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Enhancing Navigational Safety Through Increasing Situational Awareness and Teamwork in the Bridge

By

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This thesis has resulted from the author's own efforts. It has been created for the purposes of the PhD award and not been submitted for any previous examination, nor been awarded for any other degree.

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Table of abbreviations

Abbreviation	Meaning
2nd Off	Second Officer
3rd Off	Third Officer
AB	Able Seaman
AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
ATSB	Australian Transport Safety Bureau
BRM	Bridge Recourse Management
B.Sc.	Bachelor of Science degree
BTA	Bridge Team Act
BTM	Bridge Team Management
Capt.	Captain
Ch Off	Chief Officer
CoC1	Certificate of Competency level 1
CoC2	Certificate of Competency level 2
CoC3	Certificate of Competency level 3
CoE	Certificate of Endorsement
COLREG	The International Regulation for Prevention Collision at Sea 1972
CPA	Closest Point of Approach
EASA	European Union Aviation Safety Agency
ECDIS	Electronic Charts Display and Information System
ETA	Estimated Time of Arrival
FFA	Federal Aviation Administration
GPS	Global Positioning System

HELM	Human Element, Leadership and Management
IMO	International Maritime Organization
ISM	The International Safety Management Code
KPI	Key Performance Indicator
MAIB	Marine Accident Investigation Branch
NM	Nautical Mile
OOW	Officer of the Watch
OS	Ordinary Seaman
ROR	Rules of the Road
SOLAS	The International Convention of the Safety of Life at Sea 1974
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978
TCPA	Time of Closest Point of Approach
TSBC	The Transportation Safety Board of Canada
VHF	Very High Frequency
VTS	Vessel Traffic Services

Abstract

It is well reported in the literature that more than 80% of shipping accidents are attributed to human and organisational factors. Marine accidents are the result of error chains rather than single events. Prevention of accidents has gained the deserved attention by the end of the last century, as the maritime community has realised that despite all the increased safety standards and technological developments, accidents are still occurring, and the system is not resilient to errors at various levels. Furthermore, it has been often ignored that the human element of the maritime system has not been evolving the in the same way that technology is developing; and with the physical capabilities and the limitations of the human is being overlooked. It is considering that 60% of the accident are classed as grounding and collisions, which need to improve navigational safety.

This research aims to minimise the human and organisational factors in the bridge by enhancing the bridge team interaction and increasing the situational awareness of the bridge team in total. This will increase the bridge team performance to communicate and optimise teamwork between bridge team member to avoid accidents. Moreover, this thesis looks into Bridge Resource Management (BRM) elements and its deficiency and develop a new course that is flexible for all bridge team members to increase their efficiency and improve the team's decision-making based on the interpretation of the situation. The novelty of this research is to develop a BRM course to cover all bridge team members to enhance the bridge team performance to be similar to the aviation industry, which requires all aviation pilot and cabin crew to participant in Crew Resource Management (CRM) to be eligible for working in the aeroplanes.

The validation of the new course's effectiveness has been utilised in the full-mission ship's bridge navigational simulator compared to the regular course. Educational scenarios based on real accidents has been established for the validation experiment to evaluate the bridge team participants' performance and actions to avoid the collision.

1. Introduction

1.1. Chapter Overview

This chapter defines the general outcome of the themes covered in this thesis and outlines the structure of this thesis.

1.2. General Perspective

Most of the global economy relies on the maritime transportation system, as more than 1.5 billion tonnes of cargo exceeding 90% of the world trade are being transported every year by the sea. It is considered the best economical way to transport great amounts of cargo worldwide (IMO, 2020). The world seaborne trade had demonstrated substantial growth since 1983, except when the world economy collapsed in 2009. The growth of maritime transportation has been increasing side-by-side with world trade, as shown in Figure 1.1 below (UNCTAD, 2017).

Accordingly, to transport this tremendous amount of cargo, around 53000 cargo ships have been utilised, with more than 1.6 million seafarers deployed to ensure the safety of navigation and safety of the cargo (ICS, 2020; IMO, 2020). Also, maritime transportation is an international business; it requires a multinational and multicultural workforce to transport the cargo and operate the ships, which makes up approximately 70–80% of the multinational seafarers globally (Lu, Hsu and Lee, 2016).

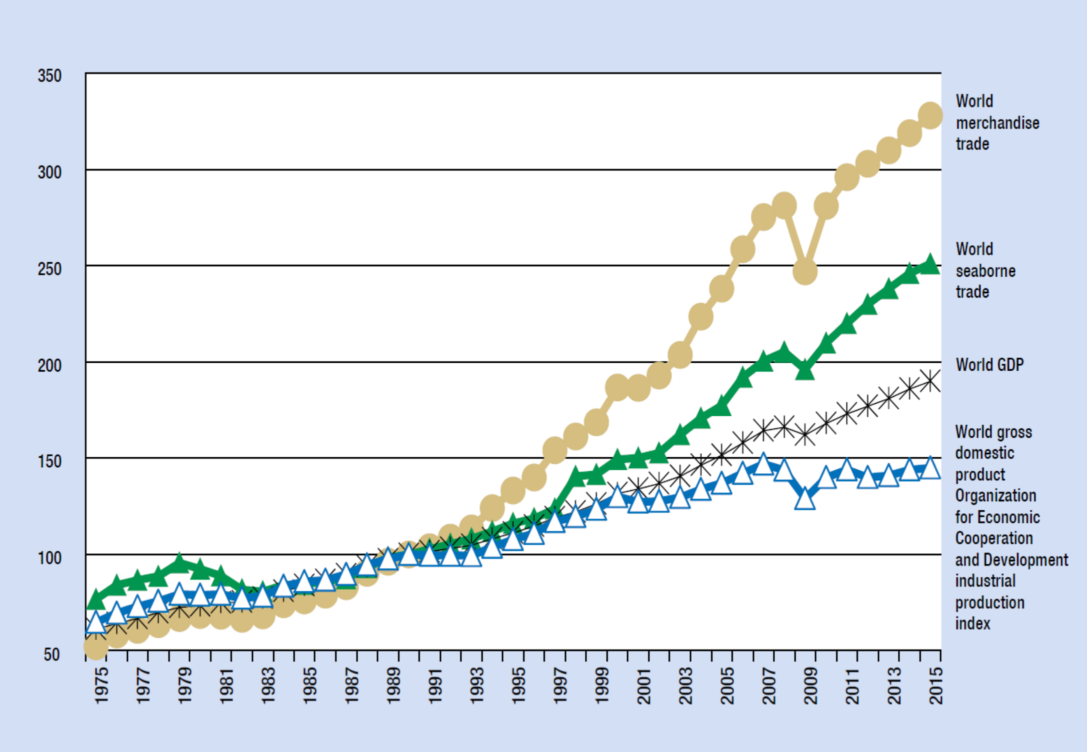

Figure 1.1 World seaborne transportation *(UNCTAD, 2017)*

Due to the high number of maritime accidents over the last century, the International Maritime Organization (IMO) established many conventions that aim to protect human life, ensure the safety of the environment and safety of the goods. In 1914 the first international convention was the International Convention for the Safety of Life at Sea (SOLAS). Afterwards, with the increasing number of maritime accidents over the years, IMO needed to improve the bridge team performance and education. So, the IMO established the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) in 1978 to increase shipping safety through increasing the education and training for the seafarers. Subsequently, in 2010 the STCW was amended to enhance marine environment awareness training, leadership and teamwork training by developing a Bridge Resource Management course (BRM) in 2012. The aim was to decrease the accidents caused by the human element (IMO, 2017). Therefore, the main aim is to enhance navigational safety by ensuring that the ship's bridge crew is using all the resources such as human, procedures, and technology that are available onboard the vessel effectively.

The maritime education sector regularly attempts to enhance the training objectives that are related to human factors, along with operating the bridge equipment in a way to achieve the safety of navigation (Hontvedt, 2015). The maritime sector believes that ships' navigational systems have become progressively complex due to technological development, which affects the experience and knowledge of the bridge team, especially when large ships are navigated. Moreover, the lack of training on the new equipment and poor application of BRM practice can adversely affect maritime safety instead of improving it. The advantage of the new equipment and automation is to decrease the physical activity of the bridge team by eliminating the movement between the bridge's equipment. However, it increases the mental load on the operator. An over-relying on such equipment can cause misinterpretation of some technical information, leading to poor decision-making and, hence, a potential accident (Badokhon, 2018a).

Based on many accident databases, the human element was a major factor influencing ship accidents, with more than 80% of the underlying reasons are identified as situation awareness and assessment (SA) and teamwork. The SA term describes the level of the people's awareness in a specific situation that requires being focused on, developed, and keeping an adequate understanding of what is happening to fulfil their task performance. The miss-assessment of the situation, lack of knowledge of the navigational equipment capabilities, and its misuse increase the risk of accidents along with poor lookout, poor decision-making, and not following the maritime regulations. In addition, poor application of bridge resource/team management (BRM/BTM) increased this risk to a higher level.

For the period between 1991 and 2001, USCG recorded over 71000 accidents and incidents, where the majority of the ship accidents were caused by human and organisational factors, and over 70% were due to the SA, as presented in Figure 1.2 below.

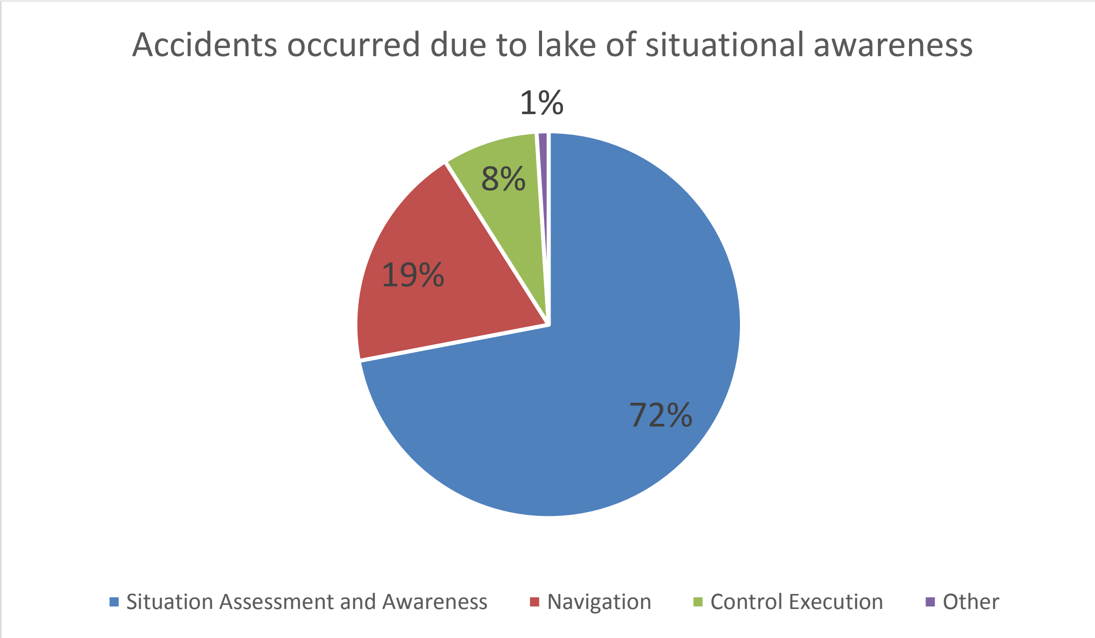

Figure 1.2 Accidents occurred due to lack of situational awareness recoded by USCG adopted by (Baker and McCafferty, 2005)

Moreover, 150 accident reports from the Australian Transportation Safety Bureau (ATSB) show that around 25% of these accidents were caused due to a lack of situation assessment and awareness, poor bridge resource management, and communications failure (Baker and McCafferty, 2005). In addition, 100 accident reports from the United Kingdom Marine Accident Investigation Board (MAIB) grouped the causes of the accidents into five categories: non-human error group, e.g. weather, material failure; maintenance group; Risk group, e.g. risk tolerance, navigation vigilance, task omission etc.; situation awareness group; and management group. Figure 1.3 below showed that situation awareness and management groups caused approximately 50% of accidents which included many factors such as situation assessment and awareness, knowledge, skills, communications, and bridge resource management.

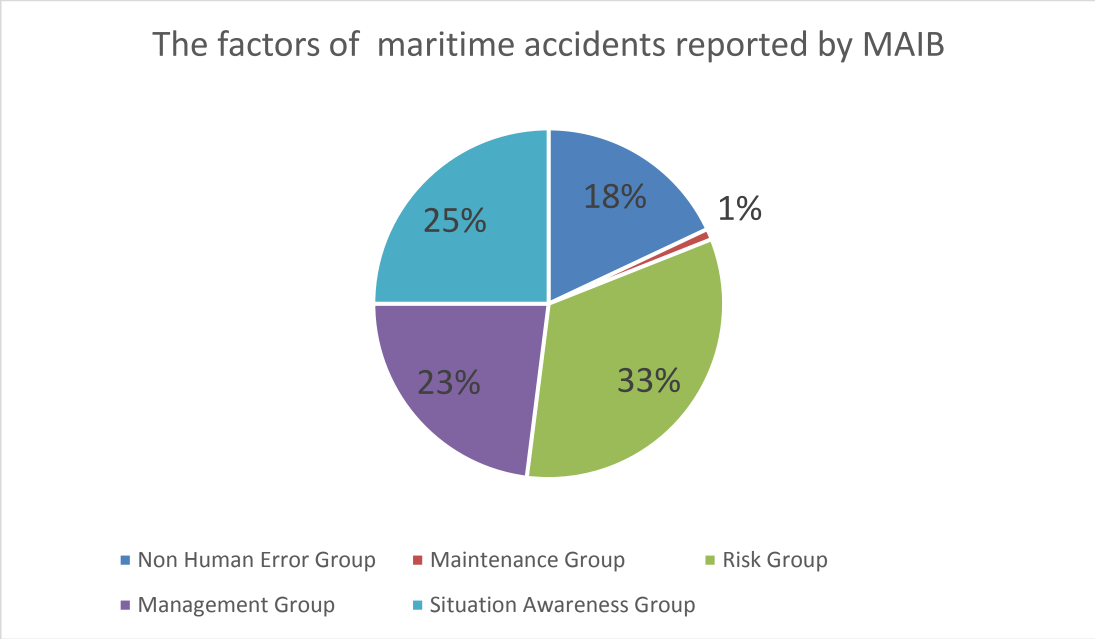

Figure 1.3 The factors of maritime accidents reported by MAIB adopted by (Baker and McCafferty, 2005)

From 2011 to 2018, the European Maritime Safety Agency (EMSA) has recorded more than 23000 ship incidents or accidents which the human and organisational factors represented 58% of these accidents. Additionally, around 8700 maritime accidents occurred due to the lack of navigational safety (EMSA, 2018).

The motivation to conduct this research is the lack of transmission of navigational information and situational awareness among the crew members without hesitation or fearing from the consequences that the information is wrong. Additionally, the availability of a huge amount of information resources available in the bridge will have a significant positive impact on the bridge team's performance and navigational safety, provided this information is used and shared effectively. This will enhance the bridge team’s situational awareness and their decision-making to use it in normal or critical situations. Moreover, this will remove the over-relying on bridge equipment and start making the best use of it and sharing the information to avoid collision situation. Finally, reviewing other industries’ such as the aviation sector, for enhancing the bridge team interaction that can be implemented for the ships to enhance the safety of ship navigation.

1.3. Structure of this Thesis

The structure of this thesis is briefed below:

- Chapter 1 outline the background of the development of the IMO conventions that serve maritime safety and the importance of the shipping industry. Background of information about situational awareness, Bridge Resource Management (BRM), the causes of maritime accident and the output of this thesis.
- Chapter 2 the aim and the objectives of this research which will be achieved through this study. It includes the motivation behind this research.
- Chapter 3 presents the literature and critical review on maritime safety culture, maritime accidents and the contribution of the human factor to the accidents. Review BRM literature and its element, situational awareness models and bridge simulation experiment are also included in this chapter.
- Chapter 4 presents a survey about the crew's situational awareness, which was collected from seafarers and utilised as a case study. Furthermore, the implementation methodology of the thesis to conduct this research is also included in chapter 4.
- Chapter 5 present a review of accident investigations from three different maritime investigation branches and highlight the root causes of losing situational awareness of the bridge team.
- Chapter 6 presents the result of the situational awareness derived from the crew survey (case study), which was analysed under five domains of situational awareness assessment.
- Chapter 7 presents the differentiation between the bridge resource management courses offered by different institutions and the proposal for the new BRM course.

- Chapter 8 presents a comparative assessment of the existing and proposed BRM course to validate the new BRM through a full-mission bridge navigational simulator by performing different navigational scenarios to measure the bridge team performance.
- Chapter 9 details the research's contribution, its outcome and the benefit of the developed course to the state-of-art knowledge and how the aim and objectives were achieved. The gaps in this research and the recommendations for future work are also presented in chapter 9.
- Chapter 10 summarises the main findings of the thesis. This includes a conclusion of this research and the contributions that have been achieved through this thesis.

2. Research Aim and objectives

2.1. Chapter Overview

This chapter presents the motivation behind this work, the aim and objectives of this research.

2.2. Problem identification

Bridge team performance can be affected adversely by many factors, such as fatigue, extra workload, communication difficulties, inappropriate leadership skills, inattention in duty, etc., and these factors may lead to a navigational hazard or an accident. As a result of this, the bridge team's situational awareness could collapse, which lead to misunderstanding of the navigational situation. The bridge team's decisions based on inaccurate information might lead to maritime accidents. Furthermore, the bridge's information resources, such as navigational equipment, books, etc., are beyond the human capability to be handled or memorised. Accordingly, this research focuses on sharing situational awareness and improve team performance to enhance bridge performance and navigational safety.

2.3. Motivation

The human factors which contributed to maritime accidents showed a significant impact of the bridge team's actions (or no actions) on these accidents (Chauvin, 2011a; EMSA, 2018). Additionally, recent research in maritime technology has invested in ship automation to decrease human and organisational factors and human interaction with navigational safety (Abdushkour *et al.*, 2018).

BRM course aimed to enhance the skills of the bridge team by using the best of the resources available in the bridge to ensure the safety of navigation. However, the course is prepared for the captains, OOWs and pilots but not for other bridge team members such as lookout, wheelman, and cadets. Moreover, after studying BRM course contents over many maritime institutions, it was found that there are some differences in the course contents. The aviation industry provides a similar course which is called Crew Resource Management (CRM), with no differences in contents between the aviation institutions, for all planes' crew to enhance the crew performance in normal and critical situations (Hayward and Lowe, 2010).

2.4. Gaps

- There is no standardisation of BRM course contents between different maritime institutions.
- There is no course that includes the other bridge team members such as cadets, lookouts, and wheelman, which will improve the interaction and teamwork between bridge members.

2.5. Aims and Objectives

The main aim of this research is to enhance navigational safety by increasing situational awareness and teamwork in the bridge. The detailed objectives of the research are given below:

- To review the literature on situational awareness and how situational awareness was achieved among the bridge team members.
- To create a maritime accidents database to identify the key factors that led to the loss of situational awareness of the bridge team by analysing previous accident reports.
- To develop a questionnaire for crew members to capture the gaps of their attitudes and teamwork towards the safe practise of ship bridge activates by distributing this questionnaire to different shipping companies.

- To attend various BRM courses offered by various maritime institutions to identify the best practices as well as the gaps and differences between different courses.
- Based on the database analysis and the feedback from the seafarers, develop a new Bridge Resource/Team Management (BRM/BTM) Course to enhance the navigational resilience by enhancing communication, Sharing situational awareness and knowledge of the surrounding situation among the bridge team members.
- Validate and test the new course in a full-mission simulator environment by performing a comparative assessment of the normal bridge working practices and the new course approach proposed by the author.

2.6. Chapter Summary

The chapter has presented the motivation of this study, aims and objectives of this research.

3. Chapter Overview

A critical review is performed and presented along with the brief theoretical information required in this study.

3.1. Introduction

Based on many accidents databases, the human element was a major factor influencing ship accidents, of which the main two components are situational awareness and assessment (SA) and teamwork. The misunderstanding of the situation, lack of knowledge about the capabilities of the navigational equipment as well as incorrect use of equipment raise accident risks. In addition, poor application of bridge resource/team management (BRM/BTM) increased this risk to a higher level. The human and organisational factors increase due to misjudgement, poor situational awareness and practising workaround while neglecting the official rules (Kumar, 2014). This chapter will cover; an overview of maritime accidents and the role of human and organisational factors in these accidents; a brief review of BRM historical development, elements and the differences between maritime BRM and aviation Crew Resource Management (CRM); definitions of SA, models of SA and team SA; finally, an overview of the role of the maritime simulator in maritime research studies.

3.2. Maritime Accidents Overview

For the purpose of understanding maritime accidents, it is crucial to determine the causes of maritime accidents and to know the main contributing factors for maritime accidents. These causes of prevalent maritime accidents types are explained in the pie chart (EMSA, 2020). Collision, contact and grounding were found to represent 45% of the accidents that occurred from 2014 to 2019, as presented in Figure 3.1 below. Consequently, reducing collision and grounding accidents will decrease the overall maritime accidents significantly. Moreover, EMSA (2020) highlighted that the main factors leading to maritime accidents are human factors (66%), which related to training, skills and operations, and failure to comply with regulations/legislation (15%). Thus, to lower maritime accidents, it is important to decrease human and organisational factors and increase the efficiency of bridge team actions to enhance the navigational safety.

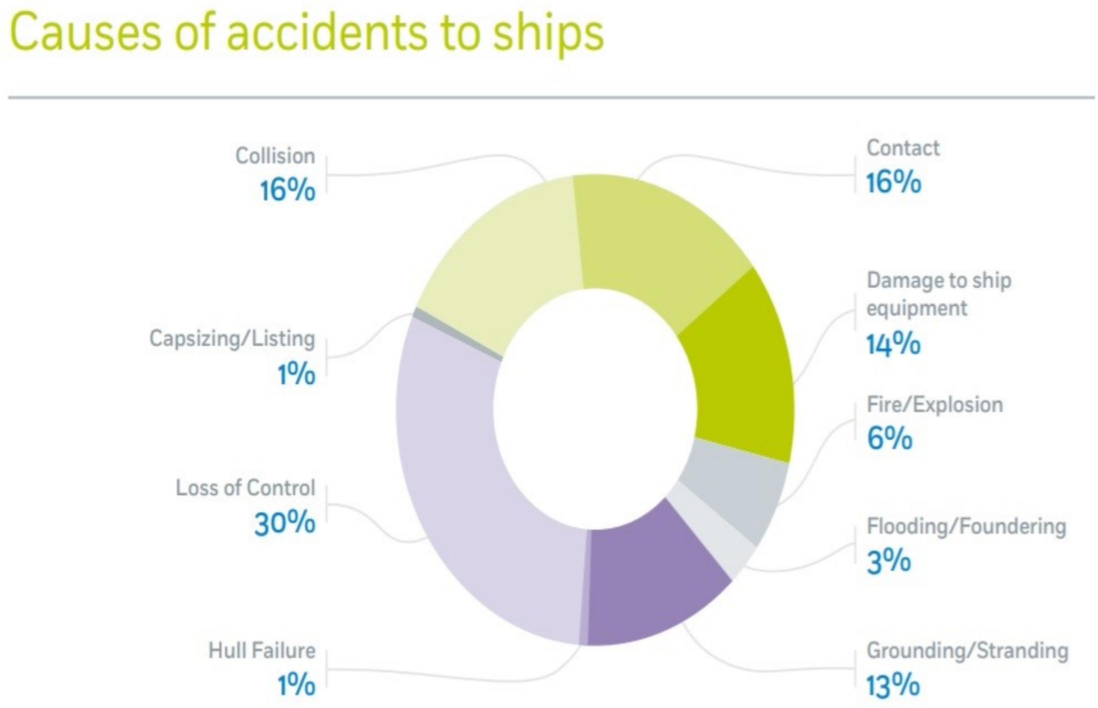

Figure 3.1 Maritime accidents causations (EMSA, 2020)

The global economy is highly dependent on maritime transportation, where about 90% of global trading is transported by ships (ICS, 2020). It is more economical to transport raw materials and stocks all over the globe using ships (Hetherington, Flin and Mearns, 2006), and shipping has demonstrated superior competency in transporting different products cost-effectively compared to other modes of transport (ICS, 2020).

On the contrary, major maritime accidents can have disastrous effects on the lives, assets and environment (Chauvin, 2011b). Many marine maritime researchers have shown that 80% of all accidents are directly or indirectly caused by human and organisational factors (Grech, Horberry and Smith, 2002; Baker and McCafferty, 2005; Batalden and Sydnes, 2017).

Determining the main causes of marine navigational accidents will help develop preventive measures that will considerably reduce the occurrence and outcomes of such accidents (Montewka *et al.*, 2017). The following section will discuss the effect of human factors on maritime accidents.

3.4. Human and organisational factors

In the shipping industry, in general, the crew members are often blamed for accidents and incidents while they are penalised for every error/incident that is occurred onboard the ship. However, recent research studies recognised that accidents are created due to the organisational factors that affect individuals' choices (Chauvin, 2011b).

According to ABS technical report by Baker and McCafferty (2005) and Hetherington, Flin and Mearns (2006), they stated that more than 80% of maritime accidents occur due to human and organisational factors, and the majority of these accidents occur because of a lack of situational awareness and situation assessment.

This part will focus on four categories that could influence human judgement. They are automation on the bridge, neglecting the rules, lookout, and bridge resource management elements (communication, teamwork and situational awareness). They are discussed below.

3.4.1. Integrated bridge and installation of a new system (Bridge Automation)

Usually, human take shortcuts to reach their goals, including avoiding some parts of the rules, which may lead to potential errors in the operational chain (Hadnett, 2008). Hadnett (2008) mentioned that an integrated bridge could increase an officer's situational awareness by gathering all equipment in one system, which allows the officer to concentrate on one system only (Hadnett, 2008). However, the poor practice of job performance by over-relying on bridge equipment and forgetting to use human skills such as communicating with bridge member, thinking of the situation, and not sharing this thinking among the team will lead to gaps (errors) in the human operational chain which are considered as main points in bridge resource management (BRM) as discussed further below.

Due to misunderstanding and poor application of COLREG rules, Baker and McCafferty (2005) and Szlapczynski and Szlapczynska (2015a) proposed a new system that provides information to OOW with regards to the COLREGS and environment. The proposed system visualises the physical data and all the information about other targets (speed, course, and action to be taken) in one device to support the operator. They added that more training and familiarisation would be required when this system is installed.

3.4.2. Lookout

The IMO stated a rule for lookout in the International Regulations for Prevention of Collisions at Sea, which is rule 5 "*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 make a full appraisal of the situation and or the risk of collision*" (IMO, 1972). However, despite the well-defined regulations, many of ship accidents occur due to the poor lookout, which leads to collisions that are, according to some MAIB reports, "the collision was a surprise for both vessels" (Baker and McCafferty, 2005; Hetherington, Flin and Mearns, 2006).

3.4.3. Negligence of the rules

According to Collision Regulations COLREG, all the maritime navigation manoeuvring should be done to avoid a collision. These rules helped the bridge team maintain ship safety by advising the OOWs to avoid collision actions to be taken in every situation. However, accidents still occurred (Demirel and Bayer, 2015). However, COLREG rules subject to the understanding and interpretation by the OOW, who decides the type of avoidance action and the suitable time (Szlapczynski and Szlapczynska, 2015b). Many authors mentioned that most of OOWs are not following the rules because they think that other ship's officer has more information and knowledge than them. Another suggestion is that some officers are not following the rules because the rules are not clear for them (Baker and McCafferty, 2005; Hetherington, Flin and Mearns, 2006). Furthermore, the rules' ambiguity when more than two ships are involved in the risk of collision, where there are no clear instructions on which rule(s) to follow to avoid a collision. Besides, in some cases where the risk of collision exists, the OOW's decisions might go against the rules to avoid the collision due to an agreement between the two bridges or due to an enough sea-room available on the other side of the manoeuvrability situation (Szlapczynski and Szlapczynska, 2015b; Demirel and Bayer, 2015).

3.5. Bridge Resource Management

3.5.1. History of Bridge Resource Management

Many books defined BRM as *" Bridge Resource Management constructs and procedures specifically intended to address the needs and concerns of vessel personnel, maritime operations, and conduct of the vessel in the presence of the marine pilot, and in an emergency to ensure safe and efficient conduct of the vessel*" (A. J. Swift, 2004; Parrott, 2011; Maritime Professional Training, 2016). The beginning of Bridge Resource Management (BRM) concept goes back to 90s after many accidents (Parrott, 2011). However, it is an outgrowth of the Crew Resource Management (CRM) from the aviation sector, which was applied in USA military flight in the 80s and then through the commercial flight crew (Wahl and Kongsvik, 2018). Thus, the concept and benefits of CRM spread to health care, rail and offshore industries over the years (Hayward and Lowe, 2010). The intention of BRM is to improve communication, teamwork, situational awareness, decision-making and leadership (Parrott, 2011; Wahl and Kongsvik, 2018). In addition, BRM enhances how the crew deal with emergencies, risk assessment and fatigue if it existed

(Parrott, 2011; Maritime Professional Training, 2016), as shown in Figure 3.2 below. In 2001, the Standards of Training, Certification, and Watchkeeping (STCW) convention highlighted the accidents, which occurred due to human factor failures, and STCW started to develop the BRM until it became compulsory in Manila amendments in 2010 (IMO, 2011).

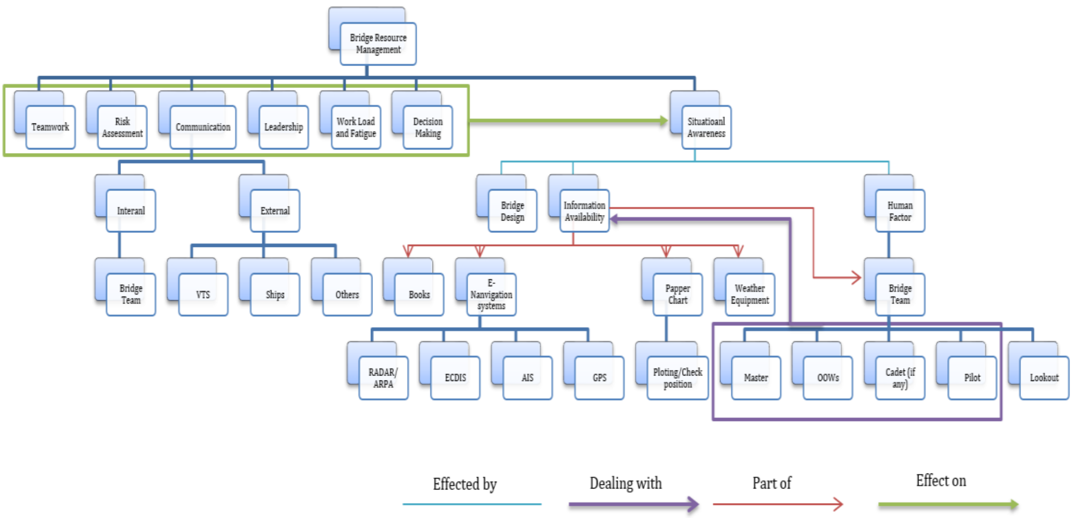

Figure 3.2 Hierarchy of Bridge Resource Management

In their review, Baker and McCafferty (2005) have reviewed and analysed the causes of marine accidents. They identified the root causes of the accidents to highlight the critical elements of accident causation. However, based on the author's search, no recent study has been carried out to follow the recent developments except O'Connor (2011) when he tried to assess the effectiveness of BRM training compare to the aviation Crew Resource Management (CRM) course, which he found that it is not possible due to the differences between the contents of the two courses. In addition, his research was on naval marine officers which they got more training compared to the officers on commercial ships. Even though the annual reports from MAIB, ASTB and TSBC contained an overview of maritime accidents, how many accidents are reported and investigated, they only show the percentage of the prime elements of causation. Many research studies came after that and outlined the general purposes of marine accidents without focusing on the accident's main cause, which is either human and organisational factors, technical failure or others (Hetherington, Flin and Mearns, 2006; Turan *et al.*, 2016).

3.5.2. Bridge Team Members

The bridge team covers all crew who have duty on the ship's bridge. The Safety Of Life At Sea (SOLAS) convention, through the flag state, ensures that every ship should maintain a minimum safe manning, holding appropriate documentation, check the crew safety performance and ensure the working language is applied (IMO, 1974). The STCW provides international standards for the minimum requirements for every rank on the ship, including the minimum age for working onboard ships, sea-time service, and knowledge requisition for every crew and certification specifications (IMO, 2017). During the normal bridge-watch as minimum manning, the bridge must be occupied by an officer of the watch (OOW) along with rating crew, Ordinary seaman (OS) or Able Seaman (AB), for lookout or controlling the wheel (IMO, 1998). In critical circumstances, the ship's captain/master should be on the bridge to support the bridge team. Certain conditions, such as training and entering/leaving the port, require a deck cadet and a pilot to be available on the bridge to support the bridge team.

3.5.2.1. Captain/Master

The ship's captain/master is the highest certified rank on the ship and the ship commander, and he/she must hold a Certificate of Competency grade 1 (CoC) or equivalent Certificate of Endorsement (CoE) and BRM certificate as a requirement of STCW Convention, which requires a maritime education, training and sea-time service. He/she must ensure the efficiency of the bridge operation, safety, controlling and following the regulation. He/she must be in charge of the bridge team along with all resources that are available on the bridge while making sure that the bridge navigation is performed in a safe manner.

3.5.2.2. Officer of the Watch (OOW)

The OOW is the responsible officer to maintain a safe navigational watch when the master is off charge. The OOW must hold a (CoC) or equivalent grade 2 to 4 depends on the rank before he can undertake bridge duties as well as a BRM certificate. The 1st/Chief Officer is the second of the command after the captain holds CoC 2, the 2nd Officer hold CoC 3, and the 3rd Officer hold CoC 4. The OOW must perform a safe navigational watch, follow the bridge procedures at all time. The OOW should not leave the bridge unmanned under any circumstances unless an equivalent OOW or the captain is available and carried out a good lookout by utilising all navigational equipment available in the bridge. Moreover, he/she must communicate and perform teamwork with other bridge team members.

3.5.2.3. Deck Rating

The deck crew are members of the ship who do not need a CoC to work onboard the ship; accordingly, they are not participating in the BRM course while they require to participate in some safety courses. Their duty is to assist the captain and the OOW during the navigational watch as a lookout or control the wheel if required. As rating crew have duties on the bridge, they must perform a sharp lookout, communicate with other team members and not hesitate to report any hazard that can affect the safety of navigation.

3.5.2.4. Deck Cadet

The deck cadet is a seafarer who joins the ship to complete his/her practical training after/or during the nautical studies in a maritime institution to fulfil the CoC criteria. The cadet must serve between 12-18 months onboard the ship to finish his/her sea-time to be qualified for the CoC examination to be an OOW. As the rating, the cadet needs to attend several safety courses before joining the ship; BRM is not one of them, but during his/her studies, the cadet takes BRM fundamentals through many teaching modules. For his/her duty onboard the ship, the cadet must serve in both bridge and deck under the OOW and the Bosun supervision. The cadet must maintain a full navigational watch that includes communication, teamwork, lookout, etc. and any additional work that can be assigned by the captain or OOW. Therefore, despite the fact that it is not compulsory for Cadets, BRM is essential for cadets considering their duties and possible impact on team performance.

