuvre is a crucial risk factor and negatively affects the safety of the pilotage operations, and in order to ensure effective and safe piloting operations, both the ship’s master and pilot should exchange information prior to the commencement of a manoeuvre.

One Expert interviewed confirmed that marine pilots and ships’ crewmembers need to obtain the right information regarding details of the passage and berthing plan, as knowledge of these will assist both the pilot and the ship’s master, to be aware of the whole situation and enable them to easily identify the ship’s manoeuvring characteristics, and quickly assess the skills needed to make the correct decision and prepare a proper and effective berthing plan to control the ship and handle it to its destination successfully and safely. This opinion was confirmed by MAIB (2013) in their annual report, in order to maintain overall situational awareness when navigating with a pilot, it is critical that information is exchanged regularly so that all members of the bridge team are aware of the pilot's intentions and can provide assistance or timely advice and observations.

One expert marine captain pointed out that before entering the port and starting manoeuvring, the ship’s master and pilot must provide accurate information regarding the manoeuvring and how it will be conducted in order to avoid the risks and to ensure safe passage and successful manoeuvring. He went on to state that the pilot master exchange should have covered most of the principals, how the vessels is going to be manoeuvred, where, when, at what point and what they should expect.

One of the interviewed participants had a different opinion, as he believed that; it was unnecessary to constantly exchange information. He gave an example that if the vessel comes regularly to the port, it is well known by the captain and the pilot knows the ship's characteristics and how it should be manoeuvred, then the exchange of information may be limited to any defects or if there is anything new that the pilot needs to know about. Another example he suggested was, in the event that there was anything out of the ordinary which would lead to the pilot having to adjust how the operation will be conducted. However, he confirmed that, both the ship’s master and pilot should prepare a passage and berthing plan prior to the commencement of the manoeuvre.

Nevertheless, one interviewed senior pilot stated that "every manoeuvre is different even if the same ship is in the same berth and the exchange of information between pilot and master is significant for ensuring effective berthing operations". This is an opinion was supported by Armstrong (2007, p.3) who stated that, there are many variables including wind, tide, visibility and draught. Even the same ship in the same berth behaves differently each time, the pilot handle some kinds of ships he sees for the first time, and others he guides frequently".

4.3.1.4.4. The passage plan and its effect on Pilotage operations safety

How far do you agree with statement that many berthing accidents occur as a result of performing manoeuvring without a plan? The questionnaire intended to obtain information on whether the responses support the statement that failure to prepare a passage plan before manoeuvring commences is a contributing factor to maritime accidents.

The above results shown in Table 4.4 highlighted the views of respondents towards the ship's passage and berthing plan and its effects on pilotage operations safety. The survey results show that only 8% neither agreed nor disagreed whilst 28% of the respondents strongly agreed and 64 % agreed that in order to ensure effective and safe piloting operations, both the master and pilot should prepare a passage and berthing plan prior to the commencement of the manoeuvre.

During the interviews the same question was asked. Most of the interviewed participants confirmed that establishing the ship's passage and berthing operation plan is a contributing factor to reducing the risk of marine accidents during pilotage operations. According to the perceptions of the pilots and captains interviewed, failure to prepare a proper manoeuvring plan prior to piloting vessel is considered to be an unsafe act, and a contributing factor to maritime accidents. This fact was further supported in Gard (2014); and the previous marine accidents investigation reports, where it was noted that a considerable number of accidents occurred due to the lack of berthing planning. The grounding of M/V Tundra on 28 November 2012, was one of the best case examples that demonstrate how the failure of preparing a passage plan could contribute to the accidents (TSB, 2014).

One professional senior pilot stated that in order to ensure effective and safe piloting operations, after exchanging information and before manoeuvring commences, the pilot and master should give an outline of the ship's suggested passage and berthing operation plan and how the manoeuvre will be conducted. The pilot and master should agree and be satisfied with the overall final plan. He considered that the primary task for the ship's master and pilot is to provide accurate information regarding the manoeuvring and how it will be carried out in order to avoid the risks and to ensure a safe passage plan and successful manoeuvring.

4.3.1.4.5. Views on distraction and its effect on Pilotage operations safety

Distraction during pilotage operations is one of the biggest contributory factors to maritime accidents. The participants of the survey were asked to express their views on the above statement and whether they agree that distraction can affect pilotage operations safety performance. Data from the survey shows that most of the participants agreed with the statement. The same questions were put to the interviewees. The responses collected from the interview participants strongly support the statement, and all participants interviewed agreed that distraction negatively affects the safety of the pilotage operations.

One experienced expert stated that ship's crewmembers or pilot are often distracted while they are performing the manoeuvring as a result of many reasons such as the use of personal communication devices (such as mobile phones), or when the operator concentrating too much on one navigational instrument such as radar or ECDIS as a result of unfamiliarity with the electronic navigational equipment knowledge. This point of view was confirmed by Grech et al (2008) (MAIB) (2005), and (NTSB, 2011a).

4.3.1.4.6. Lack of situation awareness and its effect on Pilotage operations safety

Several research studies and an analysis of a considerable number of pilotage accidents shows that lack of situation awareness (SA) of the surrounding environment during pilotage operations is a high risk factor and one of the main contributory factors of marine accident. Poor shared situation awareness in the bridge team has a negative influence on the safety performance of pilotage operations.

The participants of the survey were asked to express their views on the above statement. Data from the survey shows that most of the participants confirmed that the loss of situation awareness of crew members and pilot during ships piloting is a significant risk which contributes to maritime incidents.

The same questions were asked to the interviewees. The responses collected from the interview participants, strongly support the statement, and the sweeping majority of participants considered it as one of the most significant human causal factors that contribute to the marine casualties and negatively affects the safety of the pilotage operations.

When one experienced pilot was asked about the causes of the loss of situation awareness, he stated that, during manoeuvring, lack of planning and lack of exchange of information between the pilot and captain of the ship due to lack of communication and poor language of the pilot or ship's bridge staff, are significant causes for the loss of situation awareness.

One of the interviewed experts mentioned that the ship's master or pilot might lose the awareness of the situation as result of distraction due to the use of electronic devices and mobile phones during the manoeuvring. In addition, the mariner's mental high workload due to momentary task distraction and of using the new technology and long-time monitoring of navigational aids equipment can also lead to memory loss and misperception of data. Therefore, controlling work load is a key factor with new technology, training and other forms of procedural guidance needed in order to make seafarers aware of capabilities and limitations of new technologies.

4.3.1.4.7. Lack of familiarity with the electronic navigational equipment knowledge and its effect on pilotage operations safety

A fact described previously in the literature review is that ineffective use of the navigational equipment such as, ECDIS, AIS, Echo Sounder, RADAR, and GPS, etc., as a result of a lack of familiarity with the electronic navigational equipment knowledge, is considered a high risk and has a greater potential to cause major accidents.

The participants of the survey were asked to express their views and whether they agree on the above statement. The question intended to investigate whether the lack of experience and poor knowledge of the use of navigational aids during pilotage operations is a cause and contributing factor leading to maritime accidents. The findings of the survey in the current study (table 4.3 and 4.4) show that most of the respondents agreed to the above statement, they believe that the lack of familiarity with the electronic navigational equipment knowledge and inability to use these aids influence the safety performance of pilotage operations and can lead to maritime accidents.

The interviewees were asked to give their opinions on the importance of using the technology during the pilotage operations. One of the interview participants reported that, good using of navigational aids such as AIS, RADAR, GPS, and ECDIS, is important and necessary, particularly when the vessel passes through narrow passages in the dark and under poor weather conditions. However, berthing operations inside the port particularly close to the berth, do not require the use of such navigational aids.

It is worth mentioning by experts that the chance for human error increases when things are complicated, new, and unfamiliar. One senior pilot pointed out that when electronic navigational equipment knowledge skills are insufficient, this could lead to an increase in risk, which can lead to undesirable situations during pilotage operations. He went on to state that, the chance for human error increases when things are complicated, new, and unfamiliar, and it can result in the bridge team being fully unaware of the position of the ship and leading to loss of the whole situation awareness, particularly when the vessels navigate through narrow canals or while underway, inbound/outbound from/to ports and channels in the dark or under poor visibility conditions. Wrong handling of navigational electronic equipment when entering or leaving the port (e.g. ship on route of collision not acquired on the Radar, pilot or ship's master fail to observe the information and set warning distances on the Radar, or vessel's course and position are not efficiently monitored and plotted on the electronic chart), can negatively affect pilotage operation safety and lead to marine disasters.

One of the interviewees reported that the use of technology is considered one of the most important issues. However, if the crew are unfamiliar with them and do not know how to set them up, they will make wrong decisions because they may be obtaining the wrong information from them. The use of technology is definitely helpful for pilot and ship's crewmembers to avoid collisions and grounding as long as it is being used properly, however, it is not if they are putting too much reliance on it. Particularly, if the ship's crewmembers are not properly trained and experienced in using technology, they will make wrong decisions as a result of wrong information they are obtaining. This was confirmed by Armstrong (2007, p.2), who stated that electronic aids are helpful for the pilot and ship's master to make their tasks easier, more accurate and safer, however, they should not be totally dependent upon them.

4.3.1.4.8. The excessive speed of ship during berthing operations and its impact on safety

How far do you agree with the statement that many berthing accidents occur because the speed of approach is too high?

The above item intended to examine whether the excessive speed of a ship during berthing operations is one of the influencing factors towards maritime causalities. Data from the survey shows that 64% of the respondents strongly agree, and 28% agree with the statement that approaching the port at high speed is risky and could lead to maritime accidents. Meanwhile only 8% neither agreed nor disagreed (Table 4.4).

During the interviews the same question was asked. One pilot confirmed that safe speed is a contributing factor to safety during ship berthing and failure to proceed with safe speed as stipulated in COLREG is high risk and can negatively affect operation safety and lead to marine disasters. However, in order to control the ship steering, high speed sometimes is needed, particularly, in severe weather conditions.

4.3.1.4.9. Boarding and disembarking of pilot too close to breakwater

The feedback of accident investigations reports indicated that the boarding and disembarking of the pilot too close to the breakwater is a contributory factor of the pilotage accidents. The participants of the survey were asked whether they agree with this statement, and how this action might affect pilotage safety. Data from the survey shows that almost half of the respondents strongly agree and 36% agree that many incidents occur as result of the pilot boarding and disembarking close to the port entrance. Meanwhile, 8% of the respondents neither agreed nor disagreed (Table 4.4).

Two participants of the interviews were asked the same question and they confirmed that the boarding and disembarking of the pilot close to the port entrance is a risk and that could lead to dangerous situations and considered it to be one of the main factors contributing towards maritime disasters particularly, when the captain of the ship has not obtained the competence in coming so close to the port entrance or is not familiar with the port area. They also stressed the fact described previously in the literature review that when the pilot embarks at the breakwater there is insufficient time for the captain of the vessel to exchange information with the pilot, thus there is not enough time to prepare the ship berthing plan and this results in an undesired situation for the pilot and ship's master.

4.3.1.4.10. The mental and physical work load and its effect on Pilotage operations safety

The increased workload is often presented as a predominant concern in pilotage operations. As mentioned earlier in the literature review, the mariner's high mental workload due to the use of technology and continuous monitoring of navigational equipment can lead to memory loss and misperception of data especially if the ship's operators are fatigued or not sufficiently trained. Analysis of a considerable number of pilotage accidents also reveals that the excessive mental and physical workload is a contributing factor to human error and has a negative impact on performance which in turn can lead to maritime disasters.

The participants of the survey were asked in the questionnaire to express their views on the above statement. The rationale behind the question was to assess the perspective and views of respondents whether the factor mentioned above impacts pilotage operations safety. The result of the questionnaire indicates that most respondents believe that the above-mentioned factors increase the probability of errors and influence the pilotage performance and are contributing factors to naval accidents (Table 4.3 and 4.4).

During the interviews the same question was asked. The question was to which extent high physical and mental workload affects the ship's crewmembers' and pilot's performance. There is a general consensus among all the pilots and captains interviewed that this factor plays a significant role in marine accidents. Most of the interviewed participants confirmed that increasing the level of mental and physical workload during the manoeuvring negatively influences the ship's crewmembers and pilot's performance and plays a significant role in marine accidents causation.

One expert stated that, because of the lowering of the number of staff, and increasing the level of automation in tasks, particularly with regard to navigation systems, ships' crewmembers perform many more tasks than before. In addition, nowadays maritime pilots on the bridge are exposed to information from several sources, from crew verbal instructions, from multiple instrument displays, and communication systems which have increased the work burden. Moreover, the complexity of the maritime pilotage operations and large number of tasks, such as long-time monitoring of navigational aids equipment, speaking on handheld radio to tugs operators, mooring boats and shore personnel, required high levels of skills, concentration, accuracy, and greater knowledge, and proficiency and need to be carried out at simultaneously. All of these factors can lead to an increase in the pilot's mental and physical workload, which in turn negatively influences the pilot’s performance and plays a significant role in the marine safety of the pilotage operation.

4.3.1.4.11. Stress and its effect on pilotage operations safety

The previous study shows that stress can influence the decision-making process of the pilot and ship’s master, particular during ship manoeuvring in restricted areas (Gerigk & Hejmlich, 2015).

The experts in this study were asked, whether they agree with the statement that many berthing accidents occur as a result of stress. The above question was intended to obtain information on whether the responses support the statement. Data from the survey shows that 72% of the respondents strongly agree, and 20% agree with the statement. Meanwhile only 8% neither agreed nor disagreed (Table 4.4).

The same question was asked in interviews with a ship’s master and senior pilot. They asserted that, handling a large vessel in constrained waters such as a port or narrow channel is a high-risk task and the pilot with the ship’s master assigned to that task have a responsibility to handle the ship to its destination safely, because of the complexity of maritime pilotage operations and the large number of tasks involved which require high levels of skill and concentration and need to be carried out simultaneously. Additionally, piloting ships in harsh working conditions. Moreover, the short time allocated to achieve the tasks has increased the level of stress for the pilotage operators, and consequently the risk of error increases.

Moving different types of large vessels in constrained waters is a high-risk task and the pilot assigned to that task has a responsibility to handle the ship to its destination safely. In addition, Introducing the new technology in the shipping industry and, which need a high level of accuracy, proficiency, high level of skills, and intelligence, and due to the number of tasks which need to be carried out at simultaneously such as speaking on a handheld radio to tugs operators and shore personnel; furthermore, the short time allocated to achieve the task, has increased the work burden, and level of stress for the pilot.

Moreover, the unique environment of seafaring is characterised by harsh working conditions including the excessive noise vibration coming from the main engines, manoeuvring devices such as the steering gear, the auxiliary systems such as the heating ventilation and air conditioning units, heat and bad weather, increase in stress level and fear, also impact and impair the performance of pilots and ship's crewmembers during manoeuvres, which in turn contributes to the maritime accidents (Grech et al., 2008, p.91). The complexity of the task required high levels of skills and concentration.

4.3.1.4.12. Fatigue and its effect on pilotage operations safety

A fact described previously in the literature review was that fatigue during pilotage operations is considered a high risk and has a greater effect on seafarers and potential to cause major accidents. The participants of the survey were asked to express their views and whether they agree on the above statement. The question intended to investigate whether fatigue is a contributing factor leading to maritime accidents. The results of the survey presented in the tables above (table 4.3 and 4.4) show that most respondents agreed with the above statement, they believe that fatigue negatively influences the performance of ship handlers and contributes to maritime accidents

The findings indicate that most of the surveyed and interviewed respondents feel that fatigue impairs pilot and crew members' performance and contributes to maritime disasters. 68% of survey participants strongly agree with the statement and 24% agree. Meanwhile, only 8% neither agree nor disagree (Table 4.4).

When the interviewees were asked to express their views on fatigue and whether they agree with the statement that fatigue impairs the performance of pilots and ship's crew members and contributes to maritime disasters during ships pilotage, most of the participants share common beliefs and agreed with the statement made in the literature review.

One expert captain pointed out that "Certainly fatigue leads to less concentration and makes one more prone to making errors, but if the person is suitably trained and experienced he will be sure that he is not fatigued.", he went on to state that

“Crewmembers have work/rest hours regulations to ensure that they are not fatigued (whether they follow/comply is a different matter), but pilots do not comply with the regulation and are often overworked and rushed from ship to ship”.

An interviewee senior pilot presented an alternative view to the previous respondent and mentioned that, "fatigue can be an issue but if the work pattern of a pilot is properly organised, then they should not be fatigued. Also, he reported that fatigue for crew members was more serious, particularly because before they get to the port, they have probably been in the bridge for twelve or more hours, working at night without a rest period and an adequate nap”.

4.3.1.5: The findings of the part C of the questionnaire

From your experience do you know any additional causal factors that might affect pilotage operations performance? Have you had any issues or incidents in the past which affected the safety of the ship piloting?

In the above questionnaire a particular question was asked in order to provide the respondents of the survey and interviews the opportunity to give their views through their observations and long practical experience on board ships about the human element factors which might affect the safety performance of the pilotage operations.

In addition to the 12 aforementioned contributing factors, the experts have highlighted additional serious human element factors which can lead to maritime accidents. These factors presented in the table below (table 4.5) include the following:

Table 4.5 Contributory causal factors of the maritime pilotage accident

No	Contributory causal factors of the maritime pilotage accidents
1	Lack of ship handling skills due to lack of experience and improper training
2	Failure of pilot to give precise instructions.
3	Failure of the ship's master to correctly follow the pilot directions
4	Improper/ inadequate use of tugs.
5	Lack of skills of the crewmember on ship board, tugs, and shore mooring personnel
6	Orders regarding anchoring, steering, and engine requests, are not following out by ship's crewmembers correctly.
7	Failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power.
8	Failing to inspect the tugs towing equipment
9	Pilot failing to think ahead for developing situations.
10	The ineffective monitoring of the tugboats, mooring boats, and shore mooring personnel performance and vessel's progress
11	Piloting ships outside established rule in poor weather condition due to commercial pressure.
12	The blind trust and reliance on the pilot during berthing operations.
13	Using mobile phones during berthing operations.

Ships piloting was considered as one of the most complex tasks. It requires high standards of professional ship handling skills. According to the perceptions of most of the experts interviewed, a lack of ship handling skills, due to lack of experience, and improper training, was identified by experts as one of the most significant factors that may adversely affect the safety of manoeuvring. It is considered among the most important causes of accidents in pilotage operations. Therefore, Marine pilots and all ship's handlers should possess high levels of ship handling skills and navigational experience. The Collision of Ursine with the Pride of Bruges, in King George Dock, Hull, on the east coast of England on the 13th November 2007, during ship berthing, demonstrated how the shortcomings of ship handling knowledge and lack of experience of pilot and ship's master affected the safety of manoeuvring and contributed to the accident (MAIB, 2008a).

Ship handling is defined as an acquired art practised by harbour pilots, ship's masters and officers of proper control of a ship while underway, especially in harbours, around docks and piers (Armstrong, 2007, p.1). However, Murdoch et al., (2012) described ship handling as an art rather than a science, but a ship handler who is familiar with the science will be better at their art and this will enable them to easily identify a ship's manoeuvring characteristics, and quickly assess the skills needed to control the ship. The most basic thing to be understood in ship handling is to know and anticipate how a ship behaves under all circumstances and what orders should be given in order to make the ship behave and move exactly the way you want her to (Murdoch et al., 2012).

One expert pilot stated that, during ship piloting, marine pilots are employed on board ships to give navigational advice to captains and guide vessels into or out of port safely. The pilot is also responsible for giving commands to assisting parties such as tugs, shore mooring men, mooring boats, and giving his instructions to the ship's master. He must have a good knowledge of ships handling, because failure of the pilot to give precise instructions, or any flawed commands that the pilot gives to the tug's masters, or any wrong orders given to the helmsman, engine room, or the fore and aft stations, could result in an undesirable situation and could affect the safety of the mooring operation and cause marine accidents.

One interviewed expert stated that, the ship's captain is responsible for giving orders to the ship's crew, officers on the bridge, and officers at the ship's bow and stern on what the pilot has suggested or instructed; an accident in pilotage is likely to occur as a result of failure of the ship's master to correctly follow the pilot's directions during manoeuvring .This conclusion was supported by Darbra et al. (2007), who stated that these occurrences (e.g. incorrect interpretations, refusal, rejection, intervention by master, etc.) are quite frequent making the pilot's task much more difficult and increasing the potential of accidents.

Experienced experts attributed this mistake to many reasons such as, an ineffective working environment and poor relationship on the bridge of a ship between the pilot and ship's captain and failure of pilot and ship's master to exchange information and establish a proper passage and berthing plan prior to piloting vessel. The other reason that might lead the master of the ship to interfere or refuse the pilot's advice or instructions during the period of ship piloting, is when the pilot is not qualified or gives wrong commands. However, according to the expert's opinion the ship's master of the piloted ship should have a good relationship with the pilot and be confident that the pilot is doing his duties correctly and should not interfere and challenge the pilot or give conflicting orders unless the pilot's actions are clearly negligent, or he is behaving irresponsibly, because failure of ship's master to follow the pilot's directions, is considered very hazardous and can affect ship navigation safety and contribute to disaster in ports.

According to the perceptions of one of the experts interviewed, the lack of skills of the crewmembers on board ship, tugs masters, and shore mooring personnel is considered high-risk and can negatively influence the operations and contribute to pilotage accidents. During berthing operations, operators' work characteristics such as professional skills and work attitudes, are very significant factors that can affect ships' navigation safety. For instance, failure of crewmembers on board ship to carry out the pilot's instructions regarding anchoring, and engine requests precisely results in high-risk situations and can cause accidents, or when the pilot or master gives orders regarding steering and those orders are not carried out by the helmsman correctly, this failure can affect the safety of the ship berthing.

One expert mentioned that, during berthing operations many factors affect ship handling. For example, communication failure from the bridge to the engine room or vice-versa, or to the fore and aft stations could result in an undesirable situation. Mutual misunderstanding in the bridge could be another ship posing a potential accident threat, when the pilot or master gives the order regarding steering, and this is not carried out correctly by the helmsman. Therefore, during ship handling, to be protected against the mutual misunderstanding, and support bridge team situation awareness, Pilot and bridge staff should be communicating with each other in sufficient detail to allow all to achieve a mutual understanding and close the loop. This opinion was confirmed by Grech et al., (2008, p.79) and TSB (2013a), they stated that rudder commands should be given by the pilot or master, and repeated by the helmsman clearly and loudly, and re-confirmed by the senders, this strategy is called closed-loop communication. This is the best method to ensure that a command is being followed and is a vital part of the bridge team management (Gard, 2007). One example was described by Murdoch et al (2012) which demonstrate how the mistakes of operators could contribute to the accident, when the pilot gave the orders and the helmsman applied them incorrectly. The pilot commanded starboard helm, however the helmsman applied port helm. By the time this mistake was discovered, the vessel was swinging towards rather than away from the berth.

As has been mentioned previously, the interaction and interdependence, in addition, the multiplicity of the entities who are performing ships berthing operations add to the complexity of the task. Handling ships such as large passenger ships, container ships with towering deck cargo, high free board car carriers, mammoth tankers, and deep draught bulk carriers are considered complex tasks, and cannot be handled and treated the same way as small cargo ships (Armstrong, 2007, p.1).

One expert pilot mentioned that, it requires intense concentration and special attention, as well as high standards of professional skills, and an adequate number of powerful tugboats. The pilot stated that, ineffective use of tugboats is one of the causes of marine accidents in ports. Practically, the factors affecting the quality of tugboat operations include the number of tugboats, the horsepower of the tugboat, and the operating skills of tugboat drivers. There is need for the assistance of sufficient numbers of powerful tugboats, which are necessary, particularly in adverse weather conditions.

The main purpose of tugboats is to assist ships, such as pushing and towing the vessels. Tugboats play a significant role in assisting vessels in berthing alongside and unberthing from the berth, and as a result, failure to use sufficient numbers and sufficiently powerful tugboats, is considered high-risk and can negatively affect the manoeuvring and contribute to a ship's berthing accident. In addition, improper use of tugs as a result of lack of skills of tugboats' masters is considered by the interviewed experts as a high risk and can affect the manoeuvring negatively and contribute to a ship's berthing accidents.

For instance, failure of the tugs' masters to correctly follow the pilot directions (e.g. incorrect interpretations, refusal, rejection, and intervention), or a delay between the pilot's order and the execution of the order can affect the safety of manoeuvring. Furthermore, failure of the tug's masters to carry out the pilot's instructions precisely with respect to position and towing power could also affect manoeuvring safety or delays in securing a tug as a result of lack of skills of mooring parties, putting time pressure on the crew and thereby increasing the risk of the vessel sailing in unsafe conditions. As result, the compliance of tugs operators, shore-side mooring personnel and mooring boats with the instructions of the Pilot effectively, will support a safe and efficient mooring operation.

Piloting ships in bad weather conditions, and navigating vessels outside published guidelines or draft limits is also considered by experts as a high risk and contributing factor to maritime accidents. One of the interviewees who has vast experience as a senior pilot in one of the biggest ports in the Mediterranean, mentioned that, piloting ships in adverse weather conditions frequently happened due to many reasons. One of these reasons is the commercial pressure, which is usually attributed to port authorities' administration managers, ship's owners, charterers, and agents. The interviewed considered it a high risk and affect negatively on the pilotage operations safety.

During berthing operations the ineffective monitoring of the tugboats masters, mooring boats, and shore mooring personnel performance and vessel's progress is considered by experts a high risk and contributing factor to maritime accidents. Therefore, good observing is considered by experts as one of the most significant factors for achieving effective and safe mooring operations.

Ship's crewmembers, and assisting parties (tugs masters, VTS, and shore personnel) must work together with the pilot in good teamwork with the objective of guiding the ship safely to its berth and not just rely on the pilot during berthing operations. This is considered crucial, particularly when a vessel is operating in intense fog and poor visibility conditions in restricted waters or congested areas.

Hetherington et al (2006) stated that failure to comply with regulations is the major contributory factor for many maritime disasters and the majority of human errors have been caused. Based on this statement, this issue raises the question, why are the pilots and ship's staff making errors in spite of the rules and regulations? In this study this question was asked to a captain who has a long period experience in the maritime field. According to the expert, lack of experience and proper training is the root cause of errors. Governing bodies, such as ships companies and port authorities still fail to implement the principles of IMO regulations. Nevertheless, port states cannot check what is happening while the ship is under navigation, so they can only check whatever they see on paper which will always be fine. Port control is doing whatever they can, however, the issue here is that even though on paper everything is fine, it does not mean that in realty the crew is following the procedures and regulations and have high standard of training. There is still no real occupation standards/ certification/ measurement of competence for pilots and mariners who are performing pilotage operations.

One interviewed pilot stated that, an increasing number of regulations does not equate to safer operations, rather, a change in mentality is what required. A continuous improvement in pilots and crew members' safety culture and standard of training can minimize the number of marine accidents caused by human error. Enforcement and implementation of the IMO legislation is considered an important factor that affects the human element and pilotage operations safety.

It can be justified to say that the IMO has been successful in addressing many issues related to pilotage operations safety and often recommended the ships operators to comply and fulfil the requirements of the adopted rules and regulation. The IMO resolution A. 960 (23) is one of the most important of the pilotage operations safety regulations, nevertheless, the issue of interpretation and lack of enforcement prevent its full success. Governing bodies, such as governments and port authorities in some countries still fail to control the principles of IMO A. 960. Enforcement and implementation of the IMO legislations is considered an important factor that affects the human element and pilotage operations safety.

The IMO is incapable of effective control and has absolutely no powers of enforcement. Therefore, in order to implement and enforce regulations in a good order, other players, such as flag states, regional Port States Control (PSC) authorities and classification societies should play key roles in the implementation and enforcement of maritime safety regulations and establish an advance monitoring system. (Akyuza and Celik (2014a).

4.3.2 DEVELOPMENT AND ASSESSMENT OF THE RISK FACTORS (HCFs) TAXONOMY

The literature review showed that many researchers have identified several different maritime accidents risk classification methods, sources, or types (Yee et al., 2005; O'Connor and Long, 2011; Wang et al., 2013a; Chauvin et al., 2013; and Akhtar and Utne, 2015, Akyuz et al., 2016; Akyuz, 2017 and Fu et al., 2018). However, the literature review also showed the lack of a common methodology or consensus among researchers that can outline a universally risk factors classification. The lack of a standard classification for pilotage operations has resulted in a research gap due to the conception of risks. Thus, it is necessary to establish a standard vocabulary that can be used to assess and to identify hman related risk factors in pilotage operations for a strategy with the most potential to mitigate risks. While there are risk factors taxonomies being used in assessment in other safety-critical industries around the world, in the maritime industry in particular pilotage operations, human relate risk factors (HCFs) taxonomy is a relatively new concept and it is important to develop a risk taxonomy first

This section describes the human-related risk classification technique used in this study. Classification of the relevant pilotage operations human-related risk factors is the vital step for employing efficient risk management in the maritime industry. Risk classification enables the interpretation (Ugurlu et al., 2015), and facilitates the evaluation. In addition, it helps risk managers to understand the events and the circumstances from which they arise (Pak et al., 2015).

In this study, in order to classify the human relate risk factors (HCFs) and create a new taxonomy, three main steps has been conducted. Firstly, this research started with identifying the risk factors that have been addressed in the relevant works of literature (shown in Chapter two), in addition, as mentioned previously, this study reviewed the previous relevant studies which have been conducted related to human factors and maritime accidents and other published materials such as analysis of various reports of investigations into real world maritime incidents relating to vessels under pilotage operations during the period 1995 and 2015.

And to ensure that all the causal factors contributing to pilotage accidents (HCFs) are identified, survey questionnaire and semi-structured interviews with experienced marine experts were carried out in this study, attempting to validate and test the feasibility of the selected factors, as well as to explore new potential causes that may affect pilotage performance. This step leads up to in a composite of the twenty-five human causal factors (HCFs) affecting safety performance in the marine pilotage operations environment. These factors are presented in the table 4.4 and 4.5. After having identified the contributory human causal factors of the maritime pilotage accidents (HCFs), a preliminary hierarchical structure for these factors (HCFs) was developed. The developed hierarchical structure of the identified risk factors is then modified and further validated through experienced marine experts as illustrated in Table 4.6.

This research presents a modified comprehensive taxonomy and classification approach to decompose the unstructured human risk factors to strengthen the knowledge base in pilotage risk assessment. The hierarchical decision model is a proper application for effectively introducing MCDM problems. In addition, in a complex decision-making issue, the hierarchical decision model is a beneficial tool and facilitates the complexity to be simplified (Yeo et al., 2014). Furthermore, the model easily adds or modifies new data in a flexible and instant way (Yang et al., 2009).

4.3.2.1 The contributory factors of the pilotage accidents classification and validation process

To develop the taxonomy for the contributory causal factors of pilotage accidents the following steps were performed in this chapter:

After having identified the twenty five contributory factors of the pilotage accidents (HCFs) and based on previous maritime safety studies related to human factors and risk classification model, with the assistance of two experienced ship's captains, a hierarchal structure as a taxonomy is initially constructed. The experts were academics with education level PhD degree from an educational institution, staff who have more than 10 years teaching and researching experience and have a good understanding of marine operations risk research. They had also served long periods on-board a variety of vessels which are navigating and visiting sea ports worldwide.

First of all, the two experts were invited to conduct a review and evaluate the preliminary taxonomy and provide their opinion with respect to level of each factor. They were asked how the grouped factors should be presented in a hierarchy properly, and to help in categorising and placing the accident causal factors in the correct position in the taxonomy. The main questions in the interviews were asked to classify twenty-five factors which can represent their associated main factors (categories) and sub-factors and the questions were:

Do you think the main group factors (categories) and their sub-factors are well classified?"

"Could you classify the main factors to represent their associated sub-factors?", and if necessary, modification, removal, division and combination are allowable.

Through the iterations and feedbacks, some factors (HCFs) were modified, removed, and combined. For instances, they combined the error factors with the same meaning in accidents' causal factors into a new one. This research found that the factors "using mobile phones" and "distraction" have a relatively similar meaning with regard to error factors which are more likely to influence the occurrence of an accident. Hence, these two factors were combined into one factor named distraction. Also, the blind trust and reliance on the pilot during berthing operations and lack of team work. In addition, improper/ inadequate use of tugs and failing to inspect the tug's towing equipment. Finally, instead of twenty-five factors identified, the experts selected only twenty-one factors and classified the factors into five main factor groups , each group was then divided into several (4 or 5) sub-factors as illustrated in Table 4.6.

Thereafter, to assure the validity and confirm the reliability of the developed hierarchy diagram, a panel consisting of six experienced experts belonging to the maritime sector were consulted. Emails distributed and face-to-face and telephone interviews with the validation team were subsequently conducted. The experts were all experienced ship masters who had served long periods on-board a variety of vessels, including two academics with education level PhD degree from a maritime educational institution staff who have good experience in maritime risk assessment research, two senior pilots currently working in different ports companies in the UK with a bachelor degree, one who has 30 years of marine experience and is currently working in the port of London and one senior pilot who has worked for a long period of time on a variety of ships, four years as ship master, two years as marine operations and safety manager, 20 years as a marine senior pilot in the port of Liverpool and is working as a lecturer at Liverpool John Moores University.

One expert is a Master Mariner with education level of bachelor degree, who has vast experience as a director in the maritime sector, he worked also for a long period of time as a sea pilot in an Asian port. In addition, he has held many positions such as, harbour master, director of maritime affairs, assistant chairman of port, and acting chairman of port management. One expert is an insurance company manager, he sailed as a master mariner on gas tankers, consequently worked as a marine superintendent for an oil/gas/chemical ship management company, followed by a spell as an external independent surveyor, and the last five years worked as an internal surveyor for Standard P&I Club and took over as Director of Loss Prevention in 2013. They were asked to review and validate the effectiveness of the developed taxonomy and to confirm if the identified factors were grouped in accordance with their characteristics. Finally, the experts agreed and the developed hierarchy diagram was accepted without any modification as shown in table 4.6.

In the hierarchical model, the overall goal is illustrated in the first level. That is, the most contributory causal human factors of maritime pilotage accidents. This structure consist of five group main factors and each one is divided into sub-factors. The main factors are the criteria, which are, (F1, F2, F3, F3, and F4). The sub-factors are sub criteria which are, F1: (F11, F12, F13, F14 and F15), F2: (F21, F22, F23, and F24), F3: (F31, F32, F33, and F34), F4: (F41, F42, F43, and F44), and F5: (F51, F52, F53, and F54).

Table 4.6: The hierarchy for the contributory causal factors of pilotage accidents (HCFs)

Factors			Sub-factors		
1	F1	Bridge team management failure (Non-technical skills shortcoming)	F11	Lack of teamwork	1
			F12	lack of effective communication and Language barriers	2
			F13	Failure to exchange the information between pilot and ship's master prior to pilotage operation. (Master/Pilot exchange information (MPX))	3
			F14	Lack of situation awareness	4
			F15	The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats, and shore mooring personnel performance and vessel's progress	5
2	F2	(Technical skills shortcoming)	F21	Lack of ship handling skills due to improper training and lack of experience.	6
			F22	Lack of familiarity with the electronic navigational equipment knowledge	7
			F23	Lack of skills of the crewmember onboard ship, tugs, and shore mooring personnel.	8
			F24	Improper/ inadequate use of tugs.	9
3	F3	Instructions and orders failure	F31	Failure of pilot to give precise instructions.	10
			F32	Failure of the ship's master to correctly follow the pilot directions.	11
			F33	Failure of tug's masters to carry out the pilot's instructions precisely.	12

			F34	Orders regarding anchoring, steering, and engine requests, are not followed out by ship's crewmembers correctly.	13
4	F4	Rules and regulations noncompliance	F41	Failure to establish a proper manoeuvring plan prior to piloting vessel.	14
			F42	Failure to proceed with safe speed as stipulated in COLREG	15
			F43	Piloting ships in bad weather conditions or navigating vessels outside published guidelines or draft limits.	16
			F44	Poor boarding arrangements (e.g., pilot boarding and disembarking too close to breakwater)	17
5	F5	Individual- task interaction factors	F51	Fatigue.	18
			F52	Mental and physical workload.	29
			F53	Distraction during the time of berthing operations	20
			F54	Stress	21

4.3.3 CONCLUSION

This chapter recognises pilotage risk factors identification and classification as significant process for conducting an efficient risk assessment. The literature review, the questionnaire survey, and interviews serve as a base and guide to strengthening the knowledge base for pilotage human related risk factors identification. In this study in order to identify the risk factors (HCFs) that affect pilotage operations safety as completely as possible, a careful literature review, together with a considerable number of maritime pilotage accident reports were carefully investigated. Questionnaire surveys and a series of emails as well as in-depth interviews with experienced experts were carried out to validate and test the feasibility of the selected factors, as well as to explore new potential causes that may effects pilotage performance. This step led up to in a composite the human causal factors of the pilotage accidents (HCFs). After having identified the contributory factors of the pilotage accidents (HCFs) and to develop a structural hierarchy risk taxonomic diagram, interviews with experienced experts belonging to the maritime sector were established. A preliminary hierarchical structure consisting of 25 risk factors (HCFs) was developed. The developed hierarchical structure of the identified risk factors was then modified and further validated through experienced marine experts.

In the thesis, a hierarchical human error related risk classification is presented, which consists of five different risk categories. Thereafter, those five main categories of risk factors were further divided into twenty one sub-factors. The empirical studies in this chapter were carried out to make an inference about the experts' opinions in order to capture the risk factors in a more comprehensive and reliable way. Meanwhile, the importance of the performance of the identified risk factors and developed classification model for the pilotage operations was addressed.

Despite the invited participants consisting of experts from different fields and countries, the finding reflects the consensus of their opinion. This indicates that the experts have similar views on the aforementioned causal factors (HCFs) and their effects on the safety of the pilotage operations. The main challenges are: how the relevant causal factors (HCFs) to decision makers have to be dealt with; how the causal factors (HCFs) are measured, controlled, and managed. The problem with the studies above is that they could conclude that all risk factors could be considered "critical", when the respondents were assessing each of them separately. Therefore, a ranking is missing that reflects the perceived degree of importance of risk factor in relation to each other. Without such ranking, decision makers are not able to determine the relative importance of risk factors and will have difficulties in determining the right and appropriate measures to overcome them. In the next chapter, the captured risk factors can be assessed by applying both AHP and DEMATEL models to discover the priorities, and select the most important causal factors which influence a pilotage operation safety and context relations among them.

CHAPTER 5 A HYBRID APPROACH TO THE ASSESSING OF HUMAN FACTORS IN MARITIME PILOTAGE OPERATIONS USING AHP AND DEMATEL METHOD

5.1 SUMMARY

This chapter aims at proposing a generic risk assessment model for pilotage operations, to evaluate the human related risk factors influencing the safety of maritime pilotage operations, using a hybrid approach of two methodologies. The proposed model is a key part in the human-related risk management framework for pilotage operations. Assessing human related risk factors influencing the safety performance of operators and determining the root causes of maritime pilotage accidents when there is uncertainty and a complex operations environment, is considered a type of multiple criteria decision-making (MCDM) problem in nature. Thus, this chapter introduces a new methodology, based on the combination of the AHP and DEMATEL techniques, in order to apply them for solving an MCDM problem, in order to address the human factors affecting maritime pilotage operational safety, with the aim of developing appropriate solutions for reducing human error and improving the quality and efficiency of pilotage operations' performance, and thus subsequently mitigating the occurrence of pilotage accidents in the future.

First, the AHP (Analytic Hierarchy Process) is applied to determine the relative weights and rank the importance of the human factors that affect pilotage operation safety, and then the DEMATEL method is applied to identify whether there are relationships among the factors. This methodology is found to be particularly useful in dealing with the limited availability of data in the maritime domain and the complexity that exist in the quantitative analysis of human errors.

5.2 INTRODUCTION

The complexity of the human attitude involved in human operations results in difficulties in quantifying human factors/human errors and reliabilities of performance in maritime pilotage operations. In recent years many research projects regarding the maritime safety related risks have been conducted from a range of perspectives and several aspects in order to reduce the occurrence of potential human errors in maritime operations systems, but it appears from a review of the literature that a little research has been done in the maritime domain on issues related to human errors and pilotage operation safety issue, and until now, few studies have employed a decision-making method to evaluate the weight and rank the importance of human factors which influence pilotage operation safety. This results in concern for the precision of pilotage accident causal factors weight assignment, uncertainty in identifying the root causes of pilotage human error and debates on the results of maritime pilotage safety measurement, demonstrating a significant research gap needing to be addressed.

The problem with the previous studies is that they could conclude that all risks or challenges could be considered “critical” or “important”, when the respondents were assessing each of them separately. Therefore, a ranking is missing that reflects the perceived degree of importance of factors for accidents’ human causal factors in relation to each other. Without such ranking, stakeholders are not able to determine the relative importance of factors and will have difficulties in determining the right strategies to overcome them.

Therefore, in order to solve this problem, to produce more realistic and reliable results, this study aims at introducing a multi-criteria decision making (MCDM) method, the Analytical Hierarchy Process (AHP) method. The proposed methodology in this chapter overcomes the shortcomings of the previous studies by introducing an AHP approach to identify the relative importance among accidents’ human causal factors in maritime pilotage operations, by carrying out pairwise comparison among the (HCFs) as a whole, by taking subjective judgments of decision makers into consideration.

In addition, the limitation of the previous studies is that in recent years, international maritime authorities, scholars and practitioners have made a significant amount of effort to evaluate the human factor in order to identify root causes of human error and accident causations in the shipping transportation industry in order to improve safety at sea; however, most of these research studies often overlooked evaluating the causal relationships among the human factors contributing to the pilotage accidents and few of these studies focused on analysing the interaction between accident causation factors with a systematic method (Wang, 2015).

