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A human factors approach to improving safety in shipping

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A Human Factors Approach to Improving Safety in Shipping

By

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DOCTORAL THESIS

Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy

of Loughborough University

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Abstract

The commercial shipping industry is particularly challenging with respect to safety because of its global operations, multi-national and transient workforce, and fragmented organisational structure. Despite extensive attempts to introduce new legislation to improve safety, shipping accidents still occur at an alarming rate. These legislative remedies for addressing the cause of shipping accidents have traditionally been reactively applied following an accident. However, in other transport industries, particularly the aviation and rail sectors, the analysis of accident causation and the contribution of human error have been more structured and based on formalised techniques resulting in significant improvement in safety performance. The shipping industry has lagged behind other comparable industries in this regard. As a result, a more thorough and systemic investigation of causal factors related to the human element in shipping accidents is required.

Shipping can be considered a complex sociotechnical system, and causal factors of accidents can reside at all levels within that system. By understanding and identifying the underlying causal factors, the shipping industry may be able to prevent accidents in ship operations, thus improving safety for the seafarer. Additionally, if the analysis of near misses is carried out using similar human factors techniques to accident investigation, then both corrective and preventative strategies can be introduced by key stakeholders, including legislators, ship owners and ship operators, to reduce the potential for accidents.

This research uses a systems-based approach to examine the complexity of the commercial shipping industry. A number of unique factors contribute to this complexity: the global trading of ships remote from the shore organisation, the nature of the workforce including contracting and retention challenges, the difficulty of delivering training to the seafarer, the number of different types and sizes of ships, and finally, the intricacies of modern ships and the technology onboard.

Framing the commercial shipping industry as a complex system requires mixed research method approaches in order to understand the systems interconnectedness. Adopting this approach, the first part of the thesis will present an overview of the shipping industry in order to provide necessary context, followed by an analysis of incident types and causal factors leading to shipping accidents using accident databases. The second part of the thesis utilises a sequential research approach by assessing human factors and accident analysis practices in shipping. This is done through the use of a survey of internationally traded shipping companies, followed by a series of interviews with stakeholders (ship owners, ship managers, legislators, human factor specialists and independent consultants). Subsequently, a review and analysis of near miss data supplied from an internationally trading shipping company will be presented. Using a systemic accident analysis technique, a detailed analysis of an accident causation type will be completed to identify any common factors both within the accidents studied and the previous studies conducted within this research. Finally, the thesis synthesises and analyses the previous studies using a systems theoretic accident modelling and processes technique (STAMP) to give an overview of how the shipping system works, what constraints exist, what the influences are on the system (external and internal), and what negative factors contribute to human error in the industry.

The insights gained from this research will enhance the understanding of the complexity of the shipping industry, particularly the relationship between the shore and ship organisations, and suggest the benefits of a systems of systems approach to improving safety and reducing human error. This approach will help to improve the understanding of accident causation as related to human error in the shipping industry. Also, considering the causation factors of near misses, the work provides the opportunity to make recommendations to improve safety onboard ships at a working level.

Keywords:

Accident; Causation; Complex Systems; Organisation; Safety; Shipping; Sociotechnical; STAMP; Systemic.

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Abbreviations

ABS	American Bureau of Shipping
AMSA	Australian Maritime Safety Authority
ARCTM	Accident Root Causes Tracing Model
ARPA	Automatic Radar Plotting Aid
ATSB	Australian Transportation Safety Bureau
BIMCO	Baltic and International Maritime Council
BRM	Bridge Resource Management
BTM	Bridge Team Management
BWTS	Ballast Water Treatment Systems
CBT	Computer Based Training
CDI	Chemical Distribution Institute
CFAC	Contributing Factors in Accident Causation
CMS	Competence Management Systems
COLREGs	Convention on the International Regulations for Preventing Collisions at Sea
CRM	Crew Resource Management
DWT	Deadweight Tonnage
ECDIS	Electronic Chart Display and Information System
EMCIP	European Marine Casualty Information Platform
EMSA	European Maritime Safety Agency
EPTM	Emergency Preparedness and Training Manual
F, D and D	Freight, Defence & Demurrage (Insurance)
FAHP	Fuzzy analytic hierarchy process
FoC	Flag of Convenience
FRMP	Fatigue Risk Management Plan
FSO	Floating Storage and Offtake
GISIS	Global Integrated Shipping Information System
GMDSS	Global Maritime Distress and Safety System
GT	Gross Tonnage
H & M	Hull and Machinery (Insurance)