3.5.2.5. Pilot

The pilot is a seafarer who manoeuvres the ship in a special area such as ports, channels, etc., that are not frequent areas for the ship's captain and, therefore, is recognised as a hazardous navigational area. The pilot must have local knowledge and experience to navigate in that area, and in a majority of countries, the pilot must hold a CoC certificate; some countries do not require that, along with a pilot certificate. The pilot must team up, communicate and exchange the information and the berthing/unberthing instruction with the ship's captain and other bridge team member. During the pilotage operation, the pilot is responsible for steering the ship, but the captain is still responsible for the safety of the ship, and if he left the bridge, for any reason, the duty OOW takes the con after him, not the pilot.

3.5.3. Communication

Many accidents occurred due to the lack of communication between the bridge team members (including the pilot) and with other targets due to the communication problems between the parties involved, especially when approaching or leaving the ports (Baker and McCafferty, 2005; Hetherington, Flin and Mearns, 2006). It has never been cited that the IMO recommend external communication via the VHF as a tool for collision avoidance practice; instead, the bridge team could use the sound or light signals to refer to their action, which is found more difficult to memorised and applied it in critical situations comparing to using VHF as communication method (Abdushkour, 2020). Every vessel should comply with

COLREG rules in the first place. Simultaneously, it is recommended to make bridge-to-bridge communication in the collision case or remove the hesitancy between the OOWs in the local area such as US local waters (Harding, 2002). In 2003, Koester (2003) stated that when communication increases, the preparedness for the potentially safety-critical situation will increase, and this will reflect positively on managing future risky situations.

3.5.4. Teamwork

Salas *et, al.* (1995) define a team as "*a distinguishable set of two or more people who interact dynamically, interdependently and adaptively toward a common and valued goal, who have each been assigned specific roles or functions to perform and who have a limited life span of membership*".

Teamwork and taskwork are two constituents of collaborative endeavour. Teamwork is comprised of coordination and interaction between individuals to fulfil specific tasks that ultimately lead to achieving the team's goals. On the contrary, taskwork includes situations where individuals work solely on different tasks. Wilson *et al.*, (2007) define teamwork as "*a multidimensional, dynamic construct that refers to a set of interrelated cognitions, behaviours and attitudes that occur as team members perform a task that results in a coordinated and synchronised collective action*". According to Burke (2004), taskwork and teamwork are both needed to fulfil team tasks successfully. When maritime accidents due to lack of teamwork are studied, the main reasons are identified as misunderstanding between bridge team members, deficiency of communication and insufficiency of coordination (Mansson, Lutzhoft and Brooks, 2017). Moreover, Lützhöft and Bruno (2009) stated that lack of communication and trust between team members due to their role in the team, skills, incompetency and first language of communication would reduce the effectiveness of teamwork. Also, the absence of strong leadership, misdistribution of roles and duties will increase the amount of complication between the bridge team members while causing teamwork performance deficiency (Brodje *et al.*, 2013).

3.5.5. The Differences between BRM and Crew Resource Management (CRM) for Aviation

After many catastrophic aviation accidents which occurred due to human factors in the last century, several commercial aviation companies and international aviation safety agencies that include the Federal Aviation Administration (FAA), European Union Aviation Safety Agency (EASA), introduced the Cockpit Resource Management as a training course for all pilots and their assistance in the cockpit only in the beginning of the middle of 80s. However, at the beginning of the 90s, a new implementation was added to include the cabin crew, flight dispatchers and maintenance personnel in the training course, which is known nowadays as Crew Recourse Management (CRM). This is different from the maritime BRM course participants (Foushee and Helmreich, 2010; Hayward and Lowe, 2010). The aviation CRM course aims to enhance the crew performance through utilising communication, leadership, teamwork and maintenance, problem-solving, decision-making and maintaining SA (Foushee and Helmreich, 2010; Ginnett, 2010; Kanki, 2010; Orasanu, 2010). According to many aviation institutions, even those owned by commercial companies, all CRM's contents will be addressed and taught at the same quality without any difference between the institutions to ensure the equality of training efficiency for all participants worldwide. However, in many maritime institutions, it was found that there are differences in the course contents. Furthermore, some of the maritime institutions which are owned by commercial companies do not accept any participant who does not belong to this company.

3.6. Situational Awareness

3.6.1. Background

SA is the attractive term, which describes the awareness level that an individual has of a situation, an operator's dynamic understanding of "what is going on" (Endsley, 1995c). The first use of this concept was in the military aviation domain to describe a critical asset for military aircraft crews during the First World War (Endsley, 1995c). Despite this, it initiated to receive attention from academia around the beginning of the 1990s (Stanton and Young, 2000), when SA-related research studies started to appear in the aviation and air traffic control domains (Endsley and Connors, 2008; Salmon, 2008).

In 1995, the Human Factors journal started to focus on SA, which became a key topic within the HF research community, and many researchers commenced to investigate the concept in different domains (Salmon, 2008).

The SA concept has since developed into a fundamental theme within system design and evaluation and continues to dominate HF research worldwide. Moreover, a peer-reviewed academic journal article specified that SA research studies had been reported in over 20 different scientific journals covering a varied range of different sectors, ranging from HF and transportation to the sport, disaster response and artificial intelligence (Salmon, 2008).

3.6.2. Definition of Situational Awareness

For nearly half a century, many researchers tried to define what SA is. Also, they came with over 30 definitions to demonstrate and explain the SA. The most of definitions that been used in research studies up to now are summarised below.

In 1991, Fracker (1991) defined SA as "*the combining of new information with existing knowledge in working memory and the development of a composite picture of the situation* *along with projections of future status and subsequent decisions as to appropriate courses of action to take*".

In 1994, Dominquez (1994) stated SA as "*continuous extraction of environmental information, and integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing future perception and anticipating future events*".

In 1995, Smith and Hancock (1995) described SA as "*the invariant in the agent-environment system that generates the momentary knowledge and behaviour required to attain the goals specified by an arbiter of performance in the environment*".

In the same year, Endsley (1995) declared that SA is "*the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future"*. Many researchers have been using this definition until recently(Sharma, Nazir and Ernstsen, 2019).

While in 1999, Bedny and Meister (1999) stated that "*the conscious dynamic reflection on the situation by an individual. It provides a dynamic orientation to the situation, the opportunity to reflect not only on the past, present and future, but the potential features of the situation. The dynamic reflection contains logical-conceptual, imaginative, conscious and unconscious components which enable individuals to develop mental models of external events*", who discussed Endsley's concept (Salmon, 2008).

3.6.3. Individual models for situational awareness

In this section, an overview of the most common models about situational awareness used for research purposes is provided below.

3.6.3.1. Three-Level Model by Endsley

Endsley has divvied her vision of SA into three levels to explain the operator or individual situational assessment to achieve the required SA that separates it from the processes shown in Figure 3.3 below.

This model is a basic model that requires information as an input given to the system or the individual to execute some complex operation or involved in the decision-making process. When the operator acquires this information, he/she will be in a position to understand it from the set of inputs he/she got. It will lead to decision making and taking action. Endsley's model of SA achievement and maintenance is influenced by the operator experience, training, workload etc. (Endsley, 1995c).

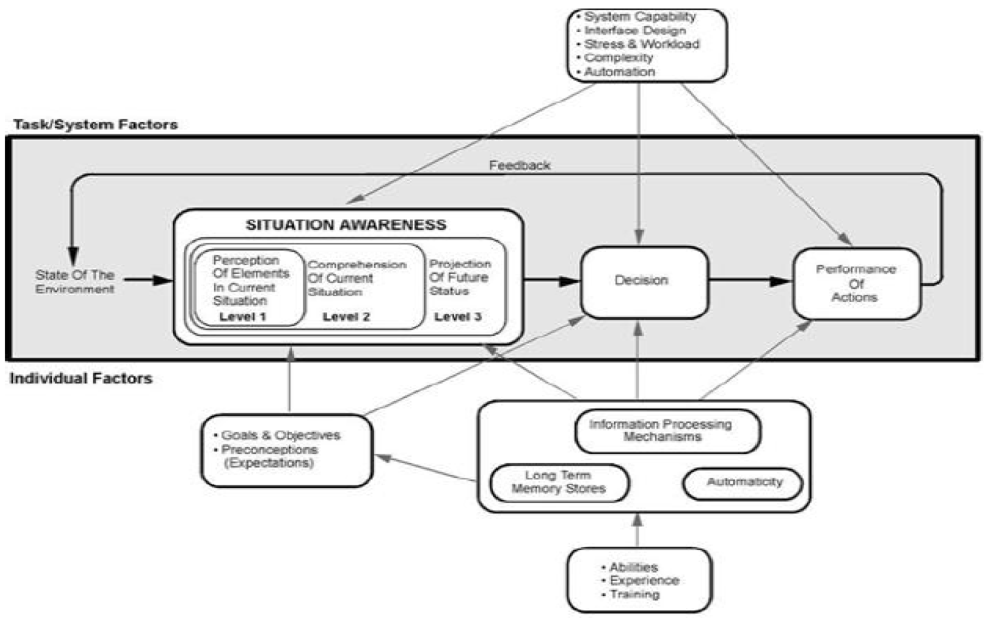

Figure 3.3 The three-level model of situational awareness (Endsley, 1995b).

Level 1: Perception of the Elements in the current situation

The first step involves recognising the status, features and dynamics of event-related elements in the surrounding environment. Endsley clarified at this point that the only important thing is to understand the input data without processing it. Some factors affect the individual's decision-making process through understanding this data, such as the nature of the task, complexity of the operation, nature of input information, level of difficulty, dependent variables, operator goals, the experience of the individual, expectations of the process and operator, design interface, system design complexity, man-machine interaction, capabilities and automation of the machinery. Moreover, Endsley added, "*a person's goals and plans direct which aspects of the environment are attended to during the development of SA*" (Endsley, 1995; Salmon, 2008; Kumar, 2014).

Level 2: Comprehension of the Current Situation

Level 2 SA is a significant stage as the event's aims depend on the understanding of the operator or an individual about the importance of data to comprehend or realise. A particular work task can be performed in a more effective and safer way. Also, in level 2 SA "*the decision-maker forms a holistic picture of the environment, comprehending the significance of objects and events*".

There are some common factors between level 1 and level 2 of SA, as the interpretation and comprehension of SA-related data is influenced by an individual's goals, expectations, experience in the form of mental models, and preconceptions regarding the situation. With this regard, operators with such experience will use the common factors to combine level 1 of SA with Level 2 to accomplish their objective in a much better and safest way. The only difference here is the individual or operator's potential to recognise the main items for achieving a particular work task's goal.

Level 3: Projection of Future Status

Level 3 of SA involves determining the system's future states and its elements for the complex and different decision-making processes, which require extreme thinking and assessment to achieve the objective in the future event unknown to this time of level 2 SA. By applying level 1 and 2 SA-related knowledge, and experience in the way of mental models, operators can predict likely future states in a particular situation.

This relationship of situational data with the experience allows operators to estimate future situational events.

Therefore, level 3 of the SA model has a magnificent role in the increase and maintenance of SA. Training and experience (mental models) are used to assist the target of SA by directing attention to important elements in the environment (level 1), gathering the elements to understand their meaning (level 2) and finally, create possible future states and events (level 3).

3.6.3.2. Active Theory by Bendy and Meister

Endsley's model describes SA as a simple activity approach focusing on different processes that are associated with the tasks to be executed by the operator, taking into consideration the human action and behaviour to achieve this task (Endsley, 1995, Salmon, 2008). The active theory model is covering the individuals' objectives that show the end state of the activity. Taking into account their motivation, the model implements exploratory actions and past experiences to complete the conceptional model, as shown in Figure 3.4 below (Bendy and Meister, 1999).

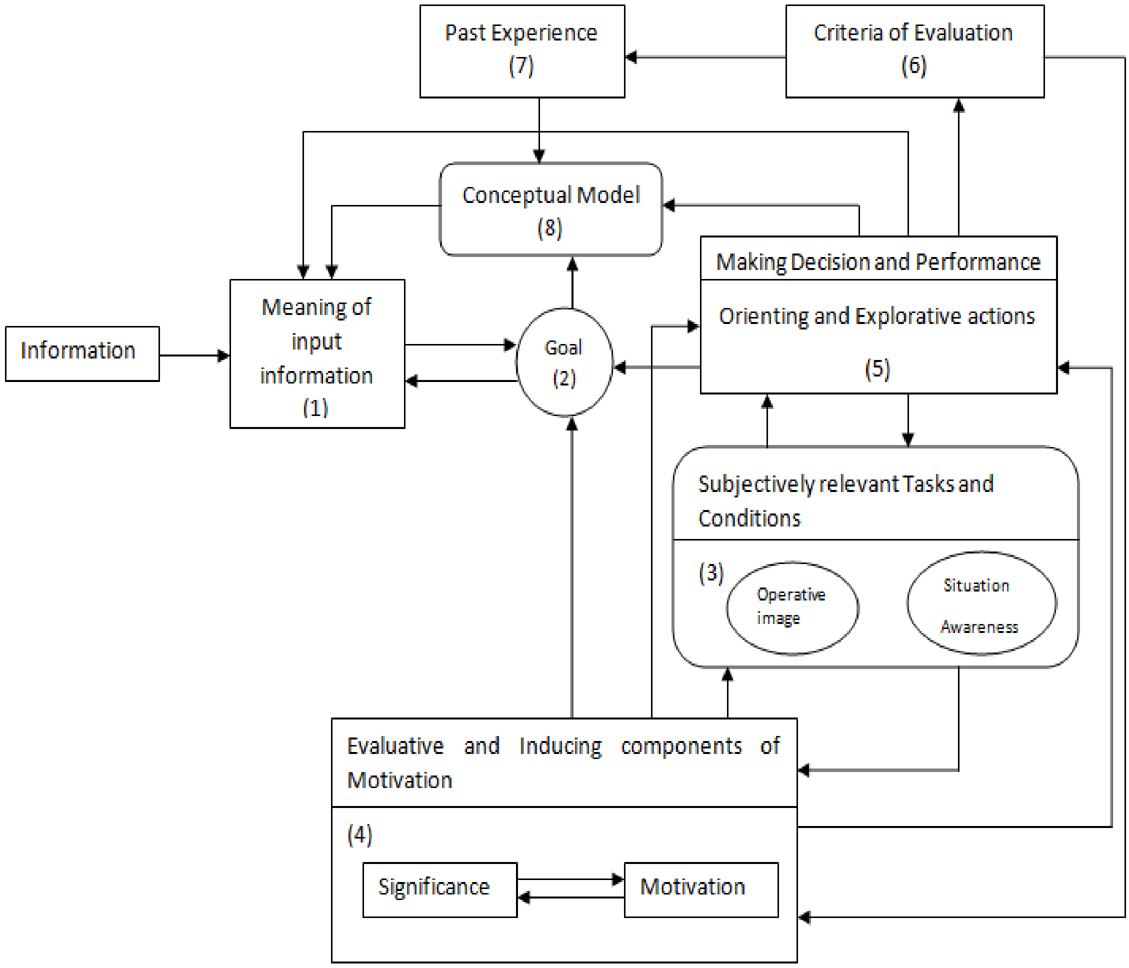

Figure 3.4 Active Theory approach to situational awareness (from Bedny and Meister, 1999).

There is a difference between the final goal and the current situation, which encourages the operator to take action to achieve this goal. Bendy and Meister divided the end state activity into three levels: firstly, the orientation level, which led to the executive and the evaluative level. The orientation level puts spotlights on the initial development stage, where the internal view of the current situation is accessed by applying the executive part to reach the optimum goal via decision-making and action to be done.

The blocks in above are carrying information that is related to each other to accomplish their exact targets. The incoming information (box 1) is supported by an individual's goals (box 2), the current situation conceptual model (box 8) and his/her experience (box 7). This form of clarification then adjusts the goals and the model of the current situation. The surrounding environmental factors are then identified (box 3), which is important in the task or the end goal with encouraging motivation components a) Sense and b) Motivation (box 4). That will lead to focusing their interaction on decision-making and performance (box 5). Then, it is extended by the operator to reach the task goals (box 2) and the evaluation of the current situation (box 6). The result of this process is saved as experience (box 7), which is linked to the conceptual model (box 8) along with the extension from (box 2).

3.6.3.3. The Perceptual Cycle Approach by Smith and Hancock

Smith and Hancock described SA as a huge quantity of knowledge, which is designed for taking actions. Smith and Hancock's model was inspired by Niesser, (1976), who created the first perceptual cycle model, which takes into account the individual's interface with the surrounding environment and information sequence role in these interfaces. The model includes the operator's observation of the external environment that is part of the knowledge model designed to do the task. This observation results in modifying the original knowledge model, which in turn directs further exploration. By using this approach, Smith and Hancock concluded that SA is information that the operator achieves through repeated interactions with the surrounding environment. They found that the process of reaching and maintaining SA takes into account internal mental models, which are built by the operator who accomplishes SA either by repeated exchange with the world or by previous experience of similar situations.

The mental models' performances as an intermediate for current situational events bring the operator to a certain level which he/she must capture the surrounding environment to understand specific tasks, and leading them to take action according to his/her knowledge gained through repeated interactions or previous experiences. Therefore, the operator would get a better understanding of the situation to meet his/her final goals. However, some doubt and unpredicted situation produce changes in the existing model, which is demonstrated in detail in Figure 3.5 shown below.

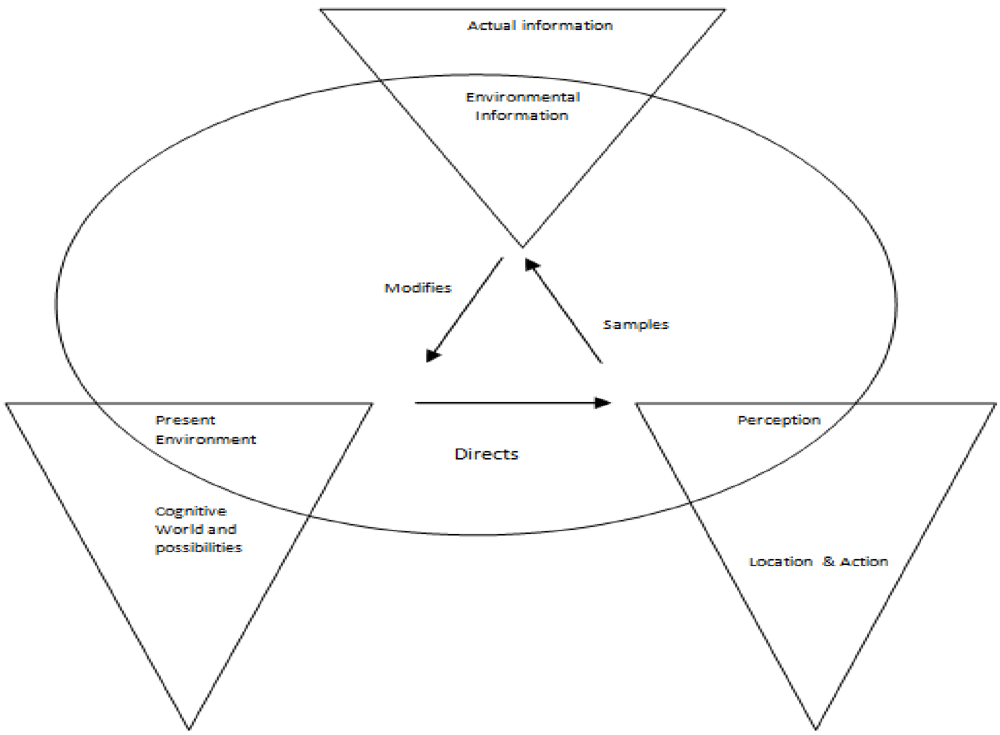

Figure 3.5 The perceptual cycle model (Smith and Hancock, 1995)(Salmon, 2008).

Here the SA is the combined process and the product, which presents a clarification of the cognitive activity involved in achieving SA and decision as to what the product of SA contains.

3.6.3.4. Comparison between SA models

Table 3.1 below shows a comparison between the most known and used SA models.

Table 3.1 The differences between the Individual SA models

	Three-Level Model	**Active Theory**	**The Perceptual Cycle Approach**
Advantages	• Widely used. • Simple to demonstrate and apply the model in different fields. • The model can be utilised for important factors such as training and workload. • Availability of measurement methods works with the model effectively (in case if needed) • This model is used in many sectors, especially in the maritime sector, in a wide range of research studies.	• The model is considered as product and process of SA. • Clear description for each block and its function.	• The model is considered as product and process of SA. • The model is based on a well-described theory.

Disadvantages	• Limited use in psychological models, e.g. information process. • The model is considered a product by dividing the SA into three levels.	• It is very complex and hard to apply this model in the maritime sector. • Limited use. • No measurement method applies to this model.	• It is complex. • Limited use.

There is no doubt that Endsley's model is the most used method in human factor literature generally, and SA precisely compares to the other models (Salmon, 2008). The model allows to measure and support the SA more efficiently and effectively by dividing the SA into three-level. Despite the disadvantages of Endsley's model, this model is easy to modify to be more suitable for the maritime sector than the other models. Also, it easy to be explained and understandable the target audience due to dividing the SA into three levels.

3.6.4. Team situational awareness

Throughout the last thirty years, there has been a substantial increase in the use of teams (Leonard, Graham and Bonacum, 2004; Stanton *et al.*, 2017). The expanding intricacy of work and work strategy and the efficacy of well-organised teams has made the use of teams superior to sole operators. This has led to the capability of conducting challenging and problematic tasks, enhanced productivity and decision making (Salmon, 2008), working under immense pressure and decreasing the amount of error (Baker and Salas, 1992; Salas, Cooke and Rosen, 2008). The majority of contemporary systems are comprised of teams; this has led to the enhanced importance of team situational awareness in the Human Factors community. Moreover, complex systems using teams will rise dramatically due to technological capabilities' continuous growth (Fiore *et al.*, 2003).

Team SA is undoubtedly more than simply joining an individual team member's situational awareness together (Salas *et al.*, 1995). Since team SA constitutes high levels of cognition, exploring its constitution is both challenging and lacking, which makes it a conflict area as individual SA is (Salas, Muniz and Prince, 2006). Team SA is allegedly multi-component and involves incorporating individual team member SA with the whole team SA, the so-called "common picture". Efforts to discern team SA focused on "shared understanding" of the same situation. (Nofi, 2000), for example, defines team SA as "a shared awareness of a particular situation", and (Perla *et al.*, 2000) suggest that "when used in the sense of shared awareness of a situation," shared SA implies that we all understand a given situation in the same way". Team SA involves every team members SA and the extent of shared understanding amongst them (Salas, Muniz and Prince, 2006). Salas *et al.*, (1995), suggested a scheme of SA, proposed that it involves two meanings: individual SA and team processes and that it relies on communications at differing magnitudes. Various team performance factors influence the comprehension of SA elements, such as the communication of mission objectives, individual tasks and roles, as well as team capability. Strategy limitations can be equilibrated by information exchange and communication guided by the coordination between team members (Salas *et al.*, 1995). It can be acknowledged that this is affected by the understanding of other team members. It is a fact that achieving team SA results in individual SA as individual SA is established and then shared with other team members, which ultimately establishes and alters team members' SA.

(Salas *et al.*, 1995) define team SA as "*the shared understanding of a situation among team members at one point in time and dissolve that team SA "occurs as a consequence of an interaction of an individual's pre-existing relevant knowledge and expectations; the information available from the environment; and cognitive processing skills that include attention allocation, perception, data extraction, comprehension and projection*".

3.6.5. Shared situational awareness

There is a difference between team SA and shared SA (Endsley, 1995c) and (Endsley and Jones, 1997). Shared SA stands for the area of intersection between team members SA elements. This means that the SA of every individual in the team required for a particular task intersects with other individual’s requirements. (Endsley and Jones, 1997) define shared SA as “the degree to which team members have the same SA on shared SA requirements”. However, they define team SA as “the degree to which every team member possesses the SA required for his or her responsibilities”. In certain situations, SA will overlap between individuals in the same team so that each individual will understand and execute SA elements pertaining to their role as well as other SA elements required by other individuals in the team (Endsley, 1995b). Team accomplishment can only be achieved when each team member has superb SA within their fundamental principles and, at the same time, equal SA for the shared elements (Endsley and Robertson, 2000).

Justification of shared SA can be used practically in several fields. For instance, in aeroplanes' maintenance teams, excellent team SA requires comprehension of the team members to share data amongst each other (Endsley and Robertson, 2000). Furthermore, Endsley and Robertson (2000) proposed that team performance's key influencers are the shared goals, self-sufficiency of team members’ activities, and the distribution of work amongst team members. This denotes that some SA requirements are independent such as the workload of the team, but at the same time, team members have shared goals and perform inter-reliant activities so that they all hold shared SA. Endsley and Robertson suggest that well-organised team execution relies on team members having well-established SA solitarily and the exact SA on shared SA requirements.

3.6.6. Development of team and shared situation awareness

The consequences of team process variables on team SA have not been thoroughly investigated (Salas *et al.*, 1995). The effect of enhanced teamwork on team SA is thought to be exponential; however, the association between team SA and team conducts and qualities is not entirely understood. Investigators have concentrated their research on communication as the most important component of the team and shared SA (Nofi, 2000). Entin and Entin (2000) describe communication as a requirement for an advanced team SA. Salas *et al.* (1995) propose that team procedure, which enhances communication, for example, confidence, preparedness, and leadership, influence SA expansion considerably. The environment that encourages clear and open communication is one of the essential elements to promote shared SA (Salas *et al.*, 2001). The same reflection was made by Endsley (1995c), who proposed that team member SA of common features could provide a guide for teamwork or team communication.

Lloyd and Alston (2003) argue that mutual team comprehension is formed by team members acquiring individual SA then conveying it across the team. Close observation is another crucial part of team SA by which team members carefully observe one another's performance, e.g. Rognin, Salembier and Zouinar, (1998), enabling the recognition of situational information and comprehension of it by other team members without the need for confrontation. Observing common activities stands for "the ability to keep track of fellow team members work, while carrying out their own work, to ensure that everything is running as expected and to ensure that they are following procedures correctly" (Wilson *et al.*, 2007); This demands team members to comprehend the individual team members, collective team tasks, knowledge of the team members' duties, commitment, and anticipation of what team members ought to implement.

A further vital notion to team SA is the concept of shared mental models. Mental models are illustrations of the inner process of a system. They have been defined as "knowledge structures, cognitive representations or mechanisms which humans use to organise new information, to describe, explain and predict events as well as to guide their interactions with others" (Paris, Cannon-Bowers and Salas, 2000). The shared mental model has been further described by Fiore *et al.* (2003) as "the activation in working memory of team and task-related knowledge while engaged in team interaction". As stated by Klein (2000), shared mental models stands for the degree that members have the same comprehension of the important factors in procedures; for instance, duties and purposes of each team member, essential qualities of the tasks, and utilisation of supplies. Stout *et al.* (1999) propose that shared mental models "*are thought to provide team members with a common understanding of who is responsible for what task and what information requirements are. In turn, this allows them to anticipate one another's needs so that they can work in sync*". In the opinion of Salas *et al.* (1995) shared mental models are prearranged form of knowledge that is common throughout team members. Cannon-Bowers and Salas (1997) advocate that shared mental paradigms consists of a combined task and team goals as well as the knowledge of individual tasks and team member duties. Endsley and Jones (1997) argue that shared mental models ought to integrate the understanding of different team roles, strategies, data necessities, possible rearrangements, and the capability to utilise the actions and counteractions of other teams. Many investigators have hypothesised the significance of shared mental models in the advancement and conservation of team SA. As Langan-Fox, Code and Langfield-Smith (2000) mentioned, for effective team functioning to be constructive, there must be a shared mental model throughout team members.

Furthermore, effective teams utilise shared mental models to manage actions (Fiore *et al.*, 2003). Shared mental models are believed to ease communications between team members Perla *et al.*, (2000), enabling team members to predict other team members' actions (Salas, Stout and Cannon-Bowers, 1994; Fiore *et al.*, 2003). Salas *et al.* (1995) go on to propose that when communication means are scarce, shared mental models permit team members to predict other team members actions and data needs. They also advocate that when it comes to team tasks, shared mental models enable team members to work within a known structure. Endsley (1995a) reasons that team SA is more dependent on shared mental models than it is on spoken communication.

3.6.7. Maritime Situational Awareness

The concept of SA was predominantly implicated in the aviation sector, which is mentioned above, for the last two decades; however, various SA research studies were conducted in the field of maritime navigation (Chauvin, Clostermann and Hoc, 2009; Gartenberg et al., 2014; Sharma, Nazir and Ernstsen, 2019).

To know the impact of SA on merchant shipping operations, Grech, Horberry and Smith, (2002) scrutinised several accident reports and studied their connection with the lack of SA. Grech, Horberry and Koester (2008) reflected that SA is a significant concern related to the performance of marine navigators. They then considered workload and attention as separate elements contributing to SA. Furthermore, Chauvin and Lardjane (2008) and Chauvin (2011) displayed the use of the Endsley SA three levels concept as a decision-making model for ships encountering manoeuvrability situations.

The methodology of SA has been progressively used for accident analysis and has been utilised in guidelines for training and operations in marine navigation. Human element importance in navigation has been studied by Hetherington, Flin and Mearns (2006), who noticed that the lack of SA is one of the leading individual factors for maritime accidents. In an attempt to analyse maritime accidents, Grech, Horberry and Smith, (2002) found that SA issues cause 71% of the human and organisational factors. Furthermore, dissection of the figures utilising Endsley's taxonomy model (Endsley, 1995a) showed a tendency in SA affiliated errors with 58.5% errors occurring at Level 1, 32.7% at Level 2 and 8.8% at Level 3. Jones and Endsley (1996) have shown similar figures as well. Several other research studies were conducted by Sneddon, Mearns and Flin (2013) and Sandhåland, Oltedal and Eid, (2015) to investigate the offshore segment and determine factors impacting SA of the maritime navigators and operators. Cordon, Mestre and Walliser (2017) identified spatial aptitude, attention, organisation, awareness, and leadership in their research and were further subcategorised by Endsley's three-level model in their aptitude model. SA of the maritime crew might potentially be the role of the captain's leadership, as suggested by Sætrevik and Hystad (2017).

With regards to Vessel Traffic Service (VTS), many research studies were published about the application of SA in the field of maritime navigation which they all refer to Endsley's model (Cordon, Mestre and Walliser, 2017; Sætrevik and Hystad, 2017; Sharma, Nazir and Ernstsen, 2019). For instance, Nilsson, Gärling and Lützhöft (2009) identified the factors to implement SA in maritime surveillance, which experienced VTS operators used. Wiersma (2010) used a practical approach of SA on the Port of Rotterdam VTS. Van Westrenen and Praetorius (2014) produced a theoretical approach utilising SA to evaluate the performance in VTS.

3.7. Maritime Simulator Experiments

The most common reasons for maritime accidents are attributed to human and organizational factors, comprising more than 80% of maritime accidents. For example, misjudgement, poor lookout and not following regulations are examples of accident causes related to human factors. Bridge operation requires performing various cognitive tasks at the same time, necessitating excellent situational awareness and correct judgement, which can sometimes fail, whereby causing a collision. The traditional method of analysing human and organizational factors is not enough, as it cannot find the relationship between performance-shaping factors and human performance during operation and is not beneficial for individual evaluation (Liu *et al.*, 2016). The maritime education domain often tries to meet training aims within the subject of human factors related to operator performance in technological working environments along with the ergonomic design of such settings (Vicente *et al.*, 2004; Hontvedt, 2015). Maritime simulators are usually utilised for learning professional skills, collaboration and teamwork in a safe operational environment. The current research indicates that simulator training can deliver content and scenarios and instructional features, including opportunities to assess individual and team activities in different professional fields, such as medical, aeronautic, and maritime (Hontvedt, 2015).

Schuffel, Boer and Van Breda (1989) conducted a study on the feasibility of an extremely automated ship's bridge for single-handed navigation. The research defined a function allocation process, which forms the foundation for an automated bridge concept that can be applied to future merchant vessels. The approach provides an effective ergonomic design to optimise the safety of the navigational system and the working conditions. It provides a balanced relationship between the four core elements of the manship system: software (procedures, rules, regulations), hardware (displays, controls, process dynamics), environment (climate, vibrations, noise) and life-ware (motivation, stress, skill). The authors believe that the most important task in the integration process is functional allocation, which concerns the differentiation between human and automated functions. This step is necessary in order to define the efficiency of the bridge layout, especially the workstation. To validate the model and the innovative bridge design, they used a sequence of simulation experiments. They investigated the navigational performance efficiency and safety during the conduct of such application. The simulator helped to verify the performance of the proposed bridge design/system by implementing the model in operating conditions similar to those in reality. The study focused on measuring the workload generated by the primary tasks. The experiments were carried out by conducting navigational tasks and Continuous Memory Tasks (CMT). The authors selected 32 OOWs for participation in the ship simulation. The results showed that correct functional allocation could increase the safety of navigation by improving task performance. The study places a large emphasis on the feasibility of human performance on the ship's bridge. The new approach did not affect the navigator's mental load. However, the consequences of repetitive duty conditions for operators' situational awareness were not discussed. Besides, not all of the functions can be automated. Furthermore, operators' skills and motivation required after changing the task structure from active manual control to passive monitoring control need further investigation.

Nilsson, Gärling and Lützhöft (2009) conducted a comparative simulator study between an integrated ship navigation system bridge and a bridge that did not contain modern conventional navigational equipment. Actual event scenarios were designed to contain several challenging conditions during sailing in a fairway. Different elements were assessed in the scenario, such as performance, workload, and effective responses. Experiment outcomes demonstrated not much of a statistical difference between both bridges' performance. Nevertheless, about technical performance, it was found that experienced navigators executed much more effectively on the conventional bridge and less experienced officers performed more effectively on the technically advanced bridge. This is due to the fact that younger people are more skilled with modern electronic systems and therefore performed well. In contrast, the older seafarers performed better with traditional systems because they are not very skilled with the latest electronic systems.

Gould *et al.* (2009) presented a study to examine mental workload and performance and used a high-speed ship simulator. It compared two navigational systems for defining the vessel location: Electronic Chart Display and Information System (ECDIS) and conventional paper charts. The experiment scenario included a navigational track of 50 nautical miles containing various sailing conditions 20 cadets performed. The results illustrated that using the ECDIS for bridge navigation significantly enhanced course-keeping quality; nonetheless, it decreased the communication among the bridge team. No differences were observed in the mental workload aspect between groups. After measuring the heart rate variability and skin conductance of different groups, it indicated a higher workload in the conventional method for navigation, but the variances were not significant.

Chauvin, Clostermann and Hoc, (2009) adapted the study to examine the impact of a training programme on the capacity of the officer of the watch (OOW) to make decisions in collision avoidance conditions in a bridge simulator. Drills were planned so as to assess the impact of the training course. It developed a set of indicators that the OOW must recognise: cue recognition, the formation of anticipation, appropriate objective identification, and realisation of distinctive actions. The simulator experiments' observation results indicated that students were incapable of managing such conditions or even remembering their key features as they learned in class. As a result, the decision-making training did not develop students' capacity to the level that helped them to examine the complex situation. It is consequently essential to develop new educational methods that give cadets the capacity to analyse a situation rapidly and precisely in order to take suitable actions. It is recommended that to improve OOWs' capacity to perform navigational tasks, and shipping organisations should replace the long onboard training with an intensive training program on maritime simulators so as to repeat the same critical situations in a safe environment.