As has been mentioned previously, using assessment methods, which disregard evaluating the influencing relationship between accidents’ causal factors, can lead analysts to risk either underestimating the factors that can have a high influence on the others or overestimating factors that do not have much influence. Yang et al. (2013b) stated that using an assessment method that ignores the relationships and interdependence between factors is not always feasible for solving real-world problems. As a result, the decision-makers will have difficulties in determining appropriate causal factors affecting pilotage operations' performance that need to be improved. Consequently, right strategies cannot be taken to mitigate the human errors effectively in the marine pilotage operations area.

Therefore, in this study, in order to address these issues successfully, and find more reasonable results, an MCDM method, such as the decision-making trial and evaluation (DEMATEL) method is utilised, taking subjective judgments of decision-makers into consideration. The DEMATEL method is chosen to do further analysis. This analysis results in the identification of the complicated cause and effect relationships among the risk factors affecting pilotage operations.

This research implies both analytic hierarchy process (AHP) and decision-making trial and evaluation laboratory (DEMATEL) methods for the following reason: A hybrid approach of two or more methodologies has been proven to be a powerful supporting tool for solving such complex decision problems. The significance of the proposed methodology is that it can help analysts in determining the most important contributing factors that may affect the pilotage operations' safety, and therefore should be the most developed. In addition, the proposed hybrid method provides a comprehensive illustration of relationships among the factors, and assists analysts to identify the influence of each factor to the others, as well as enabling decision-makers in determining whether a factor belongs to a cause or an effect group and which causal factor needs to be first improved. As a result, countermeasures can be taken to reduce the human errors during maritime pilotage operations, thus subsequently preventing or at least mitigating maritime accidents in the future.

This approach will facilitate the decision-making process for choosing appropriate strategies and take preventive/corrective actions in later stages for mitigating risks influencing pilotage operations. An analysis of the identified human factors (HCFs) influencing pilotage operations safety performance is conducted on real cases. The proposed methods is validated using case studies in major ports in the UK and Mediterranean from different marine expert perspectives. The results indicate that the hybrid approach, attempting to use quantitative modelling for dealing with the dependency and interdependency problems, for facilitating the quantification analysis of human factors in maritime pilotage operations can be successfully fulfilled.

In the next section, literature with regard to these two decision-making methods is introduced, and previous studies that used the methodology are reviewed. In section 5.4, the research methodology for the proposed novel hybrid MCDM model with a detailed description of each step is illustrated. In addition, the advantages of integrated AHP and DEMATEL methods are discussed. A case study of applying both AHP and DEMATEL methods on human factors in maritime pilotage operations is illustrated in Section 5.5, and 5.6. Finally, the conclusion is presented in section 5.7.

5.3. A BRIEF OVERVIEW ON THE METHODS

5.3.1 Overview on Analytic hierarchy process (AHP)

The Analytic Hierarchy Process (AHP) method was recognized as one of the major methods of decision making in order to solve multiple criteria decision problems in the field of management engineering after the 1980s since Professor Saaty of the University of Pittsburgh developed the method in the 1960s (Lee and Kim, 2013). The AHP approach is a multi-criteria decision making (MCDM) method, a common and widely used method in decision-making and rating tasks, which is rigorously concerned with the scaling problem and what sort of numbers to use and how to correctly combine the priorities resulting from them (Saaty, 1990). It is an appropriate application when comparing the importance of an element against that of another element at the same level in the hierarchy tree structure, using a typical pairwise comparison technique to acquire relative weights of criteria based upon a hierarchical structure (Saaty, 1980).

One of the best advantages of this method is its capability to check and minimize inconsistencies in expert judgments, by computing a Consistency Ratio (CR) (Riahi et al., 2012). In addition to this, the AHP approach is easier to understand and it can effectively handle both qualitative and quantitative data. AHP is an effective tool that is proven to be appropriately applicable for dealing with MCDM problems and allows the decision-maker to obtain both subjective and objective aspects of a decision (Saaty, 2004), and helps them to make the right decision in a complex situation (Ishikaza and Labib, 2009).

The AHP method in the individual tools and hybrid MCDM in the integrated methods were found as the first and the second methods in applications (Mardani et al., 2015). The AHP approach has been proven to be a successful tool for measuring independency among elements in the complex decision problems in various applications. It is noteworthy that a number of studies have been conducted by utilising the AHP method. AHP has been applied by Celik and Cebi (2009), in order to identify the role of human error in shipping accidents, by Saeed (2015) to select the most important of nontechnical skills required for deck officers' in the crisis situations, by Zhang et al. (2012), to establish a risk hierarchical structure and to identify the significant influencing factor of an inland waterway transportation system. Lee and Kim (2013) used Analytic Hierarchy Process (AHP) to analyse the relative importance of the risk factors of the marine traffic environment, Pak et al., (2015) to identify the factors that can affect port navigational safety, and Ugurlu et al. (2015) in order to determine the causes of ships' collisions, by Fu et al (2018) to investigate the relative importance of potential risk influencing factors of the Arctic maritime transportation systems and others, and by Saeed et al (2019) in the development of a taxonomy of merchant marine deck officers' non-technical skills (NTS).

5.3.2 Overview on DEMATEL

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method was developed by the Geneva Research Centre of the Battelle Memorial Institute (Fontela and Gabus, 1976; Gabus and Fontela, 1973). It was introduced to build the network of relationships map for illustrating the interrelations among factors (Liou et al., 2007). Recently this method has proven to be a more successful tool for measuring and illustrating the causal relationships among interdependent factors Özdemir and Güneroğlu (2015); Elham et al. (2013). The DEMATEL technique is the most significant application to be applied in the multi-criteria decision making (MCDM) field to display the cause and effect groups of a system (or subsystem) by applying matrices and digraphs to visualize the structure of complicated causal relationships (Tzeng et al., 2007; Lin and Wu, 2008; Jeng, 2012).

The DEMATEL method is an effective and innovative tool that is proven to be appropriately applicable for dealing with MCDM problems in an uncertain and complex operations environment (Liou et al., 2007; Tzeng et al., 2007). One of the greatest advantages of using DEMATEL is that a huge sample size is not required for analysis (Yang et al., 2016). It is provides more realistic solutions and more accurate results by combining the qualitative subject matter expert opinion with the quantitative in a systematic method (Lin and Tzeng, 2009). Besides the results from the final step of DEMATEL, it could also be combined with other multi criteria decision making methods (Saaty, 1996), like Analytic Hierarchy Process (AHP), (ANP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS).

Given the strength of the DEMATEL method in tackling complex problems and its ability to effectively identify the relations among the factors within a system and determine the level of interdependence between them, as well as its capability to capture the cause and effect relationship successfully (Yang et al., 2008), the DEMATEL technique has therefore been widely applied in many domains including engineering (Hori and Shimizu, 1999; Seyed-Hosseini et at., 2006), business (Wu, 2008; Hu et al., 2009; Noori and Amiri, 2009;) education (Tzeng et al., 2007), Airline safety measurement (Liou et al., 2007), maritime operations (Topcu, 2008; Xi et al., 2017) and others.

5.3.3 The application of the integrated AHP and DEMATEL technique

This study uses the integrated MCDM method, AHP (Analytic Hierarchy Process) and DEMATEL technique to combine their desired properties for facilitating the quantification analysis of human risk factors in maritime pilotage operations. The proposed methodology in this chapter overcomes the shortcomings of the previous studies by introducing AHP and DEMATL approaches to obtain the importance and weights of influence of each factor by carrying out pairwise comparison among the factors.

This research implies both analytic hierarchy process (AHP) and decision-making trial and evaluation laboratory (DEMATEL) methods for the following reason: Firstly, the integrated method has not yet been applied for identifying the relative importance and determining the mutual influence relationships among human factors in maritime pilotage operations. Secondly, the above-mentioned approaches have the capability of quantifying the subjective judgments of the respondents in a way that can be measured and evaluated (Sara et al., 2015). Thirdly, the approaches are proven to be appropriately applicable for dealing with MCDM problems in an uncertain and complex operations environment and can effectively handle both qualitative and quantitative data. The major advantage of integrating AHP and DEMATEL methods is that the decision maker such as practitioners and regulators (port authorities, shipping companies' operators, and government) can continuously improve the pilotage' performance effectively and efficiently from the short-term and long-term perspective, by determining the interrelationships among the risk factors and enables the decision-maker to clearly understand which factors have mutual influences on one another to be managed.

The integration of an MCDM technique can provide more practical solutions, (Mandal & Sakar, 2011). Each method has its own advantages and disadvantages (Mohagheghi et al., 2017). The AHP (Analytic Hierarchy Process) is applied to determine the relative weights and rank the importance of the human factors that affect pilotage operation safety. However, it assumes that the factors are independent and fails to consider their interactions and dependencies. Therefore, the technique of The Decision Making Trial and Evaluation Laboratory (DEMATEL) is applied to overcome this imperfection and provide a comprehensive illustration of relationships among the factors, taking the dependence among the factors into consideration.

It is worthwhile mentioning that the AHP method enables a complex problem to be structured and presented in a simple hierarchy form and allows assessing the consistency of the performed pairwise comparison expert judgements, by computing a Consistency Ratio (CR) (Riahi et al., 2012), which is not possible to evaluate with the method of DEMATEL. On the other hand, the advantage of using the DEMATEL method is that it can effectively analyse the mutual influences (both direct and indirect effects) among different factors. The proposed innovative approach using the DEMATEL method plays a significant role in visualizing the interrelationships between factors via an IRM and enables the decision-maker to clearly understand which factors have mutual influences on one another.

The approach of using both methods is increasingly being used for various problems in many fields and a wide range of areas. An integrated approach of the AHP and DEMATEL has been proven to be a successful and powerful tool for measuring dependency and interdependency among elements in the complex decision problems in various applications. In addition, utilisation of AHP technique together with

DEMATEL method has been widely extended in many different disciplines, such as developing the competencies of managers (Kashi, 2015), selection of allied hospitals in outpatient services (Ortíz et al., 2016), supply chain performance (Najmi and Makui, 2010), personnel estimation (Roy et al., 2012), supplier selection (Chang et al., 2011). Sara et al. (2015) used a combined method of the AHP and DEMATEL to assess carbon capture and storage (CCS) barriers in the ROAD project. The AHP was used to extract the relative weights of (CCS) barriers and DEMATEL was used to investigate interdependency among them. Wu and Tsai (2012) applied the AHP and DEMATEL approach to evaluate the criteria in the auto spare parts industry in Taiwan, and based on the diagraph derived from the DEMATEL, they suggested a long-term improvement opportunity for the auto spare parts industry.

5.4 THE METHODOLOGY

A hybrid MCDM techniques based on a combination of the AHP and DEMATEL for assessing accidents' human causal factors in pilotage operations is proposed. The AHP (Analytic Hierarchy Process) is first used to evaluate the weight and rank the importance of the identified human causal factors that affect pilotage operation safety, while the DEMATEL method is applied to determine whether there are relationships among the factors. The proposed risk assessment model and procedures to this novel hybrid MCDM method are schematically shown in Figure 5.1 and each step is elaborated in detail in the forthcoming subsections.

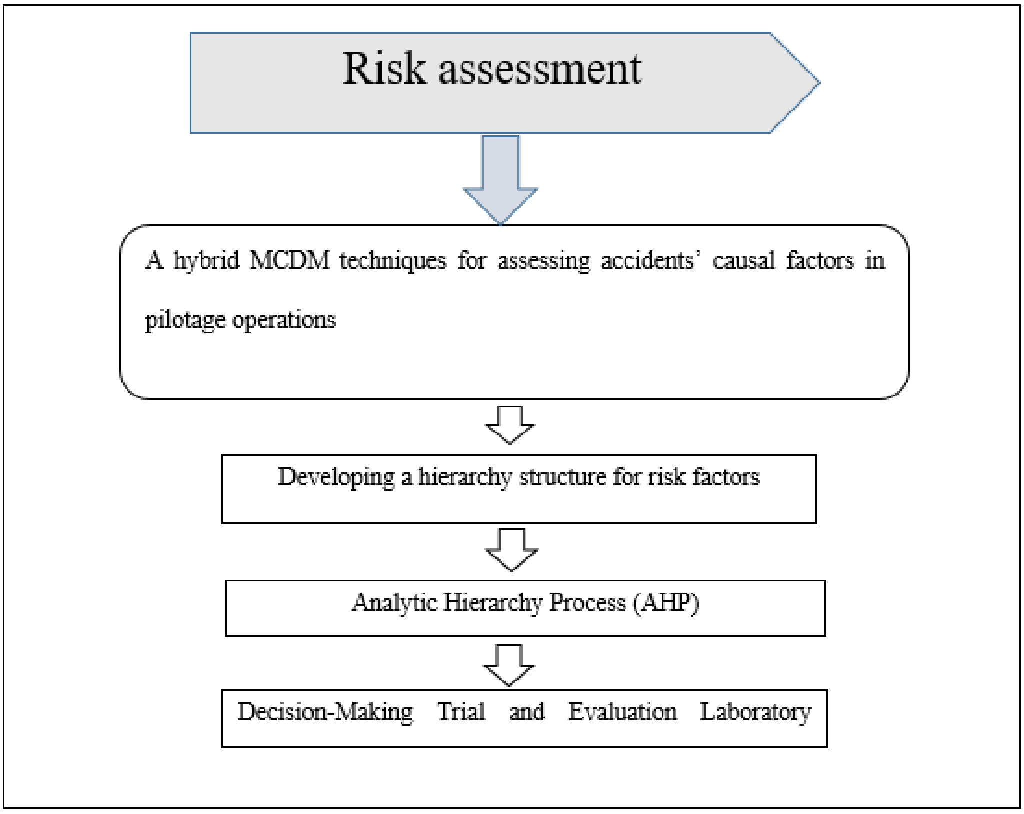


Figure 5.1: A generic risk assessment model for pilotage human-related risk factors

5.4.1 The process of an analytic hierarchy process (AHP)

This section focuses on risk assessment using the Analytic Hierarchy Process (AHP) method. In this study the AHP approach is employed to determine the most important human causal factors which are influencing pilotage operation's safety, and causing maritime accidents. The process of the proposed method is illustrated in Figure 5.2.

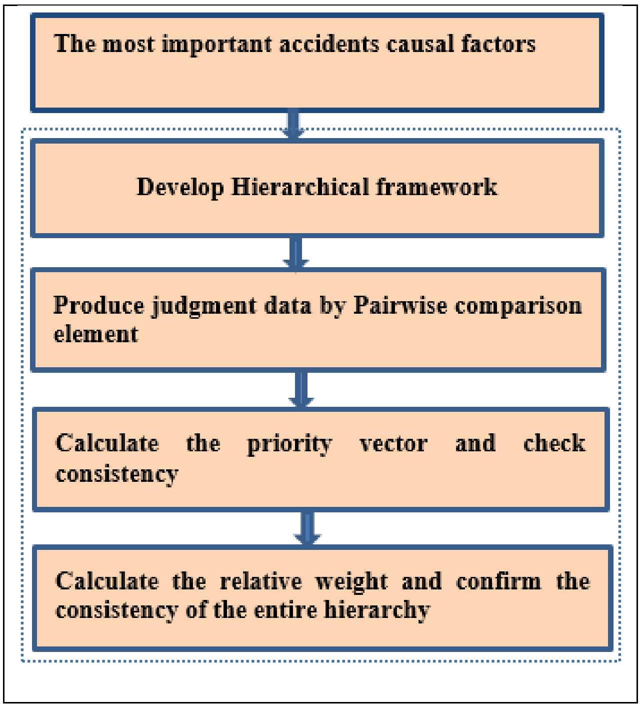


Figure 5.2 the general framework of AHP process

Generally, AHP consists of three key principles: firstly, hierarchy framework, secondly, priority analysis and finally, consistency verification. Figure 5.2 shows the AHP method in five steps: (1) determine the objective of the problem, (2) form the hierarchical structure of the problem, (3) produce judgment data by pairwise comparison (4) calculate the priorities vector and check the consistency, (5) calculate the relative weight and confirm the consistency of the entire hierarchy. The process is presented as follows.

The Analytical Hierarchy Process (AHP) method in this study is employed to evaluate the weight and rank the importance of human factors that influence pilotage operation safety performance and cause maritime accidents. In order to achieve this aim, the first step is to develop a generic hierarchical structure based on the identified risk factors. Each factor and sub-factor was obtained, based on the information collected from the literature review, analysis of marine accidents investigations reports, and experienced marine experts' perspectives. This step has been done in the last chapter (chapter 4).

Relative weights of human causal factors' independency at the same level can be obtained using pair-wise comparisons. Conducting the AHP based questionnaire survey to obtain the experts' judgement and opinions, the significance of the identified risk factors will be explored. The decision is made based on scores obtained by pairwise comparisons between the factors, in other words, the higher score, is the more important factor. The ratio scale of assessment used for the pairwise comparison between factors of each hierarchy is 1 to 9 scale (Saaty, 1994) as shown in Table 5.1.

The experts are requested to give their judgements, and before proceeding with the "Pair-wise Comparisons" technique, an expert has to understand the ratio scale measurement (Table 5.1). This table contains two parts which describe the numerical assessment together with the linguistic meaning of each number. The first part is on the left side which explains "IMPORTANT", while the right side is the second part of the table which describes "UNIMPORTANT". It's used for comparing factors with each other. The importance is rated from 1 to 9. An expert is required to give a possible judgment to all questions based on his/her expertise and experience in the maritime pilotage operations.

The decision makers should compare each element with the other by using the fundamental scale for pair-wise comparisons as shown in Table 5.1. Pair-wise comparison starts with comparison between two selected elements at the same level to get the relative importance between them. To select the most important factor, the expert will be asked to underline accordingly the rate of importance of each factor and sub-factor in the given column. For instance: only one number either on the right or the left of the scale for every comparison as shown in the example at the beginning of the questionnaire survey (see appendix III). It is important to note that the respondents have to be careful not to get logical contradiction on these questionnaires for pairwise comparison. This logical contradictions of a respondent is measured as inconsistency ratio in the AHP method.

Table 5.1: Ratio scale for pair-wise comparisons (Saaty, 1994)

Numerical Assessment	Linguistic meaning
1	Equally important
3	A little important
5	Important
7	Very important
9	Extremely important
2,4,6,8	Intermediate values of importance

Numerical Assessment	Linguistic meaning
1	Equally important
1/3	A little unimportant
1/5	Unimportant
1/7	Very unimportant
1/9	Extremely unimportant
1/2, 1/4, 1/6, 1/8	Intermediate values of unimportance

In this step, to conduct the pair-wise comparison matrix, at first, set up n criteria in the row and column of a n ×n matrix. The number of matrixes at each level depends on the number of elements at that level of hierarchy and the order of the matrixes at every level depending on the number of elements at the lower level that it connects to.

Comparison of the decision elements is organized into matrices. These matrixes consist of n columns and n rows; it is a square matrix (i.e. 'A' matrix) as shown in equation (5.1). Each element of the matrix represent the preference of the factor in row i to the factor in column j.

Where i, j = 1, 2, 3,…, n and each aij is the relative importance of attribute Ai to attribute Aj. For a matrix of order n, n (n-1)/2 comparison is necessary.

If i = j on the comparison matrix, then the value will be 1, because in this case, the related factor is compared with itself. If Ai is judged to be of equal relative importance to Aj, then aij = aji = 1. If aij = α, then aji = 1/α, α ≠ 0

$$A = a_{ij} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ {}^{a}/_{a_{12}} & 1 & \dots & \alpha_{2n} \\ . & 1 & \dots & . \\ {}^{1}/_{a1n} & {}^{1}/_{a2n} & \dots & 1 \end{bmatrix} \qquad (5.1)$$

Then, in order to determine the priorities from each pairwise matrix and to obtain the importance of each factor, the eigenvector method was used. The local weights of factors can be calculated by using the following equation;

$$W_i = \frac{1}{n} \sum_{j=1}^{n} (\frac{a_{ij}}{\sum_{i=1}^{n} \alpha ij}) \text{ , i, j, = 1, 2, 3, …, n)} \quad (5.2)$$

Where a_{ij} represents the entry of row i and column j in a comparison matrix of order n.

According to Saaty (1980), the eigenvector approach is the most proper method to determine the priorities from each pair-wise matrix. The eigenvectors for priorities can be calculated by the Average of Normalized Column (ANC) method. After the comparison matrix was completed, the process of normalisation started. According to Muhisn et al (2015) the ANC process can be done by applying three steps as follows:

1) Sum of each column in matrix

2) Each element of matrix is divided by the sum of its column

3) Normalized principle of Eigen vector and that can be done by add the element in each resulting row and then dividing this sum by the number of elements in the row (n).

1) $\sum_{j}^{n} a_{ij}$

2) $\frac{a_{ij}}{\sum_{i}^{n} a_{ij}}$

3) $\sum_{j}^{n} \frac{a_{ij}}{\sum_{i}^{n} a_{ij}}$

Since the normalised matrix is performed, to confirm the consistency of the pairwise judgement, the consistency verification is employed, which is considered as one of the most important tasks of the AHP approach. It is included to compute the consistency ratio among the pair wise comparisons (Riahi et al., 2012). In case that inconsistency ratio (CR) of pairwise comparison is zero, it means that respondents keep consistency perfectly. A good consistency is (a score <0.1). If inconsistency ratio (CR) is more than 0.10, it means lack of consistency (Saaty, 1980). A decision maker should review the pairwise judgements and is should be repeated or disregarded. The CR value is calculated according to the following equations (Saaty, 1980):

$$CR = \frac{CI}{RI} \tag{5.3}$$

$$CI = \frac{\lambda_{max} - n}{n-1}$$

$$\lambda\ max = \frac{\sum_{j=1}^{n}[(\sum_{k=1}^{n} w_k a_{jk})/wj]}{n}$$

Where CI represents the consistency index, RI is the average random index (Table 5.2), n is the matrix order and λ max is represents the maximum weight value of the n-by-n comparison matrix A.

Table 5.2: Value of RI Random Index of (AHP) Process (Saaty, 1990)

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10
Random consistency index (IR)	0	0	0.58	0.09	1.12	1.24	1.32	1.41	1.45	1.49

It is important to mention that the weights obtained are local weights at the same level. In multilevel structures, further calculations needs to be conducted to obtain the normalised weights of the bottom level factors by multiplying their local weights with the ones of their associated upper level factors.

5.4.2 The process of the DEMATEL method

In this section a novel technique is introduced to investigate the relationships among the human causal factors by using DEMATEL method. The suggested proposed method plays a significant role in providing a comprehensive illustration of influential relationships among the human factors contributing to maritime pilotage accidents. The process of the proposed method is illustrated in Figure 5.3.

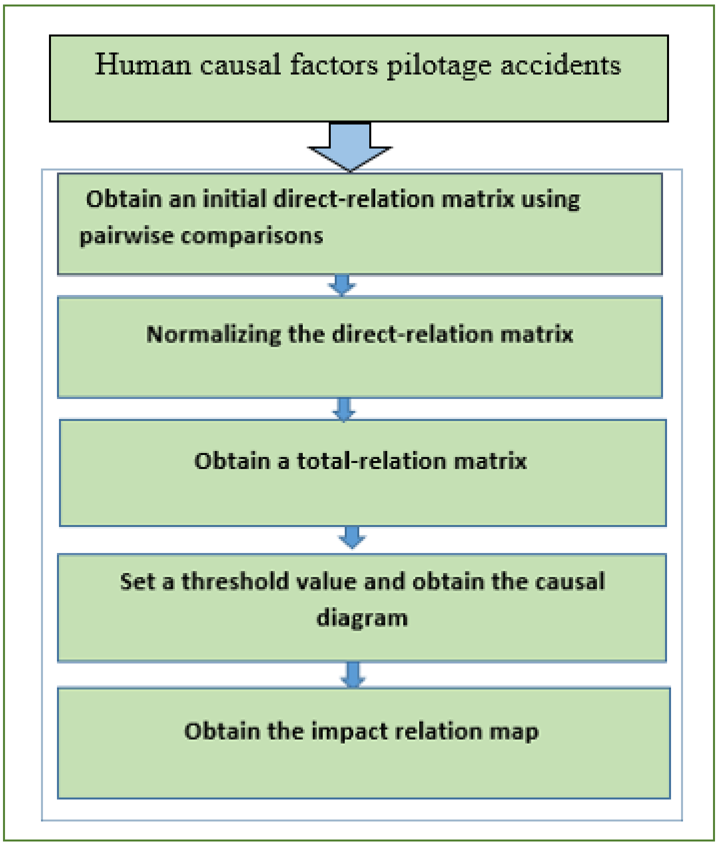


Fig. 5.3.The DEMATEL process

The DEMATEL method and the calculation steps are described below according to number of sources (Liou et al., 2007; Tzeng et al., 2007; Lin and Wu, 2008; Wu, 2008; Jeng, 2012) as follows:

Step1: Direct-relation matrix is calculated in this step. In this study it is supposed that there are "E" experts and "n" is the causal factors related to the pilotage accidents. First, to obtain a direct relation (Average) matrix; pair-wise comparison based on expert judgments in terms of the influence of the factors is carried out. Before measuring the relationship between the different accidents causal factors and proceeding with the "Pair-wise Comparisons" technique, an "E" expert has to understand the ratio scale measurement used in this study. Table 5.3 below describes the numerical assessment together with the meaning of each number. It is used for evaluating the influence level and determining the values of relationships between different factors.

Table 5.3 Evaluation scale

0	**No influence**
1	**Low influence**
2	**Medium influence**
3	**High influence**
4	**Very high influence**

A comparison scale has been designed as a pair-wise comparison scale with five levels, where scores ranging from 0 to 4 with ''no influence (0)'', or ''low influence (1)'', ''medium influence (2)'', ''high influence (3)'', and ''very high influence (4),'' respectively. The "E" experts are required to give a possible judgment and to evaluate the influence level among the factors based on his/her expertise and experience. The experts are asked to score the level of direct influence they believe each factor "i" exerts on every other factor "j", as indicated by "a_{ij}". The scores by each expert will give us "n× n" non-negative answer matrix $X^K = (X_{ij}^K)_{n\times n}$ with "$1\leq K\leq E$" ". Thus " $X^1, X^2, \ldots, X^E$, " are the answer matrices for each of the "E" experts, and each element of " X^K " is an integer denoted by "X_{ij}^K ". The diagonal elements of each answer matrix " X^K " are all set to zero.

$$A = \begin{bmatrix} 0 & a_{12} & \cdots & a_{1n} \\ a_{21} & 0 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 0 \end{bmatrix}$$

Then, as a result of these evaluations, a direct relation matrix would be created by each respondent, and then the average matrix "A" for all expert opinions can be computed by averaging "E" experts' scores as follows:

$$A = [a_{ij}]_{n\times n} = X = \frac{1}{E}\sum_{K=1}^{E}[X_{ij}^{K}]_{n\times n} \tag{5.4}$$

Step 2: Normalize the direct-relation matrix: based on the direct- relation matrix "A", the normalised direct-relation matrix "M" can be obtained using equations (5.4) and (5.5) (Wu, 2008).

$$M = A \times D \tag{5.5}$$

$$D = \frac{1}{max 1 \le i \le n \sum_{j=1}^{n} aij}, i,j = 1,2, \ldots, n$$

Step 3: Obtain a total-relation matrix T and its sum of rows and columns.

After the normalised direct-relation matrix "M" is obtained, the total relation matrix T can be acquired by using equation (5.6), in which the "I" is denoted as the identity matrix (Lin and Wu, 2008).

$$T = M(I - M)^{-1} \tag{5.6}$$

In eq. (5.7), "R_i" and "C_j" demonstrate the sums of rows and columns in the matrix T in which t_{ij} indicates the interdependent relationships value of each pair of evaluated factors. The influence of total relation matrix T is represented by R_i, $C_{j,}$ R_i+C_j and R_i-C_j. The R_i is the factor that influences others, while the $C_{j,}$ is the factor influenced by others.

The horizontal axis vector (R_i+C_j) is made by adding vector R_i to vector C_j which shows the state of the relationship among the factors, whereas the vertical axis of (R_i−C_j) is built by deducting vector R_i from vector C_j which displays the state of influence among the causal factors. The horizontal axis value pr_i^+ (R_i+ C_j) is called ''Prominence'', which exhibits the total important influence of the factor on and by others. High prominence indicates that the factor influences other factors strongly while other factors also strongly influence it, while the vertical axis value pr_i^- (R_i- C_j

) is called "Relation". Similarly, the vertical axis (R_i- C_j) separates the factors into cause and effect groups. When the value of R_i- C_j is positive, the factor belongs to the cause group, which dispatches the influence to other factors, whereas when the value of R_i- C_j is negative, the factor, belongs to the effect group, which receives the influence from the other factors. The component with the highest positive value of (R_i+ C_j) and (R_i- C_j) can be named as the master dispatcher and the component with the lowest value can be named as the master receiver.

$$R_i = \sum_{j=1}^{n} t_{ij} \ , \ C_j = \sum_{i=1}^{n} t_{ij} \qquad (\mathrm{i}, j = 1, 2, \ldots\ldots, n)$$
$$pr_i^{+} = R_i + C_i \ \ pr_i^{-} = R_i - C_i \tag{5.7}$$

Step 4: Obtain a threshold value (b) and construct a digraph:

In this step, a threshold value is obtained to construct a digraph. In order to reduce the complexity of the network relationship map (NRM), it is necessary to set a threshold value (b) in matrix T. The aim of setting a threshold value (b) is to remove some negligible effects indicated by the factors of matrix T. The threshold value can be decided by experts through discussion (Yang et al., 2013), and can also be acquired by using a mathematical equation (Özdemir et al., 2015). In this study, the threshold value was set up mathematically, by calculating the average of the value of tij, where N indicates the total number of factors (i ×j). Only the factors whose effect values of tij are greater than the threshold value can be selected and transformed into a causal relationship diagram (Tzeng et al., 2007).

$$b = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} aij}{N} \tag{5.8}$$

5.5 A CASE STUDY FOR THE WEIGHT AND RANK THE IMPORTANCE OF THE HCFs USING AHP METHOD

The objective of this study is to select the most important factors that contribute to the occurrence of maritime accidents during pilotage operations. Given the strength of the AHP method in tackling complex problems and its ability to effectively determine the relative weights of the human factors that contribute to the occurrence of maritime accidents, it (the AHP technique) has therefore been utilized in this study.

Using the analytic hierarchy process (AHP) method in this study will be beneficial to the maritime industry as an indicator to assess the human element causing human error during maritime pilotage operations, and providing a better decision-making methodology in the future. The process is presented as following subsection.

5.5.1 Develop a hierarchal structure for pilotage accidents' causal factors

The first step is to construct the problem into a hierarchy including a goal, set of criteria and sub-criteria. The hierarchy is structured on different levels from the top level, indicating the main objective in the decision-making process (the goal), the criteria in the middle, and the alternatives at the bottom. The criteria are divided into sub-criteria or sub-sub-criteria if necessary. However, as the AHP method is employed only for the risk assessment in this research, thus the decision alternatives are not carried out in the hierarchy (The alternatives are not necessary in this study). Therefore, the main factors and the sub- factors in Fig.5.4 in this study correspond to the basic AHP structure.

This structure consists of five main factors and each one is divided into sub-factors. That is, the most contributory causal human factors of maritime pilotage accidents. The main factors are the criteria, which are, (F1, F2, F3, F3, and F4). The sub-factors are sub criteria which are, F1: (F11, F12, F13, F14 and F15), F2: (F21, F22, F23, and F24), F3: (F31, F32, F33, and F34), F4: (F41, F42, F43, and F44), and F5: (F51, F52, F53, and F54). The reason behind applying this process is to enable interpretation (Ugurlu et al., 2015), and facilitate the evaluation of the factors (Pak et al., 2015).

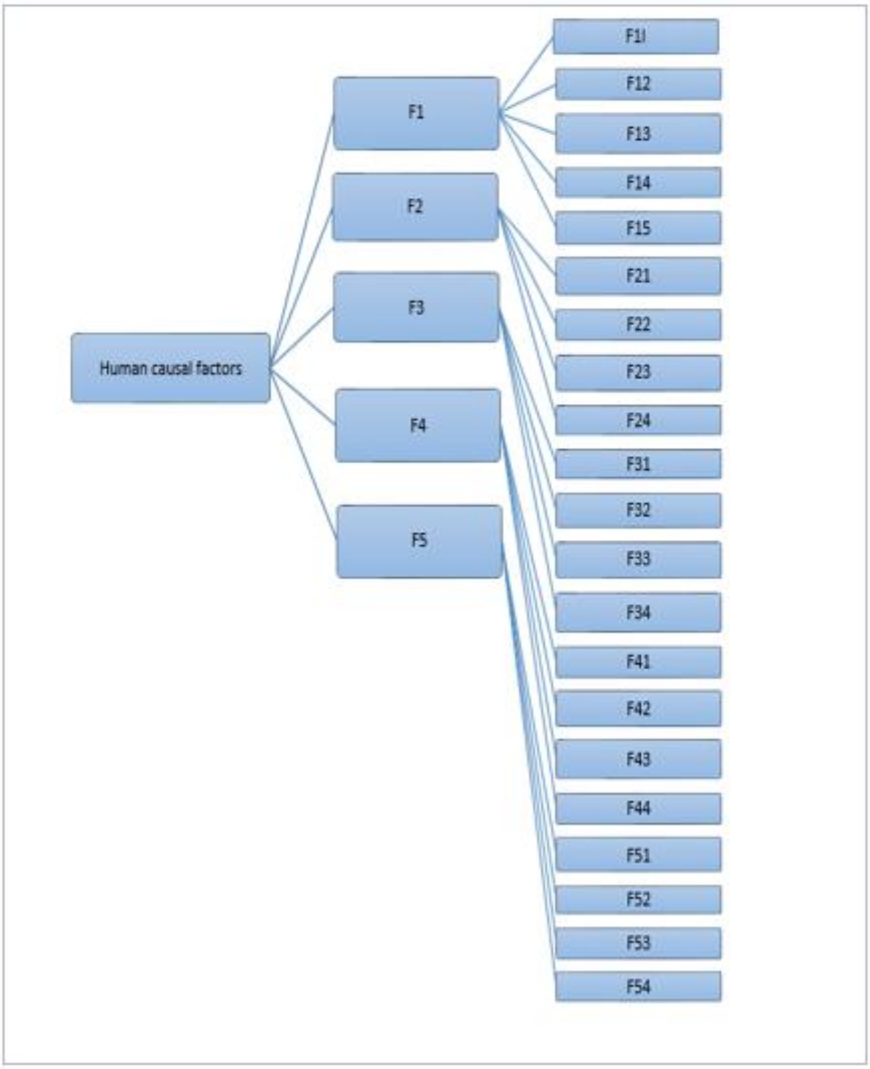


Figure 5.4 Hierarchal structure for pilotage accidents causal factors

5.5.2 Constructing a pair wise comparison and performing judgment

Once a hierarchical framework is created, to assign a weight, pairwise comparisons between the causal factors is conducted. A copy of the suggested questionnaire was sent to the supervisory team in the middle of January 2017. Based on the comments of the supervisory team, the pairwise comparisons questionnaire was adjusted. Once the questionnaire was approved, the final version was completed. AHP uses a simple Pair-wise Comparison technique to determine weights and ratings (Saaty, 2008), so that the decision-makers can focus on just two factors at the same time (Mahmoodzaden et al., 2007). In this study, as previously explained, the pair wise questionnaires were sent to the experts. The ratio scale of assessment for the pairwise comparison between factors is used, for comparing factors with each other (Saaty, 1994), as shown in Table5.2.

It was pointed out that the AHP method is a subjective methodology and a large number of experts are not required if the data collected are gathered from the experts with sufficient knowledge and experience (Saaty, 2001). The pair wise questionnaire was sent to experts belonging to various maritime sectors to contribute their judgments. In order to increase the valid response rate, the respondents were contacted in advance to determine if they would agree to participate in our survey, and each expert had to understand it before completing the pair-wise comparisons. Experts are required to give a possible judgment on all questions based on their expertise and experience.

The experts were experienced ship masters who had served long periods on-board a variety of vessels, including five senior pilots currently working in different port companies in UK and Mediterranean, one expert who is an insurance company manager, and one ship's captain with education level PhD degree from a maritime educational institution, staff all with more than 10 years working experience. Experienced professionals were selected to be the sample, as they are aware of the importance of the hazards and risk factors they are involved with, and due to their ability to compare and define which risk factors have priority over others.

All responses were collected and recorded, but while feedback of seven experts was received in this study, only five participants' results were considered as two participants' weighting data was disregarded as a result of a lack of consistency in light of the AHP formula. Once a pairwise judgement is performed, comparisons of the decision elements are organised into matrices; eigenvectors (relative value vectors) are then calculated. The weight vector of the comparison matrix provides the priority, then the consistency ratio is calculated.

5.5.3 Eigenvector (Priority) (w)

In order to determine the priorities from each pairwise matrix and to obtain the importance of each factor, the eigenvector method was used. The eigenvector (priorities) is calculated by using equation (5.2).

Table 5.4 illustrates the eigenvector (priorities) for the causal factors. For example, to calculate the priority of bridge team management failure (F1), it can be done by applying three steps as follows:

1) $\sum_{j}^{n} a_{ij}$

1+1/2+1/3+1/3+3= 5

2) $\frac{a_{ij}}{\sum_{i}^{n} a_{ij}}$

$\frac{1}{9.33}$ = 0.11

3) $\sum_{j}^{n} \frac{a_{ij}}{\sum_{i}^{n} a_{ij}}$

0.11+ 0.13 +0.09 + 0.09 + 0.20 = 0.62 and divided this sum by the number of

elements (n =

4) Thus, $\frac{0.62}{5}$ = 0.12

Each value of the matrix in the Table 5.4 is based on one expert's opinion. If several experts are involved, the geometric mean is used to find the averages of the judgments before calculating the eigenvectors. The weight value of the factor F1is found as 0.12, and the same process to calculate the weight of the other factors F2, F3, F4, and F5 were applied (see Table 5.4).

Table 5. 4. Normalised status of the five main causal factors comparison matrix and weight

Main factors	F1	F2	F3	F4	F5	(priority) (w)
F1	0.11	0.13	0.09	0.09	0.20	0.12
F2	0.21	0.26	0.27	0.28	0.20	0.25
F3	0.32	0.26	0.28	0.29	0.20	0.27
F4	0.32	0.26	0.27	0.28	0.33	0.29
F5	0.04	0.09	0.09	0.06%	0.07%	0.07
SUM	1.00	1.00	1.00	1.00	1.00	100.00%

Consistency ratio CR = 0.2

5.5.4. Perform the consistency

Since the normalised matrix is performed, to confirm the consistency of the pairwise judgement, the consistency verification is employed, which is considered as one of the most important tasks of the AHP approach according to Muhisn et al., (2015). It is included to compute the consistency ratio among the pair wise comparisons (Riahi et al., 2012). When the Consistency Ratio (CR) of pairwise comparison is zero, the respondent keeps consistency perfectly. A good consistency is (a score <0.1). If CR is more than 0.10, it means a lack of consistency (Saaty, 1980). A decision maker should review the pairwise judgements and each should be repeated or disregarded. To calculate CR, each column of the comparison matrix is multiplied to calculate the weighted aggregate matrix (AW) as follows:

$$Aw = 0.12\begin{bmatrix}1\\2\\3\\3\\1/3\end{bmatrix} + 0.25\begin{bmatrix}1\\2\\3\\3\\1/3\end{bmatrix} + 0.27\begin{bmatrix}1/3\\1\\1\\1\\1/3\end{bmatrix} + 0.29\begin{bmatrix}1/3\\1\\1\\1\\1/5\end{bmatrix} + 0.07\begin{bmatrix}3\\3\\3\\5\\1\end{bmatrix}$$

Then, each element of the weighted Aw is divided by the priority vector element to calculate the Aw/w value. The CR value is calculated by using equations (5.3).

$\lambda = \frac{(5.1+5.1+5.2+5.2+5.0)}{5} = \frac{25.6}{5}$ Lambda Max λ = 5.12

$C1 = \frac{5.12-5}{5-1} = 0.03$

$CR = \frac{0.03}{1.12} = 0.02$

Where CI represent the consistency index, RI is the average Random Index (Table 5.2), n is the matrix order and λmax is represent the maximum weight value of the n-by-n comparison matrix A.

Determining the suitable value of (RI) from the table of random index of AHP as shown in Table 5.2, for the matrix size of five, the random index will be RI = 1,12, after that calculate Consistency Ratio (CR). For instance, the calculation to consistency test for the main CR = 0.02. As the value of CR is less than 0.1, the judgements are acceptable.

In this study to evaluate the weight of the five main causal factors and the twenty-one sub-factors presented in the hierarchical structure, a comparison matrix was created. Each value of the matrix in the tables is the geometric mean of five expert judgements. The geometric mean is used to find the averages of the judgments before calculating the eigenvectors, in this study, exile software was used to calculate the priority (eigenvector) and consistency CR. Table 5.6- Table 5.11 represents the priority weight of all pilotage accidents human causal factors. Consequently, the relative importance among the five main causal factors categories and the twenty-one sub-factors are shown in Fig. 5.5, and Fig. 5.6. The software calculated the eigenvector of priorities and the C.R

It is important to mention that the weights obtained are local weights at the same level, it is necessary to obtain global weight for each of the sub-factors, which have an effect on the main goal and form the basis for further analysis, this has been conducted by multiplying the local weights of sub-factors by main factors weight value, which is the ones of their associated upper level factors. For example, the weight of sub-factor F21 (lack of ship handling skills) can be obtained by multiplying main F2 by F21 (= 0.30 ×0.39 = 0.117).