HFACS	Human Factor Analysis and Classification System
HSE	Health and Safety Executive
IACS	International Association of Classification Societies
ICS	International Chamber of Shipping
IEA	International Ergonomics Association
ILO	International Labour Organisation
IMO	International Maritime Organisation
IMCO	Inter-Governmental Maritime Consultative Organisation (Predecessor to IMO)
INTERCARGO	International Association of Dry Cargo Shipowners
INTERTANKO	International Association of Independent Tanker Owners
ISF	International Shipping Federation
ISM	International Safety Management
ITF	International Transport Workers' Federation
ITOPF	International Tanker Owners Pollution Federation
ITU	International Telecommunication Union
KPI	Key Performance Indicators
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LR2	Long Range 2 Product Tanker (105,000 to 115,000 dwt)
LTI	Lost Time Injury
MAIB	Marine Accident Investigation Branch
MARPOL	International Convention for the Prevention of Pollution from Ships
MARS	Mariners' Alerting and Reporting Scheme
MLC	Maritime Labour Convention
MODU	Mobile Offshore Drilling Unit
MORT	Management Oversight Risk Tree
MoU	Memorandum of Understanding
MR	Medium Range tanker (35,000 to 55,000 dwt)
MRCC	Maritime Rescue Co-ordination Centre

M-SCAT	Marine Systematic Cause Analysis Technique
NASA	National Aeronautics and Space Administration
NEBOSH	National Examination Board in Occupational Safety and Health
NUMAST	National Union of Marine, Aviation and Shipping Transport Officers
NYSE	New York Stock Exchange
OCIMF	Oil Companies International Marine Forum
OECD	Organisation for Economic Co-operation and Development
OVID	Offshore Vessel Inspection Database
P & I	Protection and Indemnity (Insurance)
PSC	Passenger Ship Construction or Port State Control
RO	Responsible Organisation
RO-PAX	Roll-On/Roll-Off Passenger (Ferry)
RO-RO	Roll On-Roll Off (Ferry)
SAA	Systemic accident analysis
SHELL	Software, hardware, environment, liveware
SIGTTO	Society of Gas Tanker and Terminal Operators
SIRE	Ship Inspection Report Programme
SMS	Safety Management System
SOLAS	Safety of Life at Sea
SSO	Ship Security Officer
STAMP	Systems Theoretic Accident Modelling and Processes Technique
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
SVIS™	Ship Vetting Information System
SWOT	Strengths, weaknesses, opportunities, and threats
TEU	Twenty-foot Equivalent Unit (Container)
TMSA	Tanker Management Self Assessment Programme
TRC	Total Recordable Cases

TSB	Transportation Safety Board
ULCC	Ultra Large Crude Carrier
UNCLOS	United Nations Convention on the Law of the Sea
UNCTAD	United Nations Conference of Trade and Development
USCG	United States Coast Guard
VLCC	Very Large Crude Carrier
VTS	Vessel Traffic Service
WBG	Why-Because-Graph
WHO	World Health Organisation

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Acknowledgements

This thesis has been the culmination of my many years in the shipping industry. Since 1980 after my cadetship, the majority of my career has been dealing with ship operations. Initially as a sea-going engineer, and more recently as a shipping executive, safety has been an important factor at all times. It is paramount to me that the people I work with on ships return home accident free to their families, and want to continue to work on ships that I have been responsible for. Only by having the highest safety standards onboard can this be achieved. Therefore, my first thanks go to all the seafarers working in the industry and especially to those I have discussed my work with over the last five years. My hope is this thesis contributes to a wider understanding of the challenges facing both seafarers and shipping companies.

Regarding this thesis, I would like to thank Dr. Patrick Waterson my primary supervisor. I have valued his feedback, particularly with respect to introducing me to the wider human factors academic work. I would also like to thank Dr. Thomas Jun whose structured approach has helped me continuously throughout the last five years. I have enjoyed my many meetings with both Patrick and Thomas over the last years and have valued their support and insight into the world of human factors and complex systems.

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Preface: The Researcher's Background

After a sea-going career in the Merchant Navy with Ben Line Steamers Limited and Shell Tankers (UK) Limited, the researcher completed his undergraduate degree in Marine Engineering at Newcastle University (B. Eng. Hons.) in 1988. Following the award of the degree, the researcher was employed as an Engineering Surveyor with Lloyds Register in the offshore industry based in Aberdeen. Specific responsibilities included commissioning offshore platforms, including the Piper Bravo platform, on behalf of the United Kingdom's Health and Safety Executive. Returning to Shell International as a Project Engineer in 1993, the researcher worked on the design concept for a number of projects, mainly in oil and gas shipping, within the Shell Group. This included a period in Korea overseeing the design and construction of oil and gas tankers, including VLCCs and LNG carriers.