The lack of seafarer numbers, the developed technology onboard the ship, and enhancing the crew skills to work parallel with this technology are the main concern of the shipping industry. The development of the Crew Resource Management course (CRM) has become fundamental to solve these problems. The validity of this training requires assessment, especially as the majority of accidents occur because of human and organizational factors, such as those from operators, organisation, maintenance, design, installation and assembly (Håvold *et al.*, 2015). Håvold *et al.* (2015) evaluated the effectiveness of CRM training in the anchor-handling simulator, which is expected to develop crew skills with respect to teamwork, leadership and communication. They distributed a questionnaire, which covered the course quality and contents, knowledge and skills acquired, and future application among

369 seafarers who have more than one year of experience onboard ships. The outcome results were examined by ANOVA, including other variables such as age, employment, and anchor-handling practice. The research results showed that CRM training enhanced the participants' performance, such as change-intended behaviour, improved skills, knowledge and understanding, and the course's content by more than 60%. However, the assessment of this research could be affected by the objectives of participants which are required to be explored more in the CRM area.

Liu et al. (2016) conducted research aimed to improve cadets' performance by assessing and understanding the relationship between brain workload, stress and their performance. They focused on cadets' performance by observing different brain conditions, such as workload, stress, and situational awareness during bridge operation. They used electroencephalography in a human factor analysis system designed for full-mission simulator assessment and measurement of cadets' cognitive abilities. They recorded cadets' performances in different sailing scenarios that include night and day navigation and sailing in varying weather and traffic conditions for analysis and assessment. The research results specified that the model was useful for detecting cadets' emotions, situational awareness, brain workload and stress levels during the bridge operation. Also, it was possible to assess the condition of OOWs before performing a navigation watch.

Badokhon (2018b) aimed to improve the safety and the resilience of the navigation bridge standard operating procedure by performing a developed bridge operating checklist and procedure forms to guide one of the bridge team members who participated in this test before the navigational watch. He evaluated the performance of the two teams' judgement ability, emergency preparation, situational awareness, lookout quality, alarm management, leadership, passage planning and learning by exposing them to different sailing scenarios that include normal navigation, passing agreement, restricted visibility, shallow water effect and pilot onboard. The outcome of his research is the performance of the team, who worked under the developed procedure, was 124% higher than another group. However, the research's measurement was focused on the individual skills' rather than the teamwork performance by delivering the developed procedures within the preparation time before starting the scenarios. Also, the assessment of this research could be affected by the subjectivity of participants.

Overall, the maritime simulator experiments signposted numerous gaps. The navigational operation involves performing several cognitive tasks at the same time, which require building and maintaining situational awareness along with the right decision-making to avoid a collision. The results were short of quantitative measurement due to the necessity of analysing human and organizational factors and performance with several measurement techniques that can be performed by utilising the maritime simulator. The experienced OOWs have performed more effectively on a traditional bridge operation, while the less experienced OOWs have performed much efficiently on the technically advanced bridge operation. Also, the review shows that using electronic navigational equipment has enhanced the navigational practice but, it decreased the communication and teamwork among the bridge team, which has been suggested that more research is required in the bridge resources management area.

3.8. Summary

The literature on enhancing navigational safety through increasing situational awareness and teamwork methods was reviewed, and gaps were identified. Even though a significant number of research studies has been conducted in this area, a comprehensive assessment to increase the seafarers' skills by performing an efficient bridge resource management among the bridge team that includes all the bridge members, according to the best of this author's knowledge, does not exist.

4. Methodology

4.1. Chapter Overview

This chapter presents the approach adopted and the methodology to conduct the aims and objectives of this research.

4.2. Improving Navigational Safety by Enhancing the Performance of Crew

Based on the research problem identified in Chapter 2 and the maritime accidents analysed, this research's aims and objectives will be achieved by focusing on crew performance as a team. The assessment for the situational awareness of crew members is established as the main area for enhancing navigational safety and teamwork in the bridge. Identification of the interaction issues among bridge team members will be studied, including the weaknesses of teamwork, sharing situational awareness through communication. Various BRM courses in different maritime institutions will be attended to observe the current practice of addressing the above issues through training. Finally, a new BRM course that can improve the performance of the bridge team will be developed. The effectiveness of the new course will be assessed via a case study in the maritime simulator to measure the quality and the performance of the bridge team actions. The proposed methodology, as shown in Figure 4.1 The proposed Navigational Safety for Crew Member Assessment and Improvement Methodology below, comprises of three assessments and two improvement sub-methods, which are:

- Review of Maritime Accidents
- Situation Awareness Survey for Crew Members.
- Identify the differences among various BRM Courses.
- Develop Bridge Resource Management for Seafarers.

- Perform Simulator Experiments to test and validate the proposed BRM approach.

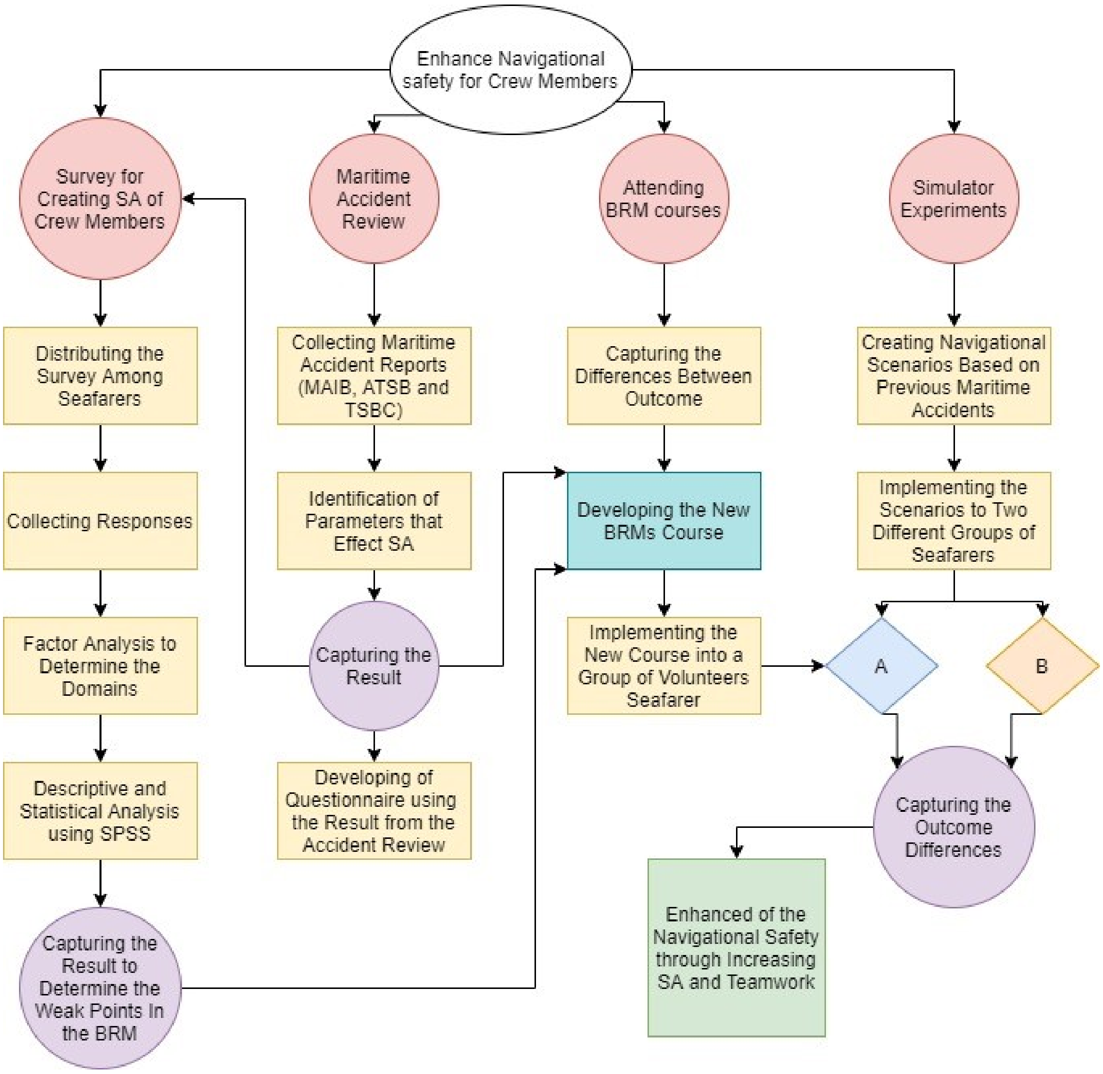

Figure 4.1 The proposed Navigational Safety for Crew Member Assessment and Improvement Methodology

Each step of those methodologies will go through the development and an improvement phase. Then, data collection will be performed. Therefore, each method is applied independently, but all of them are linked to support each other to achieve this research's main aim.

In order to find the weaknesses within the seafarers' performance on the bridge, the following step will occur, which shows above in Figure 4.1. A review of many accident reports will take place to identify the factors that affect the bridge team's SA. Then, a survey will be established; each question will represent an accident or more, to be distributed to the seafarers and collect their responses to be analysed afterwards. Later, attending BRM courses in different maritime institutions to highlight BRM gaps that might affect the bridge team's performance might affect the bridge team's performance. Therefore, finally, proper improvement plans will be proposed and tested based on the problems identified. The developed course and the simulator experiments are designed to complement each other. The new BRM course is proposed to help the seafarers enhance their skills by addressing all weakness identified. Then, the proposed course is validated by using the full-mission bridge simulator experiments to enhance the quality proposed of the BRM course. The overall structure is briefly described below:Firstly, the maritime accidents were collected from three different marine accident investigation boards (MAIB, ATSB and TSBC). They were then reviewed to select the accidents caused by the bridge team's errors. Those accidents are then analysed in order to capture the underlying reasons that led to the loss of SA of the bridge team. Underlying reasons are collected and utilised to develop the questions for the questionnaire. Secondly, the questionnaire is distributed to the seafarers to capture their attitude towards navigational safety. The collected feedback will be analysed to determine the weakness of the BRM,

Finally, a comparison had been made to capture the differences between BRM courses offered by different institutions to highlight the deficiency of BRM contents and teaching methods after attending various courses in different maritime institutions. When all the assessments are completed and all the gaps are identified through these assessments methodologies, a new Bridge Resource Management for seafarers (BRMs) course is developed. The new BRM course will be delivered to a group of seafarer volunteers and tested using a full-mission maritime simulator to validate the methodology.

4.2.1. Review of the Maritime Accidents

Maritime accident reports from MAIB, ATSB and TSBC will be collected and reviewed based on various accidents (collision, grounding, contact, ***etc.***) that occurred due to lack of situational awareness. Then, they will be categorised into two parts: those occurring during five years before and after the BRM came into force in 2012 (IMO, 2011), to see whether the BRM course affected shipping safety. Each report will then be analysed and reviewed to find the underlying reasons for the accidents, which are related to lack of situational awareness. Also, the analysis will take into consideration how the bridge team act and sometimes trace back the time of the accident to an hour, two hours or to a day past to see if the fatigue is causing a lack of SA.

4.2.2. Questionnaire to Assess Situation Awareness Issues for Crew Members

An online questionnaire will be developed based on the maritime accident review for crew members to analyse their attitude towards working as a team in the bridge and optimise the necessary level of SA to ensure navigational safety. After introducing the study and the survey, the questionnaire will be distributed among the seafarers as a web-based online survey, which is developed using the Qualtrics Survey Software.

After distributing the survey and collecting the seafarers' responses, the responses will be analysed using various approaches. All the numerical values under the domain score section are presented by colour code. The colour coding adopted in Table 4.1, as suggested was suggested by (Arslan, 2018) for the safety climate survey, is used for the analyses of the survey results and the following assessments are performed:

- The first part of the assessment is as shown below:
  - ➢ Calculate the arithmetic mean of each statement for the seafarers.
  - ➢ Calculate the arithmetic mean of each domain factor.

- The second part of the safety climate assessment consist of the following:
  - Identify statistical differences between groups like ranks, nationality, age, gender and sea-time experience.

Statistical analysis will be performed by utilising SPSS to focus on the differences between domains through the ANOVA test. This test will be utilised to identify the statistical differences between different groups such as age, ranks, nationalities etc. By using this method, the results are validated by removing the chance factor from the analysis. The statistically significant (p-value < 0.05) interactions will be determined for each question under a different domain.

Table 4.1 Mean score interpretation.

Mean Score	**Results**
100% to 90%	Very Good
89.99% to 80%	Good
79.99% to 70%	Average
Below 69.99%	Very poor

As per Table 4.1 shown above, the statement and the dimension that is coloured by the dark green colour code represent ‘no improvement is required. While the statement coloured by the light green colour is presenting, a slight improvement is required. The amber colour is covering that, all statements that require medium room for improvement. Finally, the red colour code presents statements that require a significant improvement to achieve the safety climate level.

4.2.3. Attending BRM courses

After searching the Bridge Resource Management courses offered by many maritime institutions, it will be established whether there are some differences between them. So, the BRM courses offered by different institutions will be attended, where possible. Attending BRM course in different institutions will provide an opportunity to evaluate the followings; why is there a difference in the course contents, why some institutions give the course in three days, and others give it in five days, are there any differences in teaching methods or quality and what is the approach the instructor/instructors adopt(s) to cover the critical elements of BRM.

4.2.4. Improvement Methodologies and Action Plans

The most important part of the whole framework is the improvement methodologies and action plans part since all the identified gaps and weaknesses will adversely affect navigation safety if the appropriate action plans are not implemented thoroughly. All the gaps and improvement areas are determined by utilising the proposed framework earlier.

As all bridge navigational operations are run through BRM, it is important to improve BRM course quality to minimise accidents and incidents in the shipping industry. In order to address the identified problems and gaps through the assessment methods, the improvement methodologies are developed as the following:

- Develop the Bridge Resource Management course for all the Seafarers.
- Create a Case Study and Validate BRM

4.2.4.1. Development of the Bridge Resource Management course for Seafarers

After highlighting the gaps of bridge team acts from the methodological assessments, the new course will be developed to focus on the bridge team behaviour, bridge team act and the bridge team's knowledge. The course will be designed by following the IMO criteria for the bridge resource management course (International Maritime Organisation, 2013).

4.2.4.2. Case Study and the Validation

The application of the method will determine whether the proposed solutions will improve the navigational performance of the bridge team in terms of the bridge procedures, bridge team knowledge and bridge team skills. The case study aims to validate the implementation of the BRMs course. The maritime simulator will be utilised to perform the defined scenarios to assess the quality of the bridge team performance.

The experiments include two groups, and each bridge team contains one Captain, one OOW, one Cadet/Pilot, one Lookout and one helmsman. Group A will perform the experiments by applying the new methods and technics, which are explained and taught in the BRM course in chapter 8, while group B will attend the BRM course by applying the routine procedures, which are currently implemented in the simulator centre. Both teams perform the tasks without knowing the scenario's details, which gives more originality and random action to their behaviours. The experiments include four different scenarios, which are open-water navigation, Master-Pilot exchange (Berthing/Unberthing), restricted visibility and emergency situations. The two groups will be measured according to the following indicators: situational awareness, lookout quality, communication, leadership, teamwork and decision-making and taking action time.

4.3. Chapter Summary

The general methodology of this PhD research is presented to assess existing BRM courses and propose a new BRM course. This included analysing maritime accidents through collected data, comparing BRM courses offered by different maritime institutions, building a new BRM course, and testing it in a full mission bridge simulator.

5. Maritime Accident Database Review

5.1. Introduction

Many research studies have been carried out over the years to find the main causes of maritime accidents. Human and organizational factors were found to be the prime causative factor as more than 80 % of the accidents are claimed to be due to human and organizational factors. By looking closer into this large share, it was found that in some accidents reviews, lack of SA was highlighted as the most important factor in the human and organizational factors chain (Baker and McCafferty, 2005; Popa, 2015; Graziano, Teixeira and Guedes Soares, 2016). However, there is no recent paper studying the accidents that occurred due to lack of SA or the bridge team's performance. This chapter investigates the maritime accidents caused by the absence of situational awareness, which affects the bridge team performance by looking at what happened before the accident, what kind of action was taken, and how the bridge team reacted.

A review of the accident reports from UK Marine Accident Investigation Branch (MAIB), Australian Transport Safety Bureau (ATSB) and Transportation Safety Board of Canada (TSBC) has been carried out to investigate accidents linked to activities on the ship bridge and underlying reasons linked to the bridge team members (master, an officer of the watch (OOW), cadet, wheelman, lookout and pilot). The accident reports analysis included the vessels sailing in the United Kingdom, Australian and Canadian territorial waters, or vessels under the UK, Australian and Canadian flags.

5.2. Methodology

The maritime accident reports from MAIB, ATSB and TSBC were reviewed based on accidents (collision, grounding, contact, ***etc.***) occurring due to lack of situational awareness. Then, they were categorised into two parts: those occurring before and after 01/01/2012, when the bridge resource management (BRM) came into force (IMO, 2011), to see whether the BRM course had any positive effect on the performance of bridge team members including reactions and decisions. Each report was reviewed and analysed to find the causes of the accident, which is related to lack of situational awareness. It was identified that some of the accidents had more than one reason that caused the loss of situational awareness of the bridge team members. The study focuses not only on the time of the accident to identify the cause of the lack of SA but also on how the bridge team acted and their conditions up to a day before the accident to identify if the fatigue played a part in the lack of SA. In addition, all vessels, which were investigated in this study are above 500 gross tonnages and excluding the accidents of fishing vessels and pleasure crafts because mostly they require solo watchkeeping on the bridge.

The study considered the model of situation awareness created by Endsley when she divided human situation awareness into three levels. Level 1-perception of the element in the current situation, level 2-comprehension of the current situation and level 3-projection of the future situation (Endsley, 1995c). Also, the adjustment in this model, which was done by (Chauvin, Clostermann and Hoc, 2008), clarified level 1 as the available information from the ARPA/Radar, level 2 as the assessment of the current situation, and level 3 as what the result will be in the future situation. However, this review was done on the basis that:

- level 1 is the available information from any equipment in the bridge, including paper chart, notices, and master’s standing order, ***etc***.
- level 2, what is happening in the current situation, and
- level 3 is the prediction of the officer of the watch, or any bridge team member, of what will happen in the future.

5.3. Findings

5.3.1. Overall

The number of maritime accidents reported in MAIB from 2007 to 2011 and 2012 to 2017 is 161 and 186. For the same periods, 59 maritime accident reports from 2007 to 2011 and 53 maritime accident reports from 2012 to 2017 have been investigated by ATSB. The TSCB recorded 37 maritime accidents from 2007 to 2011 and 79 maritime accidents from 2012 to 2017.Table 5.1 below shows that the number of maritime accidents exceeds the number of the investigated reports as some of the accidents are registered under several types of accidents that were found to be challenging to follow and record the actual number and type of accidents. Additionally, some of these accidents were recorded as fatal occupational accidents, and some of the accidents were not investigated.

Table 5.1 Number and type of maritime accidents occurred from 2007 to 2017 in different investigation branches (ATSB, 2017; MAIB, 2017; TSBC, 2017; CHIRP, 2020)

No. of accidents from 2007-2011			Type of accident	No. of accidents from 2012-2017		
MAIB	ATSB	TSBC		MAIB	ATSB	TSBC
13	58	263	Fire/explosion	11	16	204
36	40	390	Grounding/Stranding	30	20	368
24	50	17	Contact	13	17	9
44	22	412	Collision	22	7	489
7	11	N/A	Flooding	5	8	N/A
14	7	45	Capsizing/listing	14	5	39

In total, more than 200 marine accidents and near-miss reports have been reviewed over the period of 2007 to 2017, of which 144 of them were from MAIB, 28 of them were from ASTB and 31 of them were from TSBC. A review of the individual reports indicated that more than 58% of OOWs or bridge team members failed to fulfil the *level 1 situational awareness,* as shown in Figure 5.1.and demonstrated in Table 5.2 Also, it shows that the number of accidents decreased after 2012 by nearly 50%, highlighting the effectiveness of BRM for this reduction.

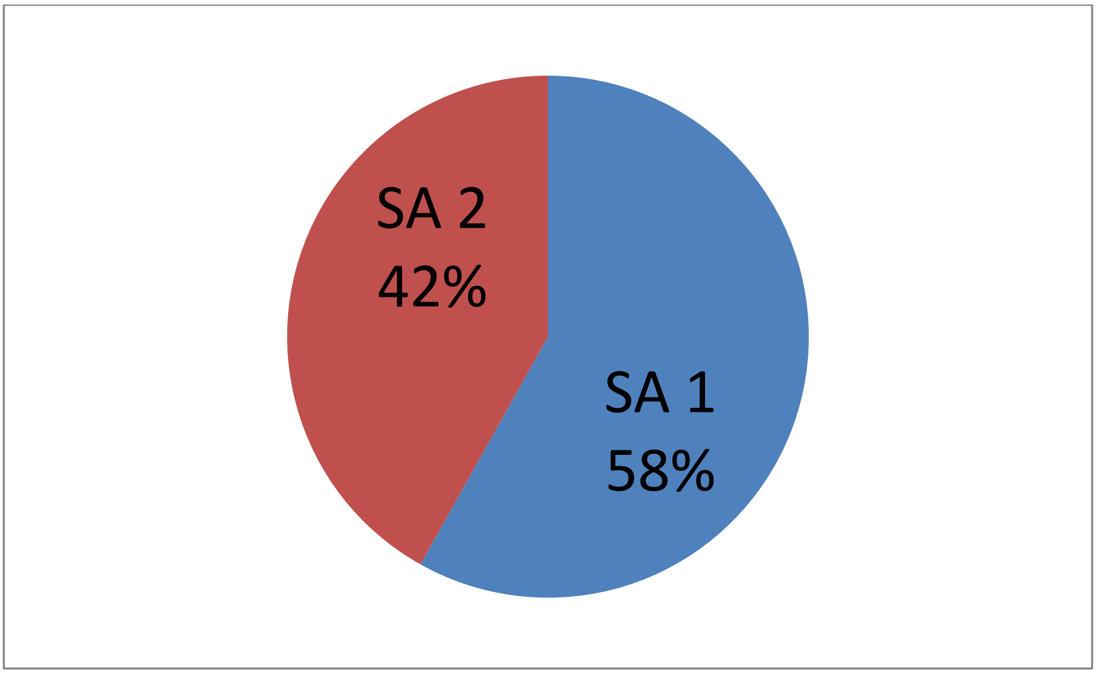

Figure 5.1 Percentage of failure in situational awareness levels in marine accidents

Figure 5.2 and Figure 5.3 shown below indicate the percentage of the accidents that occurred due to lack of communication, wrong/misuse of the available information and manning decreases after 2012. This indicates that BRM is found to be useful in some of its elements. However, the interaction between the bridge team member, poor decision-making, and poor navigational practice causes a significant impact on maritime accidents after 2012, indicating the gaps with BRM overall.

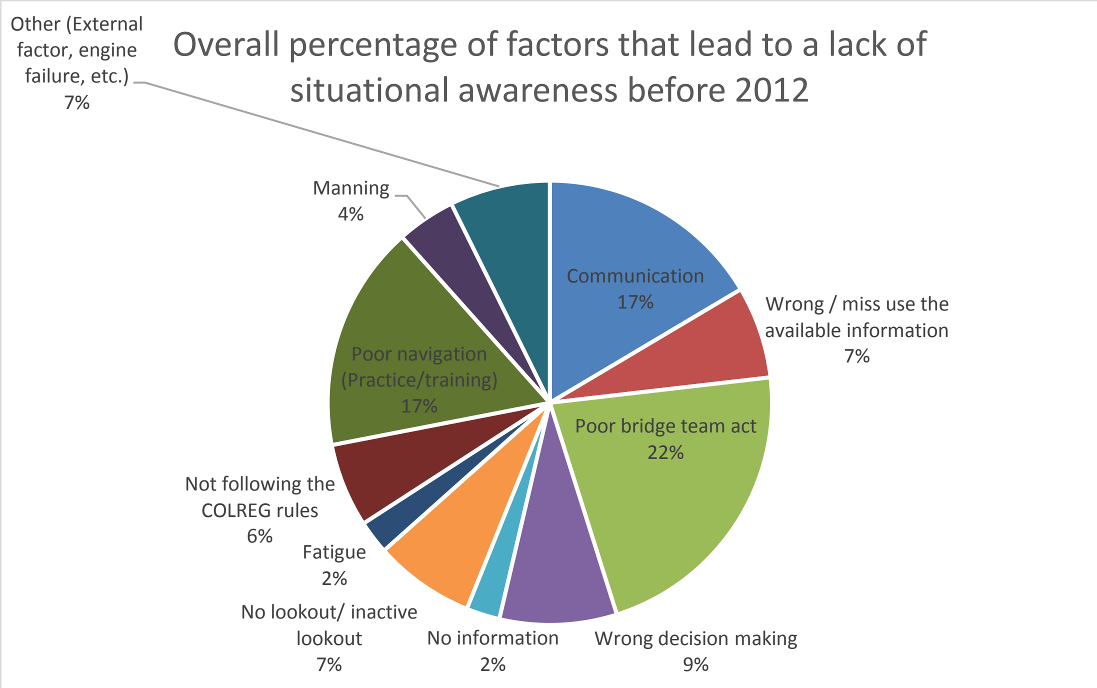

Figure 5.2 Overall factors that lead to a lack of situational awareness before 2012

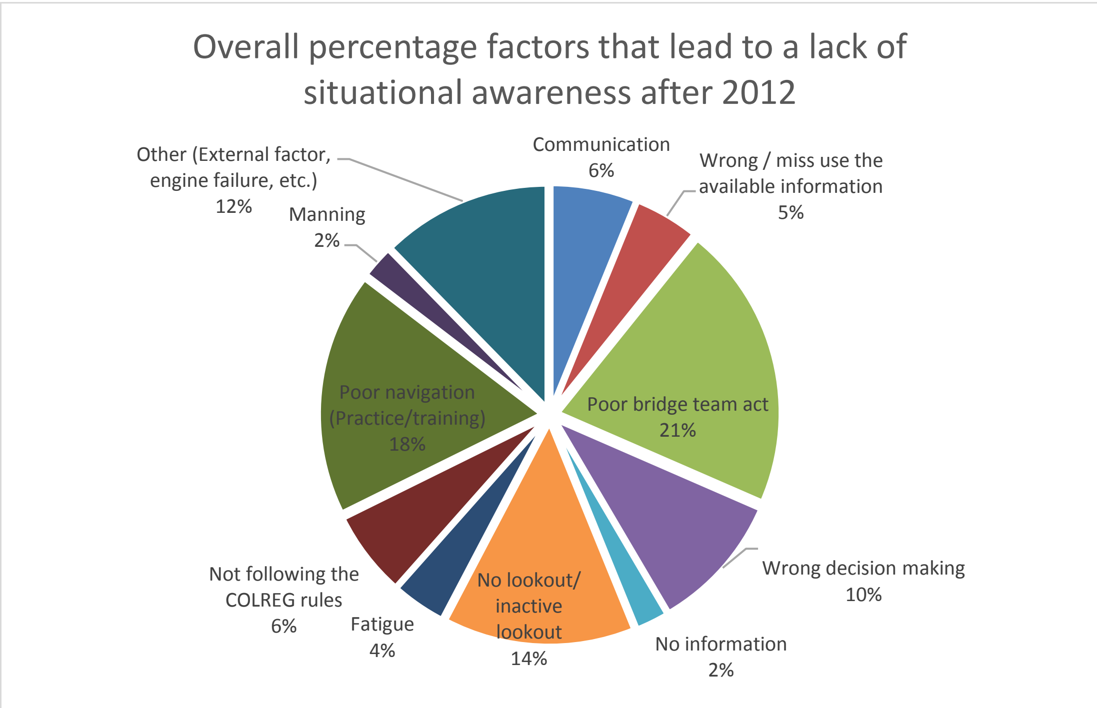

Figure 5.3 Overall factors that lead to a lack of situational awareness after 2012.

Table 5.2 Overall factors that lead to a lack of situational awareness before and after 2012.

Count (Before 2012) 133 Accidents			Factor	Count (After 2012) 70 Accidents		
SA1	SA2	Total		SA1	SA2	Total
11	16	27	Communication	7	1	8
7	4	11	Wrong / miss use the available information	6	0	6
15	21	36	Poor bridge team act	12	15	27
5	9	14	Wrong decision making	7	6	13
4	0	4	No information	3	0	3
9	3	12	No lookout/ inactive lookout	14	4	18
2	2	4	Fatigue	3	2	5
8	2	10	Not following the COLREG rules	5	3	8
21	6	27	Poor navigation (Practice/training)	14	9	23
6	1	7	Manning	2	1	3
7	5	12	Other (External factor, engine failure, etc.)	7	9	16

5.3.2. Missing SA factors

5.3.2.1. External Communication

Lack of communication always affects team behaviour, particularly in critical situations. MAIB accident reports reveal the bridge team's communication problems (especially between master and external pilot) before the accidents occurred. According to Figure 5.4, the ratio of accidents that occurred due to the lack of communication decreased from 1:4.9 before 2012 to 1:8.7 after 2012. The reduction in accident rates possibly indicates that BRM improved communication among the team members on the ship bridge but has not eliminated the communication problem completely. In addition, poor communication, misunderstanding between two bridge teams or failing to reach an agreement about the avoidance manoeuvring are factors that affect the situational awareness for the bridge team members.

Some researchers found that forgetfulness and exhaustion influenced efficient communication adversely (Ziarati, Ziarati and Turan, 2010). Furthermore, the fear of being blamed by higher-ranked officers, assuming that another team member knows the communication failures, or doubting if the transferred information is correct or not all contributed to the maritime accidents considerably (Vrbnjak *et al.*, 2016).

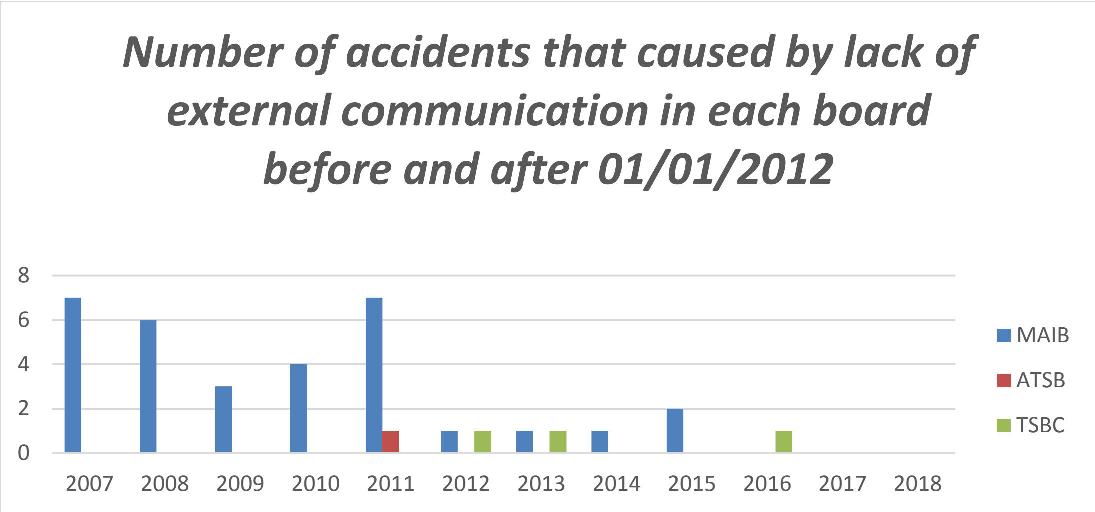

Figure 5.4 Number of accidents that caused by poor communication onboard of each ship before and after 01/01/2012.

5.3.2.2.Wrong/miss use of the available information.

With the tremendous amount of information available on the bridge, some accidents are related to OOWs who were not utilising all the information, were not following the rules or were using the information only from one or two sources all the time, e.g. the ship's position. Even if the OOW have the correct information, he/she misuses it (e.g. change the ship's speed or heading) to avoid the accident or got confused between true and relative bearings. This had occurred regularly and happened depending on the equipment preference by the OOW. The rate of this type of accidents had decreased from 1:14.9 before 2012 to 1:21.6 after 2012, as shown in Figure 5.5. If the bridge team lacks the knowledge or skills to understand information or do not know how to respond to them, a maritime accident's risk increases substantially. These numbers indicate that there is room for improvement through BRM courses in the provision of training to ratings on the bridge.

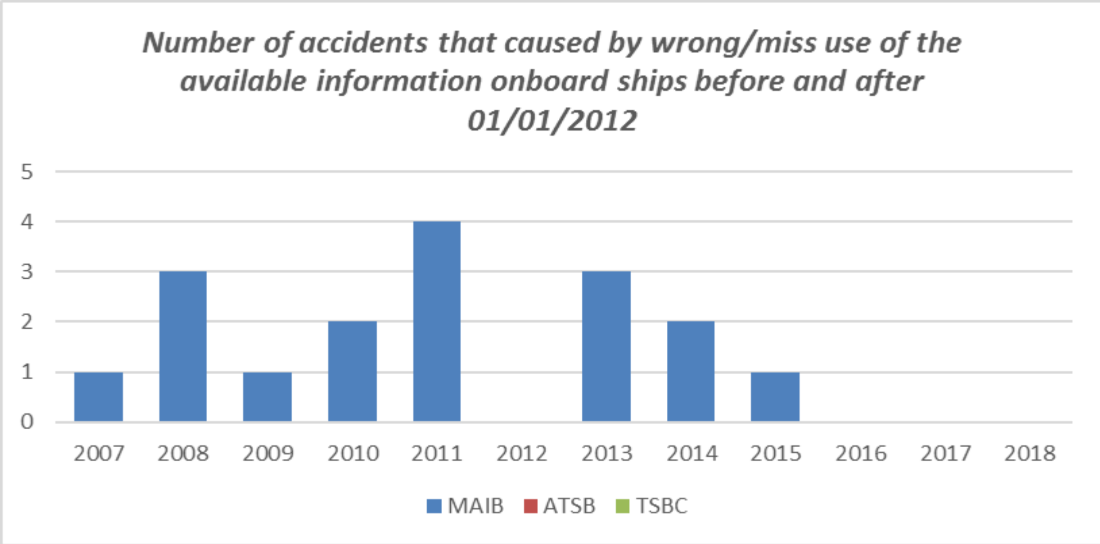

Figure 5.5 Number of accidents that caused by poor or wrong/miss use of the available information onboard ships before and after 01/01/2012

5.3.2.3. The information is not there.

Figure 5.6 shows that the accidents that occurred due to unavailable information were few because of the new technology, and the overall ratio scored 1:41 and 1:43 before and after 2012. However, some of the bridge equipment needs to be upgraded/updated or corrected from time to time, such as ECDIS, paper chart, ***etc.,*** to have the correct information available to use. For example, many ships ran aground due to the OOW losing his situational awareness because he did not know the object was there. All information must be made available to the bridge team in time to use it in a correct way to avoid accidents.