5.5.5 Results and discussion

Table 5.5: Weight and consistency ratio of the 5 main causal factor

Main factors	F1	F2	F3	F4	F5	Weight (w)
F1	0.34	0.33	0.38	0.35	0.29	33.84%
F2	0.31	0.31	0.32	0.31	0.27	30.48%
F3	0.10	0.11	0.11	0.19	0.13	12.72%
F4	0.08	0.09	0.05	0.09	0.18	9.71%
F5	0.17	0.16	0.13	0.07	0.14	13.25%
SUM	1.00	1.00	1.00	1.00	1.00	100.00%

Consistency Ratio (CR) = 0.04

Table 5.6. Weight and consistency ratio of sub-factors (F1)

Sub-factors (F1)	F11	F12	F13	F14	F15	Weight (w)
F11	0.21	0.28	0.23	0.15	0.19	21.32%
F12	0.19	0.25	0.27	0.30	0.26	25.38%
F13	0.23	0.24	0.25	0.30	0.23	24.87%
F14	0.27	0.16	0.16	0.19	0.24	20.40%
F15	0.09	0.08	0.09	0.06	0.08	08.03%
SUM	1.00	1.00	1.00	1.00	1.00	100.00%

Consistency Ratio (CR) = 0.01

Table 5.7. Weight and consistency ratio of sub-factors (F2)

Sub-actor (F2)	F21	F22	F23	F24	Weight (w)
F21	0.39	0.46	0.39	0.33	39.20%
F22	0.20	0.23	0.25	0.28	24.04%
F23	0.19	0.17	0.19	0.21	18.93%
F24	0.22	0.15	0.17	0.18	17.83%
SUM	1.00	1.00	1.00	1.00	100.00%

Consistency Ratio (CR) = 0.01

Table 5.8. Weight and consistency ratio of sub-factors (F3)

Sub-factor (F3)	F31	F32	F33	F34	Weight (W)
F31	0.38	0.43	0.41	0.27	37.13%
F32	0.21	0.24	0.29	0.24	24.68%
F33	0.18	0.16	0.20	0.33	21.90%
F34	0.23	0.16	0.10	0.16	16.10%
SUM	1.00	1.00	1.00	1.00	100.00%

Consistency Ratio (CR) = 0.04

Table 5.9. Weight and consistency ratio of sub-factors (F4)

Sub-factor (F4)	F41	F42	F43	F44	Weight (W)
F41	0.36	0.42	0.37	0.23	34.58%
F42	0.22	0.26	0.29	0.33	27.26%
F43	0.24	0.22	0.25	0.32	25.61%
F44	0.19	0.10	0.09	0.12	12.55%
SUM	1.00	1.00	1.00	1.00	100.00%

Consistency Ratio (CR) = 0.03

Table 5.10. Weight and consistency ratio of sub-factors (F5)

Sub-factor (F5)	F51	F52	F53	F54	Weight (W)
F51	0.51	0.60	0.45	0.41	49.35%
F52	0.16	0.19	0.30	0.22	21.94%
F53	0.20	0.11	0.17	0.26	18.50%
F54	0.13	0.09	0.07	0.11	10.21%
SUM	1.00	1.00	1.00	1.00	100.00%

Consistency Ratio (CR) = 0.04

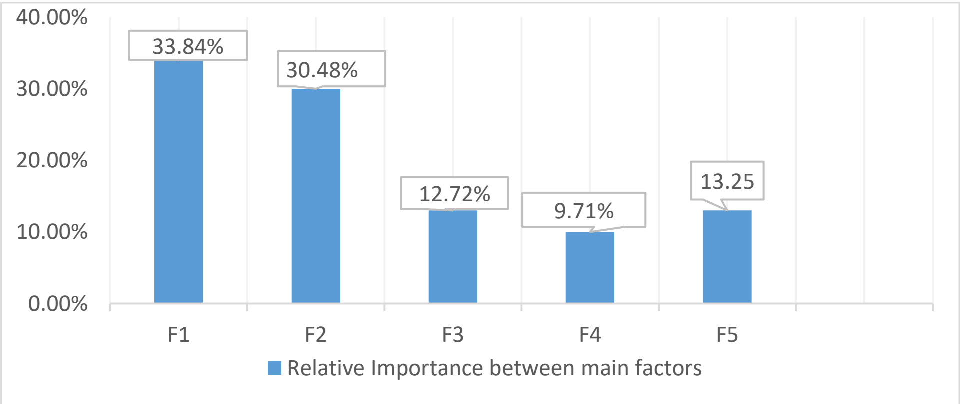


Figure 5.5 Relative weights of 5 main group of (HCFs)

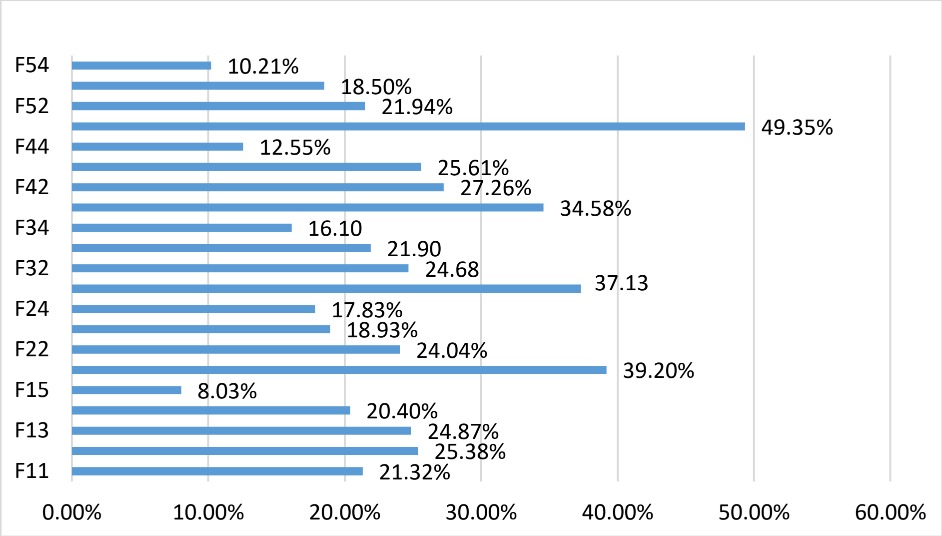


Figure 5.6 Relative Importance among the 21 sub-factors (HCFs)

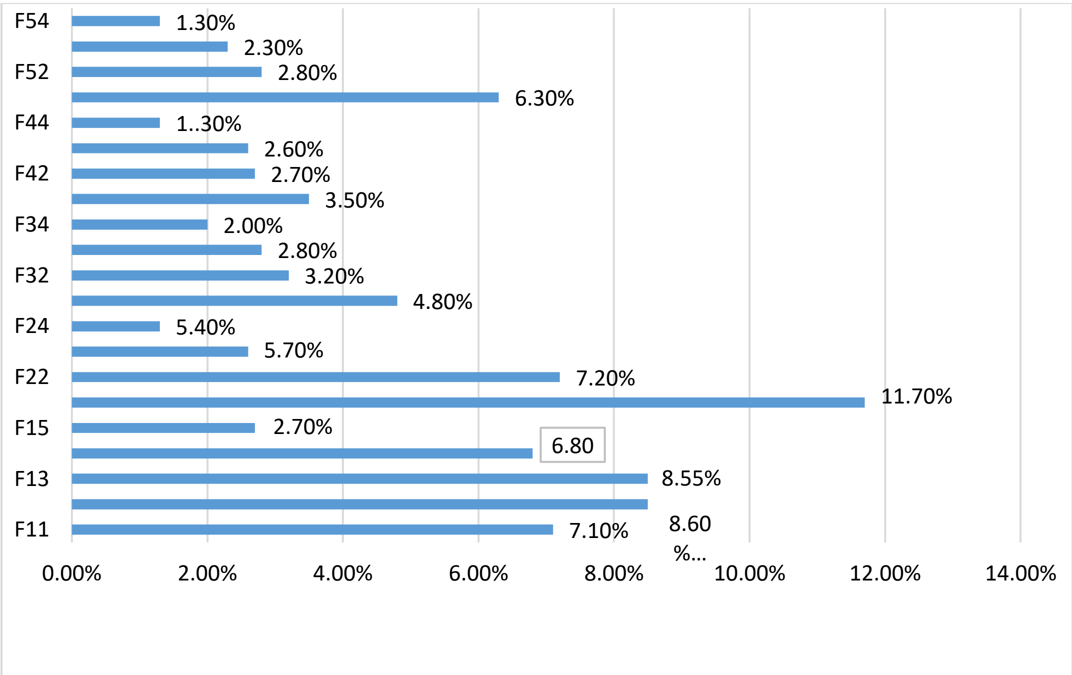


Figure 5.7 Global weight of the 21 factors contributing to pilotage accidents

The results in Table 5.5 show the relative weights among the five main groups of the causal factors of pilotage accidents. The data revealed that the most significant causes of human error-related pilotage accidents can be ranked as follows: F1 (bridge team management failure), F2 (technical skills shortcoming), F3 (instructions and orders failure), F4 (rules and regulations noncompliance), and F5 Individual- task interaction factors. The top three factors are F1, F2, and F5 with total weight rate 33.84%, 30.48%, 13.25%, respectively.

In Table 5.6, it can be seen that the sub-factor F12 (language barriers and lack of effective communication) was ranked as the most important contributing causal factor among the F1 sub-factors, 25.38%, whereas the sub-factor F13 (failure to exchange the information between pilot and ship's master) was ranked as the second most causal factor with total weight rate 24.87%. The sub-factor F11 (lack of team work) was the third most critical contributing causal factor which has the third highest priority weight among the F1 sub-factors while F14 (lack of situation awareness in the bridge team), was in fourth place. It can be seen that there is no big difference between the weight value of sub factors F11 and F14, as they are nearly the same, while F11 is 21.32%, F14 is 20.40%. However, the sub-factor F15 (The master's and pilot's ineffective monitoring of the external parties and vessel's progress) was ranked as the least important one at 8.03%.

The results in Table 5.7 show that the sub-factor F21 (lack of ship handling skills) is the most significant causal factor for pilotage accidents since it has the highest priority weight among the F2 sub-factors with a total weight rate of 39.20%. It is followed by the sub-factor F22 (lack of familiarity with the navigational systems) which was ranked as the second most important causal factor at 24.04%, and the sub- factor F23 (lack of skills of crewmembers on-board ship, tugs and mooring boats masters, and shore mooring personnel) is ranked in the third place at 18.93%, and F24 (improper/ inadequate use of tugs) is ranked in the fourth place at 17.83%.

Table 5.8 shows that the priority weights of the causal factor F31 (failure of pilot to give precise instructions) is the highest among the F3 sub-factors at 37.13%, followed by the causal factor F32 (failure of the ship's master to correctly follow the pilot directions) at 24.68%, which ranked as the second largest cause of piloting accidents. The causal factor F33 (failure of tug masters to carry out the pilot's instructions precisely) was ranked as the third most important cause with a total weight rate of 21.90% F34 (failure of ship's crewmembers to follow orders regarding anchoring, steering, and engine requests correctly) was ranked in fourth place at 16.10%.

Table 5.9 shows that the sub-factor F41 (failure to establish a proper manoeuvring plan prior to piloting vessel) is the most significant causal factor among the F4 sub-factors for pilotage accidents since it has the highest priority weight of 34.58%. The sub-factor F42 (failure to proceed with safe speed as stipulated in COLREG) was ranked as the second most important causal factor among the F4 sub-factors, with total weight rate of 27.26%. The sub-factor F43 (piloting ships in bad weather conditions and navigating vessels outside published guidelines or draft limits) was ranked in third place with a total weight rate 25.61%. F44 (pilot boarding and disembarking too close to breakwater) was ranked in fourth place at 12.55%.

Table 5.10 shows the priority weights of the F5 sub-factors. The data reveals that the most important contributory causal factors of pilotage accidents among the F5 sub-factors, can be ranked as follows: F51 (fatigue), F52 (mental and physical work load), F53 (distraction during the time of berthing operations), and F54 (stress). The top three factors are F51, F52, and F53 have total weight rate 49.35%, 21.94%, 18.50%, respectively. There is a general consensus among all the pilots and captains interviewed that these factors play a significant role in pilotage accidents (see chapter 4).

Derived from the results of AHP, lack of ship handling skills (F21) is the most important causal factor among the entire hierarchy, which has a relative importance value of 0.117, followed by language barriers and lack of effective communication (F12, 0.085), failure to exchange information between pilot and ship's master (F13, 0,085), lack of familiarity with the navigational systems (F22, 0.072), lack of team work (F11, 0. 071), lack of situation awareness in the bridge team (F14, 0.068), fatigue (F51, 0.063), lack of skills of crewmembers on-board ship, tugs and mooring boats masters, and shore mooring personnel (F23, 0.057), Improper/ inadequate use of tugs (F24, 0.054), and failure of pilot to give precise instructions (F31, 0.048) as illustrated the top 10 highest scores in a bar graph 5.7.

The results of this study corroborate the findings of the Marine Accident Investigation Branch of the UK (MAIB) (2015), who investigated the accidents that occurred in UK territorial waters during the period 2005 to 2013 in which a pilot was on board. The major cause of the accidents which occurred was the human factor, and in the majority of cases reviewed they were due to one or more of the following: the pilot-master information exchange failure, poor bridge team-pilot integration, lack of communication, lack of planning, lack of ship handling skills, and pilot distracted/ overloaded (MAIB, 2015). The results also support some existing findings, e.g., findings from Darbra et al., (2007), and Chauvin et al., (2013), who investigated the risks contributing to maritime accidents during pilotage operations.

This finding is also in line with some results of research conducted by the Transportation Safety Board of Canada (TSB) (1995) who found that the inadequate interpersonal communications among the bridge team, lack of adequate information exchange, incomplete understanding of the intended manoeuvre, and loss of situational awareness were the most important factors. Based on these results, it can be easy to nominate the most significant risks that have great impact on the safety of the pilotage operations. The higher the value of human causal factors is, the higher the risk of pilotage safety performance. Therefore, an effective measure should be applied to reduce or mitigate their risks and effects.

5.6. A CASE STUDY FOR IDENTIFYING THE RELATIONSHIP AMONG THE (HCFs) USING DEMATEL METHOD

In the previous section, the importance of the human causal factors related to pilotage accidents has been outlined in detail. In this section a novel technique is applied to investigate the relationships among the human causal factors by using DEMATEL method. The suggested innovative method plays a significant role in providing a comprehensive illustration of influential relationships among the human factors contributing to maritime pilotage accidents.

As has been described previously, maritime accidents are often reported as being multi-causal in nature, as highlighted by the so-called 'Swiss Cheese’ (Hollnagel, 2006, p. 12). Previous accident investigation reports revealed that the maritime accidents occurring in the pilotage area are not usually caused by a single failure or mistake, but by the confluence of a chain or series of errors. It is recognised that multiple human factors may be present at any one time and these factors have an influence on each other. The occurrence of one risk gives rise to multiple risks resulting in a cumulative effect. Therefore, it very important for decision-makers to determine and control these risks before they occur.

Previous studies, which have been conducted by considerable numbers of researchers and international maritime authorities to evaluate human error have assumed that the accidents causal factors are independent, however Accident investigation reports revealed that the cause of maritime accidents occurring in the pilotage area are usually dependent on each other. Therefore, using a traditional assessment method which fails to identify the influencing relationship between accidents' causal factors, to discover how the human factor can impact the others may introduce some level of uncertainty and could lead analysts to risk either underestimating factors that can have high influence on the others or overestimating factors that do not have much effect. In addition, the decision-makers would have difficulties in determining appropriate factors affecting pilotage operations performance that needs to be improved. Thus, in this study, to overcome this imperfection, and address these issues successfully, an MCDM method, the Decision-Making Trial and Evaluation (DEMATEL) method is utilised.

The DEMATEL method has been used in this study because of its capability of assessing the influence of each human factor on the others, and determining whether a factor belongs to a cause or an effect group. Cause and effect are two different concepts. Causes tell the reason why something happened, whereas effects are the results of that happening (Lin and Wu, 2008). Detailed knowledge of the, intertwined effects , and the interrelation between the risks related to the human factors, can be very effective in identifying the most influential human factor that contributes to the occurrence of maritime accidents, and plays a significant role in providing reliable, accurate information, and an optimal solution for decision- makers to determine which causal factors need to be improved to reduce the human errors during maritime pilotage operations, and prevent a similar incident/accident from occurring in the future.

An original aspect of the proposed approach using a DEMATEL technique is that the approach has carried out practical work that has not been done before. Additionally, the proposed approach has looked into the relationships among the risk factors that researchers in the discipline have not looked at before. This method provides more accurate and reliable results, and provide more realistic solutions. In addition, the method represent an effective performance measurement tool and offer a diagnostic instrument to ports to satisfy the port stakeholders in a flexible manner.

5.6.1. The steps of the DEMATEL technique

Step 1. Prior to employing the DEMATEL method, it is important to define the risk factors. This shall then be used as a pre-step into the DEMATEL. As has been discussed previously, a structural model was created; the list of human causal factors (HCFs) contributing to maritime accidents in pilotage operations which were required for evaluating are determined based on a literature review, accident investigations reports, and the marine experts' perspectives in previous chapters (chapter 4). This is illustrated in Table 4.6. For further information, please refer to chapter 4. (Identification and classification process).

Step 2. Carry out pairwise comparison and create the direct initial direct-relation matrix

Following the same procedure of developing the pairwise comparison questionnaire above, the questionnaire for pairwise comparison was constructed. The objective of this questionnaire is to evaluate the relationships among the contributing human factors of the pilotage accidents, to obtain a direct relation matrix. It has been concluded by Yang et al. (2016) that a small sample size can be used for analysis and five to seven experts are ideally needed in the research on group decision-making problems. Furthermore, Saaty (2001) points out that a huge sample size is not required if the data collected are gathered from the experts. This is due to that fact that the Multi-Criteria Decision Making (MCDM) method is a subjective methodology, and professionals should share consistent beliefs and thus, it diminishes the necessity for a large number sample size.

As a result, this sample size was considered acceptable for this study, and to provide a rating and to score the relationship among HCFs, five marine experts from the same panel group of experienced specialists involved in the previous survey (Chapter 4 and section 5.5.3) were chosen and participated in the judgements to provide a rating and score the relationship among factors based on the DEMATEL method. Experienced professionals were selected to be the sample, as they are aware of the importance of hazards and risk factors they are involved with, and due to their ability to compare and define which risk factors have the higher impact on the others. The experts were professional ship masters who had served long periods on-board a variety of vessels, including four senior pilots currently working in different port companies in the UK and the Mediterranean, and one who is an insurance company manager in the UK, all with more than 10 years working experience. The five decision makers gave their opinions on a 0 to 4 scale.

The initial direct-relation 21×21$matrix$ A is obtained by using eq. (5.4). Table 5.11 illustrates the results of the expert judgments pairwise comparison in terms of the influence among the 21 HCFs.

Table 5.11 the initial direct-relation $matrix$ “A” (21 x 21HCFs)

Factors	F11	F12	F13	F14	F15	F21	F22	F23	F24	F31	F32	F33	F34	F41	F42	F43	F44	F51	F52	F53	F54
F11	0	1.6	2.2	3.4	2.6	0.4	0.4	0.2	0.8	2	3	1	2.4	3	2.4	2.8	3.2	2.2	2.8	2.8	3.4
F12	15	0	3.6	3.6	3.4	0.8	2.2	1.8	2.4	3.4	3.4	3.2	3.6	2.8	1.8	2,4	1.2	0.4	2.2	2	2.6
F13	2.8	1	0	3.4	1.8	0.4	o.6	1	2.6	3	2.6	1	2.4	3.2	1.8	3.2	2.4	0.6	1.8	1.6	2.6
F14	3.2	1.2	2.6	0	3.2	0.6	0.8	0.2	2.6	2.6	2.8	2.2	2.6	2	3	3.4	2.4	0.4	1	1.2	2.4
F15	2.8	0.2	1.2	2.8	0	0.4	0.2	0.2	3.2	3.4	2.8	3	0.4	0.6	2.6	3.2	1	0.6	2.2	2.6	2.6
F21	2.2	0.8	2.6	3..2	3	0	1.8	0.2	3.4	3.4	3.8	2.6	2.4	3.2	3.4	3	2.4	1.2	1.2	1.6	2.4
F22	2.8	0.6	2.4	3.4	2.2	0.4	0	0.8	2.4	3.2	3.2	1.2	1.8	3.2	2.4	3.2	1.8	0.4	2.4	2.4	1
F23	0.8	1.8	2.6	2.8	1	1	0.6	0	3	2	1.2	3.4	3.2	2.8	2.6	2.8	2.6	0.8	1.6	2	2.8
F24	0.2	0	0.4	1.6	2.4	1.4	0.2	0.4	0	2.8	1.6	3.8	0.2	1.8	2.6	2.6	1.4	1.4	2	2.2	2.8
F31	2.4	0.8	1.8	2.8	1.4	0	0	0	3.2	0	3.8	3.6	3	3	3	2.6	2.8	0.6	2.2	3.2	2.4
F32	2.8	0.6	0.6	2.8	2.4	0.6	0.2	0.2	2.4	2.2	0	1	2.8	2.6	3.2	3.2	3	0.4	1.4	2.8	3.2
F33	1	0.8	0	1.2	1.8	0.4	0	0	3.4	2	0.6	0	0.2	0	1.4	2.8	0.2	0.8	2.4	2.6	3.4
F34	2.6	0.6	0.6	1.4	0.6	0	0.2	0.2	2	1	3.4	1	0	1.6	3.2	3.2	2	0.2	1.8	2.2	2.8
F41	2.8	1	2.8	2.8	3	0.6	0.2	0.4	2.8	2.8	3	3.2	3	0	3.4	3.6	2.2	1	2.4	3	2.8
F42	1	0.6	0.2	3	3	0.2	0	0.2	3.6	2.6	2.6	3.6	0.4	1.8	0	3	3.2	0.8	1.6	1.8	2.4
F43	1.6	1	0.4	3.4	3.2	0.8	2.6	0.2	3	3	2.2	2.8	1.2	1.8	3.2	0	3.2	2.4	2.6	2.8	3.4
F44	1.2	0.8	3	2	2.4	0	0	0.2	0.8	2.4	2.6	2.6	0.6	3	2	1	0	1	2.8	2.6	3.4
F51	3.8	3	3.4	3.6	3.4	3.2	3.4	3	2.4	3.2	3.2	3.2	3	3.2	2.4	3	2.2	0	3.8	3.8	3.8
F52	3.2	1	3	3.6	3	2.8	2.8	2.6	3.4	3.2	3.2	3.4	2.8	3	2.6	2.6	2.2	3.8	0	3.6	3.6
F53	3.4	2.4	3.2	3.8	3.4	1	0.4	1.2	3	3	3.4	3.2	2.2	2.4	2.8	2.8	2.4	1.6	3.2	0	2.8
F54	3.4	3.2	3.2	3.6	3.6	2.2	1.8	1.8	3	3.4	3.2	3.2	2	3	2.6	3.4	1.6	3.4	3.6	3.6	0

Step 3. Construct a normalised direct relation matrix.

A normalized direct-relation matrix “M” is obtained by using Equations (5.5). The maximum value of the sums of each row and column of the average matrix A, is calculated and determined as 58.2, which can be used to obtain the normalised direct-relation matrix M as presented in Table 5.12. Due to long and large calculation for a 21x21 matrix, the Excel software has been used.

An example of calculation to obtain normalised value of F11 to F15 by row is illustrated as follows:

M=A×D D= $\frac{1}{58.2}$ ⟶ F11 to F15 normalised value $= 2.60 \times \frac{1}{58.2} =$ 0.0447

Table 5.12. A normalized direct-relation matrix “M” (21 HCFs)

Factors	F11	F12	F13	F14	F15	F21	F22	F23	F24	F31	F32	F33	F34	F41	F42	F43	F44	F51	F52	F53	F54
F11	0	0.0275	0.0378	0.0584192	0.0447	0.0069	0.0069	0.0034364	0.0137	0.0343643	0.0515	0.0172	0.0412	0.0515464	0.0412	0.04811	0.055	0.0378	0.0481	0.0481	0.0584
F12	0.0515464	0	0.0619	0.0618557	0.0584	0.0137	0.0378	0.0309278	0.0412	0.0584192	0.0584	0.055	0.0619	0.04811	0.0309	0.041237	0.0206	0.0069	0.0378	0.0344	0.0447
F13	0.04811	0.0172	0	0.0584192	0.0309	0.0069	0.0103	0.0171821	0.0447	0.0515464	0.0447	0.0172	0.0412	0.0549828	0.0309	0.054983	0.0412	0.0103	0.0309	0.0275	0.0447
F14	0.0549828	0.0206	0.0447	0	0.055	0.0103	0.0137	0.0034364	0.0447	0.0446735	0.0481	0.0378	0.0447	0.0343643	0.0515	0.058419	0.0412	0.0069	0.0172	0.0206	0.0412
F15	0.04811	0.0034	0.0206	0.04811	0	0.0069	0.0034	0.0034364	0.055	0.0584192	0.0481	0.0515	0.0069	0.0103093	0.0447	0.054983	0.0172	0.0103	0.0378	0.0447	0.0447
F21	0.0378007	0.0137	0.0447	0.0549828	0.0515	0	0.0309	0.0034364	0.0584	0.0584192	0.0653	0.0447	0.0412	0.0549828	0.0584	0.051546	0.0412	0.0206	0.0206	0.0275	0.0412
F22	0.04811	0.0103	0.0412	0.0584192	0.0378	0.0069	0	0.0137457	0.0412	0.0549828	0.055	0.0206	0.0309	0.0549828	0.0412	0.054983	0.0309	0.0069	0.0412	0.0412	0.0172
F23	0.0137457	0.0309	0.0447	0.04811	0.0172	0.0172	0.0103	0	0.0515	0.0343643	0.0206	0.0584	0.055	0.04811	0.0447	0.04811	0.0447	0.0137	0.0275	0.0344	0.0481
F24	0.0034364	0	0.0069	0.0274914	0.0412	0.0241	0.0034	0.0068729	0	0.04811	0.0275	0.0653	0.0034	0.0309278	0.0447	0.044674	0.0241	0.0241	0.0344	0.0378	0.0481
F31	0.0412371	0.0137	0.0309	0.04811	0.0241	0	0	0	0.055	0	0.0653	0.0619	0.0515	0.0515464	0.0515	0.044674	0.0481	0.0103	0.0378	0.055	0.0412
F32	0.04811	0.0103	0.0103	0.04811	0.0412	0.0103	0.0034	0.0034364	0.0412	0.0378007	0	0.0172	0.0481	0.0446735	0.055	0.054983	0.0515	0.0069	0.0241	0.0481	0.055
F33	0.0171821	0.0137	0	0.0206186	0.0309	0.0069	0	0	0.0584	0.0343643	0.0103	0	0.0034	0	0.0241	0.04811	0.0034	0.0137	0.0412	0.0447	0.0584
F34	0.0446735	0.0103	0.0103	0.024055	0.0103	0	0.0034	0.0034364	0.0344	0.0171821	0.0584	0.0172	0	0.0274914	0.055	0.054983	0.0344	0.0034	0.0309	0.0378	0.0481
F41	0.04811	0.0172	0.0481	0.04811	0.0515	0.0103	0.0034	0.0068729	0.0481	0.04811	0.0515	0.055	0.0515	0	0.0584	0.061856	0.0378	0.0172	0.0412	0.0515	0.0481
F42	0.0171821	0.0103	0.0034	0.0515464	0.0515	0.0034	0	0.0034364	0.0619	0.0446735	0.0447	0.0619	0.0069	0.0309278	0	0.051546	0.055	0.0137	0.0275	0.0309	0.0412
F43	0.0274914	0.0172	0.0069	0.0584192	0.055	0.0137	0.0447	0.0034364	0.0515	0.0515464	0.0378	0.0481	0.0206	0.0309278	0.055	0	0.055	0.0412	0.0447	0.0481	0.0584
F44	0.0206186	0.0137	0.0515	0.0343643	0.0412	0	0	0.0034364	0.0137	0.0412371	0.0447	0.0447	0.0103	0.0515464	0.0344	0.017182	0	0.0172	0.0481	0.0447	0.0584
F51	0.0652921	0.0515	0.0584	0.0618557	0.0584	0.055	0.0584	0.0515464	0.0412	0.0549828	0.055	0.055	0.0515	0.0549828	0.0412	0.051546	0.0378	0	0.0653	0.0653	0.0653
F52	0.0549828	0.0172	0.0515	0.0618557	0.0515	0.0481	0.0481	0.0446735	0.0584	0.0549828	0.055	0.0584	0.0481	0.0515464	0.0447	0.044674	0.0378	0.0653	0	0.0619	0.0619
F53	0.0584192	0.0412	0.055	0.0652921	0.0584	0.0172	0.0069	0.0206186	0.0515	0.0515464	0.0584	0.055	0.0378	0.0412371	0.0481	0.04811	0.0412	0.0275	0.055	0	0.0481
F54	0.0584192	0.055	0.055	0.0618557	0.0619	0.0378	0.0309	0.0309278	0.0515	0.0584192	0.055	0.055	0.0344	0.0515464	0.0447	0.058419	0.0275	0.0584	0.0619	0.0619	0

Step 4. Obtain a total-relation matrix *T* and calculate its sum of rows and columns.

After the normalised direct-relation matrix “M” is obtained, the total relation matrix T can be acquired by using Equation (5.6), in which the “*I*” is denoted as the identity matrix (Lin and Wu, 2008). The *“I”* is shown in Table 5.13.

At first, to obtain (I - M) matrix, the normalised direct relation matrix M, is subtracted from an identity matrix *I*.

An example of the calculation to obtain value of F11 to F15 by row in the (I - M) matrix is shown as follows: F11to F15 (I - M) matrix value = (0 - 0.0447) = -0.0447, the (I - M) matrix is presented in Table 5.14.

This is followed by inversing the obtained matrix (I - M). For inversing a 21x21 matrix, it would be too long and involves a large calculation; therefore, Excel software has been applied. The inverse matrix of the ($I - M)^{-1}$ matrix is illustrated in Table 5.15. Lastly, the normalised direct relation matrix M is multiplied by the inversed matrix $(I - M)^{-1}$.

To obtain the total relation matrix, T. An element in the T matrix can be obtained by computing the product of multiplication of each row in the M matrix with the corresponding column in the $(I - M)^{-1}$ matrix. The total relation matrix T is illustrated in Table 5.16.

Step 5. Set the threshold value and Build a cause and effect relationship diagram

A threshold value (0.128) is calculated using Eq. (5.8), and the R_i, C_j, ($R_i + C_j$) and ($R_i - C_j$) values of the (HCFs) are obtained (Table 5.17). Based on Table 5.16 and 5.17, a causal diagram is constructed.

Table 5.13 the I Matrix of the 21 HCFs

Factors	F11	F12	F13	F14	F15	F21	F22	F23	F24	F31	F32	F33	F34	F41	F42	F43	F44	F51	F52	F53	F54
F11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F12	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F14	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F15	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F21	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F22	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F23	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
F24	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
F31	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
F32	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
F33	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F34	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
F41	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
F42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
F43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
F44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
F51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
F52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
F53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
F54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 5.14 the (I - M) Matrix of the 21 HCFs

Factors	F11	F12	F13	F14	F15	F21	F22	F23	F24	F31	F32	F33	F34	F41	F42	F43	F44	F51	F52	F53	F54
F11	1	-0.0250	-0.0344	-0.0531	-0.0406	-0.0063	-0.0063	-0.0031	-0.0125	-0.0313	-0.0469	-0.0156	-0.0375	-0.0469	-0.0375	-0.0438	-0.0500	-0.0344	-0.0438	-0.0438	-0.0531
F12	-0.0469	1	-0.0563	-0.0563	-0.0531	-0.0125	-0.0344	-0.0281	-0.0375	-0.0531	-0.0531	-0.0500	-0.0563	-0.0438	-0.0281	-0.0375	-0.0188	-0.0063	-0.0344	-0.0313	-0.0406
F13	-0.0438	-0.0156	1	-0.0531	-0.0281	-0.0063	-0.0094	-0.0156	-0.0406	-0.0469	-0.0406	-0.0156	-0.0375	-0.0500	-0.0281	-0.0500	-0.0375	-0.0094	-0.0281	-0.0250	-0.0406
F14	-0.05	-0.0188	-0.0406	1	-0.05	-0.0094	-0.0125	-0.0031	-0.0406	-0.0406	-0.0438	-0.0344	-0.0406	-0.0313	-0.0469	-0.0531	-0.0375	-0.0063	-0.0156	-0.0188	-0.0375
F15	-0.0438	-0.0031	-0.0188	-0.0438	1	-0.0063	-0.0031	-0.0031	-0.0500	-0.0531	-0.0438	-0.0469	-0.0063	-0.0094	-0.0406	-0.0500	-0.0156	-0.0094	-0.0344	-0.0406	-0.0406
F21	-0.0344	-0.0125	-0.0406	-0.0500	-0.0469	1	-0.0281	-0.0031	-0.0531	-0.0531	-0.0594	-0.0406	-0.0375	-0.0500	-0.0531	-0.0469	-0.0375	-0.0188	-0.0188	-0.0250	-0.0375
F22	-0.0438	-0.0094	-0.0375	-0.0531	-0.0344	-0.0063	1	-0.0125	-0.0375	-0.05	-0.05	-0.0188	-0.0281	-0.0500	-0.0375	-0.0500	-0.0281	-0.0063	-0.0375	-0.0375	-0.0156
F23	-0.0125	-0.0281	-0.0406	-0.0438	-0.0156	-0.0156	-0.0094	1	-0.0469	-0.0313	-0.0188	-0.0531	-0.0500	-0.0438	-0.0406	-0.0438	-0.0406	-0.0125	-0.0250	-0.0313	-0.0438
F24	-0.0031	0	-0.0063	-0.0250	-0.0375	-0.0219	-0.0031	-0.0063	1	-0.0438	-0.0250	-0.0594	-0.0031	-0.0281	-0.0406	-0.0406	-0.0219	-0.0219	-0.0313	-0.0344	-0.0438
F31	-0.0375	-0.0125	-0.0281	-0.0438	-0.0219	0	0	0	-0.05	1	-0.0594	-0.0563	-0.0469	-0.0469	-0.0469	-0.0406	-0.0438	-0.0094	-0.0344	-0.0500	-0.0375
F32	-0.0438	-0.0094	-0.0094	-0.0438	-0.0375	-0.0094	-0.0031	-0.0031	-0.0375	-0.0344	1	-0.0156	-0.0438	-0.0406	-0.0500	-0.0500	-0.0469	-0.0063	-0.0219	-0.0438	-0.0500
F33	-0.0156	-0.0125	0	-0.0188	-0.0281	-0.0063	0	0	-0.0531	-0.0313	-0.0094	1	-0.0031	0	-0.0219	-0.0438	-0.0031	-0.0125	-0.0375	-0.0406	-0.0531
F34	-0.0406	-0.0094	-0.0094	-0.0219	-0.0094	0	-0.0031	-0.0031	-0.0313	-0.0156	-0.0531	-0.0156	1	-0.025	-0.0500	-0.0500	-0.0313	-0.0031	-0.0281	-0.0344	-0.0438
F41	-0.0438	-0.0156	-0.0438	-0.0438	-0.0469	-0.0094	-0.0031	-0.0063	-0.0438	-0.0438	-0.0469	-0.0500	-0.0469	1	-0.0531	-0.0563	-0.0344	-0.0156	-0.0375	-0.0469	-0.0438
F42	-0.0156	-0.0094	-0.0031	-0.0469	-0.0469	-0.0031	0	-0.0031	-0.0563	-0.0406	-0.0406	-0.0563	-0.0063	-0.0281	1	-0.0469	-0.0500	-0.0125	-0.0250	-0.0281	-0.0375
F43	-0.0250	-0.0156	-0.0063	-0.0531	-0.05	-0.0125	-0.0406	-0.0031	-0.0469	-0.0469	-0.0344	-0.0438	-0.0188	-0.0281	-0.0500	1	-0.0500	-0.0375	-0.0406	-0.0438	-0.0531
F44	-0.0188	-0.0125	-0.0469	-0.0313	-0.0375	0	0	-0.0031	-0.0125	-0.0375	-0.0406	-0.0406	-0.0094	-0.0469	-0.0313	-0.015625	1	-0.0156	-0.0438	-0.0406	-0.0531
F51	-0.0594	-0.0469	-0.0531	-0.0563	-0.0531	-0.05	-0.0531	-0.0469	-0.0375	-0.05	-0.0500	-0.0500	-0.0469	-0.0500	-0.0375	-0.046875	-0.0344	1	-0.0594	-0.0594	-0.0594
F52	-0.05	-0.0156	-0.0469	-0.0563	-0.0469	-0.0438	-0.0438	-0.0406	-0.0531	-0.05	-0.0500	-0.0531	-0.0438	-0.0469	-0.0406	-0.040625	-0.0344	-0.0594	1	-0.0563	-0.0563
F53	-0.0531	-0.0375	-0.05	-0.0594	-0.0531	-0.0156	-0.0063	-0.0188	-0.0469	-0.0469	-0.0531	-0.0500	-0.0344	-0.0375	-0.0438	-0.04375	-0.0375	-0.0250	-0.0500	1	-0.0438
F54	-0.0531	-0.05	-0.05	-0.0563	-0.0563	-0.0344	-0.0281	-0.0281	-0.0469	-0.0531	-0.0500	-0.0500	-0.0313	-0.0469	-0.0406	-0.053125	-0.0250	-0.0531	-0.0563	-0.0563	1

Table 5.15.The $(I - M)^{-1}$ matrix of the 21 HCFs

Factors	F11	F12	F13	F14	F15	F21	F22	F23	F24	F31	F32	F33	F34	F41	F42	F43	F44	F51	F52	F53	F54
F11	1.0733	0.0603	0.0913	0.1381	0.1187	0.0328	0.0329	0.0251	0.0935	0.1125	0.1293	0.0954	0.0948	0.1151	0.1166	0.1294	0.1153	0.0736	0.1119	0.1205	0.1384
F12	0.1245	1.0379	0.1154	0.1493	0.1365	0.0397	0.0604	0.0493	0.1267	0.1412	0.1431	0.1351	0.1187	0.1188	0.1166	0.1344	0.0926	0.0492	0.1092	0.1163	0.1354
F13	0.1066	0.0469	1.0510	0.1291	0.0986	0.0292	0.0320	0.0333	0.1123	0.1189	0.1150	0.0881	0.0890	0.1113	0.1010	0.1274	0.0979	0.0457	0.0900	0.0953	0.1184
F14	0.1110	0.0486	0.0874	1.0773	0.1181	0.0311	0.0340	0.0203	0.1118	0.1124	0.1166	0.1044	0.0892	0.0919	0.1171	0.1295	0.0967	0.0418	0.0778	0.0886	0.1148
F15	0.0996	0.0321	0.0628	0.1130	1.0652	0.0279	0.0240	0.0196	0.1155	0.1182	0.1096	0.1117	0.0526	0.0659	0.1050	0.1197	0.0709	0.0435	0.0903	0.1036	0.1113
F21	0.1083	0.0481	0.0970	0.1392	0.1284	1.0262	0.0531	0.0236	0.1377	0.1381	0.1453	0.1239	0.0963	0.1213	0.1368	0.1387	0.1077	0.0594	0.0916	0.1071	0.1286
F22	0.1085	0.0408	0.0879	0.1316	0.1062	0.0293	1.0227	0.0304	0.1118	0.1240	0.1258	0.0925	0.0814	0.1129	0.1117	0.1298	0.0911	0.0430	0.1000	0.1086	0.0967
F23	0.0774	0.0596	0.0908	0.1211	0.0880	0.0390	0.0327	1.0189	0.1211	0.1060	0.0949	0.1260	0.1008	0.1059	0.1133	0.1233	0.1005	0.0489	0.0885	0.1020	0.1231
F24	0.0556	0.0265	0.0470	0.0879	0.0949	0.0412	0.0225	0.0215	1.0622	0.1032	0.0849	0.1181	0.0443	0.0769	0.0981	0.1036	0.0698	0.0517	0.0820	0.0916	0.1067
F31	0.1031	0.0452	0.0790	0.1230	0.0964	0.0244	0.0231	0.0191	0.1251	1.0771	0.1349	0.1297	0.0984	0.1097	0.1213	0.1223	0.1057	0.0475	0.0993	0.1223	0.1202
F32	0.1040	0.0401	0.0584	0.1175	0.1057	0.0313	0.0248	0.0204	0.1068	0.1047	1.0735	0.0863	0.0911	0.0994	0.1188	0.1243	0.1044	0.0421	0.0826	0.1104	0.1245
F33	0.0582	0.0343	0.0343	0.0712	0.0762	0.0240	0.0174	0.0139	0.1013	0.0809	0.0596	1.0509	0.0370	0.0420	0.0698	0.0946	0.0432	0.0392	0.0791	0.0871	0.1037
F34	0.0889	0.0344	0.0482	0.0830	0.0664	0.0187	0.0213	0.0176	0.0874	0.0733	0.1096	0.0722	1.0399	0.0737	0.1052	0.1096	0.0790	0.0332	0.0768	0.0890	0.1045
F41	0.1165	0.0518	0.0993	0.1326	0.1275	0.0361	0.0296	0.0274	0.1280	0.1279	0.1321	0.1320	0.1042	1.0719	0.1351	0.1459	0.1038	0.0576	0.1091	0.1270	0.1344
F42	0.0708	0.0365	0.0469	0.1125	0.1084	0.0240	0.0199	0.0188	0.1192	0.1048	0.1039	0.1196	0.0499	0.0807	1.0639	0.1141	0.1001	0.0446	0.0801	0.0902	0.1066
F43	0.0979	0.0516	0.0652	0.1397	0.1298	0.0397	0.0658	0.0252	0.1291	0.1301	0.1191	0.1258	0.0763	0.0985	0.1301	1.0899	0.1158	0.0774	0.1113	0.1229	0.1401
F44	0.0775	0.0415	0.0914	0.1007	0.1002	0.0218	0.0207	0.0209	0.0792	0.1029	0.1064	0.1041	0.0566	0.1010	0.0946	0.0868	1.0535	0.0483	0.0986	0.1028	0.1215
F51	0.1622	0.0969	0.1357	0.1816	0.1656	0.0864	0.0899	0.0765	0.1557	0.1685	0.1706	0.1643	0.1316	0.1512	0.1537	0.1738	0.1310	1.0580	0.1579	0.1704	0.1835
F52	0.1449	0.0639	0.1224	0.1713	0.1512	0.0781	0.0775	0.0679	0.1614	0.1593	0.1608	0.1590	0.1210	0.1400	0.1480	0.1585	0.1238	0.1102	1.0943	0.1593	0.1715
F53	0.1341	0.0767	0.1135	0.1576	0.1426	0.0456	0.0363	0.0426	0.1400	0.1408	0.1477	0.1413	0.1008	0.1171	0.1353	0.1444	0.1141	0.0708	0.1284	1.0910	0.1445
F54	0.1481	0.0956	0.1253	0.1717	0.1603	0.0691	0.0636	0.0565	0.1555	0.1624	0.1607	0.1563	0.1099	0.1394	0.1473	0.1694	0.1147	0.1043	0.1473	0.1590	1.1180

Table 5.16 the total relation matrix of the 21 HCFs

Factors	F11	F12	F13	F14	F15	F21	F22	F23	F24	F31	F32	F33	F34	F41	F42	F43	F44	F51	F52	F53	F54	R_i	C_j	$R_i + C_i$	$R_i - C_i$
F11	0.0733	0.0603	0.0913	0.1381	0.1187	0.0328	0.0329	0.0251	0.0935	0.1125	0.1293	0.0954	0.0948	0.1151	0.1166	0.1294	0.1153	0.0736	0.1119	0.1205	0.1384	2.0188	2.1711	4.1899	-0.1523
F12	0.1245	0.0379	0.1154	0.1493	0.1365	0.0397	0.0604	0.0493	0.1267	0.1412	0.1431	0.1351	0.1187	0.1188	0.1166	0.1344	0.0926	0.0492	0.1092	0.1163	0.1354	2.2504	1.0694	3.3198	1.1810
F13	0.1066	0.0469	0.0510	0.1291	0.0986	0.0292	0.0320	0.0333	0.1123	0.1189	0.1150	0.0881	0.0890	0.1113	0.1010	0.1274	0.0979	0.0457	0.0900	0.0953	0.1184	1.8373	1.7503	3.5876	0.0870
F14	0.1110	0.0486	0.0874	0.0773	0.1181	0.0311	0.0340	0.0203	0.1118	0.1124	0.1166	0.1044	0.0892	0.0919	0.1171	0.1295	0.0967	0.0418	0.0778	0.0886	0.1148	1.8205	2.6490	4.4694	-0.8285
F15	0.0996	0.0321	0.0628	0.1130	0.0652	0.0279	0.0240	0.0196	0.1155	0.1182	0.1096	0.1117	0.0526	0.0659	0.1050	0.1197	0.0709	0.0435	0.0903	0.1036	0.1113	1.6620	2.3850	4.0471	-0.7230
F21	0.1083	0.0481	0.0970	0.1392	0.1284	0.0262	0.0531	0.0236	0.1377	0.1381	0.1453	0.1239	0.0963	0.1213	0.1368	0.1387	0.1077	0.0594	0.0916	0.1071	0.1286	2.1565	0.7955	2.9521	1.3610
F22	0.1085	0.0408	0.0879	0.1316	0.1062	0.0293	0.0227	0.0304	0.1118	0.1240	0.1258	0.0925	0.0814	0.1129	0.1117	0.1298	0.0911	0.0430	0.1000	0.1086	0.0967	1.8867	0.8043	2.6909	1.0824
F23	0.0774	0.0596	0.0908	0.1211	0.0880	0.0390	0.0327	0.0189	0.1211	0.1060	0.0949	0.1260	0.1008	0.1059	0.1133	0.1233	0.1005	0.0489	0.0885	0.1020	0.1231	1.8820	0.6486	2.5305	1.2334
F24	0.0556	0.0265	0.0470	0.0879	0.0949	0.0412	0.0225	0.0215	0.0622	0.1032	0.0849	0.1181	0.0443	0.0769	0.0981	0.1036	0.0698	0.0517	0.0820	0.0916	0.1067	1.4900	2.4814	3.9714	-0.9913
F31	0.1031	0.0452	0.0790	0.1230	0.0964	0.0244	0.0231	0.0191	0.1251	0.0771	0.1349	0.1297	0.0984	0.1097	0.1213	0.1223	0.1057	0.0475	0.0993	0.1223	0.1202	1.9268	2.5074	4.4342	-0.5806
F32	0.1040	0.0401	0.0584	0.1175	0.1057	0.0313	0.0248	0.0204	0.1068	0.1047	0.0735	0.0863	0.0911	0.0994	0.1188	0.1243	0.1044	0.0421	0.0826	0.1104	0.1245	1.7710	2.5435	4.3145	-0.7725
F33	0.0582	0.0343	0.0343	0.0712	0.0762	0.0240	0.0174	0.0139	0.1013	0.0809	0.0596	0.0509	0.0370	0.0420	0.0698	0.0946	0.0432	0.0392	0.0791	0.0871	0.1037	1.2179	2.4368	3.6547	-1.2189
F34	0.0889	0.0344	0.0482	0.0830	0.0664	0.0187	0.0213	0.0176	0.0874	0.0733	0.1096	0.0722	0.0399	0.0737	0.1052	0.1096	0.0790	0.0332	0.0768	0.0890	0.1045	1.4319	1.7837	3.2156	-0.3518
F41	0.1165	0.0518	0.0993	0.1326	0.1275	0.0361	0.0296	0.0274	0.1280	0.1279	0.1321	0.1320	0.1042	0.0719	0.1351	0.1459	0.1038	0.0576	0.1091	0.1270	0.1344	2.1298	2.1447	4.2745	-0.0149
F42	0.0708	0.0365	0.0469	0.1125	0.1084	0.0240	0.0199	0.0188	0.1192	0.1048	0.1039	0.1196	0.0499	0.0807	0.0639	0.1141	0.1001	0.0446	0.0801	0.0902	0.1066	1.6157	2.4394	4.0551	-0.8236
F43	0.0979	0.0516	0.0652	0.1397	0.1298	0.0397	0.0658	0.0252	0.1291	0.1301	0.1191	0.1258	0.0763	0.0985	0.1301	0.0899	0.1158	0.0774	0.1113	0.1229	0.1401	2.0813	2.6694	4.7506	-0.5881
F44	0.0775	0.0415	0.0914	0.1007	0.1002	0.0218	0.0207	0.0209	0.0792	0.1029	0.1064	0.1041	0.0566	0.1010	0.0946	0.0868	0.0535	0.0483	0.0986	0.1028	0.1215	1.6310	2.0317	3.6627	-0.4006
F51	0.1622	0.0969	0.1357	0.1816	0.1656	0.0864	0.0899	0.0765	0.1557	0.1685	0.1706	0.1643	0.1316	0.1512	0.1537	0.1738	0.1310	0.0580	0.1579	0.1704	0.1835	2.9651	1.1900	4.1552	1.7751
F52	0.1449	0.0639	0.1224	0.1713	0.1512	0.0781	0.0775	0.0679	0.1614	0.1593	0.1608	0.1590	0.1210	0.1400	0.1480	0.1585	0.1238	0.1102	0.0943	0.1593	0.1715	2.7444	2.1062	4.8506	0.6382
F53	0.1341	0.0767	0.1135	0.1576	0.1426	0.0456	0.0363	0.0426	0.1400	0.1408	0.1477	0.1413	0.1008	0.1171	0.1353	0.1444	0.1141	0.0708	0.1284	0.0910	0.1445	2.3650	2.3652	4.7303	-0.0002
F54	0.1481	0.0956	0.1253	0.1717	0.1603	0.0691	0.0636	0.0565	0.1555	0.1624	0.1607	0.1563	0.1099	0.1394	0.1473	0.1694	0.1147	0.1043	0.1473	0.1590	0.1180	2.7345	2.6462	5.3807	0.0884
SUM	2.1711	1.0694	1.7503	2.6490	2.3850	0.7955	0.8043	0.6486	2.4814	2.5074	2.5435	2.4368	1.7837	2.1447	2.4394	2.6694	2.0317	1.1900	2.1062	2.3652	2.6462	41.6187			

Table 5.17. The R_i, C_j, $R_i + C_j$ and $R_i - C_j$ values of the HCFs

Human causal factors (HCFs)	R_i	C_j	$R_i + C_j$	$R_i - C_j$
F11	2.0188	2.1711	4.1899	-0.1523
F12	2.2504	1.0694	3.3198	1.1810
F13	1.8373	1.7503	3.5876	0.0870
F14	1.8205	2.6490	4.4694	-0.8285
F15	1.6620	2.3850	4.0471	-0.7230
F21	2.1565	0.7955	2.9521	1.3610
F22	1.8867	0.8043	2.6909	1.0824
F23	1.8820	0.6486	2.5305	1.2334
F24	1.4900	2.4814	3.9714	-0.9913
F31	1.9268	2.5074	4.4342	-0.5806
F32	1.7710	2.5435	4.3145	-0.7725
F33	1.2179	2.4368	3.6547	-1.2189
F34	1.4319	1.7837	3.2156	-0.3518
F41	2.1298	2.1447	4.2745	-0.0149
F42	1.6157	2.4394	4.0551	-0.8236
F43	2.0813	2.6694	4.7506	-0.5881
F44	1.6310	2.0317	3.6627	-0.4006
F51	2.9651	1.1900	4.1552	1.7751
F52	2.7444	2.1062	4.8506	0.6382
F53	2.3650	2.3652	4.7303	-0.0002
F54	2.7345	2.6462	5.3807	0.0884

Table 5.18 presents the value of the relationships between causes and effects of the contributory factors leading to pilotage accidents, all values of coloured cells are ignored for the computation purpose because these coloured cell values are less than the threshold value.

Table 5.18 the relationships between causes and effects

	Effect												
Cause	F11	F14	F15	F24	F31	F32	F33	F34	F41	F42	F43	F44	F53
F12	0.167	0.20	0.184	0.174	0.190	0.193	0.183	0.125	0.160	0.163	0.186	0.131	0.161
F13	0.142	0.172	0.136	0.152	0.160	0.156	0.125	0.118	0.147	0.139	0.171	0.131	0.132
F21	0.148	0.188	0.174	0.185	0.185	0.194	0.169	0.129	0.162	0.183	0.188	0.146	0.139
F22	0.145	0.176	0.145	0.152	0.166	0.168	0.131	0.110	0.149	0.152	0.174	0.124	0.148
F23	0.111	0.164	0.125	0.162	0.146	0.134	0.167	0.131	0.141	0.153	0.167	0.134	0.140
F51	0.219	0.249	0.227	0.218	0.232	0.235	0.227	0.178	0.206	0.215	0.241	0.182	0.232
F52	0.197	0.234	0.208	0.221	0.219	0.221	0.217	0.163	0.191	0.205	0.221	0.172	0.216
F54	0.201	0.234	0.218	0.214	0.222	0.221	0.214	0.157	0.190	0.204	0.233	0.162	0.216

5.6.2. Results and discussion

Derived from the results of the relationships among the identified causal factors that affect the safety of pilotage operations, it is apparent that most of factors are influenced by most of the HCFs. In terms of cause-effect relationship, (F12) lack of effective communication and language barriers, (F13) failure to exchange the information between pilot and ship's master, (F21) lack of ship handling skills due to lack of training and experience, (F22) lack of technical knowledge and failure to use the bridge navigation equipment, (F23) lack of skills of the crewmembers onboard ship, tugs, and shore mooring personnel, (F51) fatigue, (F52) mental and physical workload, and (F54) stress are classified in causal factors.

While (F11) lack of team work, (F14) lack of situation awareness, (F15) The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats, and shore mooring personnel performance and vessel's progress, (F24) improper/ inadequate use of tugs, (F31) failure of pilot to give precise instructions, (F32) failure of the ship's master to correctly follow the pilot directions, (F33) failure of tug's masters to carry out the pilot's instructions precisely, (34) failure of ship's crewmembers to follow orders regarding anchoring, steering, and engine requests correctly, (F41) failure to establish a proper manoeuvring plan, (42) failure to proceed with safe speed as stipulated in COLREG, (F43) piloting ships in bad weather condition, (F44) boarding and disembarking too close to breakwater, and (F53) distraction during the time of berthing operations are classified in the effect factors.

The results from DEMATEL show that the (F12) lack of communication due to language problems is considered one of the most influential causal factors for pilotage accidents. There is a strong relationship between this causal factor and the other factors such as the exchange of information, planning, teamwork and situation awareness which were considered as a significant factor for achieving effective and safe mooring operations. In this study, marine experts asserted that efficient pilotage is mainly dependent upon the effectiveness and understanding of the communications between the pilot and the bridge team members, between master and crew members as well as between pilot and assistant parties when manoeuvrings.

In addition, the findings further showed that, during ship berthing when crewmembers, ship's captain and pilot onboard ships do not speak the same language, and English language communication ability is insufficient, this increases the risk of misunderstandings, and can cause lack of coordination, lack of exchange of information, loss of bridge teamwork, and loss of situation awareness, which will negatively affect the safety of the pilotage operations. As good knowledge of English clearly makes it easy to understand conversations that take place during pilotage operations and also facilitates communication onboard the ship, furthermore, it makes it possible for the ship's master and crew members to keep track of any actions taken by the pilot and any external parties (vessel and the Vessel Traffic System' (VTS) operators, tug masters, mooring boat staff, and shore mooring men). It can be seen from the results that a language barrier can negatively influence communication and the exchange of information between master and pilot.

The findings of this study show that an effective exchange of information between pilot and master prior to the commencement of the manoeuvre is significant for ensuring effective berthing operations. In order to ensure effective and safe piloting operations, both the ship's master and the pilot should exchange information prior to the commencement of a manoeuvre. It is worth noting that, the feedback from marine experts showed that incorrect ship details provided to pilots such as vessel characteristics (e.g. Draft, efficiency of readiness and efficiency of navigation/propulsion equipment), or wrong information provided to ship's master about berthing/sailing information e.g. port and channel depth of water, position of the berth, tugboats' powers, and number of tugboats used etc.), prior to a pilotage operation may result in a dangerous and ambiguous situation on-board ship in particular on the bridge, and can influence the safety of a ship's manoeuvring, and lead to increase of potential risk and accidents.

Marine pilots and ships' crewmembers need to obtain the right information regarding details of passage and berthing plan, as knowledge of these will assist both the pilot and the ship master, to be aware of the whole situation and enable them to easily identify the ship's manoeuvring characteristics, and quickly assess the skills needed to control the ship and prepare a proper and effective berthing plan to make the correct decision to handle the ship to its destination successfully and safely.

The finding of this study shows that good teamwork is considered as one of the most significant factors for achieving effective and safe mooring operations. An efficient teamwork and familiarity with the situation are mainly dependent upon interactive co-operation, effectiveness of the communication between the pilot and the ship's crewmembers, and ship's captain understanding of the communication between the pilots and assisting parties, as well as the effective exchange of information between the pilot and the ship's captain.

The result in this study showed that, factors such as lack of communication, or lack of information exchange can impact on Situation awareness and decision-making processes within the maritime pilotage operations. A wrong decision made by a pilot or shipmaster as a result of lack of situation awareness could result in an accident or disaster (Grech et al., 2008, p.51). It is therefore important to consider the development of those two factors that influence the effectiveness of teamwork and situation awareness of pilotage performers.

This result was supported by Chauvin et al. (2013), who concluded that effective teamwork relies on effective closed-loop communication, cooperation and coordination which play a significant role in obtaining and maintaining situation awareness (Chauvin et al., 2013). Øvergård et al. (2015), have also confirmed that effective teamwork requires interactive communication, cooperation and coordination which play a crucial role in gaining and preservation of Situation Awareness. Furthermore, Grech et al., (2008, p.125) stated that human factors (such as teamwork and communications) have a major effect on loss of situation awareness, which in turn may influence the piloting ship safety.

Maintaining situational awareness through the practice of effective teamwork and communication between bridge team members is most important when a vessel is operating in restricted waters or areas of high traffic volume. Therefore, Pilot, ship's crewmembers, tug masters, mooring men and boat, must work together, in good teamwork with the objective of guiding the ship safely to its berth. This is considered crucial, particularly when a vessel is operating in dense fog and poor visibility conditions in restricted waters or congested areas.

The results in table 5.18 show that the causal factor F21 (lack of ship handling skills) is one of the most significant influential causal factors for the pilotage incident. The success of the ship handler during berthing operations depends on the experience, knowledge, competence and the high level of the skills that the pilot, shipmaster, crewmembers, and tugboats masters have obtained. Lack of ship handling skills of pilot and ship's master, due to the lack of experience, and improper training, were identified according to the study's findings, as one of the most significant causal factors that may affect the safety of manoeuvring adversely. It can be seen from the results that, lack of ship handling skills has a major influence on all factors particularly, the factor (F24) improper/ inadequate use of tugs, and factor (F31) the failure of the pilot to give precise instructions. This insight should help the stakeholders to concentrate on improving these particular factors that are most influential to the other factors.

In table 5.18, it can be seen that the factor F22 (lack of familiarity with the electronic navigational systems knowledge such as AIS, RADAR, GPS, and ECDIS), is one of the most influential causal factors for pilotage incidents. Ineffective use of the navigational equipment such as, ECDIS, AIS, Echo Sounder, RADAR, and GPS, etc., as a result of a lack of familiarity with the electronic navigational equipment knowledge, is considered a high risk and has a greater potential to cause major accidents. The efficient use of such technology that plays a significant role in obtaining and maintaining situation awareness, and it can result in being fully unaware of the position of the ship and leading to loss of the whole situation awareness, particularly when the vessels navigate through narrow canals or while underway, inbound/outbound from/to ports and channels in the dark or under poor visibility conditions.

In table 5.18, it can be seen that the factor (F23) lack of skills of tug masters and crewmembers on board ship, has a great impact on factor (F33) failure of tug masters to carry out the pilot's instructions precisely, factor (34) failure of ship's crewmembers to follow orders regarding anchoring, steering, and engine requests correctly, and factor (F24) the improper use of tugs, particularly in adverse weather conditions. During berthing operations, the attitude and operational skills of the ship's staff and assistant parties is very important and affects the safety performance of pilotage operations.

External parties such as tug boat masters, mooring boat, and shoreline personnel, are very important and play a significant role in ship's manoeuvring safety, they must be ready for assistance and carry out the pilot's instructions precisely. Orders regarding steering, engine requests, should be following out by ship's crewmembers correctly. As failure of tugboat's master/or personnel to correctly follow pilot's instructions affect ship navigation safety and contribute to marine accidents in ports. Lack of skills of tugboats' masters or crew members is considered high-risk and can affect the manoeuvring negatively and contribute to a ship's berthing accidents. Operators' work characteristics such as professional skills and work attitudes, are very significant factors and should be controlled.

In Table 5.18 the result reveals that the causal factor (F51) fatigue, is affected by (F52) mental and physical workload, and (F54) (stress), and all of these three causal factors have great impact on (F53) distraction which in turn can have significant impact on pilotage safety performance. There is a general consensus among all the pilots and captains interviewed that these factors play a significant role in marine accidents.

In Table 5.18 the result shows that there is a strong relationship between the situation awareness and unfamiliarity with the electronic navigational equipment knowledge, distraction and workload. The mariner's high mental workload due to the use of technology and continuous monitoring of navigational equipment can lead to memory loss and misperception of data especially if the ship's operator is fatigued or not sufficiently trained.

5.7. CONCLUSIONS

As stated earlier, the literature lacks analysis of the potential risk to pilotage operations from human actions, relative importance, and causal relationships among human factors that influence maritime pilotage operations were rarely evaluated in a systematic method. In light of these considerations, studies to determine how the human causal factors influence the safety performance of maritime pilotage operations using an MCDM method is becoming more important and necessary. In this study to evaluate the relative importance of the pilotage human factors related risk, and determine the causal relationships among them, a novel technique using AHP and a DEMATEL method is applied.

An integrated method of the AHP and DEMATEL has been applied, because using only hierarchy structure (AHP) is not enough to have a complete and correct analysis of the problem, due to its restriction and inability to illustrate the cause-effect relationship between factors, which limits its applications. The AHP method was used to evaluate and rank the human factors contributing to maritime pilotage accidents (HCFs). The DEMATEL method was used to analyse the causal relationships of (HCFs). The primary purpose of the proposed (DEMATEL) model in this study is to offer a comprehensive illustration of the causal relationships among the human factors contributing to maritime pilotage accidents, and to identify the influence of each factor on the others. The DEMATEL outputs help decision makers to understand how human factors affect each other and therefore how they affect the operator's ability to achieve their tasks effectively. Thus, utilization of AHP and DEMATEL methods can help the stakeholders and company's management in several areas, to know on which factor they need to concentrate the most and also what knowledge/skills have to be improved by the operators the most.

According to the results of AHP, (F11), (F12), (F13), (F14), (F21), (F22), (F23), (F24), (F31), (F51), and (F41) are the top important causes of human error-related pilotage accidents. In terms of cause-effect relationship, the results from DEMATEL imply that among the causal factors (F12), (F13) (F21), (F22), (F23), (F51), (F52), and (F54) are classified in causes factors that affect the most other factors. Based on these results, appropriate measures and preventive/corrective actions for mitigating the risks influencing pilotage operations will be taken.

The aforementioned methodologies facilitated the decision-making process for identifying the most important risk factors influencing the safety of maritime pilotage operations, and provided a comprehensive illustration of relationships among the factors and offered insightful understanding of the mutual influence among the risk factors. The key findings of the previous models assist the decision-making process for choosing appropriate measures and take preventive/corrective actions in later stages for mitigating the risks influencing pilotage operations, and prevent a similar incident/accident to the one investigated from occurring.

In the next chapter, based on the identified risk factors in the previous chapter, a decision-making framework for mitigating the risk factors affecting the safety performance of maritime pilotage operations is suggested. List of risk mitigation measures to improve the pilotage operations safety is determined.

CHAPTER 6 A NEW DECISION MAKING FRAMEWORK FOR SELECTING RISK MITIGATION MEASURES FOR PILOTAGE OPERATIONS

6.1 SUMMARY

This chapter proposes a decision-making framework for mitigating the human risk factors affecting the safety performance of maritime pilotage operations. In the previous chapters (i.e. chapter 5) AHP method is used to determine the relative importance weights of the most significant risk factors (the human causal factors contributing to pilotage accidents (HCFs)). The weights of the criteria are used to facilitate application of TOPSIS method in selection of the best RMMs. Based on these risk factors, the list of risk mitigation measures to improve the pilotage operations safety is identified. The identified risk mitigation measures (RMMs) are prioritized and selected over the previously identified risk factors using a TOPSIS method. The proposed model has been demonstrated through a case study and sensitivity analysis was used to evaluate the robustness of the model results. The results yielded by the proposed framework present the ranking of ideal solutions for mitigating the identified risk factors affecting the safety of pilotage operations, and enables decision makers to find optimal measures to improve performance and safety of the pilotage operations.

6.2 INTRODUCTION

Over the past decade, maritime authorities have been continuously challenged to improve the safety performance of maritime pilotage operations. Pilotage operations area is categorized as a complex, dynamic and uncertain working environment that liable to diverse risks due to interaction and interdependence, in addition, the multiplicity of the entities who are performing ships' berthing operations. It is therefore essential that operators maintain a consistently high standard of human performance in order to maintain the ship's piloting safety, as any decrease in performance can potentially lead to a disaster (CAMSS, 2012).

Maintaining safe and reliable operations in the maritime pilotage area is of great significance for the protection of human life, properties, the environment, and the economy. In this regard, it is noteworthy to mention that, numerous researches studies have been conducted by using different methods in order to reduce the occurrence of maritime accidents, however, MCDM method application on issues related to pilotage operations is quite limited. There is a need for decision makers to adopt some risk mitigation measures in order to reduce the root causes of the accidents occurring in the marine pilotage operations area.

The risk mitigation procedure represents the method of dealing with unexpected hazardous events. The literature in maritime risk management has provided extensive researches in assisting decision making for analysing and mitigating various types of maritime risks like Bayesian Theory, System Dynamics (SD), Data Envelopment Analysis and Structural Equation Modelling (SEM), etc. However, there are some disadvantages in each of these method. For example, by employing Bayesian theory, a large amount of data is required in order to generate stable results; Data Envelopment Analysis focuses on measuring organizational performance in respect of the inputs; in order to apply Artificial Neural Networks, Genetic Algorithms, and Simulation-based Methods, high computer language design skills and extensive quantitative data are usually required.

Among the aforementioned MCDM methods, TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is a practical and advantageous technique for ranking and choosing the best alternatives. The capability for TOPSIS to be effective in dealing with various weight estimation systems makes it to be a scalable method for risk mitigation strategies evaluation. TOPSIS method is ideal for determining the selection of an appropriate risk control option (RCO) by taking subjective judgments of decision makers into consideration. Therefore, in this study, in order to offer the best risk mitigation strategies with the most preferred safety control measures capable of addressing both operational efficiency and human-related risk reduction in pilotage operations, an MCDM method, such as the TOPSIS method is utilized, taking subjective judgments of decision-makers into consideration.

TOPSIS technique is reasonable, understandable, and clear and less complex to use compared to other methods (Wang and Chang, 2007). Moreover, the calculation procedures are simple, and allows the pursuit of the best alternatives criterion illustrated in a simple straightforward mathematical calculation. In addition, this approach is capable of reducing the computation time, which can provide reasonable and robust ranking results. By using the method proposed, decision-makers can select the ideal solutions or alternatives (i.e. risk mitigation measures). The use of TOPSIS in this Chapter can reasonably deal with the multiplicity of criteria and will enable the incorporation of additional criteria such as costs of the alternatives into the selection decision in the future work. Such advantages make this technique an appropriate method to be used in this research

In this context, in the previous chapters (i.e. chapter 5) all the most significant human risk factors were assessed, ranked, and prioritised by using AHP method. The aforementioned methodology facilitated the decision-making process for identifying the most important human risk factors influencing the safety of maritime pilotage operations. The key findings of the previous method assist the decision-making process for choosing appropriate measures and taking preventive/corrective actions in later stages for mitigating the risks influencing pilotage operations, and prevent a similar incident/accident to the one investigated from occurring.

This research aims to offer valuable insight to find optimal solutions to improve the pilotage operations safety performance, and ensure that safety measures can be taken to reduce the potential human errors that may occur during maritime pilotage operations in real-world practice, thus subsequently preventing or at least mitigating maritime accidents in the future. To achieve this aim, this chapter is organised as follows.

In the next section, a brief review of TOPSIS and some important previous studies that used this methodology is introduced. In section 6.4, the steps of the TOPSIS method are described. In section 6.5, the description of each step of the methodology is then elaborated in detail including the process of the risk mitigating measures identification and a case study to demonstrate the procedure of the proposed TOPSIS method and to demonstrate its usefulness and validity. Section 6.5.2.1 develops a discussion based on the results obtained. Section 6.5.2.3 concludes the chapter with a detailed description of each step.

6.3 A BRIEF REVIEW OF THE TECHNIQUE FOR ORDER PREFERNCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS)

"Multi-Criteria Decision Aid (MCDA) or Multi-Criteria Decision Making (MCDM) methods have received much attention from researchers and practitioners in evaluating, assessing and ranking alternatives across diverse industries" (Behzadian et al., 2012). The technique for order preference by similarity to ideal solution (TOPSIS) is one of the well-known ranking methods for MCDM that has been commonly used in solving decision-making problems (Ding, 2011). It was initially proposed by Hwang and Yoon (1981) to help in selecting the best alternative, and with a limited number of criteria as a simple ranking method in conception and application. The principles of the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) is that the best alternative should not only have the shortest distance from the positive ideal solution (PIS), but also have the farthest distance from the negative ideal solution (NIS) (Hung and Chen, 2009; Othman et al., 2015). The positive ideal solution comprises all best values obtained of criteria, while the negative ideal solution comprises the all worst values attained of criteria (Wang, 2007).

It is worth mentioning that numerous researches studies have been successfully conducted by using the TOPSIS methodology to solve decision-making problem in various domains with varying subjects. A literature survey on TOPSIS applications and methodologies was conducted by Behzadian et al., (2012), the review included 266 papers from 103 scholarly journals since the year 2000. They found out that the TOPSIS approach is one of the most popular methods lately used by researchers and has been successfully utilised to rank the preference order of alternatives and determine the optimal option, they indicated that the TOPSIS method has been widely and intensively applied for resolving complex decision problems in various application areas and many industrial sectors with different subjects, such as Supply Chain Management and Logistics; Design, Engineering and Manufacturing Systems; Business and Marketing Management; Health, Safety and Environment Management; Human Resources Management; Energy Management; Chemical Engineering; Water Resources Management; Education; Agriculture; Medicine; Design; Government; sport and social aspects.

In the past decades, the TOPSIS technique has been applied in numerous disciplines, however the AHP–TOPSIS application in the maritime sector particularly, on issues related to pilotage operations is quite limited. For instance, a study on TOPSIS application was utilised by Yang et al. (2011) in order to select a vessel under uncertain environment, a hybrid decision-making methodology by integrating Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) has also been applied by Nooramin et al. (2012) in order to select the most efficient gantry crane installed in a marine container yard.

Furthermore, a study on AHP–TOPSIS application was utilised by (Chang et al., 2012). In this paper, an AHP and TOPSIS method was practised in order to support the critical decision upon shipping registry selection. Another study on AHP–TOPSIS hybrid technique was performed by Akyuz and Celik (2014). This study takes the advantage of TOPSIS and AHP hybrid technique for measuring the effectiveness of SMS implementation on board ship. The TOPSIS method has also been presented by Othman et al. (2015) in order to establish effective solutions and to investigate the contributing factors to the psychological distraction and to examine its impact on Senior Deck Cadets, Senior Deck Officers, and Junior Deck Officers among Malaysian seafarers. Given the advantages of both, AHP and TOPSIS, the proposed model provides a reliable means of determining an appropriate selection of RMMs. The AHP, and TOPSIS as an integrated methodology, enabling the specific decision maker's preferences to be considered in making the strategic decision on human-related risk management.

6.4. THE PROCEDURES OF THE TOPSIS METHOD

The MCDM tool TOPSIS in this study is applied for prioritizing and selecting the risk mitigation measures related to the maritime pilotage operations. The general framework of the proposed model is illustrated in Figure 6.1. The TOPSIS method and the calculation steps are described below according to (Akyuz and Celik, 2014) as follows:

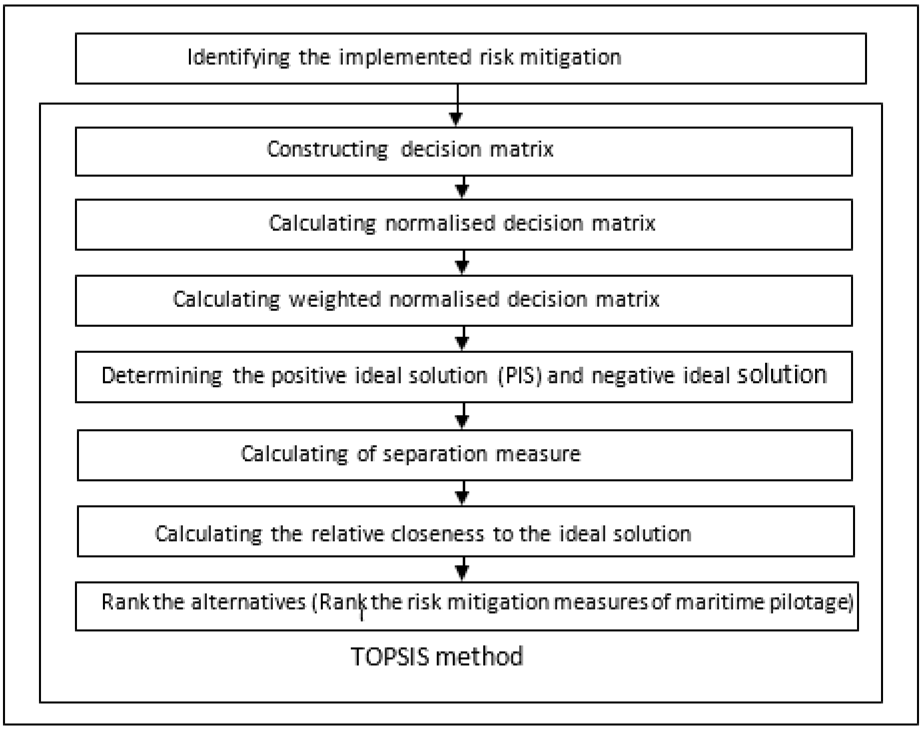


Figure 6.1. The general framework of the TOPSIS method

Step 1: The TOPSIS method begins with the construction of a decision matrix (D) shown in Equation 6.1. This step is to represent all information available for the criteria/ risk factors in the decision matrix. The structure of the decision matrix can be defined as follows;

$$
D = \begin{bmatrix} & C_1 & C_2 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ A_3 & x_{31} & x_{32} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad 6.1
$$

The MCDM problem can be demonstrated in a matrix format as shown in Equation 6.1, A_1, $A_{2,}$ …… A_m the alternatives/options related, while C_1 ,C_2 ,… C_n represents the criteria/risk factors, and x_{ij} represents the performance value of alternative/ option with respect to criteria/risk factors c_j. Then, as a result of these evaluations, a decision matrix would be created. The average for all expert opinions can be computed by averaging "E" experts' scores. In situations, where decision makers/experts are more than one and rated x_{ij}. The average of their ratings is taken as x_{ij} value. In this study, it is suggested that the experts use the five linguistic rating variables shown in Table 5.8 for rating the alternatives with respect to criteria.

Table 6.1: Evaluation scale for the alternatives rating

Linguistic Meaning	Very low	Low	Medium	High	Very high
Grade	1	2	3	4	5

Step 2: The decision matrix (D) in formula 6.1, is normalised: This step normalizes the decision matrix by using the following Equation;

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = \mathbf{1,2,3}, \ldots, m \text{ and } j = \mathbf{1,2,3}, \ldots, n. \qquad 6.2$$

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} For\, i = 1, \ldots, m; j = 1, \ldots, n$$

Wherein x_{ij} is the score of the i th option, with respect to the j th criterion.

Step3: Calculating weighted normalised decision matrix: In order to construct a weighted normalised decision matrix (v_{ij}), associated weight is to be multiplied with its normalised decision matrix. The calculation is as follows;

$$v_{ij} = w_j \times r_{ij}, \quad i = 1, 2, \ldots n, j = 1, 2\ldots, n \qquad 6.3$$

Whereas w_j according to Yoon and Hwang represents the weight of the jth criterion/risk factors, while r_{ij} represents the performance value of alternative/ option A_i with respect to criterion C_j in a weighted normalised decision matrix.

Step 4: Determining the (PIS) and (NIS): The PIS and NIS values can be determined by taking the maximum and minimum values within the row of weighted normalised decision matrix.

The PIS and NIS indicated as A^+ and A^- respectively, are mathematically determined in formulas 6.4 and 6.5, in order to ease the computation of the S_i^+ and S_i^- which are developed to measure all the alternatives/options with their PIS and NIS. The S_i^+ and S_i^- are mathematically described in Equations 6.6 and 6.7.

Positive ideal solution:

$$A^+ = \{(\max v_{ij} | j \in J) \text{ or } (\min v_{ij} | j \in J') \text{ for } i = 1,2, \ldots, m\}$$
$$= \{v_1^+, v_2^+, \ldots, v_n^+\} \qquad 6.4$$

Negative ideal solution:

$$A^- = \{(\min vij | j \in J) \text{ or } (\max v_{ij} | j \in J') \text{ for } i = 1,2, \ldots, m\}$$
$$= \{v_1^-, v_2^-, \ldots, v_n^-\} \qquad 6.5$$

where J = 1,2,3,...,n. is associated with benefit (positive criteria) and J′ = 1,2,3,...,n is associated with cost (negative criteria) (Akyuz and Celik, 2014).

Step 5: Calculate the separation measures (distance from PIS and NIS) for each alternative: The separation of each alternative from the PIS can be defined by using equations 6.6 and 6.7.

The separation from the positive ideal alternative (PIS) is:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}, i = 1,2,\ldots,m \quad 6.6$$

Likewise, the separation from the (NIS) can be defined as;

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, i = 1,2,\ldots,m \quad 6.7$$

Step 6: Calculating the relative closeness to the ideal solution. This step is provided to rank the mitigation alternatives/options A_1, A_2,..., $A_{m,}$. The relative closeness has been measured by the following equation;

$$RC_i^+ = \frac{S_I^-}{S_i^+ + S_i^-}, i=1, 2,\ldots, m \quad 6.8$$

0≤ RC_I^+≤1 and the preferred alternative/option is the one with the value of RC_I^+ closest to 1.

Step 7: Rank the preference order.

In this step, the decision maker selects the high ranked alternative.

6.5 METHODOLOGY FOR IDENTIFICATION AND EVALUATION OF RISK MITIGATION MEASURES IN PILOTAGE OPERATIONS

This study aims to propose a generic risk mitigation model for determining and evaluating the implemented risk mitigation measures. The generic framework of the proposed model and decision hierarchy of the best risk mitigation measures (RMMs) selection are illustrated in Figures 6.2 and 6.3, respectively. Figure 6.2 illustrates the research methodology, which consists of identifying the implemented risk mitigation measures and the TOPSIS application to select an appropriate RMMs. Figure 6.3 illustrates a decision hierarchy structure for the selection of the best measures to mitigate the human factors related to the risk associated with maritime pilotage operations.

In this chapter, a novel technique is introduced to investigate the risk mitigation measures for improving the pilotage operations' safety performance. The list of risk mitigation measures (RMMs) is determined based on the identified risk factors (human factors affecting maritime pilotage operations' safety performance and contributing to maritime accidents) (HCFs) in previous chapters (chapter 5) (see table 6.2), through a careful literature review, and via rules and regulations adopted by the maritime organisations and authorities. Thereafter, the validation and exploration of new risk mitigation measures are conducted via marine experts' perspectives. Afterwards, in order to obtain feasible alternatives (mitigation/control options), the identified risk mitigation measures (RMMs) are prioritized and selected over the previously ranked risk factors using an appropriate MCDM tool, a TOPSIS method. The proposed model has been demonstrated through a case study and verified using a sensitivity analysis. The description of the methodology is elaborated in detail in the following subsections.

The significance of the proposed method is that the approach has carried out an empirical work that has not been done before, and during the selecting of the risk mitigations measures (RMMs), the proposed approach has looked into the relationships among the risk factors that researchers in the discipline have not looked at before, in addition to this no risks are categorized as independent risk and with a little influence on the system, all the risk factors that have influence on the other factors were considered and selected to be managed. This study can assist in implementing effective risk reduction measures to mitigate human errors affecting the safety performance of pilotage operations and can also assist in determining appropriate preventive measures against future maritime pilotage accidents. Moreover, it can help relevant stakeholders, such as port authorities and shipping companies, in the development of better policies, safety guidelines, and risk control measures to improve the performance of operators and improve the safety of maritime pilotage operations.