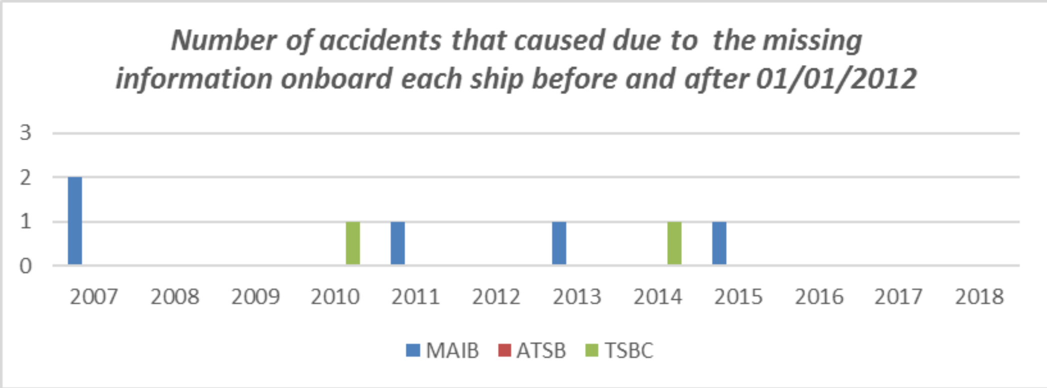

Figure 5.6 Number of accidents that caused by the missing information onboard ships before and after 01/01/2012.

5.3.2.4.Poor bridge team act (BTA)

Communication is an essential element in bridge resource management, but some other elements must be addressed. Failing to share information and situational awareness, decision making, teamwork, including master/ pilot exchange are key underlying reasons for marine accidents. The lack of communication and situational awareness between the bridge team increases the potential of misinformation such as the ship's position speed or heading, thereby reduces the efficiency/effectiveness of the team to respond timely to avoid accidents. Even after the STCW forcing the BRM certificate to be held by OOW, some errors/deficiencies have not been addressed yet. The bridge team is required to use all the resources, including human resources, that are available on the bridge. In fact, it has been cited that every year there is an accident caused by a lack of BTA (excluding Australia), as shown in Figure 5.7. Surprisingly, accidents that occurred because of poor BTA after 2012 remained high, and the ratio is the same (1:4.8) as before 2012. Such a high value shows the gaps in BRM courses and highlights that an intermediate improvement is required to enhance bridge team interaction to minimize these accidents.

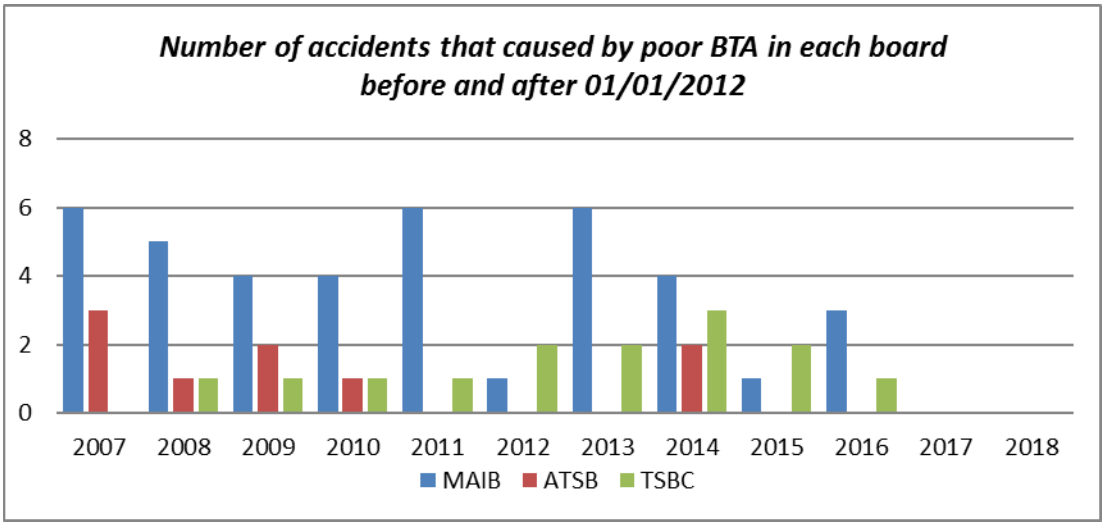

Figure 5.7 Number of accidents that caused by poor BTA onboard ships before and after 01/01/2012.

5.3.2.5. Lookout

For all the accidents that occurred under this category, the OOW was alone on the bridge or left no-lookout on the bridge, even though rule no. 5 of the COLREG convention states that all ships should keep a proper lookout out at all times (IMO, 1972). In many MAIB accident investigation reports, it was mentioned that the bridge teams in vessel A and vessel B were not aware of each other until just before the collision. Some of the vessels ran aground because the OOW slept on the bridge or he/she went to his/her room due to fatigue, and there was no lookout with him, despite the regulatory requirements. This evidence clearly indicates the scale of the problem with overall minimum manning standards and available minimum crew on duty. This is detrimental to the team situational awareness on the bridge, and the accident reports are clear evidence supporting this conclusion. Even with IMO regulations that required an active lookout, the number of accidents due to inactive lookout has increased considerably from 1:13.6 before 2012 to 1:7.2 after 2012, as shown in Figure 5.8.

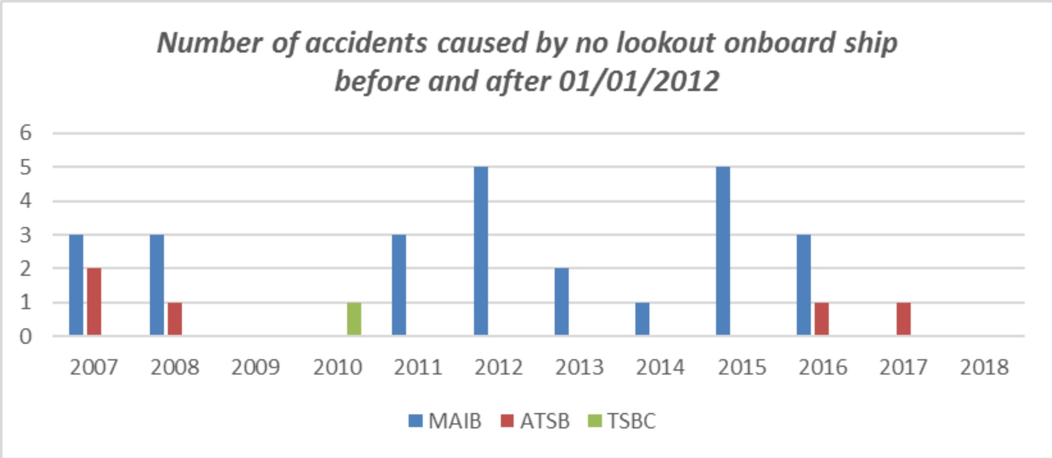

Figure 5.8 Number of accidents caused by poor of lookout onboard ships before and after 01/01/2012.

5.3.2.6. Wrong decision-making

All the factors, which were mentioned earlier, contribute to the decision-making and naturally leads to good/poor navigational practices. When a bridge team member loses his Level 1 SA or Level 2 SA and is not consulting or sharing his ideas with other team members, this influences his decision making and leads to a potential accident. The BRM course covers decision-making, which should be placed in every situation that the bridge team member faces. However, the number of accidents did not change, and the ratio of the accidents due to poor decision making increased from 1:11.7 before 2012 to 1:10 after 2012, as shown in Figure 5.9. Again this indicates the gaps with the BRM course with regards to decision making.

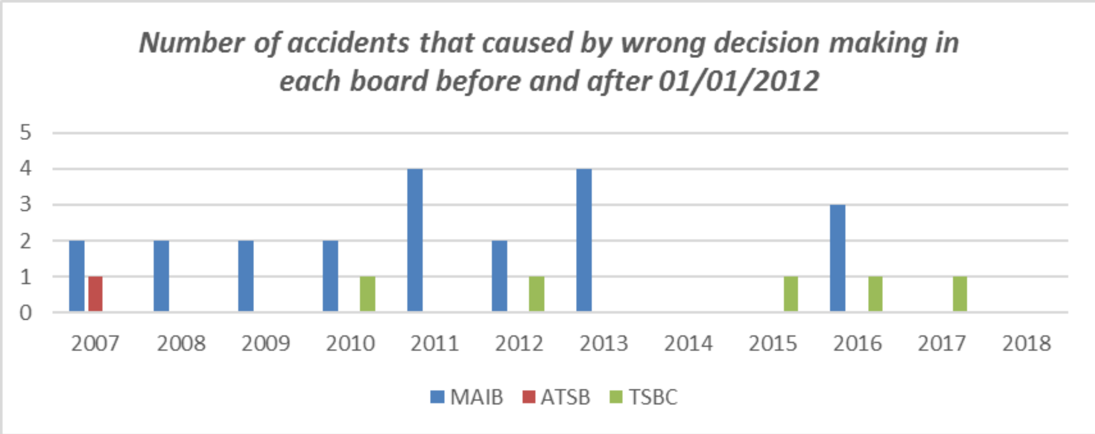

Figure 5.9 Number of accidents that caused by poor of wrong decision making in each board before and after 01/01/2012.

5.3.2.7.Not following the regulations

The review of accident reports indicated that the factors such as misunderstanding, confusion and not awareness of which rules to follow are highlighted as the main underlying reasons in each accident of this category. The number of accidents due to not following regulations decreased after 2012, but the ratio remained exactly the same (1:16), as shown in Figure 5.10 below. The OOWs sometimes get confused about which ship is the give-way vessel and the stand-on vessel. Is it a crossing situation or overtaking? These kinds of questions, which are linked to the lack of competence of the crew, affect the crew' decision making (Abdushkour *et al.*, 2018). It highlights the importance of following regulations should be an essential part of the BRM course.

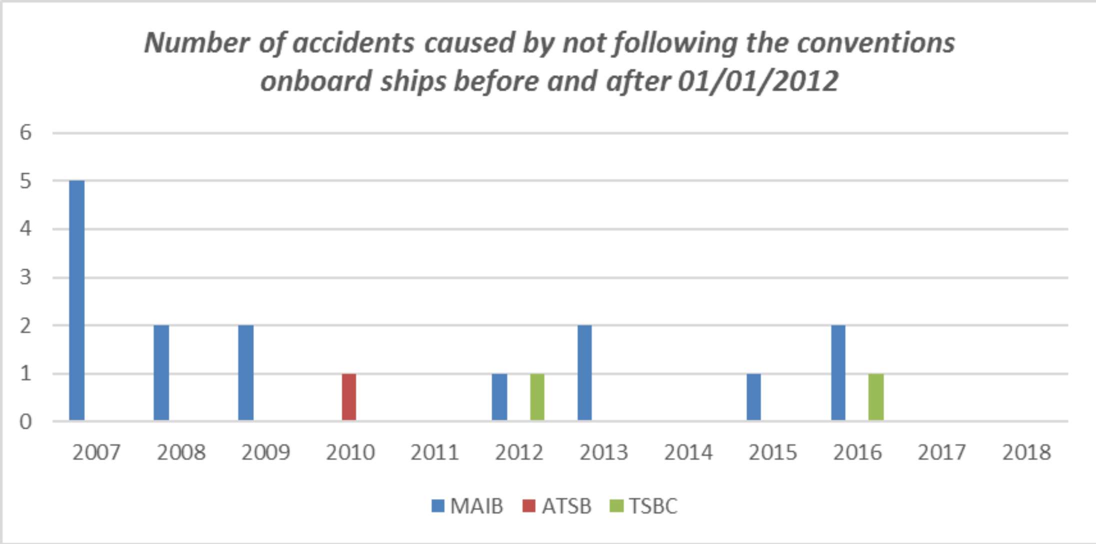

Figure 5.10 Number of accidents caused by not following the conventions onboard ships before and after 01/01/2012.

5.3.2.8.Poor navigation (Practice/training)

Safe navigational practice and handling of the ship heavily relies on the standard of knowledge and skills of the bridge team rather than relying on the sophistication of the bridge's equipment. The bridge teams' knowledge, skills, and proper training are the contributory factors to ensure the safety of the vessel, crew, cargo and the marine environment. Taking late actions, not considering the consequences of the action taken, who has control on the bridge, or not having the proper training are the key factors in this category. The overall number of accidents that occurred due to poor navigation high, and there is a slight decrease. However, considering the number of accidents, the ratio after 2012 is 1:5.65 compared to instead 1:6.05 before 2012, as shown in Figure 5.11. This clearly indicates that ration even increased slightly after 2012, indicating that BRM has not emphasised the importance of good navigation through teamwork.

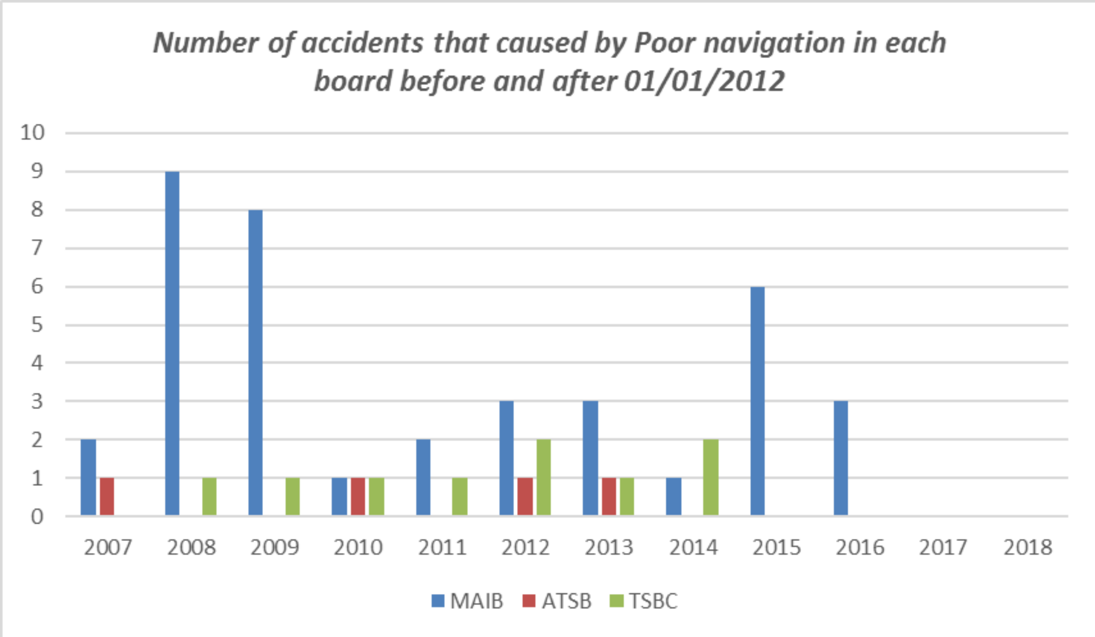

Figure 5.11 Number of accidents that caused by poor navigation before and after 01/01/2012.

5.3.2.9.Manning/Other

This section includes the bridge's poor manning, which means either the bridge is manned with fewer people than required, including a solo watchkeeper, or there is nobody on the bridge. Also, it includes external factors such as wind, anchor dredging, current and waves effect on the ship and led to an accident without being noticed by the bridge team member or hard to notice by solo watchkeeper in the bridge. Figure 5.12 shows that the number of accidents that occurred due to the manning group decreased after 2012 as accidents ratio of 1:43 after 2012 comparing to 1:23 before 2012 were observed. Figure 5.12 also shows that external factors, which led to the accidents, had increased after 2012 (1:8.1) compared to before 2012 (1:13.6).

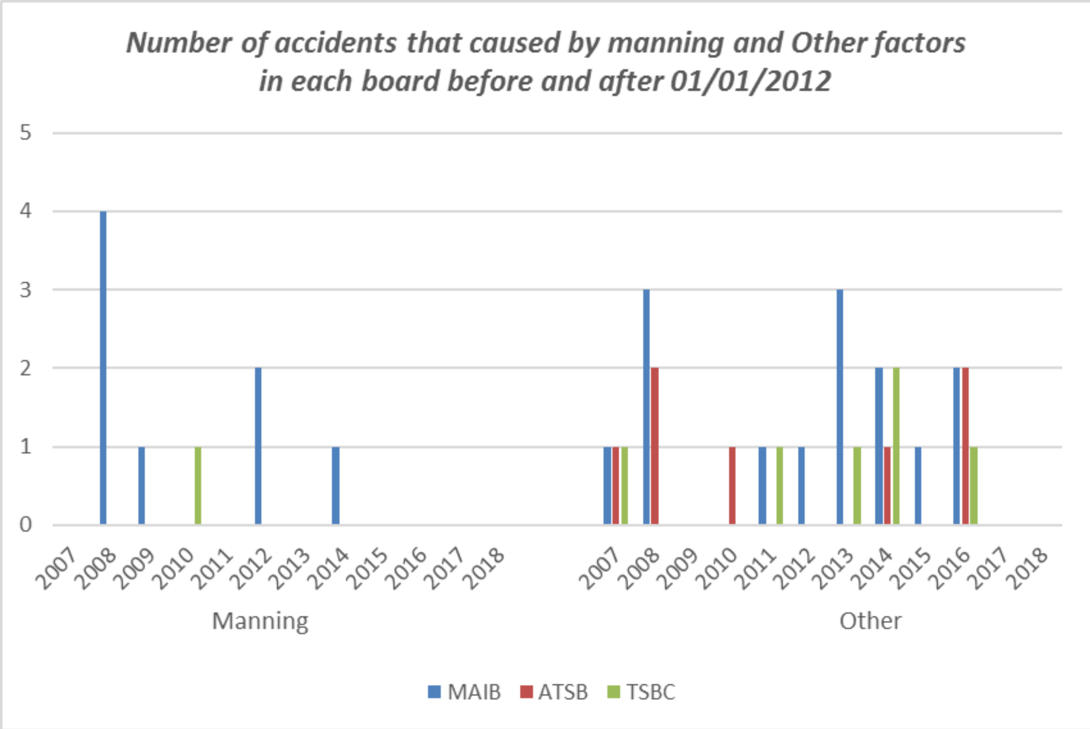

Figure 5.12 Number of accidents caused by poor of manning and other external factors onboard each vessel before and after 01/01/2012.

5.3.3. Period before 2012 MAIB

After analysing 104 accident reports, the results indicated that nearly 60% of the OOWs were unsuccessful in maintaining level 1 SA, and 43% failed to comply with level 2 SA, as shown in Figure 5.13. Lack of situational awareness occurred due to many factors listed in Table 5.3 and presented in Figure 5.14.

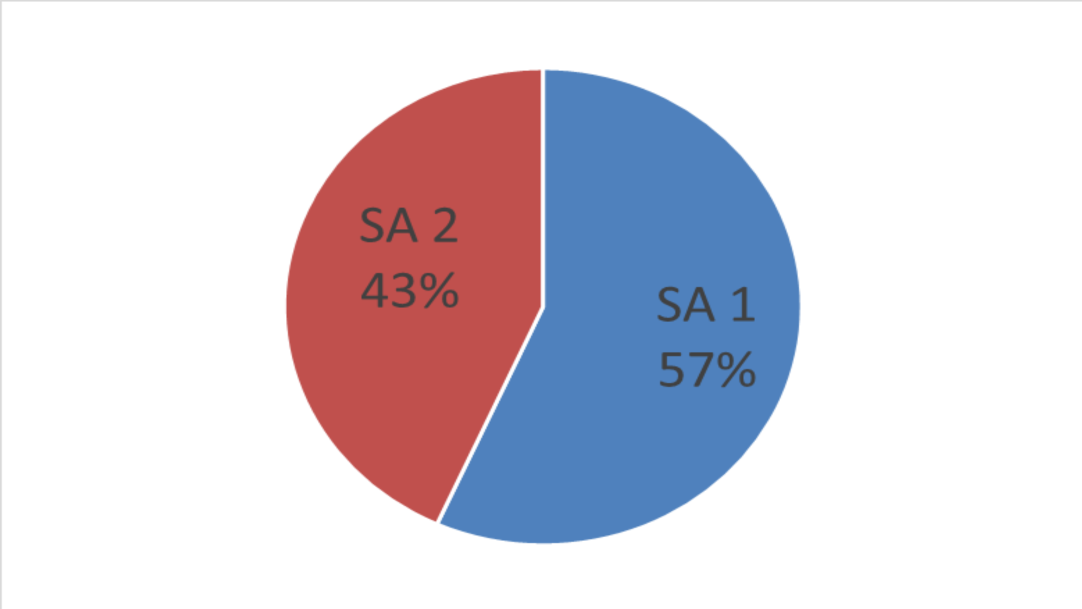

Figure 5.13 Percentage of failure in situational awareness levels in MAIB marine accidents before 01/01/2012

Table 5.3 Factors that lead to lack of situational awareness before 01/01/2012.

Factor	Count		
	SA1	SA2	Total
Communication	10	16	26
Wrong / miss use the available information	7	4	11
The poor bridge team act	11	14	25
Wrong decision making	5	7	12
No information	3	0	3
No lookout/ inactive lookout	6	3	9
Fatigue	1	1	2
Not following the COLREG rules	7	2	9
Poor navigation (Practice/training)	16	5	21

Manning	5	1	6
Other (External factor, engine failure, etc.)	3	3	6

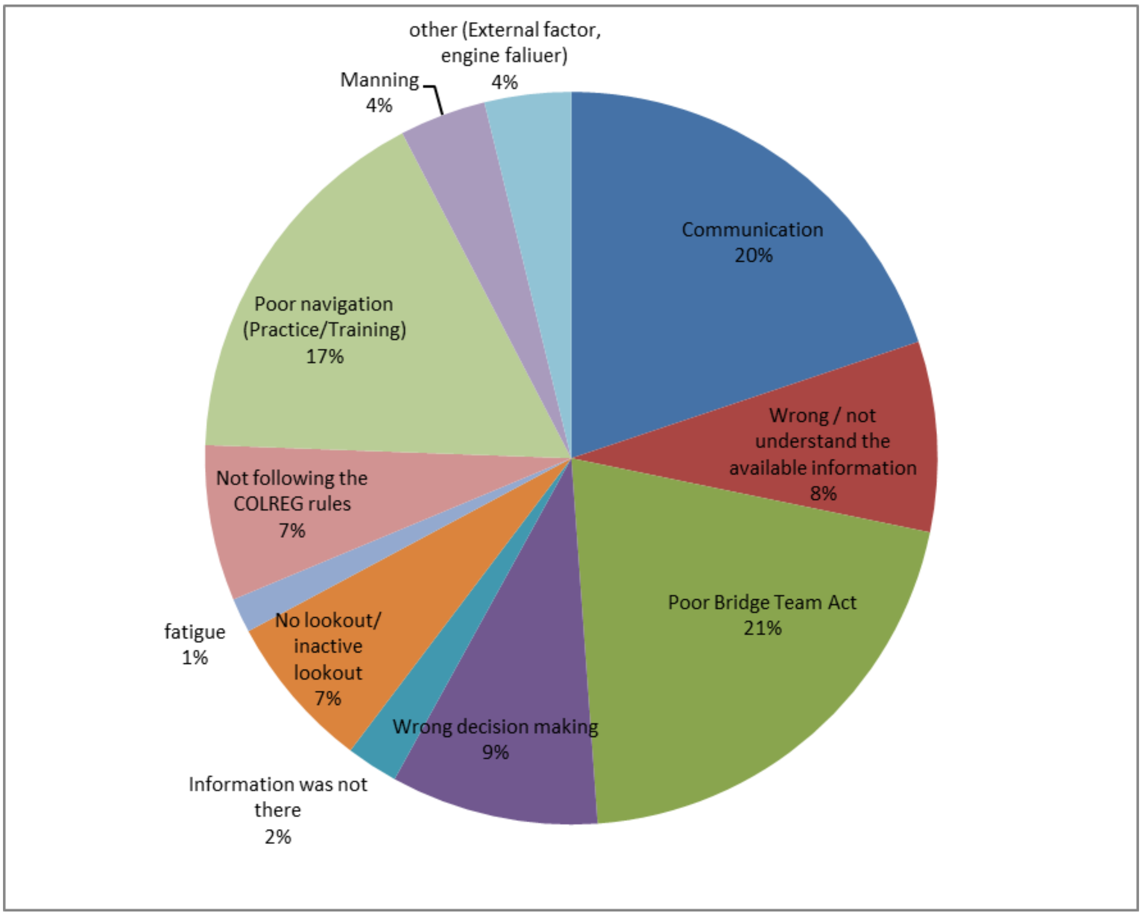

Figure 5.14 Percentage of factors that lead to lack of situational awareness before 01/01/2012

As shown in Figure 5.14, communication failings between bridge team members, ship to ship, and ship to shore, along with poor bridge team management and poor navigation practice, had a significant impact on maritime accidents that occurred before 2012. Near to 60% of these accidents occurred due to failure of the physical activity between the bridge team or as solo watchkeeper such as communication, teamwork or did proper navigational watchkeeping. It is not surprising that accidents occurred because of the absence of a bridge team act, which scored 21% because of BRM or was not mandatory. However, failing to communicate or not performing proper watchkeeping was evident due to the lack of fundamental training and education that the seafarers should gain before working onboard vessels. It seems that lack of SA contributed to cognition and decision errors, which lead to poor risk-taking and ultimately affected the decision making. The reports regularly stated that the bridge team members needed more training to enhance their communication and teamwork skills.

5.3.4. Period after 2012 MAIB

This period showed significant improvement in some of the factors that affect SA. The 40 accident reports showed that more OOWs failed to meet their SA level 1 compared to the period before 2012, as displayed in Figure 5.15.

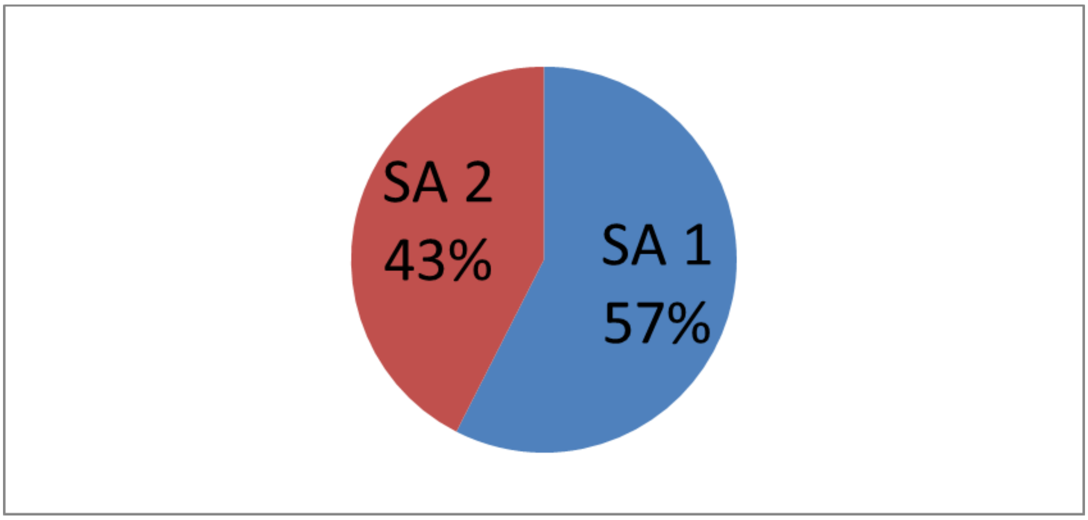

Figure 5.15 Percentage of failure in situational awareness levels in MAIB marine accidents after 01/01/2012

On the other hand, the BRM course showed some improvement in individual skills, but it failed in the main idea, which is to improve the bridge team management, as demonstrated in Table 5.4 and Figure 5.16.

Table 5.4 Factors that lead to lack of situational awareness after 01/01/2012.

Factor	Count		
	SA1	SA2	Total
Communication	4	1	5
Wrong / miss use the available information	6	0	6
Poor bridge team act	7	8	15
Wrong decision making	3	6	9
No information	2	0	2
No lookout/ inactive lookout	12	4	16
Fatigue	2	2	4
Not following the COLREG rules	3	3	6
Poor navigation (Practice/training)	12	4	16
Manning	2	1	3
Other (External factor, engine failure, ***etc.)***	2	7	9

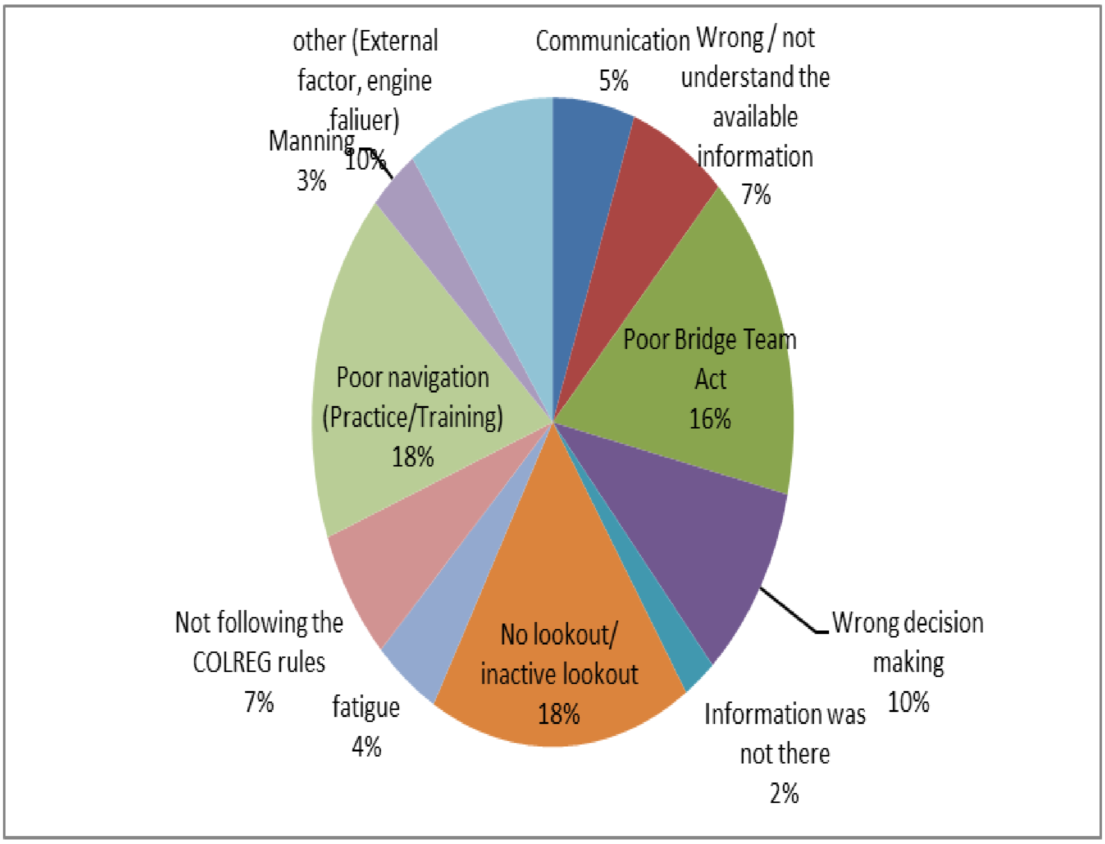

Figure 5.16 Percentage of factors that lead to lack of situational awareness after 01/01/2012.

There is no doubt that bridge teams are facing more issues other than communication. Lack of sharing the knowledge and SA, absence of teamwork, and misreporting near misses side by side with applying poor navigational practice are main factors contributing to the loss of the bridge team's SA. This made some companies take action by running a BRM course onboard the ships. Also, they sent their seafarers to nautical institutes to enhance their skills.

5.3.5. Period before 2012 ATSB

A total of 19 accident reports showed that more than 60% of the marine accidents occurred due to low SA level 1, and 37% failed to obtain SA level 2, as presented in Figure 5.17.

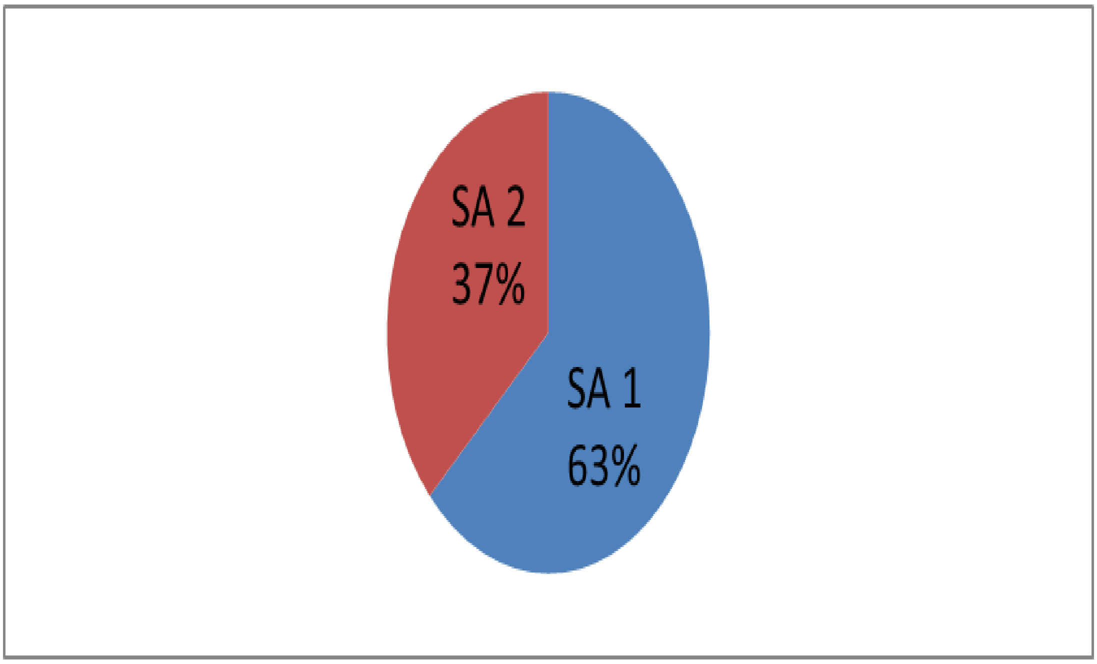

Figure 5.17 Percentage of failure in situational awareness levels in ATSB marine accidents before 01/01/2012

This percentage illustrates that OOWs failed to gather all useful resources available at the time of the accidents, as displayed in Table 5.5 and Figure 5.18.

Table 5.5 Factors that lead to lack of situational awareness before 01/01/2012.