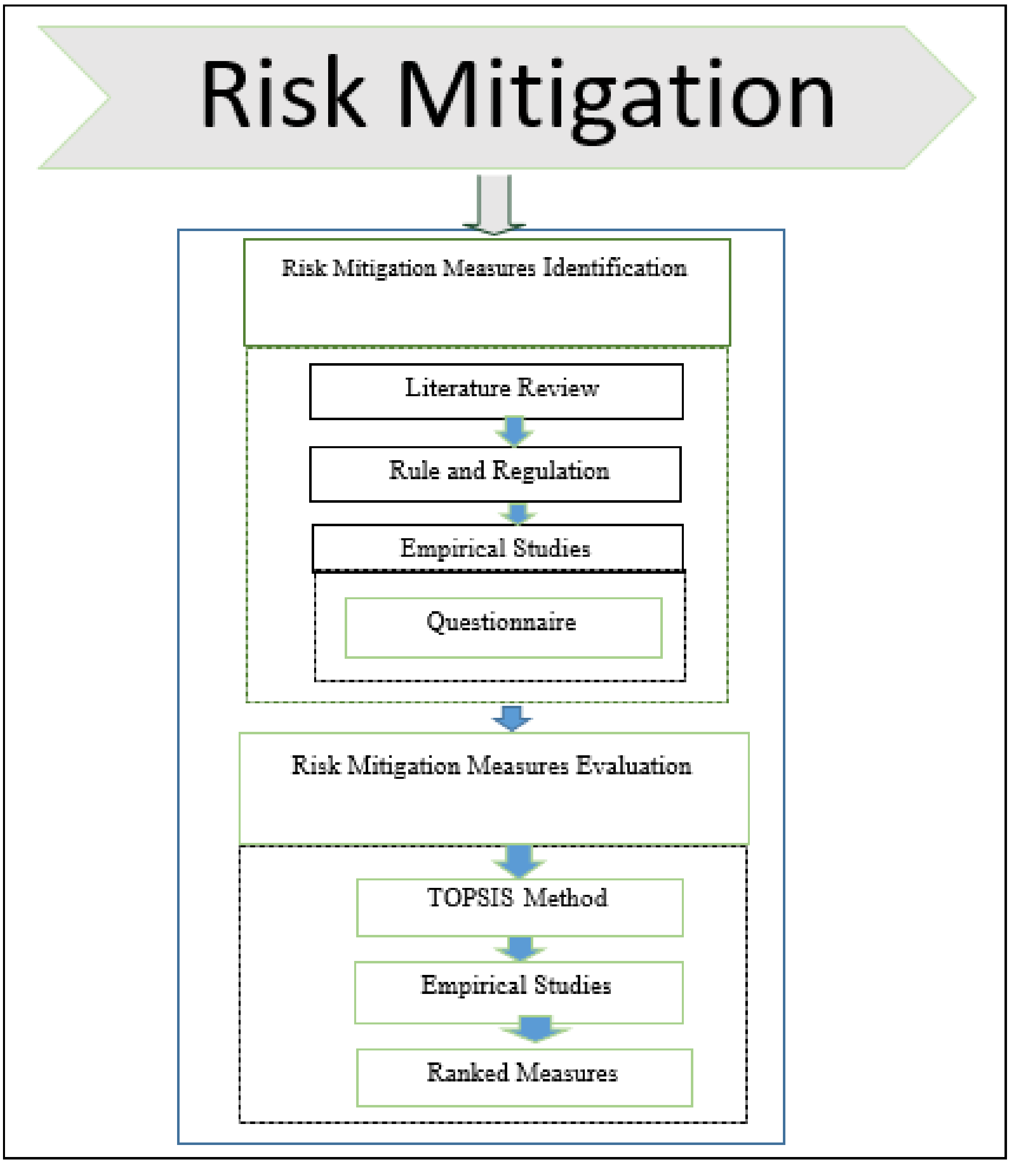


Figure 6.2: Framework for identification and evaluation of risk mitigation measures in pilotage operations

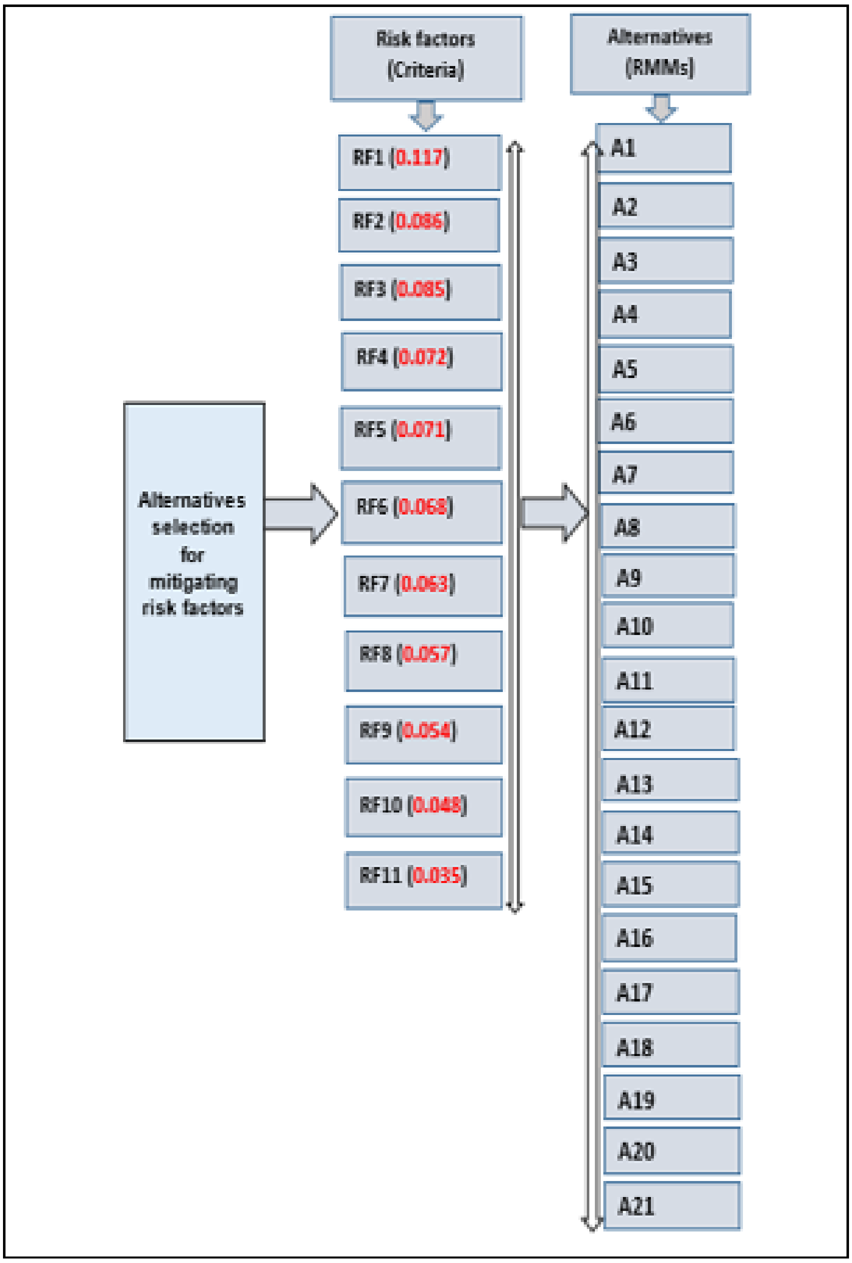


Figure 6.3: Decision hierarchy of alternative selection for mitigating risk factors

6.5.1 Identification of risk mitigation measures for pilotage

Once the AHP approach of expert judgment is applied to obtain relative weights of importance of criteria (pilotage human related risk factors) (HCFs) (chapter 5), it is necessary to identify the most ideal measures for their mitigation (Irukwu, 1991). Choosing appropriate risk mitigation measures is deemed to be an important step in improving the performance and mitigating maritime pilotage human error related risks. Risk mitigation is a decision-making process whereby actions are taken in view of the results of risk assessment. The Institute of Risk Management IRM (2002) pointed out that "risk treatment is a process of selecting and implementing measures to modify the risk". Risk treatment includes as its major element, risk control/mitigation. According to IMO (2018) "Risk control measures (RCMs) should in general be aimed at one or more of the following: (1 reducing the frequency of failures through better design, procedures, organizational policies, training, etc.; (2 mitigating the effect of failures in order to prevent accidents; (3 alleviating the circumstances in which failures may occur; and (4 mitigating the consequences of accidents". In this research, based on the identified risk factors in previous chapters, twenty-one risk mitigation measures were identified (see table 6.3) and their efficiency will be evaluated through the developed method.

The risk mitigation measures identification methods are implemented through the following steps:

In this study in order to extract the most appropriate risk mitigation measures that can reflect the current situation for further evaluation, multiple sources of evidence were employed for data collection. The study followed the particular steps to ensure that all sources were used in the study. The studies were conducted in three phases: (1) careful literature review, (2) review of rules and regulations, and (3) Empirical studies were conducted in some of the major ports in the UK and Mediterranean maritime industries. Each of the phases is discussed below. As a result, the hierarchy is constructed in Figure 6.2 with 11 risk factors and 21 alternatives (risk mitigation measures).

6.5.1.1. Description of the process of selecting the risk mitigating measures

Phase (1) careful literature review

In order to identify the risk reduction measures to mitigate the identified risk factors, some relevant studies that can reflect the latest information about the current situation of the last implemented risk mitigation measures in maritime pilotage practice were reviewed critically through an appropriate literature review. A literature review can provide significant data and information about what has been done in the past in the research area. Nonetheless, after the review, only some mitigation measures were identified because the existing literature is rather limited and fragmented. Therefore other methods have been used in this research to overcome this weakness.

Phase (2) review of regulations

Instead of identifying the risk mitigation strategies through a literature review, this research explored the currently implemented measures which turned out to be more reasonable in actual situations, all the recommendations, regulations, and rules adopted by maritime authorities for maritime pilotage safety performance improvement have been reviewed. Marine authorities have been attempting to reduce and prevent marine accidents in recent decades in accordance with regulation requirements (Akyuz and Celik, 2014). For instance, International maritime authorities have adopted several regulations in parallel with considerable efforts to maintain a high level of safety standards at sea to improve maritime safety and mitigate marine accidents, (Hetherington et al., 2006). All statutory regulations introduced by international bodies including classification society rules, recommendations issued by organizations, and IMO Conventions and Codes are deemed typical examples of strategies used for the purpose of risk control.

A careful review of related rules and regulations in the maritime pilotage field is an effective mechanism to track the development of relevant regulations and policies over a long period of time. In addition, it provides significant data about what preventative measures have been done in the past to improve maritime pilotage safety, and also it is less costly than other techniques, especially when information may be accessed easily. Understanding the evolution of the changes over the past decades can help the researcher to know what has been done in the past, how maritime safety can be improved, and how to reduce or eliminate the risks to ships in the future (Luo and Shin, 2016)..

Furthermore, using such an approach has the advantage of ensuring that the researcher gains access to the information that offers valuable solutions for decision-makers to use, to take the correct actions in order to improve the quality of pilotage performance and reduce maritime accidents, which would otherwise be challenging to acquire using other means like human beings, who may be difficult to track down or maybe unwilling to engage in an official study. And sometimes human beings, by their very nature, would not normally be willing to tell their thoughts during interviews or to write their honest opinions on questionnaires. As Yang et al., (2013) pointed out that, experts may overlook certain safety aspects in a brainstorming session as a risk event might be considered ‘natural’ from their point of view.

Phase (3) Empirical studies to collect domain experts' opinions

At the beginning, a draft version of the questionnaire was examined by three academic researchers from a UK University to comment on the appropriateness and clarity of the questions. Moreover, the ethical approval was also obtained to further validate questionnaire contents and participant consent. The revised questionnaire as represented at the end was sent out to experts for data collection. A sample copy of this questionnaire is shown in Appendix IIII-1.

The survey questionnaires were conducted and took place in March 2019 in the maritime industry, by inviting five experts from the United Kingdom and Mediterranean maritime industry, whose levels of experiences have been detailed previously to take part in the survey, one is a captain who is a general manager of an insurance company and another four experts are marine pilots from different ports companies. All respondents have been involved in our previous surveys and regular contact was maintained from the point of contacting until the research project’s completion. All the experts were professional shipmasters who had served long periods on board a variety of vessels, all with more than 10 years of working experience. The experts selected, based on their adequate qualifications, skills, and experience on the field. Consequently, integrating the abovementioned three sources, ensured research with reduced bias. In the end, 21 risk mitigation measures were identified and discussed below.

6.5.1.2 Description of the risk mitigation measures of pilotage operations

The following risk factors shown in the table below (table 6.2) are identified as contributory causes of maritime pilotage accidents. In addition, these factors have been weighted by the experts as the most significant risk factors (HCFs) leading to pilotage accidents. And in order to mitigate their negative influences on pilotage safety performance and prevent or at least reduce the maritime pilotage accidents, the relevant risk mitigation measures for each risk factor are determined. As illustrated in (table 6.3) the identified risk mitigation measures are summarized and more details will be discussed below.

Table.6.2 the most important contributory factors to maritime pilotage accidents (HCFs)

S/N	Contributory factors to maritime pilotage accidents
RF1	Lack of ship handling skills.
RF2	Lack of communication and language barriers.
RF3	Failure to exchange the information between pilot and ship's master prior to pilotage operation
RF4	Lack of bridge navigation equipment knowledge and failure to use the electronic navigational systems properly (Lack of familiarity with the navigational systems)
RF5	Lack of teamwork
RF6	Lack of situation awareness
RF7	Fatigue
RF8	Lack of skills of the crewmember on board ship, tugboat crews, and shore mooring personnel (linesmen)
RF9	Improper/ inadequate use of tugs
RF10	Failure of pilot to give precise or correct instructions
RF11	Failure of pilot and ship's master to establish a proper passage and berthing plan prior to piloting vessel

Table 6.3 Risk mitigation measures (RMMs) for improving pilotage operations performance

S/N	**Risk mitigation measures (RMMs)**
A1	Pilots should have an appropriate experience as a ship master before becoming a pilot.
A2	Implement safety management system (SMS) for pilotage operations
A3	Providing an adequate and a high standard of theoretical and practical training courses with regular renewal training including ship handling, bridge simulator training, bridge resource management (BRM), ECDIS, and NAEST generic training courses.
A4	Using common communication language on board.
A5	Improving the pilotage operators' English language skills.
A6	Ship's staff, pilot, and assisting parties should maintain effective communication, cooperation, an effective co-ordination, and effective exchange of information.
A7	A standard marine vocabulary should be used during the manoeuvrings.
A8	Compliance with resolution A.893 (21) on Guidelines for voyage planning.
A9	An effective working environment and close working relationship on the bridge of a ship between pilot and ship's captain should be created.
A10	Provide an adequate number of qualified, experienced, and well trained ship's crew members, pilots and tugs operators working on shift (adherence to MLC rest hour maritime regulations).

A11	Tasks and responsibilities should be understood and distributed properly among the bridge team members.
A12	Providing training courses in safety and cultural awareness
A13	Keeping high level of alertness and avoiding distractions elements
A14	All pilotage performers should be in good physical and mental fitness and not under the effect of drugs or alcohol
A15	Implement standard operating procedures (SOP's) for ship board operations
A16	Pilot boarding point should be at a sufficient distance from the commencement of the act of pilotage.
A17	During pilotage operations distractions elements should be avoided.
A18	Not to squeeze pilots or ship's captains for working outside established rules or piloting ships in poor weather condition situations due to commercial pressure.
A19	Keeping a high level of alertness, and maintaining continuous watchkeeping (the surrounding area, tug's, and piloted ship's performance and progress should be monitored effectively and continuously to be aware of the whole situation properly).
A20	Provide sufficient and the required number of powerful tugboats which are necessary for all kind of ships manoeuvers.
A21	Compliance with the principles and the requirements of IMO resolution A960

6.5.1.2.1 Measures for mitigating the risks due to the lack of ship handling skills (RF1).

Lack of ship handling skills, due to lack of experience, and improper training, were identified as the most significant factors that may affect the safety performance of manoeuvring adversely. It is considered among the most important causes of accidents in pilotage operations. Therefore, in order to mitigate the effects of this failure and ensure safe and efficient ship-handling, qualified and well-trained pilots and ship's masters should be employed by the port authorities and shipping companies. Employing qualified pilots in approaches to ports and other areas where specialised local knowledge is the most important step in mitigating maritime pilotage related risks. This was formally recognized by the IMO in 1968 when the organisation adopted the Assembly Resolution A.159 (ES.IV) recommendation on pilotage.

In order to provide high standards of pilotage services, every ship's master and pilot must possess a Master Mariner certificate. The certificates should be appropriate to the service in which the vessel was engaged. In addition, the pilot should hold an appropriate pilotage certificate or license issued by the competent pilotage authority, furthermore, pilots should have appropriate experience as a shipmaster before becoming a pilot. Such a prior background provides appropriate skills to deal with any situation, and enable pilots to carry out their tasks safely and efficiently, in addition, experience in both positions (master and pilot) enables a pilot to relate more easily to a master when performing a pilot's task (Darbra et al., 2007). Employing a highly experienced captains is deemed a significant factor to prevent maritime accidents (Akyuz, 2015).

Ship handling was considered as one of the most complex tasks; particularly, when navigating a ship in restricted waterways, or in harbour basin or alongside the quay. Ship Handling is defined as an acquired art practised by marine pilots, masters, and officers of proper control of a ship while underway, especially in harbours, around docks and piers (Armstrong, 2007, p.1). One expert pilot mentioned that "it needs to be understood that not everyone has the aptitude to become a skilled ship handler. Ship handling is an art rather than a science, but a ship handler who is familiar with the science will be better at their art and this will enable them to easily identify a ship's manoeuvring characteristics, and quickly assess the skills needed to control the ship safely".

This was also confirmed by Murdoch et al. (2012), efficient ship-handling during berthing and un-berthing operations is extremely important to the safety of the ship, which requires the master to understand what is happening to the ship and, what will happen a short time in the future. Ship handling skills is considered as one of the most important aspect of knowledge that must be gained by any pilot, ship's master, officers and others who assist the pilot. The safety of the ship handling during berthing operations depends on the navigational experience, competence and the high level of skills that the pilot, and master of the ship who have the command of the ship have obtained. Ship-handling skills are acquired through a combination of formal training and practical experience.

According to Yang et al. (2013) in spite of the International Maritime Organization (IMO) attention through international standards, training regimes and assessment are not consistent as a result of poor regulation implementation and this may lead to variations in seafarers' competence. Therefore, in order to lower the risks, ensure a high standard of operation and improve maritime safety, companies have to be competitive and have well trained crews (Barsan et al 2012). And this can be done, according to Berg et al. (2013), by good quality training. An appropriate education and training for pilots and ship crewmembers is the best method to proceed toward this aim and considered one of the most important risk mitigation measures (Akyuz, 2017).

Previous related studies revealed that improving the operator's professional skills should be an important issue for port authorities to consider, and regular training should be provided for marine pilots and tugboat masters (Hsu, 20012). One expert pilot pointed out that, to ensure that the training will impact on their knowledge and attitude, shipping companies and competent pilotage authorities should provide an adequate training period for its pilots, ships' masters, tugs' crews, and deck officers, and the level and standards of training for certification or licensing should be real, proper, and of a higher standard and the content of courses should be higher quality and meet the IMO requirement, the expert also mentioned that refresher training for their mariners should be reinforced, and pilotage standard operating procedures (SOP) should be implemented.

An expert marine pilot who working at one of the biggest see ports in UK confirmed that, to ensure safe pilotage operations, the principles and requirements of the IMO's resolution A960 should be embraced by all ports authorities and implemented by all pilotage performers. He considered it as one of the most effective ways to improve the safety performance of pilotage operations. In this respect, in order to provide high standards of pilotage services, the resolution A960 (23), recommended each applicant for a pilot certificate or license to be familiar with the necessary knowledge of the ship-handling for piloting, anchoring, berthing and unberthing, manoeuvring with and without tugs, and emergency situations.

In order to ensure the continued proficiency of pilots and updating of their knowledge, the Resolution A.960 encouraged competent pilotage authorities to provide sufficient and high-quality training with regular refreshers (renewal training), include; courses in bridge simulator training (simulation exercises), which may include radar training and emergency ship-handling procedures; and courses in ship-handling training centres using manned models, particularly, the courses that include ship simulator training scenarios, scenarios of simulation manoeuvres under control of an experienced pilot in particularly dangerous manoeuvres, when the vessels navigate through narrow canals or during entering or leaving the port in the dark or under poor visibility conditions.

All marine pilots have to undertake an advanced training course. The training should include both theoretical and practical ship-handling training courses. Practical ship-handling experience should be gained under the close supervision of experienced pilots. This practical experience should be obtained on vessels under actual piloting conditions and should be supplemented by simulation, both computer and manned model, classroom instruction, or other training methods. Ship-handling simulator training courses can help operators acquire skills, learn vessel navigation, and understand the causes of and preventive measures against accidents (Akyuz, 2017). Simulator training is valuable training and an assessment tool which provides a realistic environment for trainees. Simulation exercises have proven to be very successful in high risk domains non-technical skills training and assessments (Wanger et al., 2013). It has been utilised in diverse research studies to analyse different maritime related topics such as the effectiveness of officer competence under various circumstances (Saeed, 2015).

6.5.1.2.2 Measures for mitigating the risks due to the lack of communication and language problems (RF2).

It can be seen from the results shown in the previous studies that lack of communication due to language barriers on foreign ships continues to be a serious obstacle to the safe navigation of these vessels in pilotage areas. In this study, the results also show that the lack of effective communication and misunderstandings among operators due to language problems are among the most contributing factors to pilotage accidents. Therefore, a common working language is very significant and should be used during pilotage manoeuvring, and because the common communication language during periods of pilotage is English according to the revised STCW Convention 1995, both Pilot and crew must be able to communicate effectively to ensure navigation safety.

According to the expert senior pilot, a common working language during pilotage manoeuvring should be used, and because the common communication language in maritime is English, competency in spoken English is important and leads to fewer accidents. Most of the participants of the study confirmed that proper knowledge of English clearly makes it easier to understand conversations that take place during pilotage operations. In addition, it facilitates communication on board the ship and contributes considerably to the ship's manoeuvring safety. Furthermore, it makes it possible for the ship's master and crew members to keep track of any actions taken by the pilot and those external parties (VTS operators, tug masters, mooring boat staff, and shore mooring men), and any actions taken by ship passage in the surrounding area. Enhancing operators' English language skills abilities could not only help facilitate communication on board the ship, it also facilitates the exchange of information between pilot and ship's master, and assists them to be fully aware of situations and help to avoid pilotage operations disasters.

Effectiveness and understanding of the communications between the pilot and the bridge team members, between master and crewmembers as well as between pilot and assistant parties when manoeuvring, is mainly dependent upon proper knowledge and competence of English language. Therefore, in order to mitigate the risk of misunderstanding and lack of communication between pilot and the bridge staff member, operators' English languages skills should be enhanced, and more attention needs to be paid to the quality of English tuition as a second language for all non-native English speakers, and a high quality of training courses is necessary and should be provided to improve the proficiency in the English language. As Hsu (2012), pointed out, to avoid pilotage accidents, operators' English language communication abilities should be enhanced, and regular training, by port authorities should be provided. "The level of English taught in maritime education has to be advanced and also implemented for on shore operators such as port operators" (Berg et al., 2013).

The use of English as the working language on the bridge is obligatory on all ships except warships, ships below 150 gross tonnage on any voyage, ships below 500 gross tonnage not on international voyages and fishing vessels (IMO, 1997). On this basis, IMO resolution A. 960 (23) attempted to overcome the issue of language barriers that may cause misunderstandings between bridge team members and risks to pilotage safety. The resolution attempts to set up the minimum language proficiency requirements for pilots, members of ships' crews, pilots, and tug masters as well.

According to the resolution, all pilots, shall have proper knowledge of English language skills, and a high level proficiency in spoken English language, especially competency in maritime English, and all other crew members, shore mooring men, tugs and mooring boats operators shall have a sufficient understanding of the English language and must be familiar with the IMO Standard Marine Communication Phrases (SMCP). The resolutions, recommended all pilotage operatives' English language should be to a standard adequate to enable them to express communications clearly. Moreover, the communications on board between the pilot and bridge crew member should be conducted in the English language or in a language other than English that is common to all those involved in the operation.

The IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978 was the first internationally-agreed Convention to address the issue of minimum standards of competence for seafarers. It is the prime authority on training that applies to ship-owners, training establishments and national maritime administrations and it concerns merchant ships in domestic or international operations. The convention applies separate requirements for each position on board a ship. It also states that "all officers must have a good command of spoken and written English".

In order to address the problem of language barriers at sea and avoid misunderstandings between bridge team members that may cause accidents, IMO's Standard Marine Communication Phrases (SMCP) were adopted by the 22nd Assembly in November 2001 as a resolution A.918 (22) IMO Standard Marine Communication Phrases. It is recognised that maritime safety can be enhanced by the improvement of crew communication, through training in the use of Standard Marine Communication Phrases (SMCP) (Hughes, 2000). The IMO SMCP replaced the Standard Marine Navigational Vocabulary (SMNV) adopted by the IMO in 1978 (and amended in 1985). SMCP has been developed as a more comprehensive, standardised safety language taking into account changing conditions in modern seafaring and covering all major safety-related verbal communication. The IMO SMCP includes phrases that have been developed to cover the most important safety-related fields of verbal shore-to-ship (and vice-versa), ship-to-ship and on-board communications. The STCW Code requires ships' masters and officers in charge of a navigational watch on vessels of 500 gross tonnages or above to be able to understand and use the Standard Marine Communication Phrases (SMCP).

A study has been conducted by Culic (2014) to present the activities undertaken since 2012 by the German Association for Maritime English (G.A.M.E) in order to address the problem of language barriers at sea and avoid misunderstandings which can cause accidents. The emphasis has been put on the pilotage and tug assistance phrases (SMCP), as the existing body of phrases has not been felt entirely suitable to the activities performed, in order to address the problems related to the tug assistance-pilot-master communication. He concluded that the existing Standard Marine Communication Phrases (SMCP) have not been considered elaborate enough for the operation. As result, a request has been made to provide pilots and tug masters with a set of phrases for their working language - English - to be used during manoeuvring (Culic, 2015).

The difficulties of communication among members of the bridge team while under way were mostly attributed to poor BRM and prevented the bridge team from serving as an efficient support for the pilot (TSB, 2013). Thus, shipping and port companies including managers need to ensure that BRM procedures are actually practised on board ships, by providing courses for all operators in bridge resource management (BRM). The obligation of BRM training was introduced by ISM code and STCW 2010 Manila amendments, which aimed to increase the knowledge and skills of seafarers worldwide, to reduce the human error, and mitigate maritime accidents.

According to Resolution A.960 (23), English language qualifications of seafarers must be enhanced. Sufficient and high quality of training courses include courses to improve proficiency in the English language where necessary should be provided for pilots. Competent pilotage authorities should provide for pilots' sessions and regular refreshers or renewal training courses in bridge resource management (BRM) for pilots to enhance the ability of pilots to communicate with local authorities and other vessels in the area. BRM training is a great step towards improving communication (Rothblum, 2000; Hetherington et al. 2006, and Chauvin et al. 2013).

6.5.1.2.3 Measures for mitigating the risks due to of the Exchange of information failure (RF3).

The findings of this study indicate that failure to exchange the information between pilot and ship's master prior to the commencement of a manoeuvre is one of the most significant factors that can cause the occurrence of accidents in pilotage operations. Thus, in order to mitigate this risk and ensure effective and safe piloting operations, both ship's master and pilot should exchange information prior to pilotage operation (Wild and Constable 2013). In accordance with Annex 2 of the IMO's Resolution A.960, "the master and the pilot should exchange information regarding navigational procedures, local conditions and rules and the ship's characteristics. This information exchange should be a continuous process that generally continues for the duration of the pilotage. According to, Resolution A.960 (23), all competent pilotage authorities should develop a standard exchange of information practice, taking into account regulatory requirements and best practices in the pilotage area. Pilots should consider using an information card, form, checklist or other memory aid to ensure that essential exchange items are covered".

The Master/Pilot exchange information (MPX) process can be divided into two parts: an exchange of technical and the non-technical information, the successful completion of an act of pilotage is dependent on both these components being undertaken effectively (Wild and Constable, 2013). The exchange of information regarding pilotage, and the passage plan should include the following information: roles and responsibilities of the master, pilot and other members of the bridge's management team; local regulations; intended courses and route, how manoeuvres will be carried out, navigational intentions; local conditions including navigational or traffic constraints; expected weather conditions; tidal and current information; details of passage and berthing plan; mooring boat use; proposed use of tugs; characteristics and ship details such as, year built, maximum allowable draft, breadth, and length of the ship; main engine, to ensure steering gears fully operational; thrusters and propeller details; and to ensure that the thrusters are fully operational before approaching the berth. The main engines should be tested ahead and astern before beginning to manoeuvre and at the pilot station, details of equipment defects and any special peculiarities that affect the ship's manoeuvrability should be noted.

It can be seen from the results of this study that, lack of information exchange between pilot and ship's master is influenced by many factors that need to be considered. Lack of communication between pilot and ship's master mainly happens due to language problems. Language barriers is one of the main communication problems found on ships, and should be taken into account (Hetherington et al., 2006). Therefore, in order to carry out an efficient Master/Pilot exchange information (MPX), a common language should be used and English language skills for pilot and ship's master should be enhanced. A proper knowledge of English language skills is considered as one of the most significant factors for achieving an adequate and effective face-to-face exchange of information. This measure will mitigate the risk of misunderstanding and facilitate the communication and help to understand the conversations that take place during exchange of information.

Additionally, the finding of this study and the previous studies conducted by Transportation Safety Board of Canada TSB (1995), and Chauvin et al. (2013) concluded that, one of the reasons for information exchange failure was attributed to deficiencies in the effectiveness of bridge team management practices in compulsory pilotage areas. As a result, to facilitate information exchange between the pilots and ship's master and lower the effect of this risk, BRM training should be provided.

This was also recommended by the IMO resolution A. 960, to facilitate information exchange between the pilot and ship's master, each pilot has to undertake high quality training courses in bridge resource management (BRM). This training should include a requirement for the pilot to conduct an exchange of information with the master and/or officer in charge of navigational watch. This signifies that the safety management system (SMS) for pilotage operations introduced by the IMO should be implemented properly to avoid the risk of vessel accident and to ensure the safety of ship berthing

Another factor that could affect exchange of information according to the finding of this study is the pilots disembarking early before the ship leaves the port entrance or embarking the ship at the breakwater, as will leave insufficient time for the captain of the vessel to exchange information with the pilot, and to arrange the passage plan which is considered as one of the most significant factors for achieving safe ship berthing. As a consequence, IMO resolution A.960 (23), recommended the boarding position for pilots to be located where practical, at a great enough distance from the port, so as to allow sufficient time for a comprehensive face-to-face exchange of information and agreement of the final pilotage passage plan. Gard (2014), reported that, the pilot boarding point should be at a sufficient distance from the commencement of the act of pilotage to allow sufficient time to meet the requirements of the master-pilot information exchange and agreement of the final pilotage passage plan (Gard, 2014).

An expert senior pilot stated that, lack of safety culture and safety awareness could be another reason for the (MPX) failure. The pilot and other team members are not exchanging information, because they think that it is not necessary. They believe that the manoeuvring operation could be done by pilot and master individually. However, this is not true. Therefore, in order to improve a safety culture, safety awareness training program for pilots, and bridge team members' safety awareness should be established by on-board training. Safety regulations for pilotage operations introduced by the IMO should be implemented properly to avoid the risk of vessel accident and to ensure the safety of ship berthing.

6.5.1.2.4. Measures for mitigating the risks due to of lack of bridge navigation equipment knowledge and failure to use the electronic navigational systems properly (RF4).

As has been mentioned previously, ineffective use of the navigational equipment such as, ECDIS, AIS, Echo Sounder, radar, Automatic Radar Plotting Aids (ARPA) and Global Positioning System (GPS), etc. due to the unfamiliarity with the electronic navigational systems knowledge is considered a high risk and play a significant role in the risk of pilotage operations. Many accidents have occurred due to the failure of bridge team or pilot to use the bridge navigation equipment properly, therefore, in order to avoid some of the difficulties outlined above, operators' knowledge of bridge navigation equipment should be improved.

In order to improve operators' skills and knowledge of bridge navigation equipment, pilotage performers have to undertake specific training on the bridge equipment, including; the use of all the advanced navigation technology; navigational aids; and other electronic devices on the bridges of ships. Marine pilots, bridge team members (ship's masters, deck officers) and tug's masters are required to understand the cognitive task involved with the advanced navigation technology, as well-educated and trained crew with skills is considered an important factor for maritime pilotage safety.

According to Berg et al, (2013) "The increase of technology aboard ships has increased the need for training, especially training on modern ships". Pilots, ships' masters, deck officers and those who are in charge of a navigational watch, have to complete high standard Navigation Aids and Equipment Simulator Training (NAEST) course. All ship handlers (crew and pilot) have to undertake a high standard of generic ECDIS equipment training, including an Electronic Chart Display and Information Systems (ECDIS) simulator training course. Familiarity with the electronic navigational systems knowledge will assist both the pilot and ship's crew member to be aware of the whole situation and enable them to easily handle the ship to its destination successfully and safely.

ECDIS is a modern piece of navigation equipment designed to optimize the ship routing (Zang et al., 2007). It's an electronic chart that is connected to other bridge equipment such as radar, GPS, AIS, and Gyro, to present the ship's route for the voyage and to plot and check positions throughout the voyage, displays ship's, speed, course, leeway, depth of water, proximity to hazards, names and movements of the vessels in the surrounding area, and collision risks. Training on ECDIS, ensures that navigators can use and understand ECDIS in the context of navigation and can demonstrate all competencies contained in and implied by STCW 2010. ECDIS training will eliminate human errors and operation errors, as well as ensure maritime pilotage safety. It was considered essential, to ensure that officers understand how to deal with new technology to avoid or reduce human error during maritime operations (Saeed, 2015).

The regulatory requirements for generic training and familiarisation with ECDIS are covered by various international instruments including the IMO, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers Convention (STCW), the International Convention for the Safety of Life at Sea (SOLAS), the International Safety Management (ISM) Code, the Manila amendments to the STCW Convention and its associated Code that were adopted by the IMO at a Diplomatic Conference in Manila in June 2010. Resolution A.960 (23), has also encouraged competent pilotage authorities to provide updating and refresher training conducted for certified or licensed pilots to ensure the continuation of their proficiency and updating of their knowledge, including seminars on new bridge equipment with special regard to navigation aids; Simulation exercises, which may include radar training (use of radar), and ECDIS and other electronic devices; their limitations and capabilities as navigation and collision avoidance aids.

"ECDIS can deliver tremendous benefits for safe, compliant and efficient navigation. However, once installed, ship owners, operators and managers must fulfil their responsibilities for its ongoing use, including compliance with all relevant regulations. This includes updating their bridge procedures, upgrading their ECDIS software to the latest electronic navigational chart (ENC) standards and, above all, ensuring that bridge teams are trained and certified in the operation of ECDIS and in line with the requirements of Port State Control inspections and audits" (Martek marine, 2017). Thus, a proper education and training in ECDIS use is important and constitutes one of the most important risk reduction measures (Ugurlu et al., 2015).

6.5.1.2.5 Measures for mitigating the risks due to lack of teamwork (RF5)

Pilotage operations are categorised as a complex, dynamic and uncertain working environment and liable to diverse risks because of interaction and interdependence, in addition, the multiplicity of the entities who are performing ships' berthing operations. They are conducted by multiple operators with different responsibilities including the pilot, ship's crewmembers, tugboats and mooring boats crews, VTC regulators and shoreline personnel, who are required to work cooperatively together as one team with the objective of guiding the ship safely to its berth (Murdoch et al. 2012). A team can be described as "two or more individuals with specified roles interacting adaptively, interdependently, and dynamically toward a common and valued goal" (Salas et al., 1992). As team effectiveness and team performance depend upon a well-functioning team, a breakdown in team processes can lead to team failure which will negatively affect the whole situation (Salas et al., 2005).

The finding of this study shows that the failure of pilot, ship's staff, and assisting parties (tugs masters, VTS, and shore personnel) to work with each other cooperatively, or failure to create an effective relationship on the bridge of a ship between pilot and ship's captain can cause undesirable situations during ship berthing, which will negatively affect the safety of the pilotage operations. This was also confirmed by Grech et al. (2008), who stated that optimal teamwork is extremely important for on-board safety and plays a major role in the safety of maritime navigation, as breakdowns in teamwork can lead to undesirable situations.

In order to create efficient teamwork, pilot, ship's staff, and assisting parties (tugs masters, VTS, and shore personnel) should work with each other cooperatively. And ship's crewmembers should not rely only on the pilot. As the STCW Code stated that, "despite the duties and obligations of pilots, their presence on board does not relieve the master or officer in charge of the navigational watch from their duties and obligations for the safety of the ship. Ship's master and bridge team members should be in a higher state of attentiveness, and vigilance and not rely completely on the pilot (Gard, 2006).

To mitigate the risk due to lack of teamwork, IMO Resolution A.960 recommended, the master of the ship and the watchkeeper to always monitor the position of the ship and pilot's actions after the pilot has boarded and ensure that they are integrated into the bridge team properly. IMO Resolution A960 also recommended masters and bridge officers to support the pilot and to ensure that his/her actions are monitored at all times and the master, bridge officers and pilot must share a responsibility for good communications and understanding of each other's role for the safe conduct of the vessel in pilotage waters.

Mismanagement of tasks and failure to delegate the responsibilities of each team member during pilotage operations will degrade bridge team performance; as a result, in order to establish an effective team performance, tasks and responsibilities should be understood and distributed properly among the bridge team members. Pilot, ship's master and OOW (officer of the watch), should work with each other in mutually supportive ways, and effective communication, interactive co-operation, and co-ordination between them should be established (Flin et al., 2008, p. 94). One expert mentioned that the captain of the ship and pilot need to provide appropriate support and encouragement as well as motivate the individuals to understand their tasks and responsibilities in the team context.

Officers at the ship forward and aft must maintain closed loop communications with the bridge. Pilot, captain, and officers of the watch must keep monitoring the tugs and ship's progress during the ship's navigating. Pilot must give commands to external parties (tug boat mooring men and mooring boat) correctly. External parties such as tug boat masters, mooring boat, and shoreline personnel, must be ready for assistance and listen carefully to every command that is given by the pilot, and carry out the pilot's instructions precisely, orders regarding steering, engine requests, should be following out by ship's crewmembers correctly (Murdoch et al. 2012).

The feedback of Accident investigations reports indicated that poor team work is one of the most significant contributory factors of pilotage accidents, and according to the result of this study, poor team work is influenced by most of the other factors such as lack of communication and language barrier, insufficient information exchange, and lack of planning. Therefore, in order to mitigate its influences and prevent the occurrence of such accidents, pilot, ship's master, OOW (officer of the watch), and assistant parties should work together in accordance with the principles of BRM (MAIB, 2018), and an efficient communication between the pilot and the ship's crewmembers (Hsu, 2012), and adequate information exchange (TSB, 2013a), should be established. Efficient and successful bridge team communication is acknowledged as a key to safe operations of sea-going vessels, and enables team members to perform their specific task and thus supports effective team performance (Øvergård et al., 2015).

Exchanges of information and agreements on passage and berthing plan enable bridge team sharing of a common understanding of the manoeuvring (TSB, 2013a).) As Salas et al. (2005) stated, an exchange of information, shared mental models, and closed-loop communication are considered to be necessary for achieving optimal teamwork. In order to effectively monitor the vessel movements and assist the pilot in maintaining situational awareness, it is essential that the relevant information has been exchanged between the master and the pilot beforehand. The master-pilot exchange forms the basis for the pilot and bridge team to work cooperatively to monitor the vessel's progress (TSB, 2014a).

An efficient teamwork required that the team members possess specific knowledge, skills, and attitudes, such as; knowledge of their own and other team members' tasks and responsibilities, skill in monitoring each other's performance, and a positive attitude towards working in a team (Øvergård et al., 2015). Those operators' work characteristics, such as professional skills and work attitudes, should be enhanced by providing high quality specific training (Hsu, 2012). Additionally, bridge resource management training (BRM) for OOW (officers of the watch), ship's masters, tug operators and pilots to improve cooperation and understand roles and responsibilities should be provided (Chauvin et al., 2013). The U.S. National Transportation Safety Board (NTSB) reported that lack of proper crew interaction is a contributing factor to several marine accidents and has made many recommendations to present Bridge Resource Management (BRM) in training for deck officers on U.S.–flag vessels (TSB, 1995).

6.5.1.2.6 Measures for mitigating the risks due to of lack of situation awareness (RF6)

Situation awareness (SA) was defined by Endsley (1995), as "being aware of what is happening around you and understanding what that information means to you now and in the future".

Experienced pilots mentioned that situation awareness during ships piloting plays a significant role in the safety of the maritime pilotage operations. The importance of SA in operator decision-making processes is little understood within the maritime pilotage domain. It is an area of extreme importance within high risk industries which the maritime industry ignores. This is the underlying reason why the matter of shared situational awareness (SA) during pilotage operations is not dealt with and thus leads to often serious incidents which might otherwise have been avoided. Situational awareness error is closely connected with lack of training, experience, and familiarization. If the bridge team members and/or pilot are unfamiliar with the risks and conditions of the intended manoeuvre or the vessel, a lack of situational awareness will naturally emerge.

The results of this study show that, the factors, lack of communication and misunderstanding due to language barrier, poor teamwork, lack of exchanging of information and preparing a proper plan, lack of familiarity with the electronic navigational systems knowledge due to insufficient training, work load, and distracting elements, have a negative effect on the situation awareness and play a crucial role in situation awareness during pilotage operations. According to the result of this study, poor shared situation awareness about the current situation is a contributing factor to the maritime accidents, and the safety of the ship handling during berthing operations depends on the level of the situational awareness that the pilot, and master of the ship who have the command of the ship are able to attain. Maintaining the desired state of pilot's SA at every stage of task achievement is so important. This is of particular importance when navigating a ship in restricted waterways, or in a harbour basin or alongside a quay.

According to Chauvin et al. (2013), three key elements of bridge resource management (BRM) are monitoring the vessel's progress, sharing the voyage plan, and maintaining situational awareness. Maintaining situational awareness through the practice of effective teamwork and communication between bridge team members is most important when a vessel is operating in restricted waters or areas of high traffic volume. In addition, information exchange was associated with high levels of SA and that high levels of SA were related to high levels of performance in teams (Øvergård et al., 2015).

In order to maintain overall situational awareness when navigating with a pilot, it is critical that information is exchanged regularly so that all members of the bridge team are aware of the pilot's intentions and can provide assistance or timely advice and observations (MAIB annual report, 2013). According to TSB (2012) to be aware of the situation properly pilot and crewmembers need to obtain the right information regarding details of passage and berthing plan, tasks and responsibilities of the master, pilot, tugs operators, deck officers and other crew members prior to the commencement of the manoeuvre to assist them to be aware of the situation and enable them to easily identify the ship's manoeuvring characteristics, and quickly assess the skills needed to control the ship and handle it to the berth safely.

According to the above-mentioned conclusions, implementing the SA process and acquiring the required state of SA by the pilot and ship's crew staff is very important to the implementation of the decision-making process. Pilot and ship master should be aware of all the relevant elements influencing the quality of situational awareness. They must be aware of the all relevant factors external to the vessel constituting the situation, such as the environmental condition (wind, current, waves, visibility) particularly during the approaching and entering of the vessel to the port in adverse weather situations such as, strong current or wind, or reduced visibility.

The presence of the other vessels must be detected visually or by technical means such as radar. Ship's speed, and ship's location and its clearance from the jetty must be precisely controlled, also tugs boats and mooring boat position must be observed if they carry out the pilot's instructions precisely with respect to position and towing power requirements. In addition, pilot and ship's captain must be aware of the factors internal to the vessel such as the state of the vessel, availability and usability of the equipment, and technology, the state, attitudes and attention of the crew, for example, the pilot must be aware if the orders regarding steering and engine requests during the ship piloting are followed up by ship's crewmembers correctly.

During berthing operations any wrong commands occurring as a result of lack of situation awareness could lead to an undesirable situation, and can negatively affect the safety of the ship during berthing operations. Therefore, effective teamwork, co-operation and co-ordination, between the pilot and bridge team members should be performed, to be aware of the whole situation properly, and this could be achieved by bridge resource management (BRM) practical training on board ship for shipmasters, officers, tugs' masters and pilots. According to TSB (1995), and Ugurlu et al (2015), providing practical training on board the vessel for ship's operators, to fully understand bridge resource management (BRM) is significant and helpful for attaining the desired level of situational awareness. This was also confirmed by most of the experts surveyed in this study.

One expert mentioned that, to protect against mutual misunderstanding and to increase the situational awareness and support bridge team situation awareness during the ship handling, pilot and bridge staff should be communicating with each other in sufficient detail to allow all to achieve a mutual understanding and close the loop. The effectiveness of the communications between the pilot and ship's master, and understanding of the communication between master and crewmembers as well as between pilot and assistant parties during manoeuvring is very significant for maintaining situation awareness during ship berthing (TSB, 2013a).

A common working language (English language or a common language other than English) during pilotage manoeuvring should be used. It is particularly important that the pilot communicates with the port/tugs and other assistant parties (VTS operators, mooring boats staff, and shore mooring men), in a common language which the ship's master and crew staff can understand. This makes it easy for the ship's master and crew members to recognize the pilot's instructions and commands, as well as help them to monitor any subsequent actions taken by those external parties, or any actions taken by ships' passage in the surrounding area. As a result, to be fully aware of situations, seafarers shall have a proper knowledge of the English language. Enhancing operators' English language skills abilities could not only help facilitate communication on board the ship, it also facilitates the exchange of information between pilot and ship's master, which in turn will assist them to be fully aware of situations and help to avoid pilotage operations disasters.

To increase situational awareness during the pilotage operations, bridge crew and pilot must be attentive, and alert, as well as having the ability to assess the situation continuously and act appropriately and correctly (Akyuze, 2015). The National Transportation Safety Board (NTSB) (2011a) reported that many accidents occurred due to the failure of the ship's operators to maintain a proper lookout due to distraction and inattentiveness, which resulted from repeated personal use of a cell phone and laptop computer while they were navigating the vessel.

As a consequence the maritime and coastguard agency (MCA) (2005), issued a notice to ship owners, ship operators, charterers, masters, ships' officers, fishing and leisure vessel skippers, shipping agents, pilots, port authorities, ship chandlers, tug operators, bunkering providers, that the use of mobile phones at inappropriate times is distracting bridge management teams from their primary duties of navigating and conning their vessel. Control measures, must be taken to ensure that entertainment devices and mobile telephones are not distracting for the bridge team at a time when they should be concentrating fully on the navigation of the vessel. As a result improving the operators' cultural awareness by providing training courses is significant.

The Marine Accident Investigation Branch (MAIB) (2005) pointed out that the use of mobile telephones in the approaches to a port should be restricted, for both incoming and outgoing calls. This can be achieved by designating pilotage, and other restricted waters, as 'red zones', in which outgoing mobile telephone calls are prohibited, and incoming calls must be diverted to a message service. Use of this technique, or similar control measures, ensures that mobile telephones are not a distraction for the bridge team at a time when they should be concentrating fully on the navigation of the vessel.

One expert stated that to build and maintain a clear picture and perceive the situation correctly, during the manoeuvring, a high standard of continuous watchkeeping must be established, by using all the available electronic means on the bridge. Additionally, the bridge must maintain a proper look-out by visual sight (observations) and hearing and not just rely on electronic navigational systems during pilotage operations, particularly when the vessel navigates inside the port or while approaching close to the berth. The need for an all-round lookout should be not overlooked, to move out to the bridge wings to check the stern of the vessel on both sides, track the movement of the other ships in the surrounding area, and tug's and piloted ship's performance and progressing should be effectively and continuously monitored by pilot and master.

According to the rule 5 of the COLREGs, "every vessel shall at all times maintain a proper lookout by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to gain an appraisal of the situation and of the risk of collision". Keeping a proper lookout (watchkeepers) in accordance with the requirements of North West European Area Guidelines (NWEA) plays a significant role in detecting other vessels and assessing, obtaining and maintaining situation awareness, particularly when the vessels navigate through narrow canals or while underway, inbound/outbound from/to ports and channels in the dark or under poor visibility conditions. Keeping a good lookout (watchkeepers) at all times of the pilotage operation enables them to detect the potential navigation hazards, assess the situation effectively and acquire the desired state of SA.

Advanced maritime technology and the new electronic navigational systems have significant safety and efficiency benefits. The potential effect of automation on the performance of the shipboard tasks and the role of advanced technology systems is aimed at reducing the risk of maritime accidents. However, poor knowledge in the use of navigational aids such as; Automated Identification System (AIS), RADAR, GPS, and Electronic Chart Display and information Systems (ECDIS), can have a negative effect on SA.

Although new maritime technology can be viewed as beneficial in terms of being able to process more data, one of the consequences of an increasing level of technology is a loss of situation awareness (Sandhåland., et al, 2015), which significantly affects performance in abnormal, time-critical situations, and can lead to an accident (Grech et al., 2008, p.125). Therefore, to achieve and maintain SA effectively, Pilot, ship's masters, and officers have to undertake a high standard of watchkeeping training courses includes using all bridge navigation equipment such as echo sounders, Radar, AIS, and ECDIS. Also, an advanced training course, including simulation exercises and practical training on board ship should be provided, this will help the bridge crew and pilots to monitor, observe critical available information, discriminate and detect data correctly.

In spite of the importance and benefits of the technologies on ships through which operators obtain more data more quickly, allowing them to make timely decisions, the advanced instruments and technical innovations require greater knowledge and extensive training. Due to the complexity of the tasks involved, operators are distracted and overloaded with information and might not be aware enough of the situation to make the proper decisions during berthing operations. It is worth mentioning that the chance for human error increases when things are complicated, new, and unfamiliar. This opinion was confirmed by Grech et al (2008, p.125) who concluded that the electronic equipment such as ECDIS, AIS, and electronic navigational chart display (ENC) are considered significant factors that overload, confuse, and distract operators, rather than assisting them.

Analysis of a considerable number of pilotage accidents shows that situation awareness of the surrounding environment was lacking, and mistakes were due to failure to monitor or observe data. In most cases, these mistakes were as a result of the operator being too focused on one instrument, or of momentary task distractions, or excessive workload. The mariner's mental workload due to the use of technology and long-time continuous monitoring of navigational equipment can lead to memory loss and misperception of data especially if the ship's operator is fatigued or not sufficiently trained.

Therefore, according to the experts, controlling work load is a key factor when using new technology, and in order to mitigate operator's mental workload due to excessive workload of using new technology and long-time monitoring navigational aids equipment, tasks need to be evenly and properly distributed among the bridge team members, and bridge team members and pilot have to work cooperatively. Training and other forms of procedural guidance are needed to make seafarers aware of both the capabilities and limitations of new technologies. Previous related study revealed that providing more education and training opportunities to seafarers, promoting widespread use on board of electronic chart display and information systems, and improving seafarers' working hours and rest breaks would help to reduce the risk of high work load and prevent maritime accidents (Ugurlu, 2015).

6.5.1.2.7. Measures for mitigating the risks due to of fatigue (RF7)

As mentioned in the preceding section, human fatigue is difficult to measure and even more difficult to state as a cause of an accident, therefore, accident investigation reports are often reluctant to assign any great importance to human fatigue (Grech et al., 2008 p.59). The IMO adopted several actions, regulations, and guidelines in order to ensure maritime safety and to either eliminate or mitigate risks caused by human fatigue such as; the enforcement of the International Convention STCW (1995) related to working hours on board that produces scheduling and sufficient manning which has certainly reduced the ill effects that could lead to mental illness and fatigue among seafarers. Chapter VIII (Fitness for duty) of the STCW Convention sets limits on the hours of work and minimum rest requirements for watchkeepers. Additionally, measures have been introduced for watchkeeping personnel to prevent fatigue. Administrations are required to establish and enforce rest periods for watchkeeping personnel and to ensure that watch systems are so arranged that the efficiency of watchkeeping personnel is not impaired by fatigue.

IMO (2001) Guidance on Fatigue, has also developed practical guidance to assist interested parties to better understand and manage the issue of "fatigue." The guidelines on fatigue contain practical information that can assist interested parties (naval architects/Ship designers, owners/operators/managers, masters, officers, maritime pilots, tugboat personnel, other crew members and training institutions) to better understand and manage fatigue.

Furthermore, Maritime Labour Convention 2006 (MLC 2006) is an important international labour Convention that was adopted by the International Labour Conference of the International Labour Organization (ILO), under article 19 of its Constitution at a maritime session in February 2006 in Geneva, Switzerland. The convention addressed significant issues which might influence the seafarers on board, and maritime safety, in order to protect the seafarers from the fatigue.

According to the convention, the rest hours should be implemented in national legislation. The maximum hours of work in that legislation should not exceed 14 hours in any 24-hour period and 72 hours in any seven-day period, or at least ten hours of rest in any 24-hour period. In addition, the daily hours of rest may not be divided into more than two periods and at least six hours rest should be given consecutively in one of those two periods. In spite these above-mentioned actions, however, maintaining minimum crewing levels for reducing operational cost resulted in the risk of fatigue (Yang et al, 2013). In addition, the lack of an effective response to lessons learned from marine accident reports, also has threatened precautions already taken towards system safety.

The factors mentioned above might have resulted in additional occurrence of fatigue due to the reduced number of pilots and tug operators in shift, and the reduced number of crew members on the ships. Moreover, lack of necessary rest periods makes fatigue an essential element of human error that contributes to marine accidents. The feedback from maritime accident investigation reports show enormous challenges to preventing shipping accidents. Darbra (2007) highlighted that, a shortage of pilots in some ports, makes fatigue management more difficult, and commercial pressures sometimes do not allow fatigue to be managed as effectively as pilots would like. Therefore, Port authorities should increase the number of pilots and tug operators working on any given shift and ship owners should not reduce the number of crewmembers to avoid an increasing work load and mitigate the risk of fatigue. Operators should ensure that they are adequately rested prior to an act of pilotage, in good physical and mental fitness and not under the effect of drugs or alcohol.

In addition, in order to perform well at work, pilots, tug operators, and ship's staff should have a deep and uninterrupted sleep during rest hours. Rest breaks during work, particularly aboard ship should be sufficient and strictly complied with by the vessel's seafarers and management due to the importance of this element which can also impair the performance and alertness of seafarers during the operations. Mismanagement of workload can cause degradation in bridge team performance. Therefore, the intense workload of the officer on watch must not be reflected in the voyage's shifts, and inconvenient working hours must be avoided (Uğurlu et al., 2015a).

Pilots and ship's staff are performing a high-risk task that requires intense concentration and alertness, and any decrease in performance as a result of workload can potentially lead to a disaster. The result of this study and previous studies show that excessive workload can lead to mental fatigue which in turn impairs information processing and reaction time, increasing the probability of errors and ultimately leading to ship accidents (Hetherington et al., 2006). In busy situations this is very difficult to manage, and if tasks are not deputed properly omissions could occur and disasters could happen.

It is important to mention that nowadays maritime pilots on the bridge are exposed to information from several sources: crew verbal instructions, multiple instrument displays, and communication systems. Due to the introduction of the new communication and navigation devices on the bridge which require greater knowledge; higher levels of accuracy, proficiency, and intelligence are necessary. In addition, the complexity of maritime pilotage operations and the large number of tasks involved add to the pressure. Furthermore, harsh working conditions, and poor weather conditions add to the risk. Moreover, the short time allocated to achieve the tasks has increased the work burden, level of stress, and fear for the pilotage operators.

As a result, in order to mitigate the effects of workload during the pilotage operation, tasks need to be evenly and properly distributed among the bridge team members. As Saeed (2015) stated, on port approaches, on the bridge of a ship the master needs to make sure that the tasks are allocated properly to be sure that the whole operation is performed successfully and safely.

When responsibilities are assigned by the pilot and the captain of the ship during s pilotage operation to perform a task, then an individual is made responsible to perform one particular task and can avoid the risk of being overloaded. According to studies conducted by Chauvin et al. (2013), failure to delegate responsibilities of each team member, and inadequate task allocation are significant factors that can lead to maritime accidents. Chauvin concluded that, maintaining bridge resource management training for OOW (officers of the watch), ship's masters, and pilots to manage this issue is necessary.

6.5.1.2.8 Measures for mitigating the risk due to the improper/ inadequate use of tugs (RF8)

As mentioned earlier, handling ships such as large passenger ships, container ships with towering deck cargo, high free board car carriers, mammoth tankers, and deep draught bulk carriers is considered one of the most complex tasks, and cannot be handled and treated the same way as small cargo ships (Armstrong, 2007, p.1). It requires sufficient numbers and sufficiently powerful tugboats, particularly in adverse weather conditions (Hus, 2012). The main purpose of tugboats is to assist ships, such as pushing and towing the vessels. Tugboats play a significant role in assisting vessels in berthing alongside and unberthing from the berth safely and efficiently. The lack of using sufficient tugs is considered high-risk and can affect the manoeuvring negatively and contribute to a ship's berthing accident. It is important to highlight the fact that a shortage of tugs in some ports, makes ship's manoeuvring more difficult, and as a result, using adequate numbers and sufficiently powerful tugboats are considered a major factor for ship piloting safety.

According to the expert perspective, pilots always prefer to use adequate tugs during port manoeuvres, however due to the commercial pressure attributed to shipping companies, ship's masters use the minimum number of tugs in order to make the manoeuvres cost efficient. Flag states and port states need to reconsider the mandatory pilotage and tug usage regulations to mitigate this risk factor. This study and previous related studies showed that commercial pressures result in pilots and ship's masters working outside established rules and sometimes do not allow pilotage operations to be performed as effectively as pilots would like. Therefore, in order to mitigate this risk factor, ports authorities should not squeeze pilots or ship's captains to work outside established rules due to commercial pressure (Darbra et al., 2007).

The finding of this study shows that efficient ship-handling during berthing and unberthing operations is extremely important to the safety of the ship, which requires sufficient number and sufficiently powerful tugboats, skilful tugboat masters, and a qualified pilot. Failure to use sufficient numbers and sufficiently powerful tugboats and skilful tugboat masters may affect the quality of tugboat operations and contribute to marine accidents in ports. Therefore, in order to achieve successful and safe manoeuvres, port authorities should provide the required number of tugboats that are necessary for all kind of ships manoeuvres, particularly in adverse weather conditions. Additionally, qualified and experienced personnel should be employed and regular training for pilots and tugboat masters should be provided (Hsu, 20012).

This opinion was confirmed by an expert senior pilot, who confirmed that, in order to avoid pilotage accidents and achieve safe berthing, qualified, experienced, and well trained pilots who have an appropriate knowledge of a complex manoeuvre with multi-tugs should be employed, and personal qualifications and experience of operators should reflect the tug use in any particular operation. In order to ensure safe and efficient ship berthing, the port pilot should be familiar with the necessary knowledge of the berthing and unberthing and manoeuvring with tugs. The pilot should be fully aware of how to deal with each tug to carry out the task safely and efficiently.

In addition, theoretical and practical advanced training courses should be provided, and the level and standards of training for certification or licensing should be real, proper, and to a high standard. According to Akyuz (2017), the safety of the ship handling during berthing operations depends on the navigational experience, competence and high level of skills that the pilot, master of the ship, and tug operator have attained. Therefore, an appropriate education and training is the best method to proceed toward this aim and considered one of the most important risk mitigation measures.

6.5.1.2.9. Measures for mitigating the risk due the failure of pilot to give correct and precise instructions (RF9).

The Captain of the ship is the individual responsible for commanding the ship and giving the orders to the ship's crew, officers in the bridge, and officers at the ship's forward and aft, on what the pilot has suggested or instructed. The marine pilot in is on board ship because he is familiar with the port and the local area, he is responsible during piloting the vessel for the ship handling, as well as for other assistant parties such as tugs, shore mooring men, and mooring boats (Gard, 2014). As a result, failure of the pilot to give precise or correct instructions during ship piloting is a high risk and can lead to disaster. Thus, in order to ensure safe and efficient ship berthing, control measures must be taken to ensure that the orders given by the pilot regarding steering, engine, instructions and commands to the bridge staff and external parties are correct and precisely.

According to the experts and the results of this study, there are many contributing causal factors likely to occur during manoeuvring and affecting the pilot and preventing him from giving correct instructions. A pilot might fail to give precise instructions if he is fatigued or stressed due to high mental or physical workload or he might not be in good physical and mental fitness and under the effect of drugs or alcohol. Furthermore, the pilot might lose situational awareness, due to lack of planning for the intended manoeuvre, as a result of inadequate communication and language barriers and sometimes he is just not experienced and not a qualified pilot. Therefore, in order to mitigate the effect of this risk and reduce its frequency, it's important to employ a trained, qualified and experienced pilot who has good knowledge of ship's handling skills and is able to avoid all causes that could adversely influence his performance, and implement all the mitigations measures, to manage problems sufficiently and successfully.

The most basic thing to be understood by a pilot in ship handling is to know how a ship behaves under all circumstances and what orders should be given in order to handle the ship to its destination successfully and safely (Murdoch et al., 2012). According to experts, ship's handling characteristics must be also understood by the pilot. In addition, instructions from the pilot should be clear, simple and in a common language (English or a common language other than English). Port pilot should be familiar with the knowledge of the electronic navigational systems, principles and the requirements of IMO resolution A960, as well as being fully aware of each tug's power and how to use them properly.

Moreover, situation awareness is very important to the implementation of the decision-making process, and in order to acquire the required state of SA pilot should be familiar with the knowledge of the local area of the port, all the relevant elements influencing the quality of situational awareness, particularly during the approaching and entering of the vessel to the port in adverse weather conditions such as, strong current or wind, or reduced visibility. He must be aware of all the relevant factors external to the vessel such as tug's and piloted ship's performance, progress should be effectively and continuously monitored by the pilot

The pilot shall also have a proper knowledge of the English language to maintain an effective and closed-loop communication and exchange information with the master regarding the passage and berthing plan prior to the commencement of the manoeuvre. Knowledge of this information will help to improve the marine pilot's professional piloting ability, and will assist him, to easily identify the ship's manoeuvring characteristics, as well as enable him to quickly assess the skills needed to control the ship and make the correct decision to handle the ship to its destination successfully and safely.

The results of this study show that accidents in pilotage are likely to occur as a result of failure of the ship's master to correctly follow the pilot's directions (e.g. incorrect interpretations, refusal, rejection, intervention by master, etc.) during manoeuvring. This fact was also confirmed by Darbra et al. (2007), they reported that these occurrences are quite frequent making the pilot's task much more difficult and of increased risk. There are many reasons that might lead the master of the ship to interfere or refuse pilot's advice or instructions during the period of ship piloting. Because the pilot is human and he can make mistakes, and can become very fatigued, fall sick, and sometimes he is just not qualified (Gard, 2006). However, on the other hand, failure of ship's master to correctly follow the pilot's directions, is also considered very hazardous and can affect ship navigation safety and contribute to marine accidents in ports. Therefore, in order to mitigate the influence of this risk factor and reduce its frequency, the full bridge team is required to be involved and manoeuvring should be carefully planned and monitored. The ship's bridge team and pilot should create an effective working environment on the bridge of a ship, and shipmasters should not challenge the pilot during the pilotage task (Darbra et al., 2007). Sufficient briefing and discussion about who is in charge of the con are significant factors for achieving successful and safe ship piloting (Chauvin et al., 2013).

An experienced pilot stated that, "it has to be understood that one person only has the conduct of the vessel". If that is the pilot then the master of the piloted ship must be confident that the pilot is doing his duties correctly and should not interfere or give conflicting orders unless the pilot is clearly behaving irresponsibly. This point of view was also supported by Armstrong (2007, p.9). A mutual trust and respect between pilot, and ship's captain should be created (Salas et al., 2005). In addition, master and pilot must work as one team, and a close working relationship between pilot, and ship's captain should be created (Armstrong, 2007, p.8).

6.5.1.2.10 Measures for mitigating the risk due to the failure of pilots and ship's masters to prepare a proper passage and berthing plan (RF10).

As has been stated in the preceding section, in spite of the regulations, guidelines and large set of international conventions and codes which have been adopted by the International Maritime Organization, which aimed to either eliminate or mitigate mistakes caused by human factors during maritime operations, numerous maritime accidents still occurred as result of failure of pilots and ship's masters to conduct a proper and effective passage and berthing plan prior to piloting the vessel, and many accidents could have been avoided if the pilot and the bridge team had a common understanding about how the passage would be carried out (Gard, 2007).

Therefore, in order to avoid a crisis situation and achieve a successful and safe pilotage operation, the passage and berthing plan should be prepared and performed by the ship's master and pilot prior to the commencement of the manoeuvre. In order to establish a proper and effective berthing plan, as mentioned earlier, both ship's master and pilot must provide sufficient information regarding details of the passage and berthing plan before manoeuvring commences, marine pilot and ship's master need to obtain the right information regarding vessel characteristics and berthing/sailing information e.g. port and channel depth of water, tugboats' powers, and number of tugboats used, etc., as soon as possible once the pilot has boarded the ship and prior to pilotage operation commencing. Knowledge of this information will help to establish a shared mental model of the voyage (TSB, 2014a), and assist both the pilot and the ship's master to be aware of the whole situation (TSB, 2012), as well as help them to make the correct decisions and enable them to easily identify the ship's manoeuvring characteristics, and in addition, help them to quickly assess the skills needed to control and handle the ship to its destination successfully and safely (CAMSS, 2012).

Hetherington et al (2006) pointed out that, failure to comply with regulations is the major contributory factor for the majority of human errors that have been the cause of many maritime disasters. IMO has introduced several regulations to reduce the risk of vessel accident occurring due to failure of pilots and ship's masters to prepare a proper passage and berthing plan, nevertheless, the issue of negligence and breaching the rules and regulations introduced by maritime authorities, as well as the lack of interpretation and enforcement prevent its full success. As mentioned previously, the IMO is incapable of effective control and has absolutely no powers of enforcement. Therefore, in order to implement and enforce regulations in good order, ship management organization, flag states, port states and classification societies should play key roles in the implementation and enforcement of maritime safety regulations and establish an advance monitoring system.

According to IMO resolution A.893 (21), on Guidelines for voyage planning, voyage planning is a required task obliging the development of a plan in accordance with IMO rules and other factors specified by the master. The vessel's passage plan is intended to enhance safety by highlighting high-risk areas and providing key information in a format that is readily available to those involved in the vessel's navigation. When a pilot boards a vessel, it is important that both the vessel's passage plan and the pilot's passage plan are discussed during the master-pilot exchange. In order to avoid the risk of vessel accident and ensure safety of ship berthing, rules and regulations introduced by IMO such as safety management system (SMS) for pilotage operations and IMO resolution A. 960 (23), and IMO Resolution A. 893 ''Guidelines for voyage planning'', should be obeyed and implemented properly. Previous related studies showed that knowledge of IMO Resolution 960, IMO Resolution A. 893 ''Guidelines for voyage planning'', SMCP, and Standard Maritime Communications Phrases are contributing factors to safety of pilotage and are required (Darbra et al., 2007).

In addition, Mutual insurance organisations, which are commonly known as Protection and Indemnity clubs (P&I) have also produced guidance and an example of such is 'A Master's Guide to Berthing' (Murdoch et al., 2012). They reported that, a berthing plan and exchange of information between pilot and master is significant for ensuring effective berthing operations, the captain of ship and pilot should know from each other what the difficulties in navigating the ship are. They confirmed that the primary task for the ship's master and pilot is to provide accurate information regarding the manoeuvring, and how it will be conducted, in order to avoid the risks and to ensure safe passage and successful manoeuvring.

The findings of this study show that the language barrier, and lack of communication and master-pilot information exchange, and pilot boarding point are influencing factors on the berthing and pilotage passage plan. An expert pilot mentioned that pilot boarding point should be at a sufficient distance from the commencement of the act of pilotage to allow sufficient time to meet the requirements of the master-pilot information exchange and agreement of the final pilotage passage plan. These two factors are considered significant factors in achieving safe ship berthing, and play a major role in the safety of pilotage operations. Sharing the vessel's passage plan during the master-pilot information exchange enables pilots and bridge officers to identify and account for variables and discrepancies that may affect the safe navigation of the vessel. It also allows the pilot and all bridge team members to reach a common understanding of how the voyage will progress (TSB, 2014a).

6.5.2 A CASE STUDY FOR THE APPLICATION OF THE TOPSIS ON MARINE PILOTAGE OPERATIONS.

In Chapter 5 all of the relative weights for risk factors (i.e. criteria) in pilotage operations by use of the AHP method were calculated. In this Chapter the twenty-one mitigation options (i.e. alternatives) which were identified previously in section 6.5.1.2 and illustrated in table 6.3 will be applied on marine pilotage operations using the TOPSIS method. The hierarchical structure of this decision problem is shown in Figure 6.3. This process is carried out to rank and select the alternatives as per their priorities for risk mitigation purposes as per the following steps:

Step 1: Step 1: Creation of Decision Matrix.

In this study a questionnaire has been developed (see Appendix IIII-2) to evaluate the identified risk mitigation measures. At the beginning, a draft version of the questionnaire was developed. The questionnaire was then examined by three academic researchers from LJMU to comment on the appropriateness and clarity of the questions. The revised questionnaire as represented at the end was distributed to five experts who are working in the related field to contribute their judgements. In order to increase the valid response rate, the respondents were contacted in advance to determine if they would agree to participate in our survey. The same participating experts introduced in sections 6.5.1.1, 5.3.3, and section 5.6.1 have contributed to the evaluation purposes here in this chapter.

As a first step of the TOPSIS method, the decision matrix is created, the established decision matrices are based on the evaluation sheet shown in Appendix IIII-2. It is used for evaluating 21 various alternatives (mitigation options) for each of the 11 risk factors separately. In order to rate the alternatives, experts used the linguistic variables shown in able 6.1. This research uses the basic linguistic reference as very low (VL), low (L), medium (M), High (H) and very high (VH). After collecting the experts' opinions through the evaluation sheet constructed, explained and depicted in Appendix IIII by using Equation 6.1, the results of the evaluations (performance scores) are obtained and assigned, and a decision matrix is developed. Then the average of their ratings are calculated and illustrated in Tables 6.4. For example, regarding the risk factor (criteria) “RF1” with respect to the alternative “A1”, all of the five experts ticked the number five. Then the average rating value for such a risk is 5 (25/5). As similar calculation process is applied to all other risk factors (criteria).

Table 6.4. Standard Decision Matrix

	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11
A1	5	4.4	5	4.8	4.4	4.4	3.6	4.8	5	5	4.4
A2	3	4	4	1.4	4	4	2.4	4.2	3.4	3.4	3
A3	4.4	4	4.4	4.6	4	4	2.2	4.8	4.2	4.2	4
A4	1.6	4	4	1.2	4.2	4.2	1.8	1.4	3.8	4.2	3.8
A5	4.2	4.6	4.6	4.4	4.4	4.4	2.2	4.2	3.8	4.2	4.2
A6	1.4	1.4	4.8	1.2	4.8	4.6	3	1.4	4.6	4.6	4.6
A7	4	4.2	4.2	4	4.2	4.2	3	3.8	3.8	4.2	4.2
A8	1.6	1.6	4	1.6	2.6	4.2	2.8	1.6	4.2	4.2	5
A9	3.8	1	3.2	4.8	1.4	4.8	2.2	3.8	3	4.2	3.2
A10	4.2	1	1	4.2	4	4	2.2	4	4	4.2	3.6
A11	1.4	1.4	1	1.4	4.4	5	4.6	2	4	4	1.6
A12	1.4	1.2	3	1.8	4.4	4.4	4	1.4	4.2	4	2.6
A13	1	2.8	4	1.6	4	4	1.6	1.4	2.4	4.2	1.8
A14	1.4	1.2	1	1	2.6	5	1.6	1.4	4.2	4.2	1.4
A15	1.4	1.4	1	1.2	2.8	5	1.8	1.4	4	4.4	1.6
A16	1.4	2.4	4	1.2	3.2	4.4	2	1.4	4	3.6	4.2
A17	1.2	1.8	3.4	3.4	2.4	4	4.8	3.2	3.4	4.2	2.2
A18	1.4	1.2	1.8	1.6	2	4	3.8	1	4	4.2	2.4
A19	3	3.8	4.2	4.2	4	4.4	4.6	4	4.2	4.6	4
A20	1.4	5	1	1	3	1.6	2.8	1	5	4	2.6
A21	1.2	1	1	1	1.2	1.2	1	1	3.4	4.2	2.8

Step 2: Construct the normalised decision matrix, r_{ij}

In this research, all the criteria are the risks in the pilotage operations, as per the goal mitigation of these risks is required. Hence, all the risks are termed as cost criteria. The normalized decision matrix was obtained by reducing each value on a column to a single denominator through dividing each such value to the square root of sum of squares of all values on such column. The normalized decision matrix, created by means of rij values is computed according to the Equation 6.2, as shown in the Table 6.5.

By using the alternative 'A1' with respect to the risk factor (criteria) 'RF1' as an example, the value of rij is calculated as follows:

$$r_{ij}= \frac{5}{\sqrt{5^2+3^2+4.4^2+1.6^2+4.2^2+1.4^2+4^2+1.6^2+3.8^2+4.2^2+1.4^2+1.4^2+1^2+1.4^2+1.4^2+1.4^2+1.2^2+1.4^2+3^2+1.4^2+1.2^2}}$$

= 0.4045

In a similar way, the calculation technique is applied to all alternatives with respect to all the attributes for calculating the rij values (Table 6.5).

Table 6.5. The normalized decision matrix values for the pilotage risk mitigation measures

	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11
A1	0.404543	0.329609	0.320171	0.364895	0.268014	0.22908	0.26528	0.362061	0.274361	0.259629	0.284398
A2	0.242726	0.299644	0.256137	0.106428	0.243649	0.208254	0.176853	0.316803	0.186566	0.176548	0.193908
A3	0.355998	0.299644	0.28175	0.349691	0.243649	0.208254	0.162116	0.362061	0.230463	0.218088	0.258544
A4	0.129454	0.299644	0.256137	0.091224	0.255831	0.218667	0.13264	0.105601	0.208514	0.218088	0.245617
A5	0.339817	0.344591	0.294557	0.334487	0.268014	0.22908	0.162116	0.316803	0.208514	0.218088	0.271471
A6	0.113272	0.104876	0.307364	0.091224	0.292379	0.239492	0.221067	0.105601	0.252412	0.238859	0.297325
A7	0.323635	0.314627	0.268944	0.304079	0.255831	0.218667	0.221067	0.286631	0.208514	0.218088	0.271471
A8	0.129454	0.119858	0.256137	0.121632	0.158372	0.218667	0.206329	0.120687	0.230463	0.218088	0.32318
A9	0.307453	0.074911	0.204909	0.364895	0.085277	0.249905	0.162116	0.286631	0.164617	0.218088	0.206835
A10	0.339817	0.074911	0.064034	0.319283	0.243649	0.208254	0.162116	0.301717	0.219489	0.218088	0.232689
A11	0.113272	0.104876	0.064034	0.106428	0.268014	0.260318	0.338969	0.150859	0.219489	0.207703	0.103418
A12	0.113272	0.089893	0.192103	0.136836	0.268014	0.22908	0.294756	0.105601	0.230463	0.207703	0.168053
A13	0.080909	0.209751	0.256137	0.121632	0.243649	0.208254	0.117902	0.105601	0.131693	0.218088	0.116345
A14	0.113272	0.089893	0.064034	0.07602	0.158372	0.260318	0.117902	0.105601	0.230463	0.218088	0.09049
A15	0.113272	0.104876	0.064034	0.091224	0.170554	0.260318	0.13264	0.105601	0.219489	0.228474	0.103418
A16	0.113272	0.179787	0.256137	0.091224	0.194919	0.22908	0.147378	0.105601	0.219489	0.186933	0.271471
A17	0.09709	0.13484	0.217716	0.258467	0.146189	0.208254	0.353707	0.241374	0.186566	0.218088	0.142199
A18	0.113272	0.089893	0.115262	0.121632	0.121824	0.208254	0.280018	0.075429	0.219489	0.218088	0.155126
A19	0.242726	0.284662	0.268944	0.319283	0.243649	0.22908	0.338969	0.301717	0.230463	0.238859	0.258544
A20	0.113272	0.374555	0.064034	0.07602	0.182737	0.083302	0.206329	0.075429	0.274361	0.207703	0.168053
A21	0.09709	0.074911	0.064034	0.07602	0.073095	0.062476	0.073689	0.075429	0.186566	0.218088	0.180981

Step3: Calculating the weighted normalised decision matrix, v_{ij}

In order to construct weighted normalised decision matrix (v_{ij}), the weight of each risk factor obtained through AHP, which are 0.117, 0.086, 0.085, 0.072, 0.071, 0.068, 0.063, 0.057, 0.054, 0.048, and 0.035 respectively (see table 6.2) is multiplied with each column of the normalised decision matrix. The weighted evaluation matrix (v_{ij}), is established using the Eq. (6.3) which is shown in Table 6.6.

For instance, the v_{ij} value of the alternative 'A1' with respect to the risk factor (criteria) 'RF1' is calculated as follows:

v_{ij}= 0.117×0.4045= 0.0473

In a similar way, other values of $v_{ij}$are obtained as shown in Table 6.6.

Table 6.6: The weighted normalised decision matrix for the pilotage risk mitigation measures

	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11
A1	0.047332	0.028346	0.027215	0.026272	0.019029	0.015577	0.016713	0.020637	0.014815	0.012462	0.009954
A2	0.028399	0.025769	0.021772	0.007663	0.017299	0.014161	0.011142	0.018058	0.010075	0.008474	0.006787
A3	0.041652	0.025769	0.023949	0.025178	0.017299	0.014161	0.010213	0.020637	0.012445	0.010468	0.009049
A4	0.015146	0.025769	0.021772	0.006568	0.018164	0.014869	0.008356	0.006019	0.01126	0.010468	0.008597
A5	0.039759	0.029635	0.025037	0.024083	0.019029	0.015577	0.010213	0.018058	0.01126	0.010468	0.009501
A6	0.013253	0.009019	0.026126	0.006568	0.020759	0.016285	0.013927	0.006019	0.01363	0.011465	0.010406
A7	0.037865	0.027058	0.02286	0.021894	0.018164	0.014869	0.013927	0.016338	0.01126	0.010468	0.009501
A8	0.015146	0.010308	0.021772	0.008757	0.011244	0.014869	0.012999	0.006879	0.012445	0.010468	0.011311
A9	0.035972	0.006442	0.017417	0.026272	0.006055	0.016994	0.010213	0.016338	0.008889	0.010468	0.007239
A10	0.039759	0.006442	0.005443	0.022988	0.017299	0.014161	0.010213	0.017198	0.011852	0.010468	0.008144
A11	0.013253	0.009019	0.005443	0.007663	0.019029	0.017702	0.021355	0.008599	0.011852	0.00997	0.00362
A12	0.013253	0.007731	0.016329	0.009852	0.019029	0.015577	0.01857	0.006019	0.012445	0.00997	0.005882
A13	0.009466	0.018039	0.021772	0.008757	0.017299	0.014161	0.007428	0.006019	0.007111	0.010468	0.004072
A14	0.013253	0.007731	0.005443	0.005473	0.011244	0.017702	0.007428	0.006019	0.012445	0.010468	0.003167
A15	0.013253	0.009019	0.005443	0.006568	0.012109	0.017702	0.008356	0.006019	0.011852	0.010967	0.00362
A16	0.013253	0.015462	0.021772	0.006568	0.013839	0.015577	0.009285	0.006019	0.011852	0.008973	0.009501
A17	0.01136	0.011596	0.018506	0.01861	0.010379	0.014161	0.022284	0.013758	0.010075	0.010468	0.004977
A18	0.028399	0.024481	0.02286	0.022988	0.017299	0.015577	0.021355	0.017198	0.012445	0.011465	0.009049
A19	0.028399	0.024481	0.02286	0.022988	0.017299	0.015577	0.021355	0.017198	0.012445	0.011465	0.009049
A20	0.013253	0.032212	0.005443	0.005473	0.012974	0.005665	0.012999	0.004299	0.014815	0.00997	0.005882
A21	0.01136	0.006442	0.005443	0.005473	0.00519	0.004248	0.004642	0.004299	0.010075	0.010468	0.006334

Step 4: Determining the positive ideal solution (PIS), A^{+} and negative ideal solution (NIS), A^{-}

Based on the output values in Table 6.6, the positive and negative ideal solutions are determined respectively. As it was explained before the positive ideal solution (PIS) and the negative ideal solution (NIS) for the alternatives (mitigation options) can be determined via taking the maximum and minimum values within the row of weighted normalised decision matrix. The values of

{(maxj Vij | j € j) and {(min j Vij | j € j')} belong to the positive ideal solution and the values of {(maxj Vij | j € j) and {(min j Vij | j € j')} belong to the negative ideal solution. Table 6.7, and Equations 6.4 and 6.5 refer.

Table 6.7: The positive ideal solution (PIS) and the negative ideal solution (NIS)

	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11
A1	0.047332	0.028346	0.027215	0.026272	0.019029	0.015577	0.016713	0.020637	0.014815	0.012462	0.009954
A2	0.028399	0.025769	0.021772	0.007663	0.017299	0.014161	0.011142	0.018058	0.010075	0.008474	0.006787
A3	0.041652	0.025769	0.023949	0.025178	0.017299	0.014161	0.010213	0.020637	0.012445	0.010468	0.009049
A4	0.015146	0.025769	0.021772	0.006568	0.018164	0.014869	0.008356	0.006019	0.01126	0.010468	0.008597
A5	0.039759	0.029635	0.025037	0.024083	0.019029	0.015577	0.010213	0.018058	0.01126	0.010468	0.009501
A6	0.013253	0.009019	0.026126	0.006568	0.020759	0.016285	0.013927	0.006019	0.01363	0.011465	0.010406
A7	0.037865	0.027058	0.02286	0.021894	0.018164	0.014869	0.013927	0.016338	0.01126	0.010468	0.009501
A8	0.015146	0.010308	0.021772	0.008757	0.011244	0.014869	0.012999	0.006879	0.012445	0.010468	0.011311
A9	0.035972	0.006442	0.017417	0.026272	0.006055	0.016994	0.010213	0.016338	0.008889	0.010468	0.007239
A10	0.039759	0.006442	0.005443	0.022988	0.017299	0.014161	0.010213	0.017198	0.011852	0.010468	0.008144
A11	0.013253	0.009019	0.005443	0.007663	0.019029	0.017702	0.021355	0.008599	0.011852	0.00997	0.00362
A12	0.013253	0.007731	0.016329	0.009852	0.019029	0.015577	0.01857	0.006019	0.012445	0.00997	0.005882
A13	0.009466	0.018039	0.021772	0.008757	0.017299	0.014161	0.007428	0.006019	0.007111	0.010468	0.004072
A14	0.013253	0.007731	0.005443	0.005473	0.011244	0.017702	0.007428	0.006019	0.012445	0.010468	0.003167
A15	0.013253	0.009019	0.005443	0.006568	0.012109	0.017702	0.008356	0.006019	0.011852	0.010967	0.00362
A16	0.013253	0.015462	0.021772	0.006568	0.013839	0.015577	0.009285	0.006019	0.011852	0.008973	0.009501
A17	0.01136	0.011596	0.018506	0.01861	0.010379	0.014161	0.022284	0.013758	0.010075	0.010468	0.004977
A18	0.013253	0.009797	0.009797	0.008758	0.00865	0.014161	0.017641	0.004299	0.011852	0.010468	0.005429
A19	0.028399	0.024481	0.02286	0.022988	0.017299	0.015577	0.021355	0.017198	0.012445	0.011465	0.009049
A20	0.013253	0.032212	0.005443	0.005473	0.012974	0.005665	0.012999	0.004299	0.014815	0.00997	0.005882
A21	0.01136	0.006442	0.005443	0.005473	0.00519	0.004248	0.004642	0.004299	0.010075	0.010468	0.006334

Step 5: Calculate the distance separation measures for PIS, S_i^+ and NIS S_i^-

The distance separation is divided into two parts which are related to the PIS and NIS. The S_i^+ is calculated using formula 6.6, while the S_i^- is computed using equation 6.7. By using the distance separation values of S_i^+ and S_i^-, RC_i^+ is calculated using equation 6.8. Referring to the alternative 'A1' as an example, the values of S_i^+ and S_i^- are obtained as follows:

$$\sqrt{(0.0473-0.0473)^2+(0.0283-0.0322)^2+(0.0272-0.0272)^2+(0.0262-0.0262)^2+(0.0190-0.0207)^2 +(0.0155-0.0177)^2+(0.0167-0.0222)^2+(0.0206-0.0206)^2+(0.0148-0.0148)^2 +(0.0124-0.124)^2+(0.0099-0.0113)^2}$$

$S_i^+ = \sqrt{0.0125} = 01118$

$$\sqrt{(0.0473-0.0113)^2+(0.0283-0.0064)^2+(0.0272-0.0054)^2+(0.0262-0.0054)^2+(0.0190-0.0051)^2 +(0.0155-0.0042)^2+(0.0167-0.0046)^2+(0.0206-0.0043)^2+(0.0148-0.0088)^2+(0.0124-0.0084)^2+(0.0099-0.0031)^2}$$

$S_i^- = \sqrt{0.00351} = 0.0593$

In a similar way, the calculation technique is applied to the other alternative with respect to all factors for obtaining values of $A^{+}$and A^{-}. Table 6.8 illustrate the values of the distance separation and closeness of each alternative.