Factor	Count		
	SA1	SA2	Total
Communication	1	0	1
Wrong / miss use the available information	0	0	0
Poor bridge team act	2	5	7
Wrong decision making	0	1	1
No information	0	0	0
No lookout/ inactive lookout	3	0	3
Fatigue	1	1	2
Not following the COLREG rules	1	0	1
Poor navigation (Practice/training)	2	0	2
Manning	0	0	0
Other (External factor, engine failure, *etc.)*	2	2	4

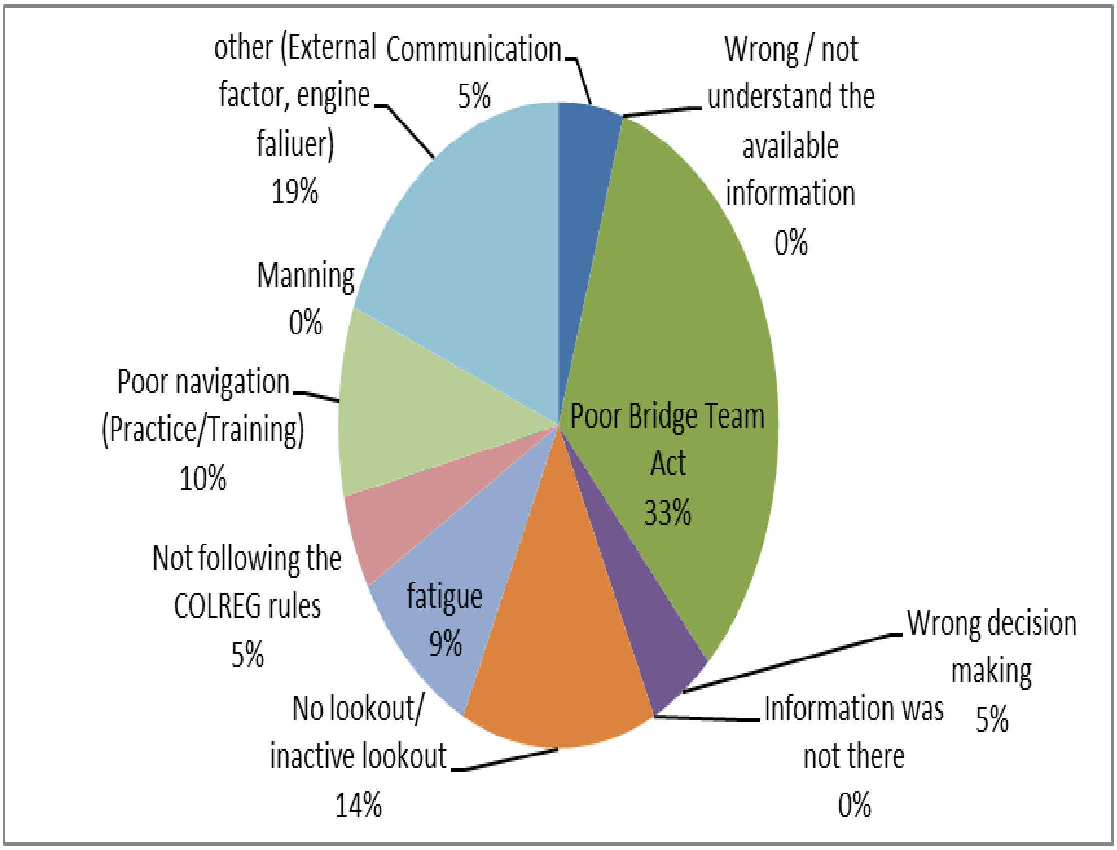

Figure 5.18 Percentage of factors that lead to lack of situational awareness before 01/01/2012.

As it is clear from the figures, the poor of BTM/BRM was the main cause of the maritime accidents in Australia, which were identified almost in each report and another factor.

5.3.6. Period after 2012 ATSB

Only nine accident reports were linked to the SA issues after 2012. The analysis of those nine reports showed that nearly 70% of the maritime accidents happened due to lack of level 1 SA, and about 33% of the accidents occurred due to lack of level 2 of SA, as shown in Figure 5.19. All the bridge activities were the main causes of the accidents that include lack of BTM/BRM, inactive lookout and incapable of executing good navigational practices, as presented in Table 5.6 and Figure 5.20.

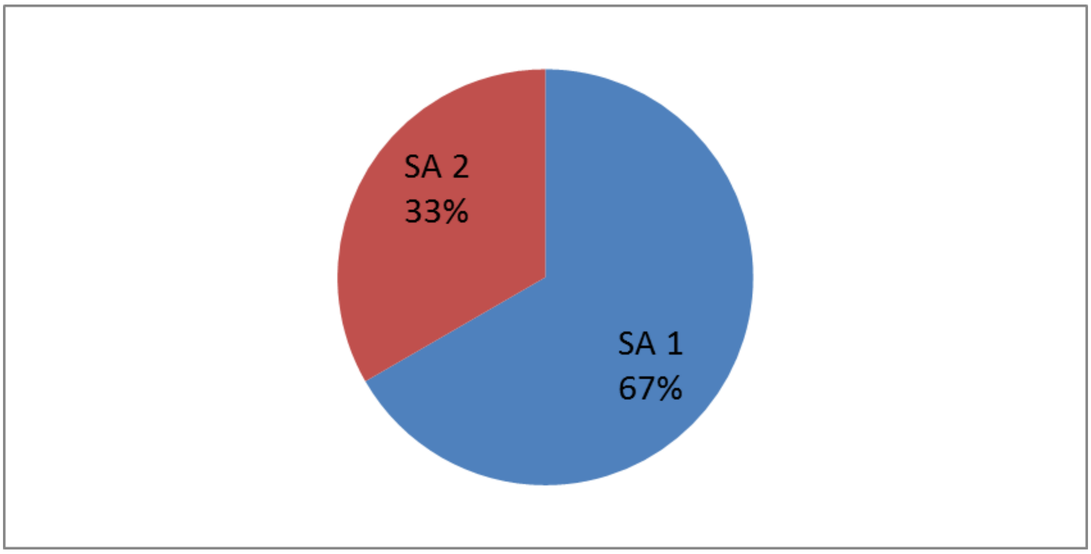

Figure 5.19 Percentage of failure in situational awareness levels in ATSB marine accidents after 01/01/2012

Table 5.6 Factors that lead to lack of situational awareness after 01/01/2012.

Factor	Count		
	SA1	SA2	Total
Communication	0	0	0
Wrong / miss use the available information	0	0	0
The poor bridge team act	1	1	2
Wrong decision making	0	0	0
No information	0	0	0
No lookout/ inactive lookout	2	0	2
Fatigue	0	0	0
Not following the COLREG rules	0	0	0
Poor navigation (Practice/training)	0	2	2
Manning	0	0	0
Other (External factor, engine failure, *etc.)*	3	0	3

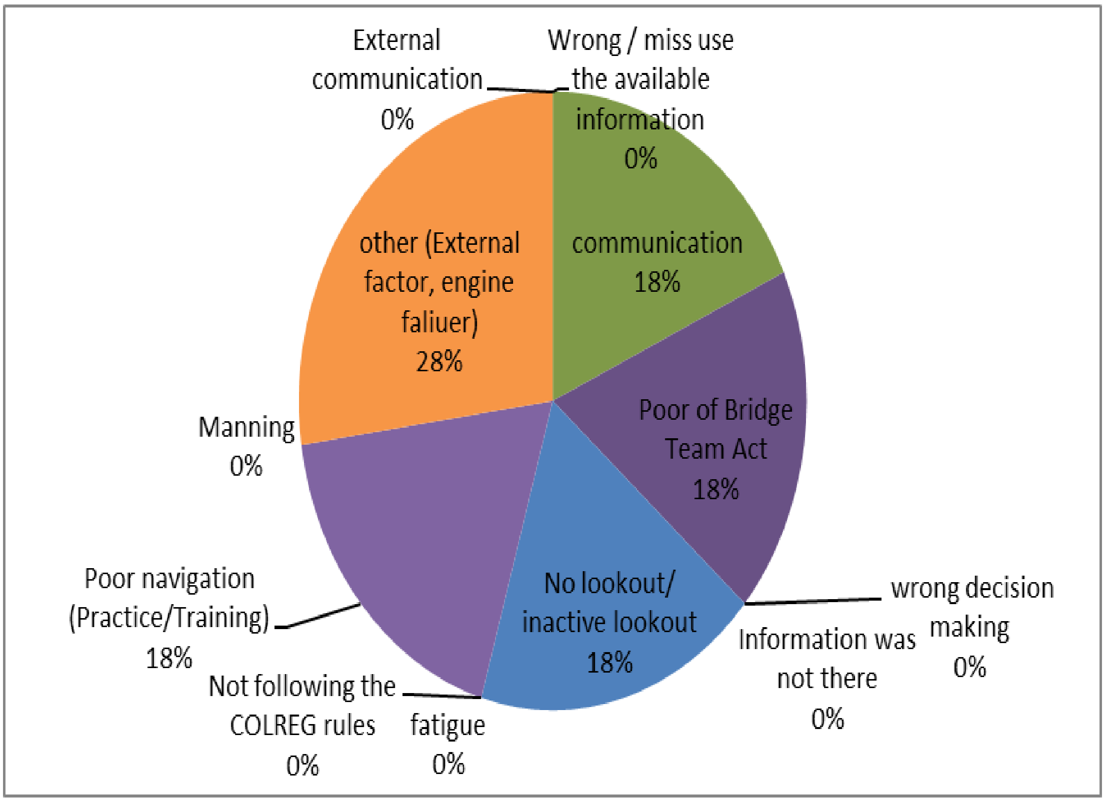

Figure 5.20 Percentage of factors that lead to lack of situational awareness after 01/01/2012.

5.3.7. Period before 2012 TSBC

Ten accident reports show that most of the marine accidents investigated by the Canadian board took place because of the human element. For 60% of the accidents, OOWs were unsuccessful in gaining level 1 SA, while 40% failed to obtain level 2 SA, as shown in Figure 5.21.

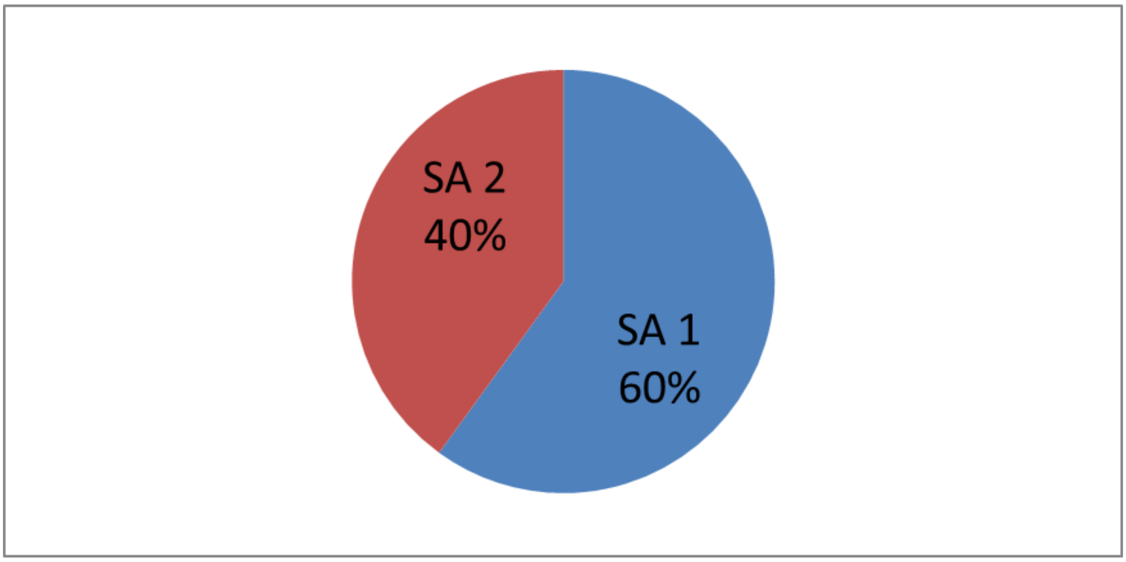

Figure 5.21 Percentage of failure in situational awareness levels in TSBC marine accidents before 01/01/2012

Poor work practice as a team and poor use of all resources on the bridge, and a lack of navigational practices and training were the major factors contributing to the absence of SA. Nearly 40% of the accidents occurred due to different reasons, as displayed in Figure 5.22 and Table 5.7.

Table 5.7 Factors that lead to lack of situational awareness before 01/01/2012.

Factor	Count		
	SA1	SA2	Total
Communication	0	0	0
Wrong / miss use the available information	0	0	0
Poor bridge team act	2	2	4
Wrong decision making	0	1	1
No information	1	0	1
No lookout/ inactive lookout	0	0	0
Fatigue	0	0	0
Not following the COLREG rules	0	0	0
Poor navigation (Practice/training)	3	1	4
Manning	1	0	1
Other (External factor, engine failure, ***etc.)***	2	0	2

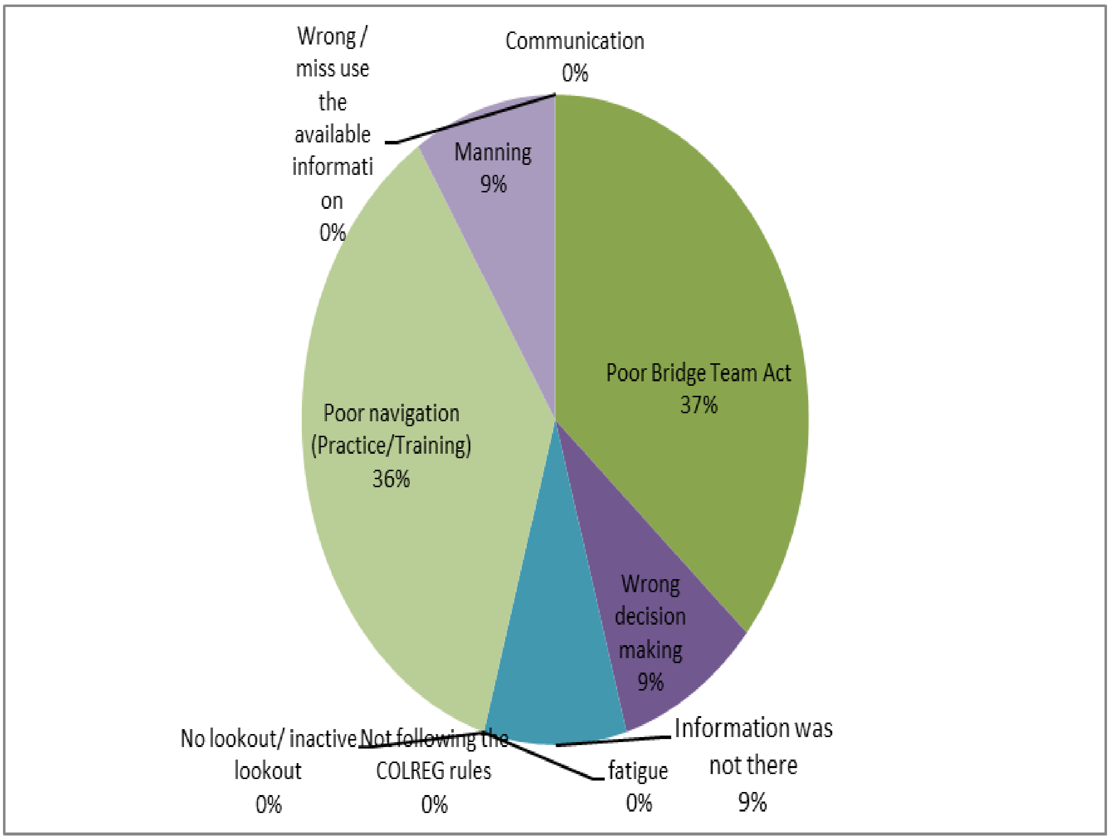

Figure 5.22 Percentage of factors that lead to lack of situational awareness before 01/01/2012.

5.3.8. Period after 2012 TSBC

In this period, 21 accident reports were analysed; the OOWs failed to gain level 1 SA and Level 2 SA by 57% and 43%, respectively, as shown in Figure 5.23. The prime cause of these accidents was the bridge performance; it was observed that BTM/BRM was inefficient with 34% and been reported almost in half of the accident cases. This issue affects directly the other aspects found in Table 5.8 and presented in Figure 5.24.

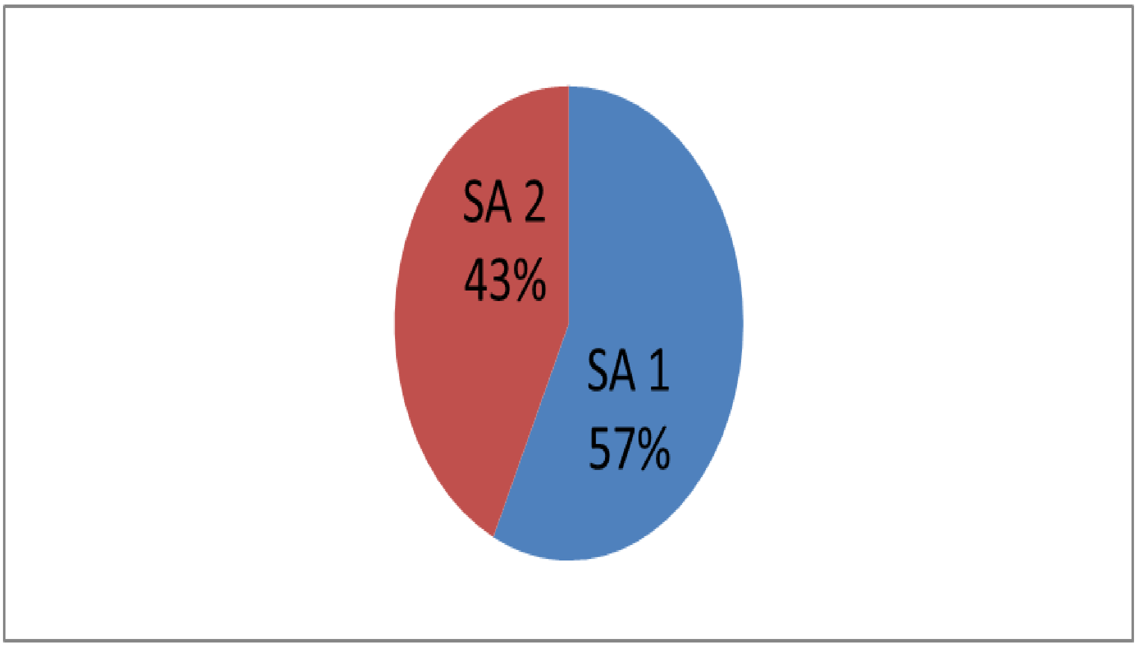

Figure 5.23 Percentage of failure in situational awareness levels in TSBC marine accidents after 01/01/2012

Table 5.8 Factors that lead to lack of situational awareness after 01/01/2012.

Factor	Count		
	SA1	SA2	Total
Communication	3	0	3
Wrong / miss use the available information	0	0	0
Poor bridge team act	4	6	10
Wrong decision making	4	0	4
No information	1	0	1
No lookout/ inactive lookout	0	0	0
Fatigue	1	0	1
Not following the COLREG rules	2	0	2
Poor navigation (Practice/training)	2	3	5
Manning	0	0	0
Other (External factor, engine failure, *etc.)*	2	2	4

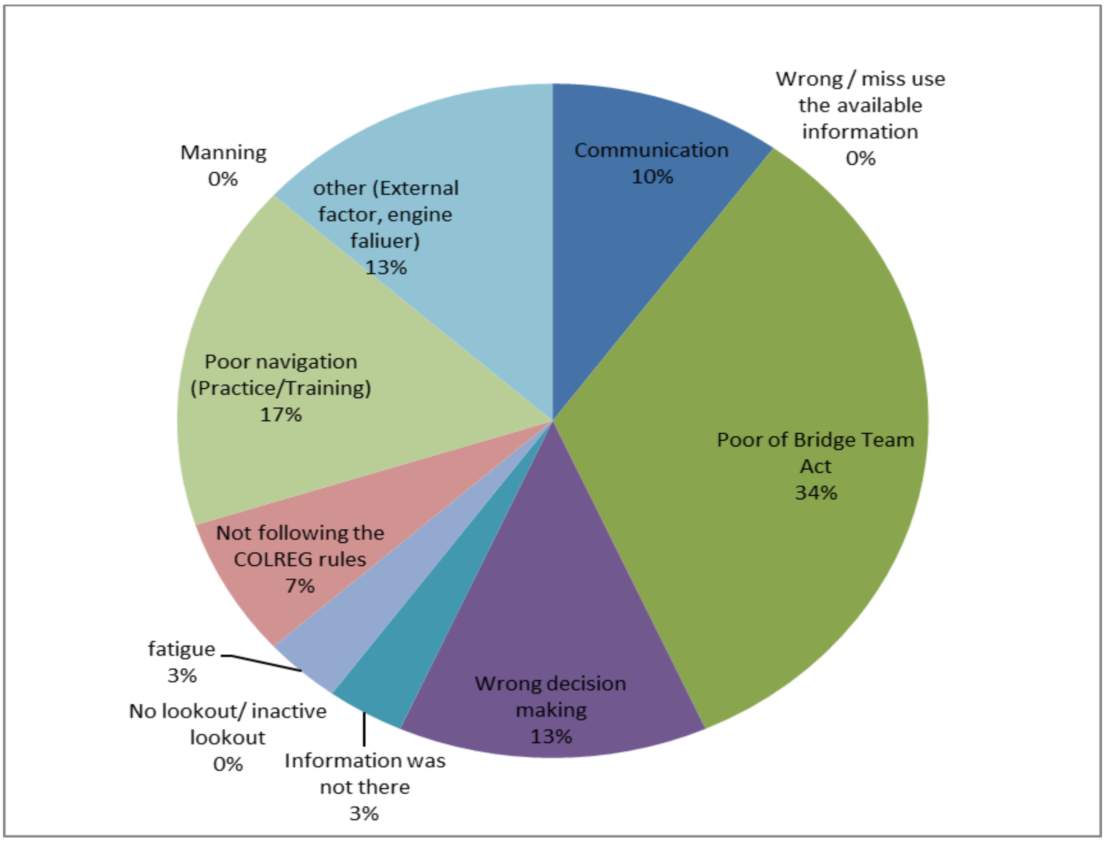

Figure 5.24 Percentage of factors that lead to lack of situational awareness after 01/01/2012.

5.4. Conclusion

The human element was a major factor influencing ship accidents which have been reviewed, which; the main two components are situational awareness and assessment (SA) and teamwork. The misunderstanding of the situation, lack of knowledge about the navigational equipment's capabilities, and the misuse of it increased the risk of accidents. Moreover, poor application of bridge team management (BTM) increased this risk to a higher level.

As it is clearly presented above, most OOWs are not achieving level 1 SA because they rely on one or two navigational equipment rather than utilising all the equipment on the bridge to create Situational Awareness. Also, the benefits of using another opinion to improve the decision have not been used regularly. Surprisingly, many accidents had occurred because of a lack of BTM/BRM even after the course has come into force. The reason could be that because of other team members such as cadets, wheelmen, lookouts, and pilots, who do not have to attend the BRM course, it is mandatory for only the OOWs and masters. Besides, the officer does not report any useful information due to the assumption that another member knows about it or he/she is afraid that this information does not belong to the situation or is wrong or afraid of another team member's reaction. Many of these accidents could be eliminated, and level 3 of SA can be maintained if the OOWs used all the available resources along with their experience. Moreover, accidents are related to lack of bridge team management, including different factors such as communication, decision-making, leadership and teamwork.

In the end, more accidents will continue to occur in the future if the same circumstances still exist. Therefore, those circumstances should be reviewed and addressed to maintain the highest level of Situational Awareness.

6. Situation Awareness of Crew Members: Results of the questionnaire-based study among seafarers

6.1. Chapter Overview

The situational awareness assessment is used in this study to measure the understanding of the bridge team members (crew) about the bridge resource management elements on the ship's bridge. This assessment took place by distributing a specifically designed questionnaire among the seafarers who work on the bridge or are related to bridge activities. The questionnaire's main concept was captured, and the gaps regarding teamwork and situational awareness were identified and analysed.

6.2. Introduction

The majority of seafarers think that the bridge team is made up only of masters and officers; this is not true. The bridge team includes every person with a duty on the bridge, even if it is limited by time or place, such as pilots and lookouts. The bridge resource management (BRM) course is conducted for seafarers who hold master and officer certificates. Most of the questions in this questionnaire reflect on ship accidents that involve bridge team activities.

6.3. Situational awareness for crew member questionnaire development

The questionnaire was developed based on the review of maritime accidents, which was undertaken in chapter 5. The questionnaire was established by focusing on the bridge team acts (BTA), which are related to the maritime accidents directly or indirectly, such as the communication, teamwork, situational awareness, etc., and feedback by the bridge team towards enhancing the navigational safety issues. Each maritime accident/group of accidents, which raised a question or statement regarding BTA, was covered to examine the navigational safety culture in the bridge in detail. Based on the Likert Scale (6 points), each statement and question in the questionnaire aims to collect responses from seafarers and pilots in the form of agreement levels, which are (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree, and I do not know). For the analysis, the Likert scale was converted to the numerical values, which has a range from 6 (strongly agree) to 1 (strongly disagree. Zero value is assigned to for (I do not know) responses.

After the questionnaire was completed, it was checked by two experts for the final approval for distribution through an anonymous link by using Qualtrics. The link was sent to shipping companies to get feedback from their seafarers.

6.4. Situational awareness assessment questionnaire data collection

The questionnaire was distributed by using an anonymous link to the participants. It targets all seafarers who are involved in ship bridge activities. It was also distributed among the cadets, who have been onboard ships, and lecturers of maritime institutions. One hundred and fifty-eight completed questionnaires were collected. The questionnaire contained five domains (Bridge Resource Management, Teamwork, Navigational safety, Involvement and Situation Awareness) in addition to the demographic domain with a total of forty-three questions. The "Do not Know" answers in this questionnaire are considered as missing data for the analysis.

6.4.1. Demographic

The beginning of the questionnaire aimed to capture the demographics of all participants who took part in the questionnaire. All participants are seafarers from different regions and held different qualification. One hundred fifty-five of them were related to bridge activity, and the remaining three participants were marine engineers with different positions.

6.4.1.1. Age and Gender

All participants who took part in this survey are male. Participants' ages varied between 18 and 64, and the age range was divided into six categories (there is no participant over 65 years old), as shown in Figure 6.1. The largest age group among participants is 25-34 (46.2%) followed by 35-44 (24.68%) and 45-54 (15.82%). The 18-24 age group had only 8.86% who are possibly not even aware of BRM.

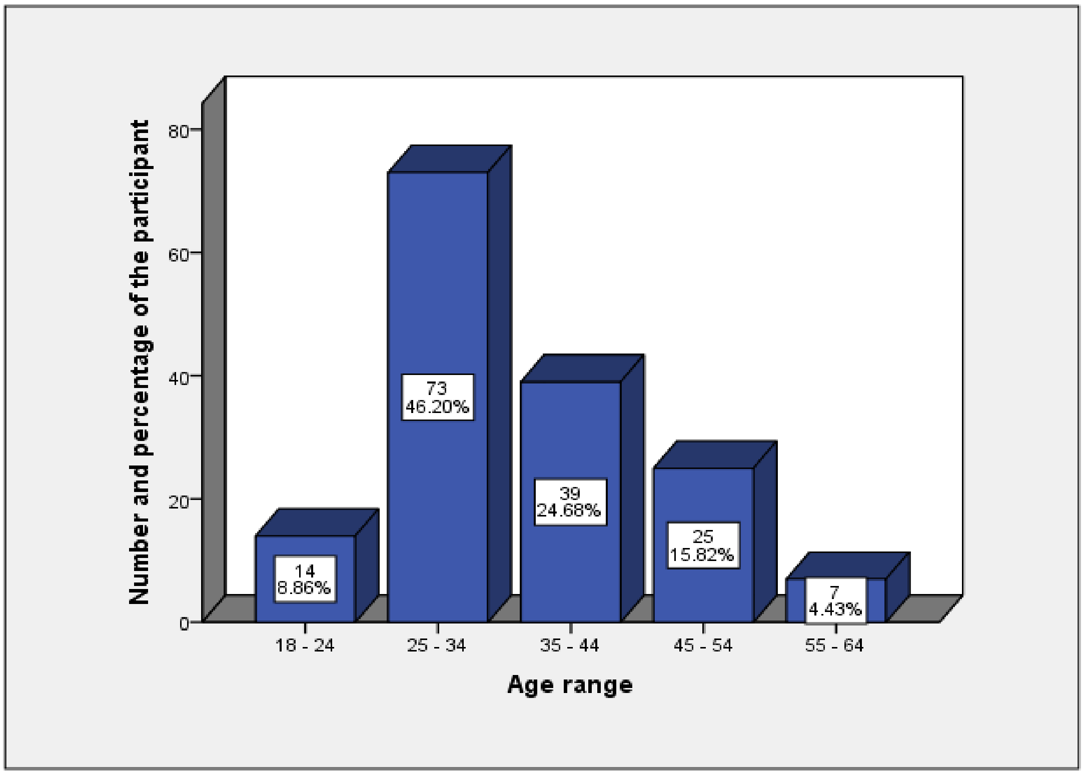

Figure 6.1 Age range of all participants

6.4.1.2. Rank

All seafarers who took part in this survey are related to the bridge team with different positions. The range of positions can be divided into two groups; The first group, The Bridge Team, include the master, the officer of the watch (OOW), the lookout, the wheelman (helmsman) and the deck cadet. Moreover, the survey recorded participants from the second group, which is from outside the bridge, but they are connected to the bridge operation such as the pilot (tug master and marine engineers named as other) for the purpose of the analyses. Marine engineers take a course similar to Bridge Resource Management which is called Engine Resource Management. Reviewing the responses from the marine engineers will provide the opportunity to identify any potential gaps for a wide range of ranks, which are linked to the bridge teamwork and communications.

Figure 6.2 shows that more than 140 participants are working in the same environment, which is the bridge operation group. The senior and the junior parties, which include (master and OOWs) make up 58.5% of the participants.

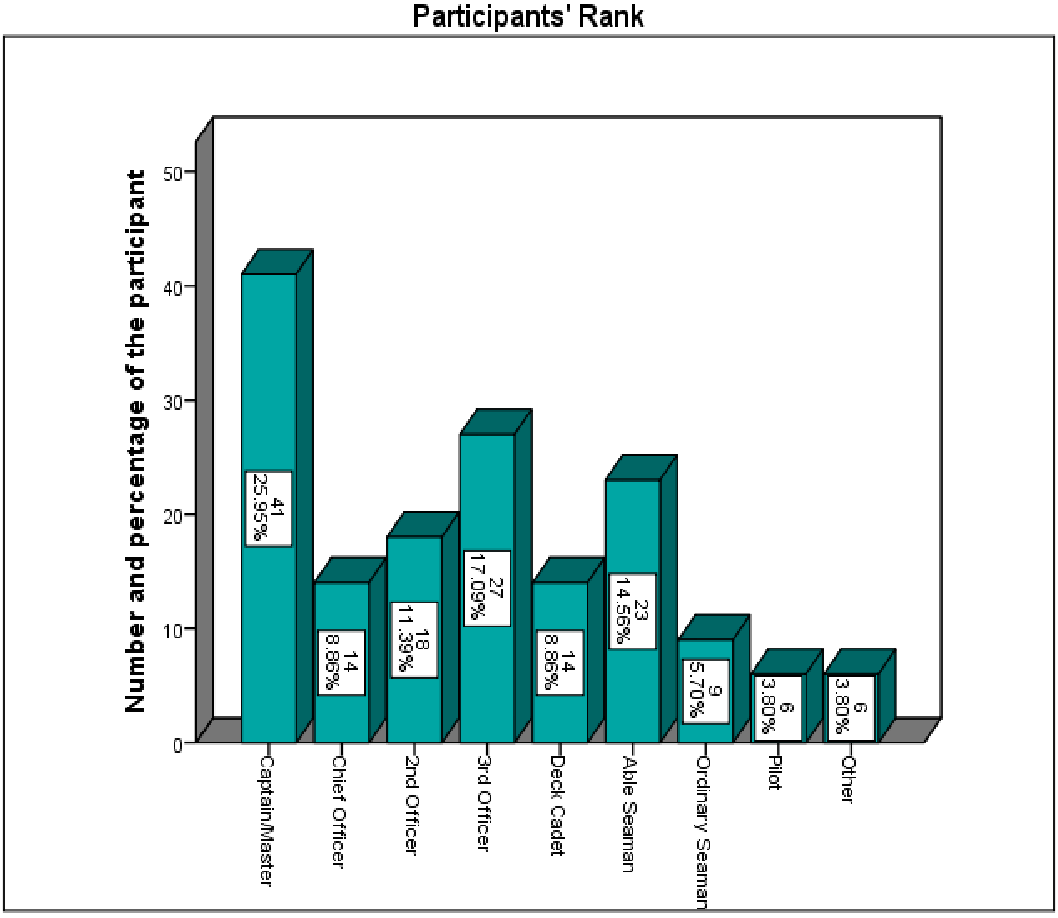

Figure 6.2 Range of positions for all participants

6.4.1.3. Sea-time Experience

It is helpful to know if the experience can affect the seafarer's judgment. The distribution of sea-time experience is presented in Figure 6.3. Over 50% of the participants have a sea-time experience for more than eight years. On the other hand, the fresh minds or just graduated from nautical colleges got the lower score which is only 7%. The benefit of getting feedback from seafarers with a wide range of sea-time experience is to determine whether the knowledge gained in the college is equal to the experience that seafarers can gain over the years.

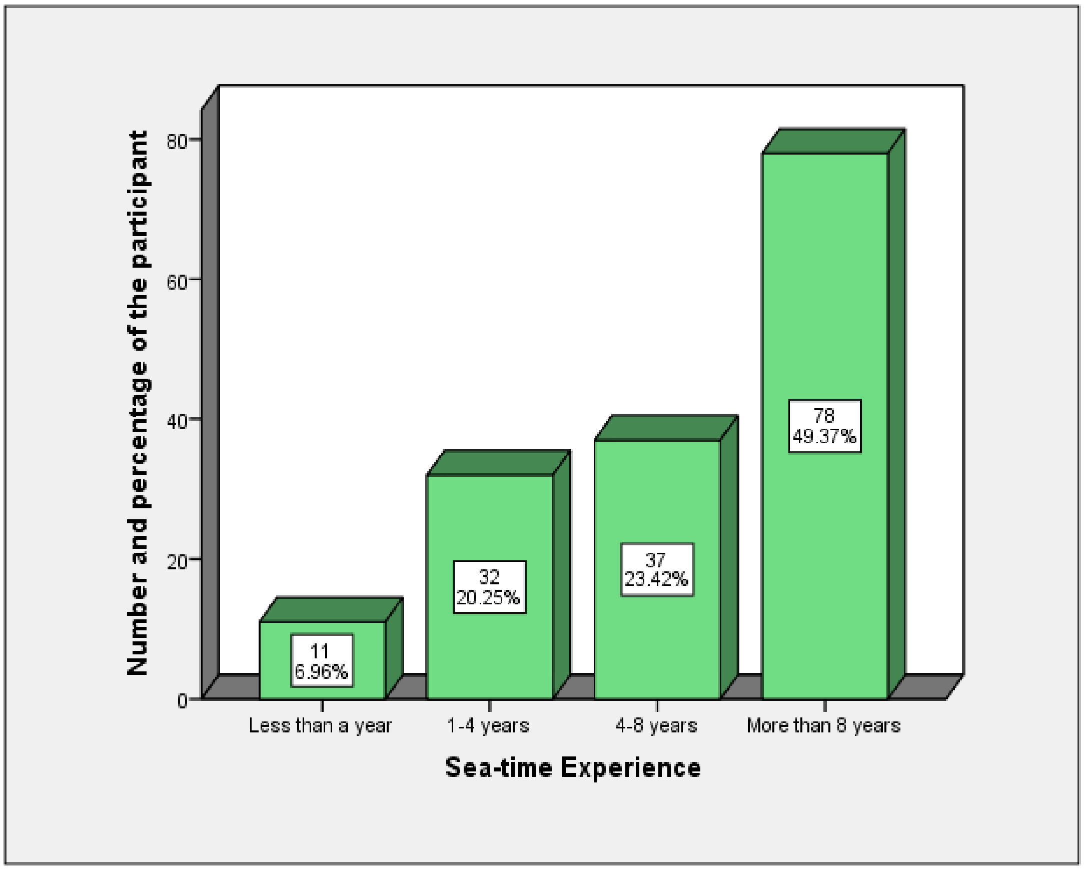

Figure 6.3 Range of sea-time experience for all participants

6.4.1.4. Nationalities

In total, seafarers from 15 nationalities participated in the questionnaire. The majority of the participants were from India with 31%, followed by Saudi nationals with 25%, Filipino 14.5% and Russian 7.6%, as shown in Figure 6.4. There are further six nationalities grouped in the other category due to small size and included Pakistani, Yemeni, Georgian, Ukrainian, Bulgarian and Montenegro) seafarers.