Table 6.8. The distance separation and closeness of each alternative for the pilotage risk mitigation

Alternatives/ Options	S_i^{+}	S_i^{-}
A1	0.1118	0.0593
A2	0.1197	0.0378
A3	0.0164	0.0536
A4	0.0441	0.0315
A5	0.0159	0.0516
A6	0.0488	0.0570
A7	0.1148	0.0475
A8	0.0474	0.0248
A9	0.0364	0.0392
A10	0.0748	0.0399
A11	0.0524	0.0264
A12	0.1243	0.0261
A13	0.1243	0.0260
A14	0.1272	0.0159
A15	0.1261	0.0102
A16	0.1247	0.0251
A17	0.1225	0.0301
A18	0.0527	0.0185
A19	0.0222	0.0473
A20	0.0517	0.0291
A21	0.0627	3.9611

Step 6: Calculate the relative closeness to the idial solution RC_i^{+}

The best solutions for pilotage risk mitigation will be selected based on the RC_i^{+} value closest to the one which has the shortest distance from the positive idial solution point and the farthest distance from the negative idial solution point. The RC_i^+ values will be used to show how important each alternative is through ranking. Alternative with high RC_i^+ value is more important than the one with low RC_i^+ value. Refering to the alternative "A1" as example and the S_i^+ and S_i^- value from Table 6.8 the value of RC_i^+ is calculated using equation 6.8. as follows:

$$RC_i^+ \text{ A1} = \frac{0.0593}{0.1118+0.0593} = 0.3465$$

The RC_i^+ of the other alternatives can be computed and ranked accordingly in a similar way and their results are shown in Table 6.9.

Table 6.9 illustrates TOPSIS results and final ranking for the implementation of risk mitigation measures as follows:

Tble 6.9: S_i^+, S_i^- and RC_i^+ values and ranking of all alternatives

Alternatives/ Options	S_i^+	S_i^-	RC_i^+	Rank
A1	0.1118	0.0593	0.3465	10
A2	0.1197	0.0378	0.2400	15
A3	0.0164	0.0536	0.7657	2
A4	0.0441	0.0315	0.4167	7
A5	0.0159	0.0516	0.7644	3
A6	0.0488	0.0570	0.5388	5
A7	0.1148	0.0475	0.2927	13
A8	0.0474	0.0248	0.3439	11
A9	0.0364	0.0392	0.5185	6
A10	0.0748	0.0399	0.3479	9
A11	0.0524	0.0264	0.3350	12
A12	0.1243	0.0261	0.1735	17
A13	0.1243	0.0260	0.1729	18
A14	0.1272	0.0159	0.1111	20
A15	0.1261	0.0102	0.0748	21
A16	0.1247	0.0251	0.1676	19
A17	0.1225	0.0301	0.1972	16
A18	0.0527	0.0185	0.2598	14
A19	0.0222	0.0473	0.6806	4
A20	0.0517	0.0291	0.3601	8
A21	0.0627	3.9611	0.9844	1

Step 7: Ranking the preference alternatives

Based on the results shown in table 6.9, it is obvious that the value of RC_i^+ for the A21, A3, A5, A19, A6, A9, A4, A20, A10, and A1, are ranked according to their overall priorities by experts as the most optimal measures for safety performance improvement of pilotage operations and best solutions for mitigating the human related risk factors contributing to pilotage accidents.

6.5.2.1. Result and discussion

The final results shown in table 6.9 indicate that A21 "compliance with the principles and the requirements of IMO resolution A960" with RC_i^+ value of 0.9844, A3 "providing an adequate and a high standard of theoretical and practical training courses with regular renewal training including; ship handling, bridge simulator, BRM, ECDIS, and NAEST training courses to improve knowledge and competence" with RC_i^+ value of 0.7657, A5 "improving the pilotage operators' English language skills" with RC_i^+ value of 0.7644, A19 "maintaining continuous watch keeping (surrounding area, tug's and piloted ship's performance and progressing should be monitored effectively and continuously)" with RC_i^+ value of 0.6806, A6 "Ship's staff, pilot, and assisting parties should maintain effective communication, cooperation, effective co-ordination, and an effective exchange of information" with RC_i^+ value of 0.5388, A9 " Close working relationship on the bridge of a ship between pilot and ship's captain should be created" with RC_i^+ value of 0.5185, A4 "using common communication language on board" with RC_i^+ value of 0.4167 and A20 "Provide sufficient and the required number of powerful tugboats which are necessary for all kind of ships manoeuvres" with RC_i^+ value of 0.3601, A10 "Provide an adequate number of qualified, experienced, and well trained ship's crew members, pilots and tugs operators working on shift (adherence to MLC rest hour maritime regulations)" with RC_i^+ value of 0.3479, A1 Pilots should have an appropriate experience as a ship master before becoming a pilot RC_i^+ value of 0.3465, A8 "Compliance with resolution A.893 (21) on Guidelines for voyage planning with RC_i^+ value of 0.3439, and A11 "Tasks and responsibilities should be understood and distributed properly among the bridge team members" with RC_i^+ value of 0.3350, have the highest relative closeness indices and should therefore be recommended as the top risk mitigation measures for the maritime pilotage operations to be implemented.

Resolution A.960 (23), recommendations on training and certification and on operational procedures for maritime pilots other than deep sea-pilots have been introduced by the International Maritime Organization (IMO) in 2003 in order to provide high standards of pilotage services. IMO resolution A960 (23), is the main reference guide available for the management of maritime pilotage safety. Its recommendations represent the essential demands to be considered in establishing pilotage operations' safety. It is aimed at ensuring pilotage safety performance at sea, preventing human injury or loss of life, and avoiding damage to the maritime environment and property (IMO, 2003). It encourages all port competent pilotage authorities to embrace and implement its principles and requirements. Therefore, to ensure safe pilotage operations and manage pilotage related risk, the principles and requirements of the IMO's resolution A960 are considered as one of the most effective ways to improve the safety performance of pilotage operations and should be embraced and implemented by all pilotage performers.

6.5.2.2 Model robustness evaluation process/ Sensitivity analysis

In this study, evaluating the robustness of the model results delivered in the proposed model is conducted through sensitivity analysis. A sensitivity analysis is a method for verifying the robustness of the model employed and testing the degree of sensitivity of a model's variables and deemed by some as necessary for model building in diagnostic or prognostic setting (Saltelli, 2002). In MCDM methods, sensitivity analysis is a commonly suggested method to validate the feasibility and robustness of MCDM methods (Satty and Ergu, 2015).

A sensitivity analysis is proposed to investigate the influence of different criteria weights on selection of risk mitigation measures. It generates different scenarios that may change the ranking of alternatives. If the ranking order is changed by increasing or decreasing the importance of the criteria (the identified 11 risk factors), the results are expressed to be sensible, otherwise it is robust. In this research, sensitivity analysis is implemented to investigate the effect of different criteria weights on the selection of risk mitigation measures, to see how sensitively the alternatives change with the importance of the criteria (human risk factors). More specifically, each risk's weights value has been exchanged with another risk's weights.

The weight matched with one criterion is increased separately by 10, and 20% and for each condition, the relative closeness to the ideal solution RC_i^+ was computed. The sensitivity of the twenty-one RMMs has been analysed when the most important criterion "risk factors" is increased separately by 10, 20% sequentially. It is noted that a slight increase in the value of distance separation measure for the PIS, S_i^+ for an RMM, resulted in a slight change of the relative closeness to an ideal solution RC_i^+, for a the most of RMMs. The results of sensitivity analysis are presented in the graphical representation of these results in Figure 6.4.

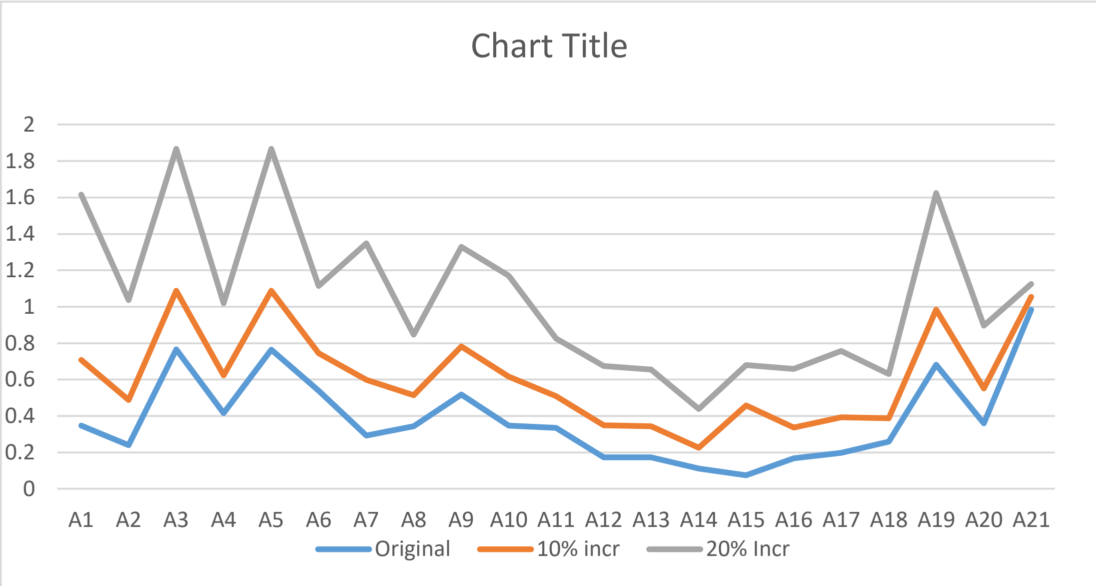


Figure 6-4: Sensitivity analysis: computation of the relative closeness to the ideal solution

6.5.2.3 Conclusion

This chapter presented the last step in the pilotage risk/safety management process, i.e. risk mitigation measures identification and evaluation. Selecting the optimal risk mitigation measures is considered to be an important step in mitigating maritime pilotage related risks. In this research, instead of identifying the relevant mitigation measures based on the literature review, the current implemented measures were identified through the existing regulation, rules, and recommendations adopted by the IMO and other organizations and via experts' perspectives. And then a risk mitigation measures questionnaire survey was used to rank the importance of the identified measures.

Mitigation of human related risk factor and determining an appropriate selection of RMMs in pilotage operations by taking subjective judgments of decision makers into consideration, is a complex subject involving vagueness and uncertainty in the decision-making process. Therefore, a novel integrated AHP and TOPSIS model is proposed to select the optimal mitigation measures in relation to the most significant risk factors in this chapter. An AHP method is used to determine the weight of each HCF derived from a previous chapter. Then a TOPSIS method is employed to determine the ranking of the RMMs.

The mechanism of the TOPSIS method was to analyse five experts' subjective judgments. It is an appropriate instrument to help MCDM under uncertain environment where the available data is subjective and vague. Moreover, these measures consider all potential risks and the effectiveness of individual measures in mitigating these risks. It provides a practical decision support tool for taking explicit account of multiple types of risk in assisting decision-making and compares as well as ranks alternative measures in an indicator basis individually. By using the method proposed and presented in this chapter, decision makers can select the ideal solutions or alternatives (i.e. mitigation measures).

The measures A21, A3, A5, A19, A6, A9, A4, A20, A10, A1, A8, and A11 were selected according to their overall priorities by experts as the best solutions for mitigating the human-related risk factors contributing to pilotage accidents, and the most optimal measures for performance improvement of pilotage operations and should, therefore, be recommended as the top measures to implement, for improving pilotage operations' safety performance and mitigating the human-related risk factors contributing to pilotage accidents.

The proposed model provides a reliable means of determining an appropriate selection of RMMs. Additionally, the innovative proposed model has been demonstrated by a case study and partially validated using a sensitivity analysis. The significance of the proposed model is that it could assist decision makers to determine an ideal RMMs in terms of overcoming the root cause of an incident/accident effectively. As a result, preventive measures can be taken to reduce human errors within pilotage environments, efficiently preventing or at least mitigating the risk of a similar incident/accident occurring in the future.

The use of TOPSIS in this Chapter will enable the incorporation of additional criteria such as costs of the alternatives into the selection decision in future. The contributions made on this thesis and the areas of future work will be discussed in the next chapter.

CHAPTER SEVEN - CONCLUSIONS

7.1 SUMMARY

In the previous chapters, the various technical models involved in the development of the human error quantification in pilotage operations have been outlined in detail. As a whole, the research has provided a comprehensive a new conceptual decision making framework in order to provide an effective risk factors assessment tool, and offer a diagnostic instrument to reduce the human error, and enhance the maritime pilotage safety performance. This concluding chapter briefly summarises overall results and the findings of this research, it also introduces the themes for which further efforts are required in order to improve the developed subject matter in the research. The chapter highlights determined research objectives and research questions, and it is followed by a description of the contribution to the established knowledge and its practical implications. Finally, this chapter finishes with a discussion of research limitations and recommendations for further research.

7.2 RESEARCH FINDINGS

In this study to address the gaps, research questions for this study were developed. To answer the questions, a multi-methodology approach involving comprehensive literature review, questionnaire survey, and semi-structured interviews were adopted. Research question 1 was concerned with the developed appropriate frameworks to identify and classify the human related risk factors contributing to pilotage accidents, research questions 2, and 3 were concerned with a proposed novel conceptual framework which presents a mixed methodology (i.e. hybrid approach) that uses different decision making approaches for human related risk assessment, whereas research question 4 focused on risk mitigation. The proposed models are validated using case studies in some of the major ports and pilotage areas of the UK and Mediterranean from different marine experts' perspectives. A summary of the research outputs specific to each question are demonstrated as follows:

i) The first objective of this study was to develop a comprehensive human factor related risk identification and classification model within the context of the maritime pilotage operations. As has been mentioned previously, the procedure for risk factors identification is one of the most significant steps in the pilotage safety/risk management process. Risk identification enables decision-makers to classify, evaluate, and mitigate the contributory causal factors that can lead to maritime accidents during pilotage operations. As a result, in this research by using the human factor identification process, it was possible to evaluate and mitigate threats that influence maritime pilotage operations' safety performance.

This research would not be limited only to identifying the root causes of an incident/accident that are already known. The investigation provided a complete solution for the potential causes which may lead to accidents in the future but have not happened yet, taking into consideration the ones which have previously occurred. To ensure that all the risk factors are identified, human related risk factors identification was carried out by using more than one method. In this thesis, the author identifies a list of risk factors initially through a literature review. In addition, to determine the existing root causes that play a central role in the causal chain of maritime pilotage accidents, an analysis of a considerable number of worldwide marine accident investigation reports relating to vessels under pilotage operations were reviewed and examined.

Moreover, an empirical study has been conducted, interviews, and survey questionnaires with professional marine experts were carried out through which it was be possible to validate the existing risk factors and explore the other potential risk factors which may influence operators' performance and contribute to pilotage accidents in the future. The human causal factors (HCFs) are identified and classified into five group main factors and each one is divided into sub-factors. An initial structural hierarchy risk taxonomic diagram is developed, and then validated by experienced experts from the maritime sector.

ii) In this research a novel technique for HCFs evaluation was introduced. The proposed methodology fills the gaps and overcomes the shortcomings of the previous traditional assessment methods, which disregard the rank and evaluate the relative weight and the causal relationships among the human-related risk factors. As a result, this research adopts a mixed methodology (i.e. hybrid approach) MCDM methods AHP and DEMATEL as a data analysis technique. Applying a mixed approach that uses different techniques in the same study can offset weaknesses in each.

In this research Analytical Hierarchy Process (AHP) is applied to determine the relative weights and rank the importance of the human factors that affect pilotage operation safety, while the Decision Making Trial and Evaluation Laboratory (DEMATEL) method is applied to identify whether there are relationships among these factors. By using the hybrid approach of two methodologies AHP and DEMATEL methods, it was possible to determine the most significant human factors that affect pilotage operation safety, and identify the relationships among these factors and determine which factors have influence on the other factors to be managed and controlled.

The empirical results indicate that the hybrid approaches, attempting to use quantitative modelling for dealing with the uncertain working environments and dependency and interdependency problems for facilitating the quantification analysis of human factors in maritime pilotage operations can be successfully fulfilled. The hybrid methodology has proven to be a sound approach in dealing with MCDM problems under uncertainty which the previous studies have done little with on the measurement of maritime pilotage operations human related risk factors.

iii) In this thesis, after the pilotage related risks factors were identified and assessed in order to manage and control these risks factors, a generic framework for determining and evaluating the implemented risk mitigation measures is developed. The implemented risk mitigation measures (RMMs) are identified by employing multiple sources for data collection in order to extract the most appropriate risk mitigation measures that can reflect the current situation for further evaluation, including a careful literature review, rules and regulations adopted by maritime authorities.

In addition, in order to explore other mitigation measures that have not been mentioned in the literature and other documentation, questionnaire surveys were conducted with experienced marine experts from the UK and Mideterainean maritime domain. Finally, twenty-one risk mitigation measures (RMMs) were identified. Afterwards, in order to obtain feasible alternatives (RMMs/RCOs), the identified risk mitigation measures are prioritized and selected over the previous ranked risk factors using an appropriate

MCDM tool a TOPSIS method. The proposed model has been demonstrated through a case study and validated using a sensitivity analysis. The analysis results indicate that measures, A21, A3, A5, A19, A6, A9, A4, A20, A10, A1, A8, and A11 have the highest ranking among the alternative mitigation measures and should, therefore, be recommended. They are considered as the top risk mitigation measures that can ensure optimal operations of the pilotage operations and must be implemented.

7.3 CONTRIBUTION TO THE FIELD

According to the literature review, there are a small number of studies specifically focused on the human factor risk assessment, especially in pilotage operations. Nevertheless, the findings of the literature review reveal that the current human factor related risk analysis models are not capable of meeting challenges faced by maritime stakeholders. Findings from the literature have revealed that there are few human-related risk factors measurement frameworks in the pilotage and port industry. There is a distinct need for a new human-related risk factors measurement tool not only to meet the need of port stakeholders but also to develop diagnostic instruments to port and pilotage systems capable of supporting decision-making in solving complex pilotage operations problems in an uncertain environment.

Thus, this thesis has developed a comprehensive human-related risk factors measurement framework, that provides significant insights into how human-related risks in the pilotage operations area can be understood and how organizations and stakeholders involved in the maritime industry can effectively manage these risks. Specifically, this research is the first study to provide an integrated maritime pilotage risk management framework, by using both qualitative and quantitative techniques for risk factors identification, assessment, and mitigation in the maritime pilotage operations area.

The contribution mentioned above is made by identifying, assessing, and controlling the most significant HCFs in maritime pilotage operations. The framework provides an integrated approach to increase the safety and reliability of maritime pilotage operations. Also, given the dynamic nature of the complex system of pilotage operation, it provides an efficient safety prediction tool that can ease all the processes in the methods and techniques used with the risk management framework.

The proposed innovative framework provides an effective pilotage risk/safety assessment tool and offers a diagnostic instrument to help implement effective risk reduction strategies, in order to prevent or at least mitigate a human error incident/accident from occurring. The research has thus established essential findings and suggestions on risk management that will be valuable to the decision-making process in the offshore, port, and marine industry. The research has added to the frontier of knowledge in a way that has not been done before, by concentrating on the maritime pilotage operations to overcome the present limited nature of similar research in the maritime industry.

The novelty of the proposed framework lies in the fact that it incorporates the AHP, DEMATEL model, and TOPSIS as an integrated methodology, enabling the specific decision maker's preferences to be considered in making the strategic decision on a human factor related risk and safety basis, linked to pilotage operations. They have been developed for academic implications to deal with various problems and issues in an uncertain port and pilotage environment. Additionally, this research makes practical contributions by conducting empirical studies in important ports and pilotage operation areas in both the UK and the Mediterranean, in order to support a resource-effective and time-efficient decision-making tool for managers.

Academic implications

The frameworks use several decision making tools and procedures. The methods and techniques are demonstrated as follows:

Firstly, a new database of maritime related human factors has been identified. The research was not limited to only identifying the root causes of an incident/accident that are already known. The investigation provided a complete solution for the potential causes which may lead to accidents in the future but have not happened yet, taking into consideration the ones which have previously occurred. Therefore, decision-makers can evaluate the current status of their risk management efforts with the risk mitigation measures and practices suggested in this research. The last establishes a new database on human causal factors that contribute to maritime pilotage accidents, which can assist in implementing effective risk reduction strategies to mitigate operator errors during pilotage operations, and can also assist in evaluating and determining appropriate preventive measures against future accidents

Secondly, the wider scope of pilotage operations human related risks has been assessed. The risk assessment step provides a useful tool by developing advanced risk assessment based models under high uncertainties for pilotage operations, using both quantitative and qualitative data. The research has introduced a new hybrid approach to evaluate human related risk factors, using a combined AHP and DEMATEL approach, currently lacking in the maritime pilotage operations field. This last also assists in overcoming the existing delusion of assuming that the HCFs are all of equal importance and independent of each other, which in fact is not the case. The two methods with different disciplines represent a new measurement method to address the challenges in pilotage risk factor measurement. Also, the framework for modelling HCFs dependent of weights and interdependency among factors is a novelty in maritime pilotage operations.

The methodologies above facilitate the decision-making process by identifying the importance of the human factors influencing the safety of maritime pilotage operations, and provide a comprehensive illustration of relationships among the factors and also offer an insightful understanding of the mutual influence among the risk factors to be managed. Additionally, the proposed model also facilitates dealing with the limitation of the availability of data in the maritime domain, and the uncertainty and complexity that exist in the quantitative analysis of human factors.

The developed hybrid approach could help reduce the existing gap left in human factor research studies, in terms of evaluating the relative importance of pilotage human related risk factors and determining the causal relationships among them. Furthermore, the proposed model can be tailored to recognise and incorporate the relationships and interdependencies among human factor variables, involved in other transportation systems and industrial fields.

Thirdly, this research has proposed an innovative TOPSIS model to select an appropriate RMMs. The significance of applying TOPSIS method in this research is that the approach has carried out an empirical work that has not been done before, and during the selecting of the risk mitigations measures (RMMs), the proposed approach has looked into the risk factors that researchers in the discipline have not looked at before.

Fourthly, the proposed framework provides a platform to facilitate a generic risk-based method. Furthermore, the methodology is an objective way to handle subjective information in establishing a risk analysis to guide the development of risk control measures.

Finally, similar framework can be utilised for transportation systems and other industrial fields, by modifying causal diagram and classification schemes of factors to suit the industry concerned, and enhance human error and human reliability data in the related fields.

Practical implications

The application of the frameworks proposed in this study is particular useful in dealing with the following issues.

The empirical investigations in the UK and the Mediterranean ports herein are conducted to demonstrate the feasibility of the proposed frameworks. The results obtained provide both ships' operators and port authorities with valuable insights, as this framework allows them to:

1. Recognise the human related risks affecting the safety of port and maritime pilotage operations.
2. Better understand the conditions and status of their operators' performance
3. Improve competitiveness and customers' satisfaction by improving the operators' skills and increase the safety and reliability of maritime pilotage operations performance.
4. Find optimal strategies and choose optimal risk mitigation measures, which is deemed to be an important and necessary step in the improvement of pilotage operations safety performance and maritime accidents mitigation.
5. The DEMATEL outputs help decision makers to understand how human factors affect each other and therefore, how they affect the operator's ability to achieve their tasks effectively. A better understanding of the relationships among the human factor variables involved in causing an incident/accident can facilitate a reduction in human error. Thus, utilization of AHP and DEMATEL methods can help the stakeholders and companies' management in several areas; specifically to know on which factor they need to concentrate the most, and also what knowledge/skills have to be improved by the operators.

6. This study can help relevant stakeholders, such as port authorities and shipping companies, in the development of better policies, safety guidelines, and risk control measures to improve performance of operators and improve the safety of maritime pilotage operations.
7. The implemented framework provides a logical and organised procedure to guide industrial risk management professionals such as port stakeholders, pilotage risk managers, and etcetera, through a series of well-defined structured phases and steps necessary to make knowledgeable, reliable, and efficient changes to the pilotage operations processes in ports and the marine industry.

7.4 RESEARCH LIMITATIONS

Developing a risk management framework with uncertainty treatment based decision making analysis methodology to identify, assess, and mitigate the human related risk factors affecting the pilotage operations has achieved the aim of this research. Although the research attempts to provide a comprehensive analysis using risk/safety management based methodologies including many approaches and techniques to facilitate the quantitative and qualitative data in maritime pilotage operations, this study has several limitations due to scope and time constraints. In this regard, the aspects that were not covered in detail are part of the suggestions that would be desirable for further investigations in future work as follows.

In this study, the secondary data have been retrieved mainly from little research literature and accident investigation reports due to the limited research focused on pilotage operation risk management to date. Additionally, the confidential nature of the ports and maritime industry when conducting the empirical studies highlights the difficulty of gathering primary and secondary data.

The size of the sample was limited due to the time constraints, and the size of the questionnaire survey, which mostly required a pair-wise comparison between each factor. In addition, sample selection is limited to specific professional roles. Most participants involved in this research either have abundant knowledge in academia or rich practical experience in the field or hold a position at or above the manager level in practitioner fields. Therefore, a further limitation of the research is reflected in the size of the sample.

Furthermore, another factor that needs to be considered is the length of the interview. In this study, the interview questions were designed to limit interviews to one hour or less (interviewing time), but some participants might have thought that there were too many questions and these feelings would have negatively affected their attitudes toward the questions. Moreover, in this study, the empirical investigations were conducted only in some major ports in the UK and Mediterranean due to the cost and time constraints

In addition, the proposed integrated model is highly dependent on the respondents' knowledge, experience, and attitude that might lead to the subjective bias. For instance, respondents and their attitudes or perceptions might be affected by the surrounding environment in which they participated in the survey. The unexpected factors, such as personal issues, or other external factors might have impacts on their attitudes.

7.5 RECOMMENDATION AND FUTURE RESEARCH

Based on the results of this study, some future research directions and areas that can be further developed are as follows:

i). Further studies involving a wider selection of experts from different pilotage regions/areas would strengthen the validity of finding. For HCFs weights assignment, this study used the judgement of fewer than 10 experts. The weights of HCFs can be changed when more experts take part in the judgement, which may lead to a more accurate result. In addition, when using more experts from different stakeholders, the important difference between different stakeholder groups can be analysed. Hence, a future study should gather multiple responses from each stakeholder. Furthermore, further empirical study in different regions/areas can be carried out to identify the best practices/solutions of the pilotage safety performers.

ii). Although the most important human causal factors contributing to pilotage accidents are determined in this study, more research studies can be carried out to develop the present classification schemes, by including organisational factors, policy implications, and natural and political issues that may affect the pilotage operations safety.

iii). As any strategic implementation requires substantial investments, the decision to adopt appropriate risk management mitigation measures requires a trade-off between the benefits and costs involved. More work can be carried out to develop the present TOPSIS method and further research can cover the cost and benefit analysis to support significant strategic decisions on pilotage performance safety

v). This study used the DEMATEL model to evaluate the causal relationships among the human causal factors contributing to pilotage accidents, further study to develop the proposed approach using a DEMATEL model can be made by incorporating an analytic network process (ANP) technique. An ANP can be used to determine interdependent weights of the human causal factors that play important roles in causing an incident/accident.

vi). Many types of risk factors and alternatives existing in the pilotage operations, are not considered as they are less significant; nonetheless, they should be of concern. Therefore, it would be more comprehensive to consider all kinds of risks and mitigation measures in the structural model so that more complete results could be obtained.

vii).The development of shipping management resulted in an increased number of maritime based training and research simulators. Simulator based studies can be conducted to perform qualitative and quantitative analyses of human-related risk factors. The proposed framework can be designed as computer software and used in maritime simulators for pilotage performance improvement purposes.

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LIST OF APPENDICES

Appendix I: QUESTIONNAIR PARTICIPANT CONSENT FORM

School of Engineering, Technology and Maritime Operations

Liverpool John Moores University

Byrom Street

L3 3AF UK

Title of Project: The impact of human factors on safety of pilotage operations of pilotage operations

I confirm that I have read and understand the information provided for the above study.

I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights.

I understand that any personal information collected during the study will be anonymised and remain confidential.

I agree to take part in the above interview study.

Name of Participant Date Signature

Name of Researcher Date Signature

Appendix II.1: The Questionnaire used for (HCFs) identification in Chapter 4

Liverpool John Moores University

School of Engineering, Technology and

Maritime Operations

Byrom Street

L3 3AF UK

To: Whom it may concern

A research project at Liverpool John Moores University is currently being carried out with regard to the impact of human factors on maritime pilotage operations. I will be most grateful if you could kindly spend your valuable time and take part in this study. Your participation in this survey is voluntary and will only take a few minutes. All the information that you provide in the course of your interview, completion of questionnaires or in general discussion will be greatly benefit and contribute to achieve the aim of this project. The information gathered in this survey will be treated in the strictest confidence.

The questionnaire is anonymous, thus your response can not be attributed to you or your organization. Any refusal or incomplete questionnaire will be excluded without any responsibility on the participant. Completion of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have any questions about this study, please feel free to contact me either by email or by phone at the addresses listed below.

Yours faithfully,

H. Oraith,

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Section A: Introduction

Identification of the relevant pilotage operations related risk factors is the vital step for employing efficient risk management in the maritime industry. The objective of this study is to identify the human factors contributing to pilotage accidents.

The analysis of the past marine accident investigation reports showed that the main cause of the occurred accidents during pilotage operations were the human factor. For this reason, in this part of questionnaire, questions were designed to verify the extent to which of the aforementioned factors contribute to maritime accidents.

Section B: Respondent Profile

Q1. What is your job title? Please indicate your rank?

Q2. For how many years have you worked in maritime industry?

Q3. Please can you outline a bit of your background?

Section: C Identification of human factors influencing the safety of pilotage operations.

Based on the findings of the previous studies, the following human factors shown in the below table (table 1) are considered contributory factors leading to pilotage accidents. Therefore, these factors need to be evaluated by using a five point Likert scale method.

Table.1 contributory human factors to maritime pilotage accidents

Human factors affecting safety performance of pilotage operations
1. Failure to establish a proper manoeuvring plan prior to piloting vessel (RF1) 2. Stress (RF2) 3. Failure to exchange the information (RF3) 4. Lack of situation awareness (RF4) 5. Distraction (RF5) 6. Lack of effective communication and language barriers (RF6) 7. Lack of bridge navigation equipment knowledge (RF7) 8. Mental and physical work load (RF8) 9. Pilot boarding and disembarking too close to breakwater (RF9) 10. Piloting ships in poor weather condition or navigating vessels outside published guidelines or limits draft (RF10) 11. Lack of team work (RF11) 12. Fatigue (RF12)

EXPLANATIONS AND EXAMPLE

Example 1. How strongly do you agree with the statement that the fatigue is a significant factor that contributing to the occurrence of maritime accidents during pilotage operations?

Explanation of the above example

The procedures and guidelines for answering this set of questionnaires are explained as follows:

In this part of questionnaire, participants will be asked to answer the statement using the following 5 point Likert scale: strongly disagree; disagree; neither agree nor disagree; agree; and strongly agree.

Firstly before to proceed with the evaluating, an expert has to understand the ratio scale measurement used in this study. Table 2 below describe the numerical assessment together with the linguistic meaning of each rating variable. The grades illustrated in Table 2 show the effect or importance value of the risk factors. It is used for evaluating and rating of the importance of the risk factors shown in table1. An expert is required to look at the measures. Subsequently fill the empty spaces by selecting the appropriate grades from Table 2

Table 2: Five point Likert scale

Linguistic variables	Strongly disagree	disagree	neither agree nor disagree	agree	Strongly agree
score	1	2	3	4	5

An expert is required to give a possible judgment to question based on his/her expertise and experience in the shipping industry. For instance: if the expert believe that the fatigue is significant factor and contribute to the occurrence of maritime accidents during pilotage operations and strongly agree with this statement then he will tick (/) on the given table (see table 3).

Table 3. Example for selecting the factors

Risk factors	Strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Fatigue	☐	☐	☐	☐	☑

Questionnaire

In this part of questionnaire as shown in the below table, questions were designed to verify the extent to which of the aforementioned twelve factors contribute to maritime accidents.

Statements were made and participants are required to answer each statement using the 5 point Likert scale as illustrated in the example table (table 3): strongly disagree; disagree; neither agree nor disagree; agree; and strongly agree.

An expert is required to give a possible judgement to all questions based on his/her expertise and experience in pilotage operation

Q1: Please refer table 1 before answering the questionnaire. For your opinion as an expert, how strongly do you agree with the statements shown in the below table? Please kindly give your comments and select the appropriate grade from Table 2.

Table 4. Potential risk factors affecting safety performance of pilotage operations

Risk factors	Strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
RF1	☐	☐	☐	☐	☐
RF2	☐	☐	☐	☐	☐
RF3	☐	☐	☐	☐	☐
RF4	☐	☐	☐	☐	☐
RF5	☐	☐	☐	☐	☐
RF6	☐	☐	☐	☐	☐
RF7	☐	☐	☐	☐	☐
RF8	☐	☐	☐	☐	☐
RF9	☐	☐	☐	☐	☐
RF10	☐	☐	☐	☐	☐
RF11	☐	☐	☐	☐	☐
RF12	☐	☐	☐	☐	☐

Q2. Have you had any issues or incidents in the past affected the safety of the ship piloting.

Q3. From your experience do you know any additional causal factors that might affect pilotage operations performance?

THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY

Appendix II.2 List of Semi-structured Interview Questions for the purpose of Chapter four

The interviewer will ask questions where necessary to help to understand.

If the interviewer thinks something is particularly important he will ask questions for more information.

Interviewer probes as required.

Q. What is your job title? Please indicate your rank?

Q. For how many years have you worked in maritime industry?

Q. Please can you outline a bit of your background?

Q. How far do you agree with statements listed in the questionnaire?

Q. What are your views on human element factors that impact on safety during pilotage operations? Is there anything else you would like to add about human element factors?

Q. What kind of mistakes could be made by ship crew members or pilots, and tugs assistance during pilotage and ship berthing?

Q. Have you had any issues or incidents in the past affected the safety performance of the pilotage operations?

Q. How do you think if someone with less experience (e.g. ship's crew members, pilots, and tugs' operators? Can you think of any problems that would have happened or they might have encountered?

Q. In your point of view do you think that the good skills in English language is helpful during pilotage operations to avoid accidents?

Q. In your point of view do you think that the new technology is helpful during pilotage operations to avoid collisions and grounding? Explain why?

Q. Do you think that poor knowledge in the use of navigational aids such as AIS, ARPA, and ECDIS effect pilotage operation? Explain why?

Q. Do you think IMO regulations are sufficient and has successfully addressed the human element and pilotage issues?

Q. In your opinion what are the reasons that could lead pilots and ships' staff making errors in spite of existing the rules and regulations adopted by IMO?

Appendix II.3: Questionnaire used for (HCFs) classification in Chapter 4

Section A: Introduction

Based on the research, the purpose categorizing the human factor related risks in pilotage operations into five main categories: 1) Bridge team management failure (F1); 2) Technical skills shortcoming (F2); 3） Instructions and orders failure (F3); 4) Rules and regulations noncompliance (F4), and 5) The Individual- task interaction factors (F5), and each one is divided into sub-factors. That is, the most contributory causal human factors of maritime pilotage accidents. The sub-factors are sub criteria which are, F1: (F11, F12, F13, F14 and F15), F2: (F21, F22, F23, and F24), F3: (F31, F32, F33, and F34), F4: (F41, F42, F43, and F44), and F5: (F51, F52, F53, and F54). (See the table below).

The list of causal factors contributing to maritime accidents in pilotage operations

Main factors	Sub-factors
Non-Technical skills (Bridge team management failure) (F1)	Lack of team work (Poor bridge team-pilot integration, cooperation, and coordination,) (F11)
	lack of effective communication and language problems (F12)
	Failure to exchange the information between pilot and ship's master prior to pilotage operation (F13)
	Lack of situation awareness (F14)
	The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats, and shore mooring personnel performance and vessel's progress (F15)
Technical skills shortcoming(F2)	Lack of ship handling skills due to lack of improper training and experience, (F21)
	Lack of familiarity with the electronic navigational equipment knowledge (F22)
	Lack of skills of the crewmember on ship board, tugs, and shore mooring personnel (F23)
	Improper/ inadequate use of tugs (F24)
Instructions and orders failure (F3)	Failure of pilot to give precise instructions (F31)
	Failure of the ship's master to correctly follow the pilot directions (F32).
	Failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power (F33)

	Orders regarding anchoring, steering, and engine requests, are not following out by ship's crewmembers correctly(F34)
Rules and regulations noncompliance (F4)	Failure to establish a proper manoeuvring plan prior to piloting vessel (F41).
	Failure to proceed with safe speed as stipulated in COLREG (F42)
	Piloting ships in bad weather condition or navigating vessels outside published guidelines or limits draft due to subject to commercial pressure (F43)
	Poor boarding arrangements (e.g., pilot boarding and disembarking too close to breakwater (F44)
Individual- task interaction factors (F5)	Fatigue (F51)
	Mental and physical work load (F52)
	Distraction and simultaneous tasks during the time of berthing operations (F53)
	Stress (F54)

Section B: Questionnaire

The following questions are related to modifying and further validating the identified risk factors in the pilotage operations. The main question is to classify the factors which can represent their associated main factors (categories) and sub factors and the questions are: Do you think the main group factors (categories) and their sub-factors are well classified?", and if necessary, modification, removal, division and combination are allowable

1. Risk element category (F1): Bridge team management failure (Lack of non-Technical skills)

Identified Risk Factors	Yes	No	Any comments
Lack of team work (F11)			
lack of effective communication and Language problems (12)			
Failure to exchange the information between pilot and ship's master (F13)			
Lack of situation awareness (F14)			
The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats and shore mooring personnel performance and vessel's progress (F15)			
Any other elements should be considered?			

Considering the above structure, elements contributing to risks associated with Lack of non-technical skills (Bridge team management failure) (F1) are categorized into "Lack of team work", "Language problems and lack of effective communication", "Failure to exchange the information between pilot and ship's master", "Lack of situation awareness", and "The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats, and shore mooring personnel performance and vessel's progress". Do you think this categorization is appropriate?

2. Risk element category (F2): Technical skills shortcoming

Sub-factors	Yes	No	Any comments
Lack of ship handling skills due to lack of experience, improper training, and attitude (F21)			
Lack of familiarity with the electronic navigational equipment knowledge (F22)			
Lack of skills of the crewmember on ship board, tugs, and shore mooring personnel (F23)			
Improper/ inadequate use of tugs (F24)			
Any other elements should be considered?			

Considering the above structure, elements contributing to risks associated with Technical skills shortcoming (F2) are categorized into “Lack of ship handling skills due to lack of experience, improper training, and attitude”, “Lack of familiarity with the electronic navigational equipment knowledge”, “Lack of skills of the crewmember on ship board, tugs, and shore mooring personnel”, and “Improper/ inadequate use of tugs”,. Do you think this categorization is appropriate?

3. Risk element category (F3): Instructions and orders failure

Sub-factors	Yes	No	Any comments
Failure of pilot to give precise instructions (F31)			
Failure of the ship's master to correctly follow the pilot directions (F32).			
Failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power (F33)			
Orders regarding anchoring, steering, and engine requests, are not following out by ship's crewmembers correctly (F34)			
Any other elements should be considered?			

Considering the above structure, elements contributing to risks associated with Instructions and orders failure (F3) are categorized into "Failure of pilot to give precise instructions, Failure of the ship's master to correctly follow the pilot directions", "Failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power", "Orders regarding anchoring, steering, and engine requests, are not following out by ship's crewmembers correctly". Do you think this categorization is appropriate?

4. Risk element category (F4): Rules and regulations noncompliance

Sub-factors	Yes	No	Any comments
Failure to establish a proper manoeuvring plan prior to piloting vessel (F41).			
Failure to proceed with safe speed as stipulated in COLREG (F42)			
Piloting ships in bad weather condition or navigating vessels outside published guidelines or limits draft due to subject to commercial pressure (F43)			
Poor boarding arrangements (e.g., pilot boarding and disembarking too close to breakwater (F44)			
Any other elements should be considered?			

Considering the above structure, elements contributing to risks associated with Rules and regulations noncompliance (F4) are categorized into "Failure to establish a proper manoeuvring plan prior to piloting vessel", "Failure to proceed with safe speed as stipulated in COLREG", "Piloting ships in bad weather condition or navigating vessels outside published guidelines or limits draft due to subject to commercial pressure", and "Poor boarding arrangements (e.g., pilot boarding and disembarking too close to breakwater ". Do you think this categorization is appropriate?

5. Risk element category (F5): Individual- task interaction factors

Sub-factors	Yes	No	Any comments
Fatigue (F51)			
Mental and physical work load (F52)			
Distraction and simultaneous tasks during the time of berthing operations (F53)			
Stress (F54)			
Any other elements should be considered?			

Considering the above structure, elements contributing to risks associated with Individual- task interaction factors (F5) are categorized into “Fatigue”, “Mental and physical work load”, “Distraction and simultaneous tasks during the time of berthing operations ”, and “Stress”. Do you think this categorization is appropriate?