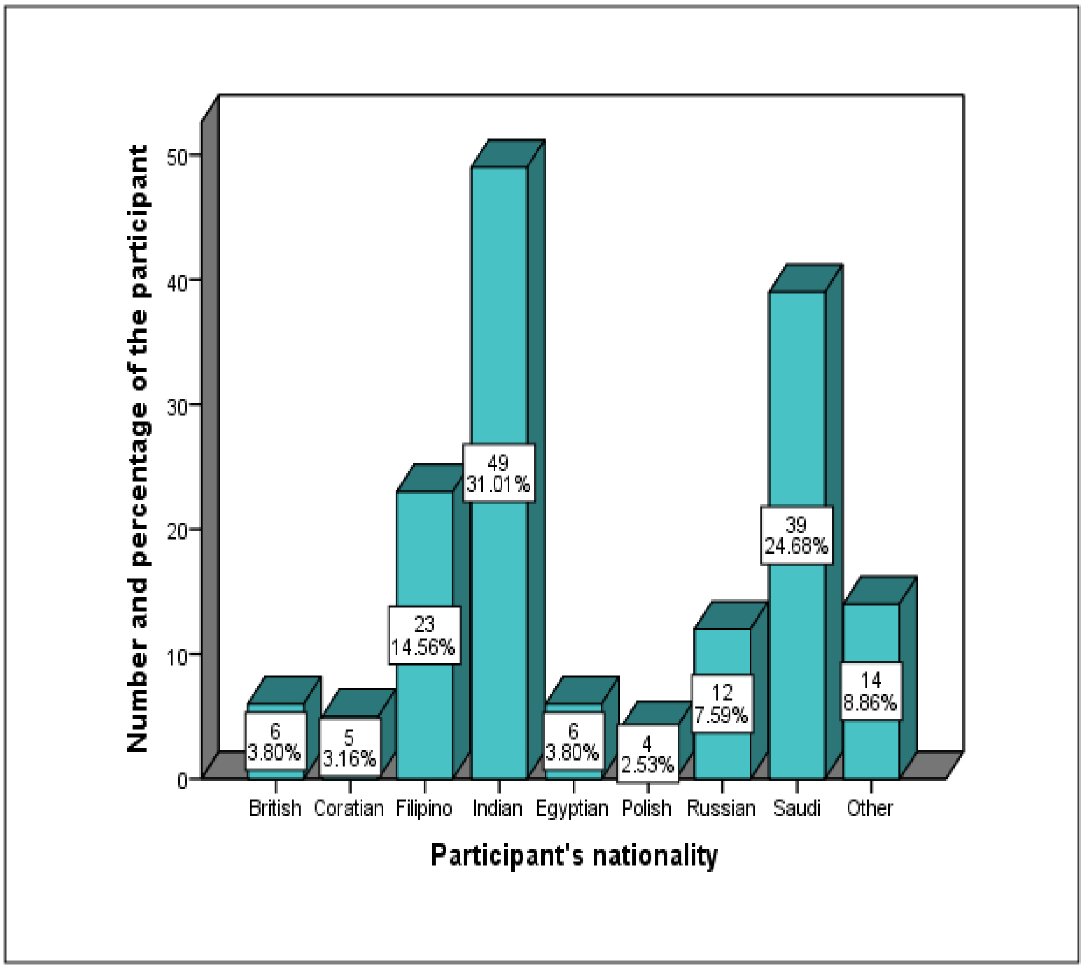

Figure 6.4 Distribution of nationalities

6.4.2. Factor analysis

- Pre-analysis

A total of 158 valid responses were collected through the questionnaire (all do not know, and missing data are excluded in this analysis). The analysis has been tested through the SPSS tool using KMO (Kaiser-Meyer-Olkin) test (Kaiser, 1970; Hollenbeck, 1972) to measure the adequacy of the sample. Table 6.1 below shows that KMO measurement was found as 0.727, which is considered between 'meritorious and middling' according to the KMO assessment category proposed by (Kaiser and Rice, 1974). In addition, Barlett's Test of Sphericity value was also found significant (0.000), which also shows there are correlations between the questions.

Table 6.1 KMO and Barlett's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.727
Bartlett's Test of Sphericity	Approx. Chi-Square	3563.835
	df	903
	Sig.	.000

The factor analysis is performed by carrying out an Exploratory Factor Analysis (EFA). The analysis shows the questionnaire's validity by exploiting principal axis factoring and the rotation factor of the SPSS (Tinsley and Tinsley, 1987). Table 6.2 below demonstrates the five components (based on the fixed number of values), which were obtained from the data collected for the analysis, which shows a total of 46.76% variance. (Zwick and Velicer, 1986) suggested that each factor must contain three loadings as a minimum to run the analysis. All questions should have a correlation coefficient of more than 0.3, which is considered that there is sufficient correlation within the component (Tabachnick and Fidell, 2014). As a result, the five domains were taken from the data, as presented in Table 6.3. The factor analysis has been processed through the following steps:

- Main analysis

According to (Tabachnick and Fidell, 2014) suggestions, the correlation coefficients must be above 0.3, so the correlation matrix could be created. Otherwise, the factor analysis could not be found if it is less than 0.3.

Table 6.2 exploratory factor analysis for the fixed number of values and percentage of variance

Total Variance Explained						
Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	9.139	21.254	21.254	4.708	10.948	10.948
2	3.743	8.706	29.959	4.706	10.944	21.891
3	2.820	6.557	36.516	3.918	9.111	31.002
4	2.446	5.687	42.204	3.662	8.515	39.518
5	1.962	4.563	46.767	3.117	7.249	46.767

Table 6.3 exploratory factor analysis pattern matrix factor loadings

Questions	1	2	3	4	5
Q21	.643				
Q11	.611				
Q12	.598				
Q22	.596				
Q43	.589				
Q17	.578				

Q5	.523				
Q6	.482				
Q42	.391				
Q35		.726			
Q20		.700			
Q36		.692			
Q4		.631			
Q2		.625			
Q31		.567			
Q39		.551			
Q19		.527			
Q3.		.487			
Q30		.472			
Q1		.309			
Q23		.307			
Q28			.657		
Q25			.336		
Q29			.634		
Q34			.602		
Q14			.587		
Q37			.552		
Q26			.505		
Q32			.451		
Q7			.425		
Q13				.901	
Q9				.889	
Q8				.860	
Q16				.540	
Q27				-.331	
Q10					-.343
Q33					.576

Q40					.552
Q18					.527
Q41					.472
Q38					.436
Q24					.409
Q15					.382

Table 6.4 below is designed to collocate all domains, factor, questions and its loading result. The grouping is based on the component matrix, which resulted from the factor analysis test above. Each component groups contain all questions that scored a loading of 0.3 or more.

Table 6.4 Factor Loadings

Domains	Factors	Questions	Loading
Safe bridge environment and teamwork	1	Q21 I can ask other bridge team member when I doubted.	.643
	1	Q11 Bridge members should question a higher rank officer's/pilot's decision not even when safety is affected	.611
	1	Q12 Whenever I see a navigational warning, I always report it.	.598
	1	Q22 Asking for assistance can make me look competent.	.596
	1	Q43 I know that fatigue can affect my situational awareness in the bridge.	.589
	1	Q17 I get the benefit of other bridge member's experience to make a safe and effective decision.	.578
	1	Q5 I always ask questions if I do not understand or unsure about any information or instructions were given to me.	.523

	1	Q6 I can report anything related to safe navigation without fearing from the consequences, especially at night.	.482
	1	Q42 Following the COLREGs can improve my situational awareness.	.391
Communication	2	Q35 Mistakes are corrected without punishment and treated as a learning opportunity	.726
	2	Q20 I found a good atmosphere of teamwork in the bridge.	.700
	2	Q36 Watch hand-overs are thorough and not hurried.	.692
	2	Q4 Operational values, objectives and targets are effectively communicated.	.631
	2	Q2 There is a good communication environment in the bridge.	.625
	2	Q31 I receive feedback about my compliance with the safety of navigation.	.567
	2	Q39 There is sufficient time allocated for the hand-overs when joining the ship	.551
	2	Q19 There is a briefing between the bridge team before the watch started.	.527
	2	Q3 There is no difficulty in using English as a communication language.	.487
	2	Q30 Other bridge members encourage me to report unsafe events.	.472
	2	Q1 Language/dialect related issues amongst bridge members are not a threat to safety.	.309
	2	Q23 There is a collaboration between bridge team members to ensure safe navigation.	.307
Bridgework	3	Q28 I am confident that I can operate the navigational equipment within my area of responsibility safely	.657
	3	Q25 A good leadership can improve	.336

		teamwork.	
	3	Q29 I fully understand my responsibilities for my duty in the bridge.	.634
	3	Q34 I have sufficient control of my work to ensure it is always completed safely.	.602
	3	Q14 I use all resources that available in the bridge to ensure safe passage.	.587
	3	Q37 I can easily maintain my situational awareness during my watch	.552
	3	Q26 I found no difficulty in using navigational equipment to ensure safe passage.	.505
	3	Q32 Bridge members are encouraged to improve navigational safety.	.451
	3	Q7 I can establish/ understand any communication between my vessel and others.	.425
Bridge resource management	4	Q13 I found that the BRM course improved my skills.	.901
	4	Q9 The course is helping me to cooperate with bridge members.	.889
	4	Q8 I found the BRM course useful for each bridge members	.860
	4	Q16 I do a risk assessment when the ship passes through heavy traffic areas	.540
	4	Q27 I rely on electronic navigation equipment for a safe passage.	-.331
Safety awareness	5	Q10 It is better to conduct a monthly meeting for bridge team members.	-.343
	5	Q33 I am consulted about and invited to get involved in changes that affect teamwork in the bridge.	.576
	5	Q40 We are sharing the same situational awareness in the bridge.	.552

	5	Q18 I found that maritime institutions are providing different content of BRM course.	.527
	5	Q41 I can easily predict what will happen during my watch.	.472
	5	Q38 A good manning in the bridge can improve situational awareness.	.436
	5	Q24 I can correct the information for another bridge team member even if he/she higher ranks than me.	.409
	5	Q15 I can deal with any emergency navigational situation by myself.	.382

- Post analysis check

The reliability analysis has been done by using Cronbach's alpha statistics tool (Cronbach, 1951). The reliability test score is determined in Table 6-5. Alpha 0.6789, which shows good reliability according to (Nunnally, 1978), which specified that the alpha value must be above 0.6 (Achour, 2017). While (Hair *et al.*, 1998) stated that the reliability analysis score must be over 0.7 to show a high internal consistency (Ghonaim, 2020). Table 6-5 below shows the Cronbach's Alpha value for each domain. By looking at the safety awareness domain, which is scored less than the accepted score, but near to the acceptable score, which can be adjusted in future work by conducting a pilot study for all domains and enhancing it if necessary before continuing this study to achieve a higher reliability score than what we have. However, the overall reliability score for this study within the acceptable score. Therefore, appropriate reliability for situational awareness for crew member questionnaire has acquire after conducting the EFA.

Table 6.5 Reliability Scales

Domains	Cronbach's Alpha value	
Safe bridge environment and teamwork	0.634	
Communication	0.811	
Bridgework	0.694	
Bridge resource management	0.68	
Safety awareness	0.58	
	Total score	0.6798

6.4.3. Results for Situational Awareness domain

In total, 158 participants had filled the questionnaire without missing data in each domain. All the analyses were performed using the SPSS tool. The results are presented in the tables from 6-8 to 6-12, including the question, mean, standard deviation (Std. Dev) and the agreement score in percentage for each domain. All the values under the domain score section are categorised using a colour code. The representation of the colour coding has been used before as a safety climate score which was suggested by (Arslan, 2018).

Table 6-6 and Table 6-7 show that the scores from 90% to 100% are represented by the dark green colour, which means no action is required to improve it and highlighted the 'strongly agree' statement. The score from 80% to 90% is represented by the light green colour, which indicates slight improvement is required and highlights the 'agree' statement. The score from 70% to 80%, represented by the yellow colour, indicates medium improvement is required to achieve the desired level of safety and highlights the ‘agree’ statement as well. However, the red colour, which represents the scores below 70%, means a significant improvement is required; depending on the mean score red colour represents both ‘disagree’ and ‘strongly disagree’ statements. The mean score in percentage is calculated using equation 1 below. Then, the mean score will be shown next to each question in each domain in the following tables.

$$\text{score in percentage } (\%) = \frac{\text{Mean}-1}{5-1} * 100 \text{ (equation 1)}$$

the mean limit was calculated using equation 2 below:

(5-1)/5= 0.833 (equation 2)

Table 6.6 Mean score interpretation.

Mean Score	**Results**
100 to 90	Very Good
90 to 80	Good
80 to 70	Average
Below 70	Very poor

Table 6.7 Mean limit interpretation.

Agreement degree	Mean limits	Colour code
I do not know	Zero (Missing value)	<70%
Strongly Disagree	1 –1.833	
Disagree	1.83 – 2.666	
Neither agree nor disagree	2.666 – 3.499	
Agree	3.499 – 4.332	70% - 80%
	4.332 – 5.156	80% - 90%
Strongly Agree	5.156 – 6	>90%

6.4.3.1. Safe bridge environment and teamwork

The safe bridge environment and teamwork domain consist of nine statements, which has a mean of 4.36, and the agreement score is 83.97%. This means a slight room for improvement is required. Table 6.8 shows that some of the statements which are not in green colour need medium improvement. The statement "*Asking for assistance can make me look competent*" got the lowest score in this domain.

Statement Q22 detects a problem among the seafarers, as almost 20% of the participants agreed that asking for help makes them look unprofessional and unfit to be suitable for their duty. Most of the seafarers don't ask for assistance because they think that asking any question regarding work, knowledge, or information will make them incompetent for their position. Some masters stated that in their standing order, onboard the ship, *ask if you are in doubt*. This statement clarifies that whatever is their rank, age, and experience at sea, they should ask for help/clarification if they needed to remove the ambiguity. Therefore, the seafarers must enhance their communication, teamwork, and asking for help by attending a suitable course, such as the new BRM course, which its effectiveness shows clearly in chapter 8.

Table 6.8 Safe bridge environment and teamwork Domain

Statements	Mean	Stan Dev.	Agreement score %
Q21 I can ask other bridge team member when I doubted.	4.42	0.545	85.5
Q11 Bridge members should question a higher rank officer's/ pilot's decision not even when safety is affected	4.34	1.02	83.5
Q12 Whenever I see a navigational warning, I always report it.	4.49	0.639	87.25
Q22 Asking for assistance can make me look competent.	3.93	0.978	73.25
Q43 I know that fatigue can affect my situational awareness in the bridge.	4.41	0.845	85.25
Q17 I get the benefit of other bridge member's experience to make a safe and effective decision.	4.25	0.781	81.25

Q5 I always ask questions if I do not understand or unsure about any information or instructions were given to me.	4.50	0.665	87.5
Q6 I can report anything related to safe navigation without fearing from the consequences, especially at night.	4.41	0.740	85.25
Q42 Following the COLREGs can improve my situational awareness.	4.48	0.594	87.0
Total Domain	4.36	0.756	83.97

6.4.3.2. Communication domain

The communication domain contains twelve statements, and the mean score for this domain is 3.87, and the agreement score is 71.77%. This means there is major room for improvement as far as the communication domain is concerned. Thus, a new BRM course for all seafarers, including ratings, is recommended to fill this gap. According to Table 6.9, most of the statements require some improvement to achieve a higher safety barrier with regards to communication. The statements "Q31-*I received feedback about my compliance to the safety of navigation, Q39-there is sufficient time allocated for the hand-over when joining the ship, and Q1-Language/dialect related issues amongst bridge members are not a threat to safety*" have the lowest scores, which are 66.5%, 64.75% and 40% respectively.

Communication is one of the most important performance indicators of bridge resource management. Therefore, all the crew onboard the ship should have the ability to speak and understand the English maritime language, and more than 80% of the participants agreed to this statement. However, more than 50% of the participants agreed that communication language between bridge members is not a threat to safety, while almost 40% thought it is.

The ship might contain more than three nationalities onboard ship, and their first language is not English. Naturally, this leads to the use of their mother tongue as a communication language, which will create a major barrier on the bridge where they have to use the ship's official communication language to perform the navigational duties. Many maritime accidents were reported due to language problems, which prevented accurate or timely communication. On the other hand, many accidents were prevented due to the excellent communication among the bridge team made up of the same nationality. However, the same advantage turned to a disadvantage and led to accidents when the bridge team communicate in the national language when the pilot from different nationality is on the bridge.

Q39 statement "*There is sufficient time allocated for the hand-overs when joining the ship*" scores 64.75%, which clearly indicates that the time allocated for the crew change-over (hand-over/take-over joining/leaving the ship) sometimes is not enough due to problems with the flight arrangement for the hand-over crew or the time allocated for the ship when she is at berth. This leads to a lack of shared situational awareness and a lack of familiarity that lead to safety barrier deficiencies and communication problems.

Q31, which has a score of 66.5%, clearly shows that the crew do not receive any or proper feedback or comment about their compliance with the navigation safety then the opportunity of learning from the mistakes is missed significantly. This does not help to enhance seafarers' skills and experience with regards to not only communication but also the individual and organisational safety culture. It is highly recommended to ensure a good environment of communication between crew, bridge team to avoid any miscommunication during the ship navigations. This can be enhanced through training and improved company procedures as well as the commitment of the management.

Table 6.9 Communication Domain

Statements	Mean	Stan Dev.	Agreement score %
Q35 Mistakes are corrected without punishment and treated as a learning opportunity	3.94	1.05	73.5
Q20 I found a good atmosphere of teamwork in the bridge.	4.13	0.73	78.25
Q36 Watch hand-overs are thorough and not hurried.	4.06	0.992	76.5
Q4 Operational values, objectives and targets are effectively communicated.	4.09	0.626	77.25
Q2 There is a good communication environment in the bridge.	4.26	0.759	81.5
Q31 I receive feedback about my compliance to the safety of navigation.	3.66	1.06	66.5
Q39 There is sufficient time allocated for the hand-overs when joining the ship	3.59	0.978	64.75
Q19 There is a briefing between the bridge team before the watch started.	3.92	1.123	73
Q3 There is no difficulty in using English as a communication language.	4.16	0.85	79
Q30 Other bridge members encourage me to report unsafe events.	3.93	1.029	73.25
Q1 Language/dialect related issues amongst bridge members are not a threat to safety.	2.6	1.32	40.00
Q23 There is a collaboration between bridge team members to ensure safe navigation.	4.11	0.907	77.75
Total Domain	3.87	0.952	71.77

6.4.3.3. Bridgework Domain

The Bridgework domain contains nine statements, and the mean score for this domain is 4.33, while the agreement score is 83.28%. According to Table 6.10, most of the statements do not require any major improvement except the statements Q26 and Q37. The statements "*I found no difficulty of using navigational equipment to ensure safe passage and I can easily maintain my situational awareness during my watch*" got the lowest scores in this domain.

According to the responses, some of the bridge team members (ratings and cadets) are not allowed to deal with the bridge navigational equipment unless if the captain or OOW say so. In the Author's opinion, it works against rule 5 of the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) (IMO, 1972). COLREG rule 5 states, "*every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision", and* this includes the bridge navigational equipment such as RADAR, ARPA and AIS.

Statement Q37 "*I can easily maintain my situational awareness during my watch",* which scored nearly 80%, shows that more than 50 % of the participants agreed to this statement. On the other hand, around 13% of the participants, most of them are ratings, fluctuated between neither agree nor disagree and do not know responses. This can explain that some of the seafarers do not know the meaning of SA or how they can build and maintain their SA during the watch with the help of alternative information resources that are available on the bridge. Moreover, the statements Q28, Q34 and Q7, which are scored slightly more than 80%, can confirm that there is a hesitation with regards to the bridgework, which can cause a deficiency in the bridge team act and lead to a maritime accident.

Table 6.10 Bridgework Domain

Statements	Mean	Stan Dev.	Agreement score %
Q28 I am confident that I can operate the navigational equipment within my area of responsibility safely.	4.23	0.697	80.75
Q25 A good leadership can improve the teamwork.	4.71	0.556	92.75
Q29 I fully understand my responsibilities for my duty in the bridge.	4.54	0.634	88.5
Q34 I have sufficient control of my work to ensure it is always completed safely.	4.23	0.750	80.75
Q14 I use all resources that available in the bridge to ensure safe passage.	4.54	0.583	88.5
Q37 I can easily maintain my situational awareness during my watch	4.19	0.904	79.75
Q26 I found no difficulty of using navigational equipment to ensure safe passage.	4.03	0.906	75.75
Q32 Bridge members are encouraged to improve navigational safety.	4.30	0.615	82.5
Q7 I can establish/ understand any communication between my vessel and others.	4.21	0.814	80.25
Total Domain	4.33	0.718	83.28

6.4.3.4. Bridge Resource Management

The Bridge Resource Management domain contains five statements, and the mean score for the domain is 3.59, while the agreement score is 64.75%. This means significant improvement is required to achieve the required level of safety. The low score for this domain was expected due to the varied range of ranks who participated in this questionnaire, whereas the ratings, cadets and some pilots are not required to take the BRM course by STCW. Because it is not mandatory for their job specification or they are not qualified to take the course as per their rank description, shipping companies do not send their ratings to the BRM course. In the Author's opinion, this is a major weakness in current BRM requirements as the only officers within the bridge team have the BRM certificates. This means the bridge team as a whole do not have the shared situational awareness and ratings do not know how they can support the bridge team in case of emergency.

According to Table 6.11, all the statements require more attention to achieve a higher safety level except the statement Q16, *"I do a risk assessment when the ship passes through heavy traffic areas"*.

There are no surprises with the responses regarding this domain as most of the responses answered with 'I do not know and 'neither agree nor disagree', 'resources are there but can't utilise it' sectors exceed 33% of the participants' responses for the statements Q13, Q9 and Q8. The bridge resource management, as mentioned earlier, is a course designed for officers of the watch, masters and pilots. However, a wide range of feedback came from cadets, ABs and OSs, who stated that they had no clue about this course. This issue was clearly identified, and the Author proposed a solution by developing a new BRM course suitable for all seafarers, as presented in chapter 7.

Regarding Q27, which scored 53.25%, most of the responses were in disagreement as more than 60% of the participants refused to rely on navigational equipment only to ensure a safe passage.

This domain was designed to inquire about the participants' opinion about the benefits of the BRM course for all bridge team members. However, the responses clarify that there is a missing link between the seafarers who took the course and those who have not. More details will be given in the next section.

Regarding Q27, which scored 53.25%, the majority of the responses were in disagreement as more than 60% of the participants refuse to rely on navigational equipment only to ensure a safe passage.

This domain was designed to inquire about the participants' opinion about the benefits of the BRM course for all bridge team members. However, the responses clarify that there is a missing link between the seafarers who took the course and those who have not. More details will be given in the next section.

Table 6.11 Bridge Resource Management Domain

Statements	Mean	Stan Dev.	Agreement score %
Q13 I found that the BRM course improved my skills.	3.51	1.505	62.75
Q9 The course is helping me to cooperate with bridge members.	3.70	1.45	67.5
Q8 I found the BRM course useful for each bridge members	3.72	1.42	68
Q16 I do a risk assessment when the ship passes through heavy traffic areas	3.89	1.14	72.25
Q27 I rely on electronic navigation equipment for a safe passage.	3.13	1.20	53.25
Total Domain	3.59	1.343	64.75

6.4.3.5. Safety Awareness

The Safety Awareness domain contains eight statements, and the mean score for this domain is 3.65, while the agreement score is 66.34% which is required significant improvement to achieve the level of safety culture. According to Table 6.12, all of the statements require more attention to achieve a higher safety level except the statement Q38, "A good manning in the bridge can improve the situational awareness".

The statements of this domain have fluctuated between the disagreement and agreement response. The statement Q18, "*I found that maritime institutions are providing different contents of BRM course*", got the lowest score in this domain which is 39.5%, where many seafarers who took the BRM course will be returning back to a maritime institution after five years to take the course again to renew his certificate, by that time the seafarer will not remember what the course contents were unless they kept the notes of the previous course. The majority of the responses from the participants are either 'Do not know or neither agree nor disagree' with 30.5% and 22%, respectively. These answers are logical as the ratings do not know anything about BRM as they are not required to attend, and the officers who took the course only once would not know anything different. This clearly amplifies the problem, how can they be part of the team if they do not know what to do as part of a team?

The statement Q41, "I *can easily predict what will happen during my watch*", scored 57%. This indicates that many OOWs and other bridge team members think that reaching level 3 of situational awareness is difficult than it seems. However, if they share their situational awareness and make the required information available, they can easily predict the situation during their watch. For Statement Q15, "*I can deal with any emergency navigational situation by myself*", which scored 57% in this domain. More than half of the participants believe that dealing with emergency situations should be placed and combined with teamwork. The survey score was as predicted because it is harder to deal with any emergency navigational situation by only the master or OOW while maintaining full situational awareness during the disaster. This is a clear indication that team situational awareness should be the ultimate goal involving every single human and equipment resources.

As the results of this domain show, many seafarers do not believe the safety performance onboard the ship is growing by attending the BRM course. Moreover, this questionnaire's distribution shows that ratings are not given the opportunity to enhance their safety a team culture compared to captains and OOWs. This is reflected by the statements Q33 and Q40, which score slightly above 70%. More details will be given in the next section.

Table 6.12 Safety Awareness Domain

Statements	Mean	Stan Dev.	Agreement score %
Q10 It is better to conduct a monthly meeting for bridge team members.	3.99	0.99	74.75
Q33 I am consulted about, and invited to get involved in changes that affect teamwork in the bridge.	3.81	1.08	70.25
Q40 We are sharing the same situational awareness in the bridge.	3.82	1.02	70.5
Q18 I found that maritime institutions are providing different content of BRM course.	2.58	1.73	39.5
Q41 I can easily predict what will happen during my watch.	3.28	1.2	57
Q38 A good manning in the bridge can improve situational awareness.	4.48	0.64	87
Q24 I can correct the information for another bridge team member even if he/she higher ranks than me.	3.99	0.814	74.75
Q15 I can deal with any emergency navigational situation by myself.	3.28	1.2	57
Total Domain	3.65	1.084	66.34

6.4.4. Statistical Results

Differences between group means were examined and tested for statistical significance by using the one-way ANOVA test. This test is applied to identify statistical differences between different groups such as age, rank etc. The result (p-value) must be equal to or above 0.05 for the question; if not, that means a significant impact between the different groups responded to that question which coloured by red. All the questions, which score a p less than 0.05, will be highlighted and analysed by the colour code mentioned earlier.

6.4.4.1. Effect of Age

The questions that are emphasised in red colour, as shown in Table 6.13, represents that there is a significant statistical difference between the age groups and their response in the questionnaire.

Table 6.13 ANOVA on Age (significant interactions, p-value < 0.05, are shown in red)

Var	p value	Var	p value	Var	p value	Var	p value	Var	p value
Q1	0.028	Q10	0.059	Q19	0.234	Q28	0.003	Q37	0.539
Q2	0.058	Q11	0.089	Q20	0.180	Q29	0.615	Q38	0.267
Q3	0.153	Q12	0.000	Q21	0.681	Q30	0.165	Q39	0.619
Q4	0.439	Q13	0.054	Q22	0.531	Q31	0.659	Q40	0.140
Q5	0.401	Q14	0.650	Q23	0.004	Q32	0.003	Q41	0.348
Q6	0.296	Q15	0.256	Q24	0.497	Q33	0.085	Q42	0.629
Q7	0.372	Q16	0.097	Q25	0.061	Q34	0.469	Q43	0.089
Q8	0.410	Q17	0.000	Q26	0.013	Q35	0.199		
Q9	0.028	Q18	0.183	Q27	0.009	Q36	0.050		

Because of the difference in sample size and non-homogeneous variances, Hochberg's GT2 and Games-Howell post hoc tests were conducted on the statistically significant variables only (the red colour cells given in the table above).

Table 6.14 Summary of the findings of post hoc tests for the interaction of Ages.

Q	Statement	18-24	25-34	35-44	45-54	55-64
1	Language/dialect related issues amongst bridge members are not a threat to safety.	50	34.5	34.5	56	50
9	The course is helping me to cooperate with bridge members.	42.8	65.4	71.7	81	67.8
12	Whenever I see a navigational warning, I always report it.	66	88.6	92.3	86	89.2
17	I get the benefit of other bridge member's experience to make a safe and effective decision.	57.1	80.8	87.8	84	89
23	There is a collaboration between bridge team members to ensure safe navigation	57.1	79.4	81.4	75	89.2
26	I found no difficulty of using navigational equipment to ensure safe passage.	60.7	76.7	76.9	74	96.4
27	I rely on electronic navigation equipment for a safe passage.	73.2	48.9	46.7	60	71.4
28	I am confident that I can operate the navigational equipment within my area of responsibility safely.	78.5	82.5	73	85	96.4
32	Bridge members are encouraged to improve navigational safety.	71.4	81.1	85.8	84	96.4

Table 6.14 above presents the variance between age groups based on the ANOVA one-way analysis test. The table above shows that younger aged (18-24) seafarers have significantly lower average scores on collaborating with other bridge team members in this study. They disagree with the given statements more than other age groups.

The younger age group thinks that asking questions or asking for help at the beginning of their carer can make them look incompetent in their duties. Also, when they encounter any difficulty in using the bridge equipment, they try to find a way to learn how to use the equipment, e.g. look over the manual, rather than asking other bridge members, which would save them much time.

The middle age groups (25-54) disagree with relying on navigational equipment only to ensure a safe passage which is opposite to the opinion of other groups. From this statement, we can highlight that the younger age group will try to use what they learn at maritime institutions, which is considered as the strongest skill that they got.

6.4.4.2. Effect of Rank

The questions that are emphasised in red colour, as shown in Table 6.15, represents that there is a significant statistical difference between the rank groups and their responses in the questionnaire.

Table 6.15 ANOVA on Rank (significant interactions, p-value < 0.05, are shown in red)

Var	p value	Var	p value	Var	p value	Var	p value	Var	p value
Q1	0.261	Q10	0.000	Q19	0.002	Q28	0.000	Q37	0.003
Q2	0.287	Q11	0.009	Q20	0.019	Q29	0.200	Q38	0.166
Q3	0.000	Q12	0.004	Q21	0.865	Q30	0.760	Q39	0.024
Q4	0.948	Q13	0.001	Q22	0.101	Q31	0.058	Q40	0.146
Q5	0.556	Q14	0.167	Q23	0.153	Q32	0.003	Q41	0.170
Q6	0.176	Q15	0.105	Q24	0.157	Q33	0.013	Q42	0.280
Q7	0.125	Q16	0.000	Q25	0.257	Q34	0.269	Q43	0.162
Q8	0.004	Q17	0.000	Q26	0.196	Q35	0.000		
Q9	0.000	Q18	0.205	Q27	0.007	Q36	0.000		

Because of the difference in sample size and non-homogeneous variances, Hochberg's GT2 and Games-Howell post hoc tests were conducted on the statistically significant variables only (the red colour cells given in the table above).

Table 6.16 Summary of the findings of post hoc tests for the interaction of Ranks.

Q	Statement	Captain/master	Ch. off.	2nd off.	3rd off.	Deck Cadet	AB	OS	Pilot	Other
3	There is no difficulty in using English as a communication language.	80.5	76.8	81.9	91.7	58.9	79.3	80.6	54.2	75
8	I found the BRM course useful for each bridge member.	75.6	69.6	80.6	79.6	50	44.6	55.6	70.8	66.7
9	The course is helping me to cooperate with bridge members.	75.6	67.9	79.2	77.8	26.8	51.1	66.7	70.8	87.5
10	It is better to conduct a monthly meeting for bridge team members.	71.8	73	87.5	84.3	67.8	77.3	80.5	45.8	95.8
11	Bridge members should question a higher rank officer's/ pilot's	86	92.9	91.7	92.6	71.4	49.6	80.6	75	70.8

	decision not even when safety is affected.									
12	Whenever I see a navigational warning, I always report it.	90.2	92.9	93.1	85.2	69.6	84.8	88.9	83.3	95.8
13	I found that the BRM course improved my skills.	68.3	62.5	76.4	78.7	26.8	50	47.2	58.3	75
16	I do risk assessment when the ship passes through heavy traffic areas.	78	76.8	77.8	85.2	37.5	62	77.8	58.3	75
17	I get the benefit of other bridge member's experience to make a safe and effective decision.	87.2	82.1	81.9	78.7	57.1	84.8	80.6	83.3	91.7
19	There is a briefing among bridge team before the watch started.	76.2	73.2	80.6	67.6	82.1	77.2	66.7	25	70.8

20	I found a good atmosphere of teamwork in the bridge.	83.5	69.6	72.2	82.4	75	80.4	80.6	75	58.3
27	I rely on electronic navigation equipment for a safe passage.	62.8	35.7	48.6	48.1	75	47.8	44.4	41.7	62.5
28	I am confident that I can operate the navigational equipment within my area of responsibility safely.	83.5	83.9	87.5	89.8	75	66.3	69.4	79.2	83.3
32	Bridge members are encouraged to improve navigational safety.	86	83.9	88.9	79.6	69.6	77.2	86.1	91.7	87.5
33	I am consulted about, and invited to get involved in changes that affect teamwork in the bridge.	78.7	76.8	55.6	73.1	58.9	60.9	66.7	87.5	79.2
35	Mistakes are corrected without	80.5	64.3	73.6	75	58.9	81.5	83.3	25	75

	punishment and treated as a learning opportunity.									
36	Watch hand-overs are thorough and not hurried.	81.1	58.9	75	83.3	69.6	83.7	91.7	25	75
37	I can easily maintain my situational awareness during my watch.	83.5	82.1	84.7	87	64.3	76.1	80.6	79.2	50
39	There is sufficient time allocated for the hand-overs when joining the ship.	70.1	51.8	55.6	59.3	69.6	72.8	66.7	79.2	50

Table 6.16 above presents the variations between different age groups based on the ANOVA one-way analysis test. It shows that the deck cadet group has the most considerable disagreements in most of the statement, and the captains and officers group have significantly higher averages on safety features. Overall, all the rank groups agree on '*it couldn't be possible to use the electronic navigation equipment to ensure a safe passage only*'. Also, they agree that '*there is no sufficient time allocated to pass the all job description, information, or important details to the hand-overs group when joining the ship*'.

According to the statements presented in Table 6.16, it could be possible to divide this group into two categories, which are; seafarers who got BRM (master, officers, pilot and other) known as team 1; and the second category seafarers did not get BRM (cadet, AB and OS) known as team 2. Team 1 finds the overall communication and teamwork better than team 2; this may be due to the BRM, including communication, teamwork, sharing situational awareness and assisting the bridge team to have superior interaction skills. Besides, team 2 has significantly lower scores than team 1 regarding involvement in the meetings or discussions during bridge meetings. Team 1 should have a meeting with team 2 to identify what type of problems or issues could be related to the safety of navigation, or both teams should attend the same course so an improvement of the shared situational awareness, safety culture and working as one team in the bridge will be enhanced.

Moreover, the seafarers who attended the BRM course can be divided into senior bridge officers, including captains and chief officers, and junior bridge officers, including the second and third officers. There is a difference between the view of the junior officers and the view of the senior officers regarding involvement and teamwork. The junior officers always deal with the ship and her manoeuvre during the navigational watch. The senior officers, like the captains, are overall in charge, and the Chief officers are responsible for the cargo and its plan, which make him fully competent with the task. However, chief officers are not involved in the navigational watch as it's happening in some companies. Therefore, junior officers do not believe that they are consulted about the changes that affect their way of working as much as the senior officers are consulted, nor do they believe that their suggestions for improving the safety of navigation are welcomed to the same extent.

In general, cadets face some difficulties with teaming up with other bridge team members because they think that they should not question the other bridge team members for their actions. Also, fearing punishment or being discharged from the vessel due to lack of their competency reflects in their confidence while they forgot that the main aim for them is to learn and train to become an officer after graduating from the maritime academy. Therefore, the opportunity to take the watch with confidence under the guidance of the OOW will increase their skills and competency as well as better communication.

Pilots must have no difficulties in talking and understanding the English language due to their job specification, which require them to deal with many nationalities and different accents. However, 33% of pilots think they cannot exchange some information with other bridge team members due to the language difficulties or time frame allocated for pilotage operation. In addition, more than 50% of pilots answered in BRM statements with ‘Do not know’.

Accordingly, this is a perfect reason to develop the new BRM course to include such seafarers to improve their skills and knowledge to address the safety of navigation in a proper and safe way. BRM courses should also be designed to mix bridge team and pilots to enhance the communication between the pilots and the bridge team.

6.4.4.3. Effect of Experience at Sea

The questions that are emphasised in red colour, as shown in Table 6.17, represent a significant statistical difference between the experience at sea groups and their responses to the questionnaire.

Table 6.17 ANOVA on Experience at Sea (significant interactions, p-value < 0.05, are shown in red)

Var	p value	Var	p value	Var	p value	Var	p value	Var	p value
Q1	0.068	Q10	0.160	Q19	0.138	Q28	0.420	Q37	0.000
Q2	0.005	Q11	0.250	Q20	0.111	Q29	0.821	Q38	0.580
Q3	0.262	Q12	0.004	Q21	0.168	Q30	0.002	Q39	0.711
Q4	0.477	Q13	0.242	Q22	0.073	Q31	0.005	Q40	0.038
Q5	0.069	Q14	0.771	Q23	0.055	Q32	0.060	Q41	0.278
Q6	0.126	Q15	0.617	Q24	0.010	Q33	0.136	Q42	0.566
Q7	0.087	Q16	0.000	Q25	0.411	Q34	0.764	Q43	0.067
Q8	0.529	Q17	0.000	Q26	0.046	Q35	0.007		

Q9	0.365	Q18	0.855	Q27	0.014	Q36	0.180	

Because of the difference in sample size and non-homogeneous variances, Hochberg's GT2 and Games-Howell post hoc tests were conducted on the statistically significant variables only (the red colour cells given in the table above).

Table 6.18 Summary of the findings of post hoc tests for the interaction of Experience at Sea.

Q	Statement	Less than a year	1-4 years	4-8 years	More than 8 years
2	There is a good communication environment on the bridge.	63.8	79.8	81	85
12	Whenever I see a navigational warning, I always report it.	70.5	85.3	90.5	88.8
16	I do a risk assessment when the ship passes through heavy traffic areas.	43.3	62.5	79.8	77
17	I get the benefit of other bridge member's experience to make a safe and effective decision.	56.8	78.3	83.8	85
24	I can correct the information for another bridge team member even if he/she higher ranks than me.	56.8	74.3	73	78.3
26	I found no difficulty in using navigational equipment to ensure safe passage.	59	74.3	75	79.3
27	I rely on electronic navigation equipment for a safe passage.	72.8	54	42	55.8
30	Other bridge members encourage me to report unsafe events.	45.5	72.8	78.5	75
31	I receive feedback about my compliance to the safety of navigation.	41	63.3	70.3	69.8
35	Mistakes are corrected without	54.5	64.8	77	78

	punishment and treated as a learning opportunity.				
37	I can easily maintain my situational awareness during my watch.	52.3	81.3	81.8	82
40	We are sharing the same situational awareness in the bridge.	50	69.5	71	73.8

Table 6.18 above presents the variations between the experience at sea groups based on the ANOVA one-way analysis test. It shows that fresh seafarers were in strong disagreement in most of the statements in the questionnaire. Seafarers' experience can solve many issues when it is related to the safety of the vessel. Therefore, experienced seafarers should come together with the least experience seafarers more frequently to identify the underlying reasons for the different perceptions and fill the gap between them. Even though experienced seafarers believe that they always put safety above their ignorance and never keep the information to themselves, there is a significant statistical difference between experienced seafarers and fresh ones regarding this issue. In addition to this, experienced seafarers gain most of their experience/practice by spending more time onboard the ships by observing the challenging working conditions and problems they face. Also, it is shown that fresh seafarers have limited use of their knowledge as they heavily rely on the equipment more than sharing the information and applying teamwork. All the bridge team members should work as a team to ensure and maintain navigational safety. Less experienced seafarers should be able to communicate without any hesitation if there is an issue with the safety of the vessel. It is well-known that people are afraid to speak or express their opinion on any issue because of the fear of punishment or criticism by the higher-ranked seafarers. Therefore, the shipping industry should eliminate the blame culture and embrace the just culture to create a learning opportunity. This will encourage the seafarers to take more responsibilities to improve the safety culture and the bridge team's resilience for avoiding a maritime accident.

6.4.4.4. Effect of Nationality

The questions that are emphasised in red colour, as shown in Table 6.19, represents that there is a significant statistical difference between the nationality groups and their response in the questionnaire.

Table 6.19 ANOVA on Nationality (significant interactions, p-value < 0.05, are shown in red)

Var	p value	Var	p value	Var	p value	Var	p value	Var	p value
Q1	0.014	Q10	0.101	Q19	0.049	Q28	0.102	Q37	0.011
Q2	0.002	Q11	0.459	Q20	0.000	Q29	0.001	Q38	0.594
Q3	0.003	Q12	0.589	Q21	0.646	Q30	0.202	Q39	0.133
Q4	0.176	Q13	0.021	Q22	0.476	Q31	0.003	Q40	0.471
Q5	0.086	Q14	0.551	Q23	0.002	Q32	0.149	Q41	0.819
Q6	0.168	Q15	0.086	Q24	0.005	Q33	0.428	Q42	0.310
Q7	0.492	Q16	0.000	Q25	0.764	Q34	0.135	Q43	0.671
Q8	0.387	Q17	0.713	Q26	0.005	Q35	0.005		
Q9	0.318	Q18	0.296	Q27	0.035	Q36	0.000		

The post-hoc test is not performed for all statements because at least one group has fewer than two cases. Therefore, the Pakistani, Yemeni, Georgian, Ukrainian, Bulgarian, Montenegro, and Romanian participants were re-categorised under the other group (the red coloured cells given in the table above).

Table 6.20 Summary of the findings of post hoc tests for the interaction of nationality.

Q	Statement	British	Croatian	Filipino	Indian	Egyptian	Polish	Russian	Saudi	Other

1	Language/dialect related issues among bridge members are not a threat to safety.	70.75	50	52.25	34.25	25	43.74	54.25	30.75	38.5
2	There is a good communication environment on the bridge.	91.8	90	85.8	85.3	87.5	93.8	85.5	70.5	75
3	There is no difficulty in using English as a communication language.	79.3	85	77.3	88.3	75.0	81.3	85.5	68	73.3
13	I found that the BRM course improved my skills.	70.8	75	67.5	63.3	83.3	87.5	79.3	43.5	69.8
16	I do risk assessment when the ship passes through heavy traffic areas	79.3	70	68.5	82.8	91.8	87.5	77	52.5	78.5
19	There is a briefing among the bridge team before the watch started.	75	50	82.5	73	87.5	81.3	73	62.8	84
20	I found a good atmosphere of teamwork in the bridge.	70.8	85	82.5	84.3	75	87.5	81.3	65.5	82.3

23	There is a collaboration between bridge team members to ensure safe navigation.	75	80	82.5	80.5	37.5	87.5	70.8	77.5	80.3
24	I can correct the information for another bridge team member even if he/she has higher ranks than me.	79.3	70	69.5	79	41.8	75	79.3	74.3	78.5
26	I found no difficulty in using navigational equipment to ensure safe passage.	75	90	77.3	81	58.3	93.8	81.3	64.8	78.5
27	I rely on electronic navigation equipment for a safe passage.	70.8	65	40.3	53.5	37.5	87.5	45.8	59	50
29	I fully understand my responsibilities for my duty on the bridge.	79.3	95	87	91.3	75	62.5	98	89.8	85.8
31	I receive feedback about my compliance to the safety of navigation.	70.8	75	74	73	70.8	43.8	68.8	51.3	73.3

35	Mistakes are corrected without punishment and treated as a learning opportunity.	75	80	77.3	80.5	75	87.5	75	57	78.5
36	Watch hand-overs are thorough and not hurried.	75	80	83.8	86.3	45.8	81.3	79.3	62.8	76.8
37	I can easily maintain my situational awareness during my watch.	75	90	81.5	86.3	79.3	87.5	87.5	67.3	78.5

Table 6.20 above presents the variations between nationalities based on the ANOVA one-way analysis test. Overall, there is a fluctuation between the disagreement and agreement responses. All nationalities find language-related issues threat to safety, and there is a need for significant improvement to solve this problem. Even though the British seafarers have a much better English language than the others, but they might struggle to communicate with other groups. The language-related communication barriers may lead to safety-critical outcomes, which require an investigation to address this issue among all seafarers. It also shows that the Saudi participants' group has the most disagreement on most of the statements linked possibly to their poor language skills.

Egyptian and Filipino participants think that lower-rank seafarers should not correct their senior’s information, which might lead to a safety concern if the safety of the vessel is affected. The new BRM course takes this point into account by improving the seafarers’ confidence level through the better communication concept between all ranks in the bridge.

Polish, Russian and Saudi seafarers feel that they do not receive enough feedback for their compliance to the safety of navigation, and this may prevent them from improving their safety-related skills and make them look incompetent. One of the new BRM course elements is enhancing the teamwork culture and improving the bridge team's resilience through dedicated simulator training.

Highlighting the issues related to English communication among all nationality, even British participants, this referred to understanding the safety of navigational aspects among bridge team members and using the navigational equipment as primary tools to ensure navigational safety.

6.5. Chapter summary

A questionnaire-based survey about the BRM was conducted and analysed in this chapter. Results of the safe environment of bridge teamwork assessments were generated for each member in the bridge. The study provided significant insight into the attitude and perceptions within the bridge team. These results will be addressed during the development of a new BRM course, which is presented in the next chapter. The new course will be designed to eliminate weaknesses and gaps identified during the questionnaire-based survey study analysis.

7. Bridge Resource Management (BRM) Course: Development of a New Course for the Bridge Team

7.1. Introduction

The IMO has reviewed the education and training standards for all seafarers through the STCW convention to enhance their knowledge and skills. However, after analysing many maritime accidents, it is shown that there is an issue with the performance of the bridge team. Furthermore, the highlighted underlying reasons derived from these accident analyses show that there is a lack of utilisation of the resources on the bridge or lack of implementation of the BRM principles among bridge team members. These findings were also supported by the survey carried out among seafarers, as presented in Chapter 6. Based on the findings in chapter 5 and chapter 6, this chapter will propose the new BRM course and compare it to the existing BRM courses. The comparison of the new and existing course will be performed in terms of practical efficiency by carrying out experiments in the navigational simulator to identify the benefits of the new course on the bridge team act and the improvement in their performance using planned scenarios.

7.2. Bridge Resource Management (BRM) courses

After searching the Bridge Resource Management courses offered by many maritime institutions, it was shown that there are some differences between them. The duration of the course and the contents are the main reasons for these differences. As part of the PhD, it was decided to take the BRM courses in different institutions to identify the differences to answer the questions like; why there are differences in the course contents? Why some institutions give the course in three days, and others give it in five days? Are there any differences in teaching methods or quality? What is the approach the instructor/instructors adopt to cover the critical elements of BRM? In order to find answers to these questions, it was planned to visit four maritime institutions certified as official training centres by the flag state on behalf of IMO. The initial plan was to focus on how the OOW can increase his/her situational awareness and the adopted methods to do so. However, the course duration and contents changed this plan. Due to the organisers' cancellation because of the lack of minimum student numbers, the comparison is made based on the courses run by two maritime institutions that the Author attended and completed successfully. This highlights the issue of running BRM courses frequently.

The courses attended were monitored by using the BRM course form, which can be found in Appendix B. Monitoring the courses aimed to highlight the differences between the courses in terms of contents, teaching method and style, the methods to increase the SA among bridge team members and the bases of the simulator training scenarios (whether it is based on the real maritime accidents or educational scenarios). Table 7-1 below summarises all the differences between these courses run in two different institutions in two different countries.

Table 7.1 Comparison of BRM courses between two maritime institutions

Aspects	IMO minimum requirement	Institution A	Institution B
Course duration		5 Days	3 Days
Number of instructors		5 Instructors (including the simulator instructor)	1 Instructor
position(s) of Lecturer(s) and experience		Assistance professors and ex-captains with over ten years of experience	Lecturer and ex-captain with over 15 years of experience
Teaching method		1. Presentation of the lectures. 2. Videos. 3. Workshops.	1. Presentation of the lectures. 2. Videos. 3. Workshops.

Course contents	1. Introduction for BRM. 2. Communication . 3. Master-Pilot exchange information. 4. Leadership. 5. Risk Assessment. 6. Situational awareness. 7. Challenge and response.	1. Review of basic principles. 2. Familiarisation with the bridge. 3. Standard manoeuvres. 4. Wind and current effects. 5. Attitude. 6. Cultural awareness. 7. Briefing and debriefing. 8. Challenge and response. 9. Shallow-water effects. 10. Bank, channel and interaction effects. 11. Planning. 12. Authority. 13. Management on the bridge. 14. Workload and stress. 15. Anchoring and single-buoy mooring. 16. Human factor errors. 17. Decision-making. 18. Crisis management. 19. Planning and carrying out a voyage in normal and emergency	1. Introduction. 2. Overview of BRM. 3. BRM Regulations and guidance. 4. Situational awareness. 5. Communication. 6. Master- Pilot Exchange and passage Planning procedures. 7. Risk Assessment. 8. Errors detection. 9. Cultural factors. 10. Stress and Decision-making. 11. Fatigue.

		situations.	
Number of students attending the course		16 Students	3 Students
Assessment Exam		No	Yes
Simulation training (available)		Yes	No
Simulation scenario(s)		1. Open sea. 2. Berthing. 3. Fog. 4. Blend condition. 5. Master-pilot exchange.	Simulator training required to have another course with extra cost. (However) 1. Open sea. 2. Master-pilot exchange. 3. Emergency situation.
Number of students attending the simulator per group and their rules		8 Students/Group 1. Captain. 2. Chief officer. 3. Second officer. 4. Third officer. 5. Cadet. 6. Lookout. 7. Pilot. 8. Wheelman.	None

The STCW convention covered the general requirements for the BRM course but did not cover the details, which are made it vague to be standardised, which can be found in Appendix C. Accordingly, every institution has to cover BRM content in its perspective to follow the IMO requirements (Taha, 2018).

- Institution A

In general, Institution A focused on increasing the knowledge of the individuals. It seems that according to them, the OOW should gain the required knowledge so that he/she can deal with the bridge activates and increase the sharing of knowledge among the bridge team members. The course has been structured to be a half-day lecture and half a day training in the simulator. All the instructors cover between 4 and 5 topics in the classroom half-day teaching, aiming to cover the course's entire contents without focusing on the key elements. However, every training scenario in the simulator was designed to evaluate the student's learning outcome from class-based teaching.

On the first day, the course coordinator divided the class into two groups, and each group contained eight students who can be accommodated in the simulator room. He explained the fundamentals and aim of the BRM and how an OOW can benefit from all resources available in the bridge to ensure the safety of navigation. After that, the first group got together in the simulator room for the exercise, which started with familiarising the bridge and its equipment. The course continued with the defined roles for everyone and their duties. The assignment for the roles was changeable so that every student can experience every different role by the end of the course. According to the Author’s view, the number of team roles and the number of students in the simulator room was not compatible as there were too many students. Therefore, the first training exercise was not realistic, but it got slightly better in the last exercise. None of the officers managed to do their duties (communication, passage planning, etc.) without interfering with each other. Also, the bridge team's communication loop was not understandable because of the background conversation by other team members, which interfered with the activities of bridge team members. This forced the captain (of every exercise) to repeat his orders many times to be understood in some parts of the training.

On the second day, normal class-based teaching was delivered by another instructor, who went through five topics (*Cultural awareness, Briefing and debriefing, Challenge and response, Shallow-water effects and Bank channel and interaction effects*), and the day ended by sailing under condition (Shallow-water) scenario. In this scenario, the ship was in critical (collision) condition due to the lack of teamwork, lookout and hesitation of the master, the ship was prevented from collision by the intervention from an experienced officer.

On the third day, a third instructor joined the class and explained the following topics (*Passage Planning, Authority, Management on the bridge, and Workload and stress)* followed by Berthing/unberthing scenarios. On the fourth day, a new instructor explained the following topics (*Anchoring and single-buoy mooring, Human factor errors, Decision-making)* and followed by the master-pilot exchange scenario. On the final day, the instructor explained (*Crisis management, Planning and carrying out a voyage in normal and emergency situations)*. The day ended with an emergency situation scenario in the simulator room. The students must attend the entire five-day course to have a Certificate of Proficiency for Bridge Resource Management under the regulation of The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

Overall, this course was planned to increase the students' knowledge instead of filling the gap in their skills. Also, the changing of instructors every day made it challenging to cover all topics, especially the core of BRM topics such as communication, situational awareness and teamwork, by explaining the headlines only because it was delivered in other courses, therefore, does not increase the skills of participants. Moreover, every instructor used his experience at sea as part of teaching, which led the student to understand and gain the required knowledge and connected to future work-life. On the other hand, the instructor’s experience can distract the student’s intention in a way that is not related to BRM. The course increased my knowledge in the navigational part, which is sailing in a narrow channel, low water surface, etc., instead of focusing on the skill that I required to do as part of the bridge team member, which appears clearly in the simulator training. From my perspective, the course covers more than the IMO requirement; however, it failed to achieve the desired outcome for the OOW's skill and fill the gap in his interaction with other bridge team members.

- Simulator Training Scenario

The simulator training's purpose was to observe that the student gained the requisite knowledge and apply it in the training exercise. The students must use navigational equipment such as RADAR/ARPA, ECDIS, etc., competently to ensure safe navigation. The instructor had made up all scenarios based on his experience, but the number of students planned was unsuccessful. Every bridge member's role was planned according to their duty onboard any commercial ship, which was shown in Table 7-2 below. However, with this number of students on the bridge, none of the bridge members managed to perform tasks according to duties successfully, except the captain, one of the navigation officers, wheelman and the pilot in case of the berthing, unberthing and master-pilot exchange. This was due to the room size and the navigational equipment, which are close to each other, as shown in Figure 7.1. Moreover, the background talk between the bridge team members, which was not related to the navigational practice, made it worse, but it improved slightly by the fourth and fifth days.

Overall, the training scenarios were related to the BRM lectures, but only four out of eight students managed to work as a team in every scenario. Moreover, although the BRM elements were covered during the simulation training, it was not sufficient in the first three days as there was no learning from mistakes briefing after each scenario. However, learning from mistakes sessions were conducted at the beginning of the fourth-day class and found to be very beneficial for the scenarios covered in the fourth and fifth days of the course.

On the other hand, the unrealistically excessive number of bridge team members in the simulator room for a cargo ship adversely affected the bridge teams' SA and decision-making instead of improving it.

Table 7.2 Role of the bridge team member

Role	Duty
Captain	Overall in charge
Ch. Off.	Communication officer/ Navigation officer
2^{nd} Off.	Navigation officer
3^{rd} Off.	Navigation officer
Pilot	Assistance (if required)
Cadet	Assistance (if required)
Lookout	Lookout/Assistance (if required)
Wheelman	Controlling the wheel of the ship

Figure 7.1 The simulator room

- Institution B

In general, Institution B focused on increasing the skills of individuals rather than their knowledge. It seems that according to the instructor, the OOW should work as part of the team rather than gaining the knowledge, which he/she should have already known from his/her previous studies. The course has been structured to be a full-day lecture, and there is no training in the simulator, which was offered as a BRM in the simulator training as an additional course with extra cost.

In the beginning, the instructor introduced the BRM as a tool that can help the OOW to communicate and work as a team with other bridge team members to ensure safe navigation. Then, he covered (*BRM Regulations and guidance, Situational awareness, Communication)* topics. On the second day, the instructor gave a quick revision for the first class before he continued. On the second day, the instructor covered *Master- Pilot Exchange and passage Planning procedures* as a full-day lecture and organised a workshop between the three students to perform passage planning for a sailing trip from point A to point B. The workshop included highlighting the risky areas, all useful information that could help the bridge team along with the trip and projection of all situations that the ship and the bridge team may face. On the third day, he covered the following topics (*Risk Assessment, Errors detection, Cultural factor, Stress and Decision-making, and Fatigue*) before conducting the exam. According to institution B's policy, the student must be marked over 70% in the exam to be certified by the Certificate of Proficiency for Bridge Resource Management under the regulation of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

Overall, this course was planned to increase the students' skills instead of filling the gap in their knowledge. This appeared clearly in the workshop activities because only one of the students, which is the researcher of this thesis, got the knowledge and the experience to explain some of the missed or unknown information to the other workshop participants. This helped in sharing information between the team, but it increased the load on the speaker to explain every piece of information.

7.3. Comparison between BRM courses

Overall, all institutions run the course to the best practice according to their understanding of the IMO requirement to achieve the aim and vision behind the BRM course. Institution A focused on increasing the amount of knowledge that was taught to the students so that they can use it to improve their decision-making to avoid accidents. However, some fundamental topics such as communication and SA were not covered as they should be, and this gap became very obvious in simulator training. On the other hand, institution B concentrated on improving the students' skills to improve communication, teamwork, SA, etc., within the bridge team. However, the amount of knowledge transferred to students was not enough, which was very apparent in the workshop activities.

The number of instructors in institution A made the teaching load on the lecturers less every day, but the randomness and distractions were clear while teaching the course. Moreover, every instructor used his past experience to address the benefit of BRM inside the bridge, but sometimes it became irrelevant to BRM, which created confusion and loss of class time. While in institution B, there was only an instructor with a full teaching load, who delivered the course for three days, which was found to be well-organised, easy and fluent to be understandable over the three days, and he took his time to explain each topic well. According to the Author, one instructor with a well-organised course is much better than a bunch of instructors with a divided teaching load and unstructured course delivery.

Originally the plan was to attend four BRM courses offered by different training institutions to identify the differences among BRM courses in terms of contents and delivery. However, over two years, several institutions regularly cancelled their BRM courses due to the lack of registered seafarers for the course. Furthermore, several institutions run the BRM course only for a group from the same company.

Following the two BRM courses attended by the Author and the insight gained during many attempts to register for other BRM courses, a more standardised and structured approach to BRM courses is strongly recommended. The BRM course is a standardised training course implemented by the IMO through the STCW convention, and this should be observed and practised. This may require specific certification of the BMR instructors, who should go through a dedicated training of trainers' course. Considering that seafarers change shipping companies regularly or change ships within the same shipping company and that a cadet/rating ranks such as AB and OS may want to take this course on his own in order to apply for a certificate of competency (COC), it is time to propose a new BRM course. This course would be designed for all seafarers, not just for officers, and would provide standardised training, including all the key soft skills required by BRM. Extending the BRM course to ratings and cadets will increase the team situational awareness and potentially prevent many accidents.

7.4. Proposal for a New Bridge Resource Management Course for All Seafarers (BRMs)

After identifying the gaps in BRM courses which are related to contents, teaching methods, availability, workshop activities and the simulation training, it was determined that an essential development activity with the BRM course should be undertaken to fill those gaps and achieve the IMO requirements at the same time. The Bridge Resource Management course for Seafarers (BRMs) is developed to improve the bridge members' knowledge and skills by implementing a simple method with regards to the interactions within the bridge team. This will enhance navigational safety, which is the ultimate aim of the BRM. The new course combines the knowledge and skills to be easily understood by every crew involved in bridge activities.

7.4.1. BRMs Preparation

After taking part in the BRM courses run by the two maritime institutions and checking other BRM courses offered by various maritime institutions, the new BRM course was designed to focus on the bridge team behaviour, bridge team act and increasing the bridge team's knowledge too. The course was designed by following the IMO criteria set for the bridge resource management course (International Maritime Organisation, 2013). Also, the course was developed after studying the BRM course notes from four different maritime institutions, two books related to BRM (A. J. Swift, 2004; Parrott, 2011), and maritime educational videos that are related to BRM. The BRMs course has been reviewed by two assistant professors, who are working in different maritime institutions, an expert lecturer retired from the maritime educational sector, and two captains, who have been working in the maritime industry to highlight any gaps and to provide feedback. Table 7-3 below shows the description of the newly proposed BRM course. According to maritime experts, the course duration must be minimised for the following reasons:

- It can be easily understandable by the participants.
- The shipping companies prefer short-time course for their crew so more crew can attend more courses in a short period.
- The overall cost to the seafarers if he/she wants to join the course using his own finances. This is a valid point as many small companies do not pay the training costs for their crew.

By taking these points into consideration, the new course was designed to be delivered in three days without losing its efficiency and effectiveness because of the time. The participants must attend three full-day lectures between 08:00 and 16:00 hours in the class with an hour and a half break-time in between. Every day between 16.00 and 17.00, simulation training is included to practice the course contents shown in Table 7.4 below.

In the full-mission simulator, the scenarios were prepared to simulate the real safety-critical situations that the bridge team might face in real life. Scenarios designed for the simulator would be covered in three days; every training session might have more than one scenario and includes Open-sea (Collision avoidance), Master-Pilot exchange (Berthing), Restricted visibility and Emergency situations. In all scenarios, the bridge team shall sail under the

Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) (IMO, 1972). Therefore, the focus will be on the actions of the bridge team based on the following rules:

Rule 5 requires that “every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision”.

Rule 6 deals with safe speed. It requires that: "Every vessel shall at all times proceed at a safe speed...”.

Rule 7 covering the risk of collision, which "assumptions shall not be made on the basis of scanty information, especially scanty radar information."

Rule 8 covers action to be taken to avoid a collision.

Rule 12 states action to be taken when two sailing vessels are approaching one another.

Rule 13 covers overtaking - the overtaking vessel should keep out of the way of the vessel being overtaken.

Rule 14 deals with head-on situations.

Rule 15 deals with Crossing situations.

Rule 16 action(s) to be taken by the give-way vessel.

Rule 17 deals with the action of the stand-on vessel, including the provision that the stand-on vessel may "take action to avoid collision by her manoeuvre alone as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action”.

Rule 19 states every vessel should proceed at a safe speed adapted to prevailing circumstances and restricted visibility.

Table 7.3 Course description

Aspects	
Course duration	3 Days.
Teaching method	1. Presentation of the lectures. 2. Videos. 3. Workshops.
Course contents	1. Bridge Formalisation. 2. BRMs Elements. 3. Situational and self-awareness. 4. Communication. 5. Lookout. 6. Leadership. 7. Passage Planning. 8. Bridge Watchkeeping. 9. Master-Pilot Exchange. 10. Accidents and Accident causation (Human factor). 11. Risk assessment. 12. Stress and Fatigue.
Number of students attending the course	5 Students
Assessment Exam during the simulator training	Yes
Simulation training (available)	Yes
Simulation scenario(s)	1. Open sea (Collision avoidance). 2. Master-Pilot exchange (Berthing). 3. Restricted visibility. 4. Emergency situations.
Number of students attending the simulator per group and their rules	1. Captain. 2. Officer of the watch (OOW). 3. Cadet/Pilot. 4. Lookout.

	5. Wheelman.

Table 7.4 BRMs timetable

Time	First day	Second day	Third day
08:00-10:30	Bridge Formalisation. BRMs Elements.	Passage Planning.	Accidents and Accident causation (Human factor).
10:30-10:45	Break time		
10:50- 12:00	Situational and self-awareness.	Passage Planning. Bridge Watchkeeping.	Accidents and Accident causation (Human factor).
12:00-13:00	Lunch break		
13:00-14:45	Communication.	Bridge Watchkeeping. Master-Pilot Exchange.	Risk assessment. Stress and Fatigue.
14:45-15:00	Break time		
15:00-16:00	Lookout. Leadership.	Master-Pilot Exchange.	Stress and Fatigue.
16:00-17:00	Simulator training		

7.5. Summary

The intention is to improve navigational safety by utilising the BRM effectively. This chapter demonstrated an overview, effectiveness, deficiency and gaps of existing BRM courses, which lead to analyses of two attended BRM courses in two different maritime institutions. Also, the process of proposing and developing a new BRM course that is suitable for all bridge team member. The efficiency and effectiveness of the new course will be tested by performing experiments in full-mission bridge simulation as presented in Chapter 8.

Besides, there is another course that most maritime institutions give, which is called Human Element, Leadership and Management course (HELM) that is similar to BRM’s contents, goals and outcomes. The initial plan to attend this course and the BRM courses highlights the differences between BRM and HELM. However, the maritime institutions' cancellation of the helm course made it difficult to achieve, but it will be available for further study soon.

8. Comparative Assessment of New BRMs Courses with the Normal Method by Performing Experiments in the Simulator

8.1. Introduction

In this chapter, the developed Bridge Resource Management course will be tested in a full-mission ship navigational bridge simulator. For testing the procedures, the prepared scenarios will be utilised in the simulator environment. These scenarios are developed using the real accidents obtained from the accident review study using the accident investigation reports from the Maritime Accidents Investigation Branch (MAIB), Australian Transport Safety Bureau (ATSB) and Transportation Safety Board of Canada (TSBC). The main goal of this experiment is to confirm the efficiency and effectiveness of the new course on the bridge team behaviour and act during the navigational operation.

The efficiency and effectiveness of the course will be determined by the enhancement in the navigational safety that would have been achieved if the bridge team act safely and work as a team to avoid a dangerous situation and prevent accidents. Therefore, the experiment will be recorded to be analysed by explaining the effect of the new course on the bridge team and, accordingly, how their performance is being enhanced after finishing all experiment activities.

In the end, results will be discussed to provide the potential benefits for implementing the developed BRM course involving all bridge team members.

8.2. Participants

Ten seafarers volunteered to join the experiment in the full-mission simulator. All the volunteers finished four years of nautical science degree in a maritime faculty, so they will earn a BSc degree in nautical science and second mate licence after finishing a year in cadetship training onboard ships. The sea-time experience for these students ranged from six months to twelve months, and working on the bridge training ranged from two to six months. The volunteers are divided into two groups A and B, and each one has 1 Capt, 1 OOW, 1 Cadet/Pilot, 1 Lookout and 1 helmsman, as shown in Figure 8.1 and Figure 8.2. Both groups took the fundamentals of BRM as part of their course plan over the four years through the maritime faculty. However, the new BRM course will be introduced to group A while group B will perform the simulator experiments based on the knowledge they gained before through their studies in the maritime college over the four years. The scenarios to be tested will not be known by both groups, and they will be instructed only before the training session.

Figure 8.1 The bridge team of group A

Figure 8.2 The bridge team of group B

8.3. The Navigation Bridge Simulator

The simulator experiments are designed to test the new BRM that took place in the *Faculty of Maritime Studies* campus. TRANSAS 270° full mission navigation bridge simulator was used to perform the scenarios, as shown in Figure 8.3. It has the capacity of training and skill assessment such as familiarisation, watchkeeping, emergency preparation and bridge resources management. It has a variety of navigation equipment that exist on commercial vessels, for instance, Radar, ECDIS, VHF, GMDSS, Echo-sounder, GPS, off-course alarm, etc. The simulator provides different operational conditions, including several weather conditions. It also has the ability to imitate the navigation of bridge of different type and sizes of ships, such as container, tankers, tug, supply boat etc.

Moreover, the simulator has the models of several sea locations and ports so it could perform different scenarios easily, such as normal sailing, berthing ships, etc. The external environment contains a diversity of traffic and weather conditions which can be applied to various maritime locations to offer real manoeuvring situation. For the experiment, only one type of vessel was used, which is a 5000 TEU container vessel.

Figure 8.3 TRANSAS 270° full mission navigation bridge simulator

8.4. BRMs Lectures

In the beginning, group A and group B have attended the simulator training room together to become familiar with the bridge equipment; each group had their turn alone (further discussion will be in the next section). While group A joined the class-based teaching after the first exercise, Group B was instructed to attend just for simulator training. In the first class, the students get to know about the new vision behind the new course, aims and objectives and how this course can enhance the bridge team's communication, SA and teamwork. Also, it has been highlighted the differences between the BRM and BRMs before starting the lecture. The topics which been covered are *BRMs Elements, Situational and self-awareness, Communication, Lookout and Leadership*. Each topic aimed to increase the participant's knowledge and improve the skills by showing what a proper collaboration among the bridge team should look like. The proper communication between the bridge team, ship to ship and ship to shore loop were introduced.

The course introduced the three levels of situational awareness and how every bridge member can gain his/her situational awareness and share it among the team. Furthermore, the lookout's critical role when he/she performs the duties on the bridge, which is not covered in the standard BRM course, was explained. Moreover, with every topic, a side topic is introduced to the participants, which is a maritime accident caused by the main topic and teach the participants how the bridge team should act and what they should do to avoid this accident.

On the second day, the topics covered in the lectures are *Passage Planning, Bridge Watchkeeping and Master-Pilot Exchange*. The participants joined a workshop as a bridge team to plan a passage to enter, pick-up pilot and berth the ship in one of the ports that are available in the simulator. After that, every team member should explain what the bridge team would do and make a plan ready to practice the plan in the simulator room. On the third day, the topics, which are covered, can be listed as *Accidents and Accident causation (Human factor), Risk assessment and Stress and Fatigue*. In this lecture, the participants get to know about the relation between human factors and maritime accidents, the emergency situations that the bridge team may face during the navigational watch and the effect of the stress and fatigue on the bridge team as an individual as well as the whole team.