Appendix III-1: The Questionnaire used for AHP Technique in Chapter 5

Liverpool John Moores University

School of Engineering, Technology and

Maritime Operations

Byrom Street

L3 3AF UK

To: Whom it may concern

A research project at Liverpool John Moores University is currently being carried out with regard to the impact of human factors on maritime pilotage operations. I will be most grateful if you could kindly spend your valuable time and take part in this study. Your participation in this survey is voluntary and will only take a few minutes. All the information that you provide in the course of your interview, completion of questionnaires or in general discussion will be greatly benefit and contribute to achieve the aim of this project. The information gathered in this survey will be treated in the strictest confidence.

The questionnaire is anonymous, thus your response can not be attributed to you or your organization. Any refusal or incomplete questionnaire will be excluded without any responsibility on the participant. Completion of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have any questions about this study, please feel free to contact me either by email or by phone at the addresses listed below.

Yours faithfully,

H. Oraith,

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Room 121, James Parsons Building

Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, UK

Introduction

Based on literature review and accident investigation reports, taxonomy including the factors influencing marine pilotage operations safety and causing accidents as shown in table1. 1, are illustrated. The goal of this study is to select the most important factor that contributing to the occurrence of maritime accidents during pilotage operations. These factors are considered to affecting the safety of the pilotage operations. Therefore, the factors and sub-factors listed in Table1.1 are the parameters that need to be evaluated by using a “Pair-wise Comparisons” technique. The pairwise comparison between the factors will be conducted using the Analytical Hierarchy Process (AHP) approach to analyse the relative importance for each different factor.

Table 1. 1: The hierarchy for the contributory causal factors of pilotage accidents (HCFs)

Factors			Sub-factors		
1	F1	**Bridge team management failure (Non-technical skills shortcoming)**	F11	Lack of team work (F11)	1
			F12	Lack of effective communication and language barriers	2
			F13	Failure to exchange the information	3
			F14	Lack of situation awareness	4
			F15	The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats, and shore mooring personnel performance and vessel's progress	5
2	F2	**(Technical skills shortcoming)**	F21	Lack of ship handling skills due to improper training and lack of experience.	6
			F22	Lack of familiarity with the electronic navigational equipment knowledge	7
			F23	Lack of skills of the crewmember onboard ship, tugs, and shore mooring personnel.	8
			F24	Improper/ inadequate use of tugs.	9
3	F3	**Instructions and orders failure**	F31	Failure of pilot to give precise instructions.	10
			F32	Failure of the ship's master to correctly follow the pilot directions.	11

			F33	Failure of tug's masters to carry out the pilot's instructions precisely.	12
			F34	Orders regarding anchoring, steering, and engine requests, are not following out by ship's crewmembers correctly.	13
4	F4	**Rules and regulations noncompliance**	F41	Failure to establish a proper manoeuvring plan prior to piloting vessel.	14
			F42	Failure to proceed with safe speed as stipulated in COLREG	15
			F43	Piloting ships in bad weather condition or navigating vessels outside published guidelines or draft limits.	16
			F44	Poor boarding arrangements (e.g., pilot boarding and disembarking too close to breakwater)	17
5	F5	**Individual- task interaction factors**	F51	Fatigue.	18
			F52	Mental and physical workload.	29
			F53	Distraction during the time of berthing operations	20
			F54	Stress	21

1.1. **The procedures and guidelines for answering this set of questionnaires are explained as follows:**

1. Pair-wise comparison

In this questionnaire there will be two type of pair-wise comparison.

There will be an example at the beginning of the questionnaire showing how the questionnaire must be filled. There will also be a scale of importance at the beginning of each questionnaire.

The first questionnaire is: Pair-wise comparison between the main five factors (F1, F2, F3, F4, and F5). Then the second questionnaire is: Pair-wise comparison between the sub-factors, which are**,** F1: (F11, F12, F13, F14 and F15), F2: (F21, F22, F23, and F24), F3: (F31, F32, F33, and F34), F4: (F41, F42, F43, and F44), and F5: (F51, F52, F53, and F54).

Before proceeding with the “Pair-wise Comparisons” technique, an expert has to understand the ratio scale measurement used in this study. The table 1.2 below describe the numerical assessment together with the linguistic meaning of each number**.** It’s used for comparing factors with each other. Importance is rated from 1 to 9, the fundamental scale of values (Saaty 2001).

Table 1. 2 Scale of importance

Intensity of importance	Definition
1	Same importance
2	Slightly more important
3	Weakly more important
4	Weakly to moderately more important
5	Moderately more important
6	Moderately to strongly more important
7	Strongly more important
8	Greatly more important
9	Absolutely more important

An expert is required to give a possible judgment to all questions based on his/her expertise and experience in the shipping industry.

To select the most important factor that contributing to the occurrence of maritime accidents during pilotage operations. The expert will be asked to underline accordingly the rate of importance of each factor and sub-factor in the given column. For instance: only one number either on the right or the left of the scale for every comparison as shown in the example at the beginning of questionnaire survey.

1.1 Example of pair-wise comparison of the main factors.

Please refer table1.1 before answering the questionnaire, in order to evaluate the importance of each factor. For instances to compare between the (bridge team management factor), and the factor of (technical skills) you should see to the table 1.2 before you judge and evaluate the rate of importance.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the factor of the bridge team management (F1) compared to technical skills shortcoming factor (F2)?

Could you please fill the questionnaire/ table here under by underlining the appropriate number refer to the factors in table1. 1, and to the scale of importance table1. 2, before answering the questionnaire

If you think bridge team management failure factor (F1) is **moderately more important** than technical skills shortcoming factor (F2) **in** contributing **to the occurrence of maritime accidents during pilotage operations,** then please underline as follows:

Factor	Intensity of relative importance																	Factor
Bridge team management (F1)	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	Technical skills (F2)

If you think technical skills shortcoming factor (F2) is **moderately more important** than bridge team management failure factor (F1) in contributing to the occurrence of maritime accidents during pilotage operations, then please underline as follows:

Factor	Intensity of relative importance																	Factor
Bridge team management failure (F1)	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	Technical skills shortcoming (F2)

If you think bridge team management failure factor (F1) and technical skills shortcoming factor (F2) **are the same important** in contributing to the occurrence of maritime accidents during pilotage operations, then please underline as follows:

Factor	Intensity of relative importance																	Factor
Bridge team management failure (F1)	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	Technical skills shortcoming (F2)

1.2 The first part of the questionnaire is: Pair-wise comparison between the main five factors (F1, F2, F3, F4, and F5).

1. Bridge team management failure (F1)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and table1.2, scale of importance before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the factor bridge team management failure (F1), compared to the other group factors?

Factor	Intensity of relative importance																	Factor
(F1)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F2)
(F2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F3)
(F3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F4)
(F4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F5)

2. Technical skills shortcoming (F2)

Could you please fill the questionnaire/ table hereunder by underlining the appropriate number (See exampl1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the factor of the technical skills shortcoming (F2), compared to the other factors?

Factor	Intensity of relative importance																	Factor
(F2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F3)
(F2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F4)
(F2)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F5)

3. Instructions and orders failure (F3)

Could you please fill the questionnaire/ table hereunder by underlining the appropriate number (See table 1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire. To select the most important factor that influence the safety of pilotage operations

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the factor of the Instructions and orders failure (F3), compared to the other factors?

Factor	Intensity of relative importance																	Factor
(F3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	((F4)
(F3)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F5)

4. Rules and regulations noncompliance (F4)

Could you please fill the questionnaire/ table hereunder by underlining the appropriate number (See table 1.1), and refer to the factors in table1.1, and table1.2, scale of importance before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the factor of the rules and regulations noncompliance (F4) compared to the other factor?

Factor	Intensity of relative importance																	Factor
(F4)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F5)

1.3 The second part of the questionnaire is: Pair-wise comparison between the sub-factors, which are: F1: (F11, F12, F13, F14 and F15), F2: (F21, F22, F23, and F24), F3: (F31, F32, F33, and F34), F4: (F41, F42, F43, and F44), and F5: (F51, F52, F53, and F54).

Group1. Bridge team management failure (Non-technical skills shortcoming) (F1)

1. Lack of team work (Poor bridge team-pilot integration, cooperation, coordination, and close loop) (F11)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See table1.1), and refer to the table1.2, scale of importance before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the factor lack of team work (Poor bridge team-pilot integration, cooperation, coordination, and close loop) (F11), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F11)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F12)
(F11))	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F13)
(F11)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F14)
(F11)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F15)

2. Lack of effective communication and Language barriers (F12)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the Lack of effective communication and language barriers (F12), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F12)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F13)
(F12)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F14)
(F12)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F15)

3. Failure to exchange the information between pilot and ship's master prior to pilotage operation (F13).

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the failure to exchange the information between pilot and ship's master (F13), compared to the other factor?

Sub-factor	Intensity of relative importance																	Sub-factor
(F13)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F14)
(F13)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F15)

4. Lack of situation awareness in the bridge team (F14)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the Poor shared situation awareness in the bridge team (CFA4) compared to the other factor?

Sub-factor	Intensity of relative importance																	Sub-factor
(F14)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F15)

Group 2. Technical skills shortcoming (F2)

1. Lack of ship handling skills due to lack of experience, improper training, and attitude (F21)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the lack of ship handling skills due to Lack of experience, improper training, and attitude (F21), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F21)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F22)
F21)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F23)
(F21)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F24)

2. Lack of technical knowledge and failure to use the bridge navigation equipment such as (RADAR, ECDIS) (the lack of familiarity with the navigational systems) (F22)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the table1.2, scale of importance before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the lack of familiarity with the electronic navigational equipment knowledge (F22), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F22)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F23)
(F22)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F24)

3. Lack of skills of the crewmember on ship board, tugs, and shore mooring personnel (F23)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the lack of skills of the crewmember on ship board, tugs, and shore mooring personnel (F23), compared to the other factor?

Sub-factor	Intensity of relative importance																	Sub-factor
(F23)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F24)

Group 3. Instructions and orders failure (F3)

1. Failure of pilot to give precise instructions (F31)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the failure of pilot to give precise instructions (F31), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F31)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F32).
(F31)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F33)
(F31)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F34)

2. Failure of the ship's master, and/or personnel to correctly follow the pilot directions (e.g. refusal, rejection, intervention by master) (F32)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the failure of the ship's master to correctly follow the pilot directions (e.g. incorrect interpretations, refusal, rejection, intervention by master, etc.) (F32), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F32).	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F33)
(F32).	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F34)

3. Failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power (F33)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power (F33), compared to the other factor?

Sub-factor	Intensity of relative importance																	Sub-factor
(F33)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F34)

Group 4. Rules and regulations noncompliance (F4)

1. Failure to establish a proper manoeuvring plan prior to piloting vessel (F41)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the failure to establish a proper manoeuvring plan prior to piloting vessel (F41), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F41)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F42)
(F41)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F43)
(F41)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F44)

2. Failure to proceed with safe speed as stipulated in COLREG (F42)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the failure to proceed with safe speed as stipulated in COLREG (F42), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F42)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F43)
(F42)																		(F44)

2. Piloting ships in bad weather condition or navigating vessels outside published guidelines or limits draft due to subject to commercial pressure (F43)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the Piloting ships in bad weather condition or navigating vessels outside published guidelines or limits draft due to subject to commercial pressure (F43) compared to the other factor?

Sub-factor	Intensity of relative importance																	Sub-factor
(F43)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F44)

Group 5. Individual- task interaction factors (F5)

1. Fatigue (F51)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the Fatigue (F51), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F51)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F52)
(F51)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F53)
(F51)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F54)

2. Mental and physical work load (F52)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the mental and physical work load (CFE2), compared to the other factors?

Sub-factor	Intensity of relative importance																	Sub-factor
(F52)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F53)
(F52)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	(F54)

3. Distraction during the time of berthing operations (F53)

Could you please fill the questionnaire/ table here under by underlining the appropriate number (See example1.1), and refer to the factors in table1.1, and to the scale of importance table1.2, before answering the questionnaire.

The goal is to compare between them and select the most important factor that could have negative impact on pilotage safety and contributing to the occurrence of maritime accidents during pilotage operations.

To achieve the above goal, how important is the Distraction during the time of berthing operations (F53), compared to the other factor?

Sub-factor	Intensity of relative importance																	Sub-factor
(F53)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Stress (F54)

THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY

Appendix III-2: The Questionnaire used for DEMATEL method in chapter 5

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School of Engineering, Technology and

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Byrom Street

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To: Whom it may concern

A research project at Liverpool John Moores University is currently being carried out with regard to the impact of human factors on maritime pilotage operations. I will be most grateful if you could kindly spend your valuable time and take part in this study. Your participation in this survey is voluntary and will only take a few minutes. All the information that you provide in the course of your interview, completion of questionnaires or in general discussion will be greatly benefit and contribute to achieve the aim of this project. The information gathered in this survey will be treated in the strictest confidence.

The questionnaire is anonymous, thus your response can not be attributed to you or your organization. Any refusal or incomplete questionnaire will be excluded without any responsibility on the participant. Completion of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have any questions about this study, please feel free to contact me either by email or by phone at the addresses listed below.

Yours faithfully,

H. Oraith,

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1. Introduction

Previous efforts to evaluate human error have assumed that accidents causal factors are independent, but reality proves otherwise. In fact, maritime accidents occurring in the pilotage area are caused by a combinations of risk factors and these risk factors are correlated to each other. Here in, the DEMATEL method is applied to assess the relationships among the causal factors and assess the cause–effect relations and the degrees of influence. This survey aims to evaluate the relationships among the causal factors of the pilotage accidents. There will be an example at the beginning of the questionnaire showing how the questionnaire must be filled. The procedures and guidelines for answering this set of questionnaires are explained as follows:

2. Pair-wise comparison

The questionnaire is: Pair-wise comparison among the accident causal factors shown in table 1, which are**, F1:** (F11, F12, F13, CF14, and F15), **F2:** (F21, F22, F23, and F24), **F3:** (F31, F32, F33, and F34), **F4:** (F41, F42, F43, and F44), and **F5:** (F51, F52, F53, and F54).

Table 1: The list of causal factors contributing to maritime accidents in pilotage operations

causal factors contributing to maritime accidents
Lack of team work (F11)
Lack of effective communication and Language problems (F12)
Failure to exchange the information between pilot and ship's master (F13)
Lack of situation awareness (F14)
The master's and pilot's ineffective monitoring of the tugboats drivers, mooring boats, and shore mooring personnel performance and vessel's progress (F15)
Lack of ship handling skills due to lack of experience, improper training, and attitude (F21)
Lack of technical knowledge and failure to use the bridge navigation equipment (F22)
Lack of skills of the crewmember onboard ship, tugs, and shore mooring personnel (F23)
Improper/ inadequate use of tugs (F24)
Failure of pilot to give precise instructions (F31)
Failure of the ship's master to correctly follow the pilot directions (F32).
Failure of tug's masters to carry out the pilot's instructions precisely with respect to position and towing power (F33)
Orders regarding anchoring, steering, and engine requests, are not following out by ship's crewmembers correctly(F34)
Failure to establish a proper manoeuvring plan prior to piloting vessel (F41).
Failure to proceed with safe speed as stipulated in COLREG (F42)
Piloting ships in bad weather condition or navigating vessels outside published guidelines or limits draft due to subject to commercial pressure (F43)
Pilot boarding and disembarking too close to breakwater (F44)
Fatigue (F51)
Mental and physical work load (F52)

Distraction and simultaneous tasks during the time of berthing operations (F53)
Stress (F54)

3. Description on how to fill up the Questionnaire

Before proceeding with the “Pair-wise Comparisons” technique, an expert has to understand the ratio scale measurement used in this study. Table 2 below describes the numerical assessment together with the linguistic meaning of each number. It is used for evaluating the influence level between the factors.

The expert is required to give a possible judgment and to evaluate the influence level among the factor based on his/her expertise and experience. The expert will be asked to score the level of the influence with ‘‘no influence (0),’’or ‘‘low influence (1),’’ ‘‘medium influence (2),’’ ‘‘high influence (3),’’ and ‘‘very high influence (4),’’ respectively.

The evaluation scale of the relationships between factors ranges from 0 to 4 as show in the table below.

Table 2 Evaluation scale

0	**No influence**
1	**Low influence**
2	**Medium influence**
3	**High influence**
4	**Very high influence**

Example - The following shows how to evaluate the relationships and the interdependency among the factors and how to fill the blanks of the evaluation forms for the accidents contributing factors.

Please answer the following questions based on pairwise comparisons, based on your experience, and judging the rate of influence of the factors by using the scale shown in Table 2 to estimate to what extent each left-side factor affects the opposite factor.

For instances, among the two factors, if you think that, lack of effective communication and language problems has high influence on the lack of exchange the information between pilot and ship's master and might play role in the occurrence of maritime accidents during pilotage operations, your evaluation scale is "3" so that you should underline "X" on the evaluation form as shown in the example below.

Sample Form:

Pairwise comparisons						
Factors	Degree of Influencing					Sub-Factors
	0	1	2	3	4	
language problems and lack of effective communication (F12)				X		Failure to exchange the information between pilot and ship's master (F13)

However, if you believe that the language problems and lack of effective communication has no influence on the exchange the information between pilot and ship's master in contributing to the occurrence of maritime accidents during pilotage operations your evaluation scale is "0" so that you should underline "X" on the evaluation form as shown in the example below.

Pairwise comparisons						
Main factors	Degree of Influencing					Sub-factors
	0	1	2	3	4	
Lack of team work (F11)	X					Lack of ship handling skills due to lack of experience, improper training, and attitude (F21)

Pairwise comparison to evaluate the rate of influence among the factors

Could you please fill the questionnaire/ table here under by underlining the appropriate number (see examples above), and refer to the table1 and scale in Table2, before answering the questionnaire.

The following questions based on pairwise comparisons, could you please, based on your experience, use the 5-scale to estimate to what extent each left-side factor affect the opposite factor; where:

0- No Influence, 1- Very Low Influence, 2- Low Influence, 3- High Influence, 4-Very High Influence

Pairwise comparisons between factors						
Factors	Degree of influencing					Factors
	0	1	2	3	4	
(F11)						(F12)
(F11)						(F13)
(F11)						(F14)
(F11)						(F15)
(F11)						(F21)
(F11)						(F22)
(F11)						(F23)
(F11)						(F24)
(F11)						(F31)
(F11)						(F32).
(F11)						(F33)
(F11)						(F34)
(F11)						(F41).
(F11)						(F42)

(F11)						(F43)
(F11)						(F44)
(F11)						(F51)
(F11)						(F52)
(F11)						(F53)
(F11)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F12)						(F11)
(F12)						(F13)
(F12)						(F14)
(F12)						(F15)
(F12)						(F21)
(F12)						(F22)
(F12)						(F23)
(F12)						(F24)
(F12)						(F31)
(F12)						(F32).
(F12)						(F33)
(F12)						(F34)

(F12)						(F41).
(F12)						(F42)
(F12)						(F43)
(F12)						(F44)
(F12)						(F51)
(F12)						(F52)
(F12)						(F53)
(F12)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F13)						(F11)
(F13)						(F12)
(F13)						(F14)
(F13)						(F15)
(F13)						(F21)
(F13)						(F22)
(F13)						(F23)
(F13)						(F24)
(F13)						(F31)
(F13)						(F32).
(F13)						(F33)
(F13)						(F34)
(F13)						(F41).

(F13)						(F42)
(F13)						(F43)
(F13)						(F44)
(F13)						(F51)
(F13)						(F52)
(F13)						(F53)
(F13)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F14)						(F11)
(F14)						(F12)
(F14)						(F13)
(F14)						(F15)
(F14)						(F21)
(F14)						(F22)
(F14)						(F23)
(F14)						(F24)
(F14)						(F31)
(F14)						(F32).
. (F14)						(F33)
(F14)						(F34)
(F14)						(F41).

(F14)						(F42)
(F14)						(F43)
(F14)						(F44)
(F14)						(F51)
(F14)						(F52)
(F14)						(F53)
(F14)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F15)						(F11)
(F15)						(F12)
(F15)						(F13)
(F15)						(F14)
(F15)						(F21)
(F15)						(F22)
(F15)						(F23)
(F15)						(F24)
(F15)						(F31)
(F15)						(F32).
(F15)						(F33)
(F15)						(F34)
(F15)						(F41).

(F15)						(F42)
(F15)						(F43)
(F15)						(F44)
(F15)						(F51)
(F15)						(F52)
(F15)						(F53)
(F15)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F21)						(F11)
(F21)						(F12)
(F21)						(F13)
(F21)						(F14)
(F21)						(F21)
(F21)						(F22)

(F21)						(F23)
(F21)						(F24)
(F21)						(F31)
(F15)						(F32).
(F21)						(F33)
(F21)						(F34)
(F21)						(F41).
(F21)						(F42)
(F21)						(F43)
(F21)						(F44)
(F21)						(F51)
(F21)						(F52)
(F21)						(F53)
(F21)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F22)						(F11)
(F22)						(F12)
(F22)						(F13)
(F22)						(F14)
(F22)						(F21)
(F22)						(F22)

(F22)						(F23)
(F22)						(F24)
(F22)						(F31)
(F22)						(F32).
(F22)						(F33)
(F22)						(F34)
(F22)						(F41).
(F22)						(F42)
(F22)						(F43)
(F22)						(F44)
(F22)						(F51)
(F22)						(F52)
(F22)						(F53)
(F22)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F23)						(F11)
(F23)						(F12)
(F23)						(F13)
(F23)						(F14)
(F23)						(F21)
(F23)						(F22)

(F23)						(F23)
(F23)						(F24)
(F23)						(F31)
(F13)						(F32).
(F23)						(F33)
(F23)						(F34)
(F23)						(F41).
(F23)						(F42)
(F23)						(F43)
(F23)						(F44)
(F23)						(F51)
(F23)						(F52)
(F23)						(F53)
(F23)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F24)						(F11)
(F24)						(F12)
(F24)						(F13)
(F24)						(F14)
(F24)						(F21)
(F24)						(F22)
(F24)						(F23)

(F24)						(F24)
(F24)						(F31)
(F24)						(F32).
(F24)						(F33)
(F24)						(F34)
(F24)						(F41).
(F24)						(F42)
(F24)						(F43)
(F24)						(F44)
(F24)						(F51)
(F24)						(F52)
(F24)						(F53)
(F24)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F31)						(F11)
(F31)						(F12)
(F31)						(F13)
(F31)						(F14)
(F31)						(F21)
(F31)						(F22)
(F31)						(F23)
(F31)						(F24)

(F31)						(F31)
(F31)						(F32).
(F31)						(F33)
(F31)						(F34)
(F31)						(F41).
(F31)						(F42)
(F31)						(F43)
(F31)						(F44)
(F31)						(F51)
(F31)						(F52)
(F31)						(F53)
(F31)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F32)						(F11)
(F32)						(F12)
(F32)						(F13)
(F32)						(F14)
(F32)						(F21)
(F32)						(F22)
(F32)						(F23)
(F32)						(F24)
(F32)						(F31)

(F32)						(F32).
(F32)						(F33)
(F32)						(F34)
(F32)						(F41).
(F32)						(F42)
(F32)						(F43)
(F32)						(F44)
(F32)						(F51)
(F32)						(F52)
(F32)						(F53)
(F32)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F33)						(F11)
(F33)						(F12)
(F33)						(F13)
(F33)						(F14)
(F33)						(F21)
(F33)						(F22)
(F33)						(F23)
(F33)						(F24)
(F33)						(F31)
(F33)						(F32).

(F33)						(F33)
(F33)						(F34)
(F33)						(F41).
(F33)						(F42)
(F33)						(F43)
(F33)						(F44)
(F33)						(F51)
(F33)						(F52)
(F33)						(F53)
(F33)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F34)						(F11)
(F34)						(F12)
(F34)						(F13)
(F34)						(F14)
(F34)						(F21)
(F34)						(F22)
(F34)						(F23)
(F34)						(F24)
(F34)						(F31)
(F34)						(F32).

(F34)						(F33)
(F34)						(F34)
(F34)						(F41).
(F34)						(F42)
(F34)						(F43)
(F34)						(F44)
(F34)						(F51)
(F34)						(F52)
(F34)						(F53)
(F34)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F41)						(F11)
(F41)						(F12)
(F41)						(F13)
(F41)						(F14)
(F41)						(F21)
(F41)						(F22)
(F41)						(F23)
(F41)						(F24)
(F41)						(F31)
(F41)						(F32).
(F41)						(F33)

(F41)						(F34)
(F41)						(F41).
(F41)						(F42)
(F41)						(F43)
(F41)						(F44)
(F41)						(F51)
(F41)						(F52)
(F41)						(F53)
(F41)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F42)						(F11)
(F42)						(F12)
(F42)						(F13)
(F42)						(F14)
(F42)						(F21)
(F42)						(F22)
(F42)						(F23)
(F42)						(F24)
(F42)						(F31)
(F42)						(F32).
(F42)						(F33)

(F42)						(F34)
(F42)						(F41).
(F42)						(F42)
(F42)						(F43)
(F42)						(F44)
(F42)						(F51)
(F42)						(F52)
(F42)						(F53)
(F42)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F43)						(F11)
(F43)						(F12)
(F43)						(F13)
(F43)						(F14)
(F43)						(F21)
(F43)						(F22)
(F43)						(F23)
(F43)						(F24)

(F43)						(F31)
(F43)						(F32).
(F43)						(F33)
(F43)						(F34)
(F43)						(F41).
(F43)						(F42)
(F43)						(F43)
(F43)						(F44)
(F43)						(F51)
(F43)						(F52)
(F43)						(F53)
(F43)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F44)						(F11)
(F44)						(F12)
(F44)						(F13)
(F44)						(F14)
(F44)						(F21)
(F44)						(F22)
(F44)						(F23)
(F44)						(F24)
(F44)						(F31)

(F44)						(F32).
(F44)						(F33)
(F44)						(F34)
(F44)						(F41).
(F44)						(F42)
(F44)						(F43)
(F44)						(F44)
(F44)						(F51)
(F44)						(F52)
(F44)						(F53)
(F44)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F51)						(F11)
(F51)						(F12)
(F51)						(F13)
(F51)						(F14)

(F51)						(F21)
(F51)						(F22)
(F51)						(F23)
(F51)						(F24)
(F51)						(F31)
(F51)						(F32).
(F51)						(F33)
(F51)						(F34)
(F51)						(F41).
(F51)						(F42)
(F51)						(F43)
(F51)						(F44)
(F51)						(F51)
(F51)						(F52)
(F51)						(F53)
(F51)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F52)						(F11)
(F52)						(F12)
(F52)						(F13)
(F52)						(F14)
(F52)						(F21)

(F52)						(F22)
(F52)						(F23)
(F52)						(F24)
(F52)						(F31)
(F52)						(F32).
(F52)						(F33)
(F52)						(F34)
(F52)						(F41).
(F52)						(F42)
(F52)						(F43)
(F52)						(F44)
(F52)						(F51)
(F52)						(F52)
(F52)						(F53)
(F52)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F53)						(F11)
(F53)						(F12)

(F53)						(F13)
(F53)						(F14)
(F53)						(F21)
(F53)						(F22)
(F53)						(F23)
(F53)						(F24)
(F53)						(F31)
(F53)						(F32).
(F53)						(F33)
(F53)						(F34)
(F53)						(F41).
(F53)						(F42)
(F53)						(F43)
(F53)						(F44)
(F53)						(F51)
(F53)						(F52)
(F53)						(F53)
(F53)						(F54)

Pairwise comparisons between factors						
Factors	Degree of Influencing					Factors
	0	1	2	3	4	
(F54)						(F11)
(F54)						(F12)
(F54)						(F13)

(F54)						(F14)
(F54)						(F21)
(F54)						(F22)
(F54)						(F23)
(F54)						(F24)
(F54)						(F31)
(F54)						(F32).
(F54)						(F33)
(F54)						(F34)
(F54)						(F41).
(F54)						(F42)
(F54)						(F43)
(F54)						(F44)
(F54)						(F51)
(F54)						(F52)
(F54)						(F53)
(F54)						(F54)

Q.1 please write your company name?

Q.2 please indicate your rank?

Q. 3 How much time have you spent at sea? Please can you outline a bit of your background?

THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY

Appendix IIII-1: The Questionnaire used for identifying risk mitigation measures in chapter 6

Liverpool John Moores University

School of Engineering, Technology and

Maritime Operations

Byrom Street

L3 3AF UK

To: Whom it may concern

A research project at Liverpool John Moores University is currently being carried out with regard to the impact of human factors on maritime pilotage operations. I will be most grateful if you could kindly spend your valuable time and take part in this study. Your participation in this survey is voluntary and will only take a few minutes. All the information that you provide in the course of your interview, completion of questionnaires or in general discussion will be greatly benefit and contribute to achieve the aim of this project. The information gathered in this survey will be treated in the strictest confidence.

The questionnaire is anonymous, thus your response can not be attributed to you or your organization. Any refusal or incomplete questionnaire will be excluded without any responsibility on the participant. Completion of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have any questions about this study, please feel free to contact me either by email or by phone at the addresses listed below.

Yours faithfully,

H. Oraith,

PhD researcher, School of Engineering, Technology and Maritime Operations

Tel: + (44)7480120401

Email: H.M.Oraith@2014.ljmu.ac.uk

Or: hemz1966@hotmail.com

Liverpool Logistics Offshore and Marine Research Institute (LOOM)

Room 121, James Parsons Building

Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, UK

Section A: Introduction

This research proposed a novel risk assessment methodology for identifying, evaluating and mitigating the risk factors that contribute to maritime pilotage accidents. Based on the findings from the previous survey, the following risk factors shown in the below table (table 2) have been weighted by the experts as the most significant contributory factors leading to pilotage accidents.

We further need to determine the relevant risk mitigation measures for each causal factor.

Section B: Example

For your opinion as an expert, please kindly give your comments and identify the optimal measure and best solutions for mitigating the risk factors shown in the below table (table 1)

Table.1 Example for selection of mitigation measures (RMMs) for reducing the risk of lack of communication and language barriers.

S/N	The most contributory factors to maritime pilotage accidents (HCFs)	Risk mitigation measures (RMMs)?
RF1	Lack of communication and language barriers	(1) Improving the pilotage operators' English language skills. (2) A standard marine vocabulary should be used during the manoeuvring. (3) Providing an adequate and a high standard of theoretical and practical training courses with regular renewal training including, bridge resource management (BRM),

Section B: Questionnaire

For your opinion as an expert, please kindly give your comments and identify the optimal measure and best solutions for mitigating the following risk factors shown in the below table (table 2)

Table.2 Selection of risk mitigation measures (RMMs) for reducing maritime pilotage related accidents

S/N	The most contributory factors to maritime pilotage accidents (HCFs)	Risk mitigation measures (RMMs)?
RF1	Lack of ship handling skills.	(1) (2) (3) (4)
RF2	Lack of communication and language barriers.	(1) (2) (3) (4)
RF3	Failure to exchange the information between pilot and ship's master prior to pilotage operation	(1) (2) (3) (4)
RF4	Lack of bridge navigation equipment knowledge and failure to use the electronic navigational systems properly (Lack of familiarity with the navigational systems)	(1) (2) (3) (4)
RF5	Lack of team work	(1) (2) (3) (4)

RF6	Lack of situation awareness	(1) (2) (3) (4)
RF7	Fatigue	(1) (2) (3) (4)
RF8	Lack of skills of the crewmember on ship board, tugboat crews, and shore mooring personnel (linesmen)	(1) (2) (3) (4)
RF9	Improper/ inadequate use of tugs	(1) (2) (3) (4)
RF10	Failure of pilot to give precise or correct instructions	(1) (2) (3) (4)
RF11	Failure of pilot and ship's master to establish a proper passage and berthing plan prior to piloting vessel	(1) (2) (3) (4)

Q. Please indicate your profession and rank?

Q. Please can you outline a bit of your working experience background (time period you have spent at sea or as pilot so far)?

This is the end of the questionnaire. Thank you very much for your help.

Appendix IIII: 2 The Questionnaire used for TOPSIS method in chapter 6

Liverpool John Moores University

School of Engineering, Technology and

Maritime Operations

Byrom Street

L3 3AF UK

To: Whom it may concern

A research project at Liverpool John Moores University is currently being carried out with regard to the impact of human factors on maritime pilotage operations. I will be most grateful if you could kindly spend your valuable time and take part in this study. Your participation in this survey is voluntary and will only take a few minutes. All the information that you provide in the course of your interview, completion of questionnaires or in general discussion will be greatly benefit and contribute to achieve the aim of this project. The information gathered in this survey will be treated in the strictest confidence.

The questionnaire is anonymous, thus your response can not be attributed to you or your organization. Any refusal or incomplete questionnaire will be excluded without any responsibility on the participant. Completion of the questionnaire will indicate your willingness to participate in this study. If you require additional information or have any questions about this study, please feel free to contact me either by email or by phone at the addresses listed below.

Yours faithfully,

H. Oraith,

PhD researcher, School of Engineering, Technology and Maritime Operations

Tel: + (44)7480120401

Email: H.M.Oraith@2014.ljmu.ac.uk

Or: hemz1966@hotmail.com

Liverpool Logistics Offshore and Marine Research Institute (LOOM)

Room 121, James Parsons Building

Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, UK

Section A: Introduction and Explanation

This research proposed a novel risk assessment methodology for identifying, evaluating and mitigating the risk factors that contribute to maritime pilotage accidents. Based on the findings from the previous survey, the following risk factors shown in the below table (table 1) have been weighted by the experts as the most significant contributory factors leading to pilotage accidents. We further need to determine which relevant risk mitigation measures for each causal factor has become the key strategic consideration.

Table.1 the most contributory factors to maritime pilotage accidents (HCFs)

S/N	**Contributory factors to maritime pilotage accidents (Criteria)**
RF1	Lack of ship handling skills.
RF2	Lack of communication and language barriers.
RF3	Failure to exchange the information between pilot and ship's master prior to pilotage operation
RF4	Lack of bridge navigation equipment knowledge and failure to use the electronic navigational systems properly (Lack of familiarity with the navigational systems)
RF5	Lack of team work
RF6	Lack of situation awareness
RF7	Fatigue as result of mental and physical work load
RF8	Lack of skills of the crewmember on ship board, tugboat crews, and shore mooring personnel (linesmen)
RF9	Improper/ inadequate use of tugs
RF10	Failure of pilot to give precise or correct instructions
RF11	Failure of pilot and ship's master to establish a proper passage and berthing plan prior to piloting vessel

SECTION B: EXPLANATIONS AND EXAMPLES

Questionnaire for selection of the best measures (Risk mitigation measures) (RMMs) for eliminating and/or mitigating the identified risk factors affecting the safety of pilotage operations is developed. The purpose of this questionnaire is to select the optimal measures and ideal solutions for mitigating the 11 risk factors illustrated in the table (table 1).

The following 21risk mitigation measures (RMMs) for reducing maritime pilotage related accidents have been determined in this research. All these risk mitigation measures are shown in the below tables (table 2), and need to be evaluated by using TOPSIS technique. This process is required to provide reliable data by identifying an expert opinion of each evaluation parameter.

Table for Risk mitigation measures (RMMs) for improving pilotage safety performance

S/N	Risk mitigation measures (RMMs)
A1	Pilots should have an appropriate experience as a ship master before becoming a pilot.
A2	Implement safety management system (SMS) for pilotage operations
A3	Providing an adequate and a high standard of theoretical and practical training courses with regular renewal training including ship handling, bridge simulator training, bridge resource management (BRM), ECDIS, and NAEST generic training courses.
A4	Using common communication language on board.
A5	Improving the pilotage operators' English language skills.
A6	Ship's staff, pilot, and assisting parties should maintain an effective communication, corporation, an effective co-ordination, and an effective exchange of information.

A7	A standard marine vocabulary should be used during the maneuvering.
A8	Compliance with resolution A.893 (21) on Guidelines for voyage planning.
A9	An effective working environment and Close working relationship on the bridge of a ship between pilot and ship's captain should be created.
A10	Provide an adequate number of qualified, experienced, and well trained ship's crew members, pilots and tugs operators working on shift (adherence to MLC rest hour maritime regulations)
A11	Tasks and responsibilities should be understood and distributed properly among the bridge team members.
A12	Providing training courses in safety and cultural awareness
A13	Keeping high level of alertness and avoid distractions elements
A14	All pilotage performers should be in good physical and mental fitness and not under the effect of drugs or alcohol
A15	Implement standard operating procedures (SOP's) for ship board operations
A16	Pilot boarding point should be at a sufficient distance from the commencement of the act of pilotage.
A17	During pilotage operations distractions elements should be avoided.
A18	Not to squeeze pilots or ship's captains for working outside established rules or piloting ships in poor weather condition situations due to commercial pressure.
A19	Maintaining continuous watchkeeping and keeping a high level of alertness (the surrounding area, tug's, and piloted ship's performance and progress should be monitored effectively and continuously to be aware of the whole situation properly).

A20	Provide sufficient and the required number of powerful tugboats which are necessary for all kind of ships manoeuvers.
A21	Compliance with the principals and the requirements of IMO resolution A960

The procedures and guidelines for answering this set of questionnaires are explained as follows:

<u>The linguistic meaning of the measurement scale</u>

To proceed with the evaluating, an expert has to understand the ratio scale measurement used in this study. Table 3 below describe the numerical assessment together with the linguistic meaning of each rating variable. The grades illustrated in Table 3 show the effect or importance value of the mitigation or control options. It is used for evaluating and rating of the measures (alternatives) for mitigating the risk factors shown in table1.

Table 3: Evaluation scale for the alternatives rating

Linguistic variables	Very low	Low	Medium	High	Very high
Grade	1	2	3	4	5

Example of answered questionnaire

With respect to manage "Lack of ship handling skills", please evaluate how effective each risk control measure is in terms of risk reduction. What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Table.4 Measures for mitigating the risks due to the lack of ship handling skills

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
Employ qualified, experienced, and well trained personnel (A1)	☐	☐	☐	☐	☒
Improving skills and knowledge by Providing theoretical and practical of advanced ship-handling training courses under close supervision of an experienced pilots (A2)	☐	☒	☐	☒	☐
The level and quality of training for certification or licensing should be adequate and higher standard (A3)	☐	☐	☒	☒	☐

Explanation of the above example

An expert is required to give a possible judgement to all questions based on his/her expertise and experience in pilotage operation. In the above example, the goal is to evaluate how effective each risk control measure is in terms of risk reduction. The description of the qualitative judgement "very Low", "Low", "Medium", "High" and "very high" is explained above.

Firstly an expert is required to look at the mitigation measures. Subsequently fill the empty spaces by selecting the appropriate grades from Table 3 the evaluation scale used for rating of the best measures (alternatives) for mitigating the risk factors

Pilots should have an appropriate experience as a ship master before becoming a pilot (A1).

Answer: Very High - Grade (5)

Improving skills and knowledge by providing theoretical and practical of advanced ship-handling training courses under close supervision of an experienced pilots (A2).

Answer: Low - Grade (2)

The level and quality of training for certification or licensing should be adequate and higher standard (A3)

Answer: Medium- Grade (3)

SECTION C: QUESTIONNAIRS

For your opinion as an expert, please kindly give your comments and select the optimal (best solutions) for mitigating the following risk factors.

Q1. With respect to manage "**Lack of ship handling skills"**, please evaluate how effective each risk control measure is in terms of risk reduction. What would be the risk reduction if you decide to apply the following risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐

A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q2. With respect to manage **"Lack of effective communication and misunderstanding due to language barriers"**, please refer to the risk mitigation measures in table1.2 and evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐

A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q3. With respect to manage **<u>“Failure to exchange the information between pilot and ship’s master prior to pilotage operation.”</u>** please refer to risk mitigation measures in table 2 and evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	Very low	Low	Medium	High	Very High
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐

A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q4. With respect to manage **"Lack of bridge navigation equipment knowledge and failure to use the electronic navigational systems properly."** please refer to risk mitigation measures in table 2 and evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐

A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q5. With respect to manage **"Lack of team work."** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐

A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q6. With respect to manage **"Lack of situation awareness."** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	Very low	Low	Medium	High	Very High
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐

A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q7. With respect to manage **"Fatigue"** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐

A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q8. With respect to manage **"Lack of skills of the crewmember on ship board, tugboat crews, and shore mooring personnel",** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	Very low	Low	Medium	High	Very High
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐

A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q9. With respect to manage **“Improper/ inadequate use of tugs”,** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐

A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q10. With respect to manage **""Failure of pilot to give correct and precise instructions",** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐
A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐

A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☐	☐	☐	☐	☐

Q11. With respect to manage **Failure to establish a proper passage and berthing plan prior to piloting vessel",** please evaluate how effective each risk control measure is in terms of risk reduction? What would be the risk reduction if you decide to apply the following alternatives or risk mitigation measures?

Risk mitigation measures	**Very low**	**Low**	**Medium**	**High**	**Very High**
A1	☐	☐	☐	☐	☐
A2	☐	☐	☐	☐	☐
A3	☐	☐	☐	☐	☐
A4	☐	☐	☐	☐	☐

A5	☐	☐	☐	☐	☐
A6	☐	☐	☐	☐	☐
A7	☐	☐	☐	☐	☐
A8	☐	☐	☐	☐	☐
A9	☐	☐	☐	☐	☐
A10	☐	☐	☐	☐	☐
A11	☐	☐	☐	☐	☐
A12	☐	☐	☐	☐	☐
A13	☐	☐	☐	☐	☐
A14	☐	☐	☐	☐	☐
A15	☐	☐	☐	☐	☐
A16	☐	☐	☐	☐	☐
A17	☐	☐	☐	☐	☐
A18	☐	☐	☐	☐	☐
A19	☐	☐	☐	☐	☐
A20	☐	☐	☐	☐	☐
A21	☒	☐	☐	☐	☐

Q. Please indicate your profession and rank?

Q. Please can you outline a bit of your working experience background (time period you have spent at sea or as pilot so far)?

THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY

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