8.5. Simulator Training Scenarios

Each group has spent 20 minutes in the simulator bridge room to get familiar with the equipment, and they are allowed to ask questions if they are in doubt or they did not know how to operate any equipment. Both groups receive an explanation about the navigation conditions in scenarios such as normal sailing in the open water area, pick up a pilot and berth the ship in the port or sailing under conditions and the characteristics and the condition of their ship too. Also, they are allocated to their roles among the bridge team, and they must act naturally during the scenario. They have to avoid grounding or collision with other ships by following COLREG rules. Every scenario lasts 30-40 minutes, and all the simulator experiments are recorded for analysis purposes.

The bridge team's performance was judged based on the time and their acts; how long the bridge team took to identify the risk of collision, and what actions they took to avoid this danger, individual/team SA decision-making, proper lookout, leadership and communication. The team is judged for their actions taken at any time before the TCPA becomes 4 min which is marked with dark green colour. If the bridge team enters the 4 min zone, then they are required to take further measures such as decreasing the ship's speed which is marked with yellow colour. Moreover, if they enter 2.5 min TCPA, then the risk of collision is very high and therefore, they are required to take emergency actions such as reversing the engine and contact the other ship to take necessary action to avoid the collision, which marked by red colour as shown in Table 8.1. The measurement of every bridge team performance is shown in Table 8.2 and Table 8.3 below. The scenarios for each day and the results for each simulator exercise are provided below.

Table 8.1 Scenario Timing

Measures	Data	Remark
Scenario starting time	00:00:00	
Time of 1st target appearance	00:07:00	
Time of detection and taking action	4-7 mins before the collision	Excellent
	3-4 mins before the collision	Moderate requires action
	0-2 mins before the collision	Poor risk of collision exists
Time of 2nd target appearance	00:20:00	
Time of detection and taking action	4-7 mins before the collision	Excellent
	3-4 mins before the collision	Moderate requires action
	0-2 mins before the collision	Poor risk of collision exists

Table 8.2 Measurement of action is taken and performance.

Action and Performance	Remark
Excellent	No need for improvement
Good	Slight improvements require
Moderate	Medium improvements require
Poor	Significant improvements require

Table 8.3 KPI for excellent performance for each rank

Ranks	KPI
Captain	Control the ship, leadership, decision-making, communication, interaction with other bridge members, teamwork, build own SA and sharing it, lookout.
OOW	Navigate the ship from hazard, leadership, decision-making, communication, interaction with other bridge members, teamwork, build own SA and sharing it, lookout.
Pilot	Exchange information with the captain and other bridge members, decision-making, communication, interaction with other bridge members, teamwork, lookout.
Cadet	Assist the OOW in the navigation duty, involve in decision-making (if require), communication, interaction with other bridge members, teamwork, build own SA and sharing it.
Lookout	Lookout, involve in decision-making (if require), communication, interaction

	with other bridge members, teamwork, build own SA and sharing it.
Wheelman	Steer the vessel by taking order from (master/OOW or Pilot), communication, interaction with other bridge members, teamwork.

- First-day scenario

The scenario was set up based on many accidents that occurred and investigated by the MAIB. Both groups must navigate in open-sea water without any condition while their ship is in the middle of traffic with several ships navigating around them. Furthermore, two other ships will cross over in front of their ship from the starboard side, and the risk of collision between the targets and their own ship is at approximately 7 and 20 minutes, respectively, with a CPA of 0.2 nm. The roles in this scenario were distributed as Captain, OOW, Cadet, Lookout and Wheelman. This scenario lasts 30 minutes.

Results

<u>Group A's performance:</u> the group showed a good practice of bridge team act between the Capt., OOW and the lookout with regards to the first manoeuvring of the ship by acquiring the target and taking action to avoid the collision. However, they detected the main target 3.5 minutes before the collision, which is considered as a late response that could lead to a disaster within the next minute. Also, the bridge team has dropped its performance during the rest of the scenario, especially during the second manoeuvre; The Capt. ignored the advice from the OOW, such as reducing the ship's speed while taking the wrong action by turning the ship to the port and communicating with other targets which increased the risk of collision with other ships. Overall, the group was focusing on the side targets, which posed a low risk of collision, instead of the primary target. Also, the bridge team were losing their

SA during the scenario after 12 minutes by unnecessarily talking to each other on irrelevant topics to the scenario, as shown in Table 8.4, Table 8.5 and Table 8.6 below.

Table 8.4 Team A measurement in the first-day scenario

Measures	Data	Remark
Scenario starting time	00:00:00	
Time of 1st target appearance	00:07:00	
Time of detection	00:03:24	Sighted and reported by the lookout and confirmed by OOW
Time of taking action	00:03:44	Turn to starboard and reducing ship speed
Time of 2nd target appearance	00:20:00	
Time of detection	00:17:48	
Time of taking action	00:18:02	Turn to port and reducing ship speed

Table 8.5 Bridge A Performance in the first-day scenario.

Rank	Overall Performance	Remarks
Captain	Moderate	Ignoring advice from other team members, poor decision-making
OOW	Good	Irrelevant talk with another team member
Cadet	Moderate	Irrelevant talk with another team member and didn't perform his duty well

Lookout	Moderate	Irrelevant talk with another team member and didn’t perform his duty well
Wheelman	Good	Irrelevant talk with another team member
Overall bridge team performance	Moderate	Irrelevant talk between team member, moderate focus on the navigational watch

<u>Group B’s performance:</u> this group showed unprofessional bridge act among the team such as background talk, not following their tasks/duties, etc., which lead to loss of the ship control by the Capt. due to his hesitation. The wheelman took a correct action by turning the ship to starboard, but he did not inform his bridge team or receiving the order for this action. The arguments between the bridge team led to the captain rejecting all the suggestions from his team. Furthermore, the OOW, Lookout and the cadet were talking to each other instead of focusing on safe navigation. Overall, this group has sailed the ship while avoiding collision, but they did not perform it as a bridge team. The wheelman was the most experienced on the bridge time, so he took most of the actions without taking an order from or consulting his team members The ego of the captain after some arguments with the team member caused him not to listen to their suggestion even though the suggestion was the correct action to do so as shown in Table 8.6 and Table 8.7 below.

Table 8.6 Team B measurement in the first-day scenario

Measures	**Data**	**Remark**
Scenario starting time	00:00:00	

Time of 1st target appearance	00:07:00	
Time of detection	00:04:48	Sighted by Capt.
Time of taking action	00:05:22	Turn to starboard by wheelman
Time of 2nd target appearance	00:20:00	
Time of detection	00:16:33	Sighted and reported by OOW
Time of taking action	00:16:48	Turn to starboard and reducing ship speed

Table 8.7 Bridge B Performance in the first-day scenario

Rank	**Overall Performance**	**Remark**
Captain	Poor	Losing control of the ship, ignore all advice, poor teamwork, poor decision-making
OOW	Moderate	Irrelevant talk with another team member, not helping the Capt. In the decision-making after the argument.
Cadet	Poor	Irrelevant talk with other team members, didn't perform his duty well
Lookout	Poor	Irrelevant talk with other team members, didn't perform his duty well

Wheelman	Good	Handling the vessel very well but didn't receive or inform the order to do so.
Overall bridge team performance	Poor	Poor teamwork, poor communication and poor decision making

- Second-day scenario

The scenario was set up for the master-pilot exchange operation. Both groups must navigate to pick up the pilot from the pilot boat at the pilot station then proceed to the berth inside the harbour. The ship is 10 nm away from the pilot station, and two ships are out-bounding from the harbour. Each group took 15 minutes to prepare the bridge equipment and planned their route to ensure a safe passage. The roles in this scenario were allocated as Capt, OOW, Cadet/Pilot, Lookout and Wheelman. This scenario lasted 40 minutes.

Results

<u>Group A's performance:</u> the group implemented the passage plan that they prepared in the classroom and applied it in the simulator. The captain defined the roles of the team members on the bridge, and he shared his SA among them. Therefore, every member of the bridge knew what would happen during the manoeuvre. A positive impact of the first teaching class appears on the bridge team's performance due to the enhanced communication and teamwork among them. However, the team dropped its performance after the pilot took over the con from the captain. The background talking was a significant reason for the loss of the SA, for the OOW and the lookout. Overall, the group enhanced their individual/team skills after the two lectures. The captain took several incompetent decisions after giving the pilot the con, which led to a loss of the bridge team act, as shown in Table 8.8.

Table 8.8 Bridge A Performance in the second-day scenario.

Rank	**Remarks**	**Overall Performance**
Captain	Capt handover the con to pilot	Moderate to Good
OOW	The background talking affect his SA	Good
Pilot	Taking the con from captain	Moderate
Lookout	The background talking affect his SA	Good
Wheelman	Excellent performance	Excellent
Overall bridge team performance	Good bridge teamwork and communication	Good

Group B performance: This group's performance suffered from the start as the captain was nervous, hesitant, and not confident to take any decision by himself, such as increase/decrease the ship's speed without any suggestions from other bridge team members. After taking the pilot from the pilot boat, the captain transferred the con to the pilot without exchanging berthing procedures. The exercise has been stopped after 15 minutes due to a collision with the inner entrance buoy of the channel. Overall, this group did not take advantage of the preparation time to discuss the manoeuvring procedures. The captain's lack of confidence made him do other bridge activities such as external communication by himself instead of asking the other team members to do so. The safe navigation of the ship was transferred from the captain to the pilot by giving him the con of the ship. There was no communication between the bridge team members, who were instead talking to each other in the background. This group has failed to work as a team which led to an accident, as shown in Table 8.9.

Table 8.9 Bridge B Performance in the second-day scenario

Rank	**Remarks**	**Overall Performance**
Captain	Poor leadership and unconfident Hand-over the con to pilot	Poor
OOW	The background talking affects his SA and not doing his duty.	Poor
Pilot	Taking the con from Capt. Not exchanging information with a bridge team member	Poor
Lookout	The background talking affect his SA and not doing his duty	Poor
Wheelman	Perform his duty well	Good
Overall bridge team performance	No bridge teamwork and no communication. The ship ran aground	Poor

- Third-day scenario

The scenario was set up similar to the first day's scenario condition in order to identify how the course affected the performance of the participants. The scenario contains two emergency situations such as failure of the steering system, gyrocompass etc. Both groups must navigate to pick up the pilot from the pilot boat at the pilot station. The ship is 25 nm away from the pilot station, with several ships navigating beside them. Furthermore, two other ships will cross over in front of their ship from the starboard side, and the risk of collision between the targets and their own ship is at approximately 7 and 20 minutes. Their ship will be facing fog with visibility less than 2 nm and an unknown emergency situation. Each group took 15 minutes to prepare the bridge equipment and planned their route to ensure a safe passage. The roles in this scenario were allocated as Captain, OOW, Cadet, Lookout and Wheelman. This scenario lasted 30 minutes.

Result

Group A performance: The captain described the role for each member in his team, their duties and sharing their SA between them. Therefore, every member of the bridge team knows what will happen during the watch. The lookout suspected that there is a risk of collision with the first target and reported back to the bridge team, and the OOW confirmed and reported that it would be after 6.5 min. The captain confirmed the situation, and then he informed the bridge team about the manoeuvring procedure and what he would expect to be reported back to him from his bridge team. After passing the first target, a fog situation was introduced in the scenario; the captain informed the bridge team about the fog procedure, such as reducing the ship's speed, post extra lookouts, signalling the fog signal, etc. After a while, the lookout reported a risk of collision with the second target, and the wheelman reported no steering, and he might face a steering failure. The OOW confirmed that there is a steering failure alarm appearing on the monitor and forgot to confirm the status of the second target. The captain confirmed the situation, and then he informed the bridge team about the steering failure procedure, such as stop the ship, call the engine room, etc. However, he did not call the other target to confirm his ship's condition that she is not under command. The lookout reported back to the captain about the second ship's status, and the wheelman confirmed that he had the steering back, and the OOW informed the captain that the TCPA was 4 min. The captain decided to take proper action by turning the ship to starboard and increased the ship's speed to avoid the collision. In this time, group B was asked to join the bridge as observers to observe the reaction and act of proper bridge teamwork. Overall, the course has enhanced the group's individual/team skills over the three days. The bridge team took professional individual/team decisions; the lookout reported every risk to his team, a stable team SA during the scenario and proper two-way communication between the bridge team as shown in Table 8.10 and Table 8.11 below.

Table 8.10 Team A measurement in the third-day scenario

Measures	**Data**	**Remark**
Scenario starting time	00:00:00	
Time of 1st target appearance	00:07:00	
Time of detection	00:01:37	Sighted and reported by the lookout and confirmed by OOW
Time of taking action	00:02:41	Turn to starboard
Emergency situation #1	00:10:00	Low visibility actions by the Capt.
Emergency situation #2	00:13:15	Steering failure actions by the captain but forget to announce the other targets
Time of 2nd target appearance	00:20:00	
Time of detection	00:13:02	Sighted and reported by the lookout and confirmed by OOW
Time of taking action	00:16:09	Turning to starboard and increase ship speed

Table 8.11 Bridge A Performance in the third-day scenario.

Rank	Overall Performance
Captain	Excellent
OOW	Excellent
Cadet	Excellent
Lookout	Excellent
Wheelman	Excellent
Overall bridge team performance	Excellent. The bridge team showed the best bridge act all over the scenario

<u>Group B performance:</u> The performance of this group has been enhanced after observing group A in the last exercise. The captain organised his team member and defined their role, but he wasted the allocated time to fix the team instead of building team SA. From the beginning, the team was focusing on the side targets, and they showed proper teamwork between them. However, the lookout/OOW missed reporting about the primary target with less than 3.5 TCPA, which created problematic manoeuvring for the ship. The captain regained the team strength, SA and encouraged his team members to communicate and focus more on the traffic condition. After that, the team was doing an impressive bridge team activity during the remaining time and against their conditions. Overall, group B enhanced their teamwork skill since the first scenario and after observing group A's performance. However, they did not reach the same safe navigation level compared to group A. The individual/team SA had fluctuated during the experiment, the two-way communication between the bridge team was weak, there was unsystematic decision-making, and the

lookout did not perform his duties as he supposed to do, as shown in Table 8.12 and Table 8.13 below.

Table 8.12 Team B measurement in the third-day scenario

Measures	**Data**	**Remark**
Scenario starting time	00:00:00	
Time of 1st target appearance	00:07:00	
Time of detection	00:03:42	Sighted by Capt.
Time of taking action	00:04:02	Turn to starboard without reducing ship speed
Emergency situation #1	00:10:00	Low visibility actions by the Capt.
Emergency situation #2	00:13:15	Steering failure actions by the captain. However, he missed some steps, and the bridge team did not notice
Time of 2nd target appearance	00:20:00	
Time of detection	00:15:09	Sighted and reported by the lookout and confirmed by OOW
Time of taking action	00:15:41	Turning to starboard

Table 8.13 Bridge B Performance in the third-day scenario

Rank	**Overall Performance**
Captain	Good
OOW	Good
Cadet	Moderate to good
Lookout	Poor
Wheelman	Excellent
Overall bridge team performance	The bridge team showed some improvement after observing bridge A practice.

8.6. Summary

The BRMs course and the simulator experiments helped assess the effectiveness of the bridge resources management integrated into the bridge operation activities as it demonstrated positive performance and skill improvement. Reactions of both groups were compared to see the effect of the new course, which included the rating and cadets, compared to routine procedures.

The goal of this study was to validate the implementation of BRM on the whole bridge team member. The purpose is to improve navigational safety by utilising teamwork, communication, SA and decision-making skills. The full mission navigation simulator helps to accomplish the prepared scenarios to evaluate the quality of the bridge team's performance. The experiments included two groups (A & B), with each group containing one captain, one officer of the Watch (OOW), one Cadet/Pilot, one lookout and one helmsman. Group A performed the experiments by applying the new methods and technics, which were explained and taught in the new course. Group B performed the watch by applying routine procedures, which were taught in their maritime education. The course focused on enhancing the safety culture on the bridge, which is essential for every condition in a way that improves the performance and does not affect the safety of navigation. In order to maintain the course's objectiveness, the details of the scenarios were not made available to both teams until they were in the simulator. The experiments included four different scenarios: open-water navigation, Master-Pilot exchange (Berthing/Unberthing), Restricted visibility and Emergency situations. The two groups were compared based on the following indicators: Situational Awareness, Lookout Quality, Communication, Leadership, Teamwork and Decision-Making and Taking action time.

The evaluation of the experiments showed a promising result for the new course. The first scenario comprised open-water navigation condition, and the analysis of the general performance of both groups demonstrated that there is no significant difference between Group A and Group B because their experience and competence are similar. The second scenario comprised master-pilot exchange, and the analysis of the general performance of both groups demonstrated that the performance of Group A was significantly better compared to Group B. The third scenario comprised the restricted visibility and emergency situation condition. The analysis of the general performance of both groups demonstrated that Group A's performance was better compared to Group B, which also performed well after observing Group A's performance.

Group B did not take the normal BRM course due to the faculty's policy, which will affect their overall performance, and therefore the result might change accordingly.

Overall, the bridge team performance for the participants for group A and B, all of them are cadets, was noticeable in their practice on the first-day training, which was the effect of the BRMs course did not appear clearly. However, on the second and third day, teamwork, sharing situational awareness, the group's decision-making, and sharing decisions for group A have enhanced their performance level significantly, which could be comparable to OOW's level.

9. Discussion

9.1. Chapter Overview

This chapter presents the outcomes generated within this thesis, along with a demonstration of how the research aim and objectives have been achieved. Also, the limitations of the study are given with the general discussion on the difficulties encountered. Finally, recommendations for future research are made.

9.2. Achievement of Research Aim and Objectives

The main aim of this research is to enhance navigational safety through an increase in situational awareness and teamwork in the bridge, which been achieved by executing the given objectives in Chapter 2 and details are outlined below:

- To review the literature on situational awareness and sharing among the bridge team members.

A general critical review on situational awareness and distributing it among a team was performed to cover many sectors such as psychology, aviation and maritime industries, as presented in Chapter 3. Also, it covered the effect of human and organizational factors on maritime accidents, which is found that more than 80% of maritime accidents occurred due to many human and organizational factors categories. Accordingly, the critical review identified the need for a novel bridge resource management course, elements, and assessment to improve the bridge team members' performance. The review showed that the bridge team faces many potential hazards during the navigational watch and responsibilities that are hard to achieve by a single watchkeeper due to the human mental load capabilities, leading to losing the individual/team SA. Moreover, as far as the maritime experiments research on the full-mission ship bridge simulator is concerned, researchers had some limitations, including conducting experiments using a desktop-based simulator rather than a full-mission simulator; seafarer participant in experiments had only theoretical knowledge but no experience with simulator environments. These limitations affect the quality of the experiments, and it influences the performance of the participants' duty in the bridge. This was covered in chapter 3.

- Creating a maritime accidents database to identify the key factors that led to losing the bridge teams' situational awareness by analysing previous accident reports.

Many research studies analysed maritime accidents to find that the leading cause is human and organizational factors. Therefore, more than 200 accident reports, which were reported between 2007-2017, were collected from the Marine Accident Investigation Branch (MAIB), Australian Transport Safety Bureau (ATSB) and Transportation Safety Board of Canada (TSBC). This enabled the author to carry out an investigation and review the lack of situation awareness by the bridge team members, including the key deficiencies in these accidents in Chapter 5.

- To develop a questionnaire for crew members to capture the gaps with their attitudes and teamwork towards the safe practice of bridgework activates and develop a benchmark by distributing this questionnaire amongst different shipping companies.

These objectives were achieved under the navigational safety for crew members section that was presented in Chapter 4. A questionnaire to capture the issues with the situational awareness of crew members was developed based on the analysed maritime accidents and distributed online to the seafarers. This questionnaire allowed the authors to gauge seafarers' attitude towards working as a team in the bridge and optimise the necessary level of SA to ensure navigational safety. The collected feedback from 158 participants was analysed, and appropriate action plans were proposed as provided in Chapter 6.

- Develop a new course for all bridge team members to enhance the good practice of Bridge Resource/Team Management (BRM/BTM) by applying communication and sharing situational awareness and knowledge of the surrounding situation among the bridge team members.

The differences exist in the contents of different bridge resource management courses offered by many maritime institutions around the world. Therefore, attending BRM courses revealed that BRM courses offered are fragmented and non-standardised in the maritime sector as the maritime sector fails to provide the same structured and quality of contents to educate the seafarers. Bridge Resource Management for Seafarers (BRMs) has been developed and implemented to confirm whether survey results are in line with the gaps found with BRM courses as given in Chapter 7.

- Validate and test the new course in a full-mission simulator environment by performing a comparative assessment of the regular bridge working practice and the new course approach proposed by the author.

The new BRMs course and assessment enhanced the bridge team performance positively during the bridge operation activities and led to an improvement of navigational safety, as proven by the analyses of two groups of seafarers. The new BRMs course enhanced the bridge team's ability to cope with teamwork, communication, SA and decision-making challenges, as given in Chapter 7.

9.3. Novelty

The main novelty achieved within this PhD thesis is given below:

Even though the STCW encourages the implementation of effective education and training for all seafarers, it does not provide structured guidance for the maritime institutions to do so. However, Numerous maritime institutions applied different methods and techniques to address their courses in a different aspect to achieve the main aim. Also, a considerable number of accidents was caused by the lack of the bridge team's SA. Therefore, the navigational safety for crew member assessment was established to enhance navigational safety through increasing the situational awareness and teamwork in the bridge by designing a BRM course for all seafarers who have a duty in the bridge not just for masters and OOWs To the best of the author's knowledge, such a comprehensive assessment of collecting accident report and analyzing it, developing a questionnaire to highlight the gap of bridge team performance and attending BRM courses in different institutions has not been performed within the maritime sector yet. The developed BRMs course approach by the author is based on a review of maritime accidents, a questionnaire survey among the seafarers and attending various BRM courses. This enabled the author to identify the weakness of current BRM courses, and the knowledge gaps among the seafarers with regard to the BRM, and bridge team interaction issues between the team members, especially for those who did not take the BRM course while they perform their duty on the bridge. The objective of the assessment method, such as (BRMs course and validation through a bridge simulator), is to provide continuous navigational safety improvement with the help of structured improvement methodologies, including the selection of KPIs deployed for bridge team performance measurement and monitoring in the navigational training exercises. The BRMs course outcomes indicate that all bridge team members should participate in such a course to enhance their teamwork efficiency and increase the team situational awareness to help each other if someone lost it. Therefore, the developed methodological assessment within this PhD thesis provides a significant contribution to maritime education required to enhance navigation safety to reduce maritime accidents.

9.4. Limitations

The limitations of this study are given below:

- Enhancing navigational safety levels among the entire bridge team members requires an excessive amount of time and effort, so the efficacy of the improvement methodologies may not be achievable within the project duration. The number of participants in the questionnaire was 158, which was acceptable. However, the accurateness of the result would be improved as more feedbacks will be received. Also, conducting a pilot study for the questionnaire and enhancing the questionnaire, if necessary, before distributing it among the participants will enhance the outcome in this study to achieve a higher reliability score than what we have with the current results.
- The Bridge Resource Management for Seafarers (BRMs) course require all different ranks of bridge team members such as master, pilots, OOWs, rating and cadets to take the proposed course. This will measure the course's effectiveness among the whole bridge team members. However, during the validation work performed in this thesis, The participants were only the cadet, some of whom could be considered as ratings due to the basic knowledge that they got as they finished one year in the college and were taught the course. Due to their duties onboard ships or current restrictions such as COVID-19, it was not suitable for other ranks, such as master, OOW, Pilot and rating, to participate in the course. Outcomes of the validation case study may have affected the outcome because of the absence of seafarer's experience with different ranks. This appeared clearly in some decision-making and sharing SA between the experiment team. Therefore, it would be beneficial to repeat such tests with the correct ranks of seafarers as a future study.
- The accidents review should have included more analysis of the reports issued by the Saudi Maritime Board. However, the permissions and the documentation required by

the authority could not be obtained in time. While the accident reports collected from ATSB and TSBC were suitable to conduct the analysis of the accidents at this stage, it can be extended to data from other administrations in future studies.

9.5. Future Work

Based on the limitations given in before, recommendations for future research are listed below:

- More observation studies should be placed to record each bridge team member's practice and performance, which needs to utilize a developed Key Performance Indicator (KPI) to detect their efficiency towards BRM during the navigational watch.
- Include different ranks in the new course and record their interactions to measure the effectiveness of sharing SA and teamwork.
- Create global accidents database that focused on the accidents that occur due to the lack of bridge team performance as an individual and team by following a Human factors taxonomy.
- More objective assessment criteria and exams for all seafarers who participate in the bridge activities.
- Utilise human factor taxonomy to capture the deficiencies of SA on the bridge.
- Attending the HELM course to highlight the differences between HELM and BRM.

9.6. Chapter Summary

In this chapter, a summary of the achievement of the research aims and objectives has been presented. Also, the limitations and recommendations for future research have been made.

10. Conclusion

Prevention of accidents through human factors has only recently gained the deserved attention, as the maritime community has realised that despite all the increased safety standards and technological developments, accidents are still occurring, and the system is not resilient to errors at various levels. Furthermore, it has been often ignored that the human element of the maritime system has not been evolving in the same way that technology is developing as the physical capabilities and human limitations are overlooked. The measures which were created by the IMO through the International Safety Management (ISM) Code, international regulations for safe vessel operation, and the training and certification of the crew members regulated by the International Convention of Standards of Training Certification and Watchkeeping for Seafarers (STCW) was not a simple task. However, after analysing more than 200 accident reports of the Marine Accident Investigation Branch (MAIB), Australian Transport Safety Bureau (ATSB) and Transportation Safety Board of Canada (TSBC), it was revealed that these accidents were caused by a lack of situational awareness and failures of bridge team members. This fact motivates the author of this thesis to work for a solution that could enhance navigational safety by increasing situational awareness and teamwork in the bridge to minimise the consequences of future SA linked issues.

This thesis examined the MAIB, ATSB and TSBC accident reports for commercial vessels which were involved in accidents between 2007-2017 as a result of lack of situational awareness. It was found that eleven human-related factors, which included Communication, Wrong / miss use the available information, Poor bridge team act, Wrong decision making, No information, No lookout/ inactive lookout, Fatigue, Not following the COLREG rules, Poor navigation (Practice/training), Manning and Other factors were identified as the failures by the bridge team, as mentioned in Chapter 5. Accordingly, a questionnaire was developed to be distributed among the seafarers to highlight the gaps in bridge team performance. As a result, Bridge Resource Management for Seafarers course (BRMs) was established to cover these gaps and to enhance the bridge team performance.

A prepared case study was used to evaluate the course's efficiency; two groups have participated, each containing a captain, an OOW, a cadet/pilot, a lookout and a helmsman. Group A performed the experiments by applying the new methods and technics, which were explained and taught in the new course. Group B performed the watch by applying routine procedures, which were taught during their education in their faculty. The study included sailing in four different scenarios: open-water navigation, Master-Pilot exchange (Berthing/Unberthing), Restricted visibility and Emergency situations. As a result, in the first scenario, both groups' performance demonstrated that there is no significant difference between Group A and Group B. In the second and third scenarios, Group A's performance was way better compared to Group B.

In conclusion, all bridge team members should be trained and educated in a way that can enhance their skills to ensure the safety of navigation, which can be done by taking into account the following suggestions, observations and conclusions:

- An accident analysis should be performed to identify the reasons for accidents caused by the bridge team's poor performance using appropriate human factors taxonomy.
- Navigational safety can be enhanced by sharing situational awareness, leadership and knowledge.
- BRMs can enhance the bridge team's skill, communication and eliminate the practising of non-standard procedures.
- The BRMs assessment against the standard procedures concluded that a bridge team's safety performance could be significantly enhanced.

- The simulator experiments clearly have shown that Group A, who took the BRMs course, enhanced its performance and skills against Group B, which followed the standard procedures.
- This research identified that all bridge members, including ratings and cadets, should be included in the BRM training.
- The content and format of the BRM courses, which are offered around the world, should be standardised.

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Appendices

Appendix A- Situational Awareness Survey for Crew Members

Your True Opinion Is Extremely Important To Enhance the Navigational Safety

Thank you in advance for participating in the situational awareness survey. Your feedback is very important for my PhD research.

This survey is conducted independently by the University of Strathclyde in collaboration with King Abdulaziz University (Faculty of Maritime Studies), to assess the situational awareness and teamwork within the bridge team member (master, OOW, deck cadet, lookout, wheelman and pilot). The University of Strathclyde guarantees that:

- Survey responses are completely anonymous.
- This survey does not aim to collect any personal information from the participants

It takes 7 to 10 minutes to complete this survey. Please try to answer the questions accurately. For any inquiries related to this survey, please do not hesitate to contact us via the information below:

Contact Person:

Full name: Mohammad Gommosani

Occupation: Researcher at University of Strathclyde, Glasgow, UK

Email: Mohammad.gommosani@strath.ac.uk

Mobile: 0044 744 969 8483

Address: Department of Naval Architecture, Ocean & Marine Engineering,

University of Strathclyde

Henry Dyer Building, 100 Montrose Street, Glasgow G4 0LZ, United Kingdom

Demography

(Please tick the appropriate question)

a. What is your age?

☐ 18-24

☐ 25-34

☐ 35-44

☐ 45-54

☐ 55-64

☐ 65+

b. What is your gender?

☐Male

☐Female

c. What is your rank?

☐ Captain/Master

☐ Chief Officer

☐ 2nd Officer

☐ 3rd Officer

☐ Deck Cadet

☐ Able Seaman

☐ Ordinary Seaman

☐ Pilot

☐ Other ………………………………….

d. How long have you been at sea?

☐ Less than a year

☐ 1-4 years

☐ 4-8 years

☐ More than 8 years

e. What is your nationality?

1. Bridge Resource Management

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do not Know
1. Language/dialect related issues amongst bridge members are a threat to safety.	☐	☐	☐	☐	☐	☐
2. There is good communication environment in the bridge.	☐	☐	☐	☐	☐	☐
3. There is no difficulty of using English as a communication language.	☐	☐	☐	☐	☐	☐
4. Operational values, objectives and targets are effectively communicated.	☐	☐	☐	☐	☐	☐
5. I always ask questions if I do not understand or	☐	☐	☐	☐	☐	☐

unsure about any information or instructions were given to me.						
6. I can report anything related to safe navigation without fearing from the consequences especially at night.	☐	☐	☐	☐	☐	☐
7. I can establish/ understand any communication between my vessel and others	☐	☐	☐	☐	☐	☐
8. I found the BRM course useful for each bridge members.	☐	☐	☐	☐	☐	☐
9. The course is helping me to cooperate with bridge members.	☐	☐	☐	☐	☐	☐
10. It is better to	☐	☐	☐	☐	☐	☐

conduct a monthly meeting for bridge team members.						
11. Bridge members should question a higher rank officer's/ pilot’s decision not even when safety is affected.	☐	☐	☐	☐	☐	☐
12. Whenever I see a navigational warning, I always report it.	☐	☐	☐	☐	☐	☐
13. I found that the BRM course improved my skills.	☐	☐	☐	☐	☐	☐
14. I use all resources that available in the bridge to ensure safe passage.	☐	☐	☐	☐	☐	☐
15. I can deal with any emergency navigational	☐	☐	☐	☐	☐	☐

situation by myself.						
16. I do risk assessment when the ship passes through heavy traffic areas.	☐	☐	☐	☐	☐	☐
17. I get the benefit of other bridge member's experience to make a safe and effective decision.	☐	☐	☐	☐	☐	☐
18. I found that maritime institutions are providing different content of BRM course.	☐	☐	☐	☐	☐	☐
19. There is a briefing between bridge team before the watch started.	☐	☐	☐	☐	☐	☐
Suggestions						

➢ Teamwork

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do not Know
20. I found a good atmosphere of teamwork in the bridge.	☐	☐	☐	☐	☐	☐
21. I can ask other bridge team member when I doubted.	☐	☐	☐	☐	☐	☐
22. Asking for assistance can make me look competent.	☐	☐	☐	☐	☐	☐
23. There is collaboration between bridge team members to ensure safe navigation.	☐	☐	☐	☐	☐	☐
24. I can correct the information for	☐	☐	☐	☐	☐	☐

another bridge team member even if he/she higher ranks than me.						
25. I good leadership can improve the teamwork.	☐	☐	☐	☐	☐	☐
Suggestions						

3. Navigational Safety

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do not Know
26. I found no difficulty of using navigational equipment to ensure safe passage.	☐	☐	☐	☐	☐	☐
27. I rely on electronic navigation equipment for a safe passage.	☐	☐	☐	☐	☐	☐
28. I am confident that I can operate the navigational equipment within my area of responsibility safely.	☐	☐	☐	☐	☐	☐
29. I fully understand my responsibilities for my duty in the bridge.	☐	☐	☐	☐	☐	☐

30. Other bridge members encourage me to report unsafe events.	☐	☐	☐	☐	☐	☐
31. I receive feedback about my compliance to the safety of navigation.	☐	☐	☐	☐	☐	☐
Suggestions						

4. Involvement

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do not Know
32. Bridge members are encouraged to improve navigational safety.	☐	☐	☐	☐	☐	☐
33 I am consulted about, and invited to get involved in changes that affect teamwork in the bridge.	☐	☐	☐	☐	☐	☐
34. I have sufficient control of my work to ensure it is always completed safely.	☐	☐	☐	☐	☐	☐

35. Mistakes are corrected without punishment and treated as a learning opportunity.	☐	☐	☐	☐	☐	☐
Suggestions						

5. Situation Awareness

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do not Know
36. Watch hand-overs are thorough and not hurried.	☐	☐	☐	☐	☐	☐
37. I can easily maintain my situational awareness during my watch.	☐	☐	☐	☐	☐	☐
38. A good manning in the bridge can improve the situational awareness	☐	☐	☐	☐	☐	☐
39. There is sufficient time allocated for the hand-overs when joining the ship.	☐	☐	☐	☐	☐	☐
40. We are	☐	☐	☐	☐	☐	☐

sharing the same situational awareness in the bridge.						
41. I can easily predict what will happen during my watch.	☐	☐	☐	☐	☐	☐
42. Following the COLREGs can improve my situational awareness.	☐	☐	☐	☐	☐	☐
43. I know that fatigue can affect my situational awareness.	☐	☐	☐	☐	☐	☐
Suggestions						

Appendix B- BRM Course Form

Name of the centre: …………………… Date: / /20

Course period: ……………… days day no.: 1/2/3/4/5

Lecturer position(s) and experience: ………………………………

Simulator scenario	Real Accidents ☐	Educational scenarios☐	Other☐	…………….
Teaching method	Normal☐	workshops☐	Other☐	…………….

Methods used to increase the SA:

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Other comment:

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Appendix C- IMO outline for BRM course

Taken from (VALIDATION OF MODEL TRAINING COURSES) SUB-COMMITTEE ON STANDARDS OF TRAINING AND WATCHKEEPING 44th session Agenda item 3 STW 44/3/5, 25 January 2013

1. Demonstrates the allocation, assignment and prioritisation of resources.
2. Demonstrates the importance of ensuring the effectiveness of communication between bridge team members.
3. Explains the importance of ensuring the effectiveness of information exchange with pilot.
4. Demonstrates effective information exchange.
5. Defines "situational leadership".
6. Explains the relationship between assertiveness and leadership.
7. Explains the importance of challenge and response.
8. Explains the importance of obtaining and maintaining situational awareness.
9. Demonstrates appropriate challenges and responses.
10. Demonstrates the ability to maintain situational awareness in complex situations.