In 1995, the researcher joined Tarquin Gas Carriers as Technical Director. During this time, the company contracted 10 fully refrigerated/semi-pressurised LPG ships in Korea. The researcher was responsible for the design concept, detailed design, delivery and entry into service of these ships. The researcher was also responsible for setting up all aspects of a newly created in-house technical management division within Tarquin International Limited including ship management operation, and technical, safety, marine and commercial operations.

The researcher subsequently established a consultancy company focusing on the oil and gas sector. Projects included the design of LPG ships and oil tankers, including the concept of a new LNG ship featuring gas-injection slow-speed engines with a cargo reliquefaction system installed.

In 2005, the researcher was appointed as Technical Manager for Overseas Shipholding Group Limited, a NYSE listed shipping company, and was responsible for the realisation of the new specification and operation of a new generation of LNG ships. This included detailed design, construction and commissioning of the ships as well as setting up the technical management operation for the ships. The researcher was also technically responsible for 80 oil and gas tankers, ranging in size from PanaMax to FSO/ULCC crude oil

tankers and LNG ships with a cargo carrying capacity of 208,000 m^3, the largest to be operated at that time. To compliment this breadth of responsibility, the researcher completed an M.Sc. in Safety and Risk Management at Heriot Watt University in 2012 in order to understand the challenges associated with improving safety in complex systems.

In 2012, the researcher became Chief Operating Officer of Thenamaris LNG, a new company set up to operate and manage all aspects of duel-fuel, diesel-electric LNG ships with a cargo capacity of 160,000 m^3. The researcher was responsible for establishing all aspects of this new company, including creating the shore and ship organisations, recruitment of shore personnel and seafarers, compliance, safety management, technical operations and commercial acceptance of the ships.

From 2017, the researcher has been an independent consultant, specialising in technical, operational and commercial aspects of shipping, with a focus on LNG and LPG shipping. Clients include ship owners, management companies, traders and energy utilities.

This research, together with the practical knowledge gained as a seafarer, will allow a greater understanding of the causal factors of shipping accidents and the contributing factors that affect safe shipping. This knowledge will give the researcher a further insight into the systemic improvements that can be made in ship operations, with a particular focus on seafarer safety.

The researcher is a Fellow of the Institute of Marine Engineering, Science and Technology and a Chartered Engineer.

Career History

1976 – 1978	Engineer Cadet, Ben Line Steamers Ltd.
1978 – 1988	Engineering Officer, Shell Tankers (UK) Ltd.
1991 – 1993	Engineer Surveyor, Lloyd's Register
1993 – 1995	Project Engineer, Shell International Petroleum Co. Ltd.
1995 – 2003	Technical Director, Tarquin Gas Carriers
2003 – 2005	Director, Muir Marine Ltd.
2005 – 2012	Technical Manager, Overseas Shipholding Group
2012 – 2017	Chief Operating Officer, Thenamaris LNG
2017 – Present	Director, MMI Consulting Ltd.

1

Introduction

Contents

1.1 – Background
1.2 – Research Aims and Objectives
1.3 – Original Contribution
1.4 – Organisation of Thesis
1.5 – Ethical Approval

1.1 - Background

Despite established and proven prescriptive safety legislation, accidents regularly occur across all sectors of shipping. For example, collisions are regularly reported; the shipping journal 'Tradewinds' (Tradewinds, 2017) reporting 51 collisions in 2017, and collisions continue to occur even when ships have experienced and trained officers onboard, and modern navigation aids are in use. It is recognised that human and organisational factors significantly contribute to these types of accidents and that countermeasures associated with these factors can make a potentially important contribution to minimising such accidents. However, there is limited research concerning human and organisational factors as causal factors in shipping accidents. This research aims to fill this gap.

There have been many approaches to identifying causations and the associated factors in accident investigation by considering the initial event, which in many reported cases becomes the headline. Examples from other industries include the 1988 Piper Alpha disaster in which 167 people lost

their lives, the headline causation being 'Explosion' (www.lloyds.com, 2018). More recently, in 2005 the Texas City refinery accident occurred with the initial causation being reported as an explosion (CBS News, 2018). However, behind the headlines of both of these accidents, much work was completed by the investigators in order to identify the fundamental factors that had occurred and resulted in a chain of events that contributed to the accident.

The formal reports of both investigations showed that, while there were individual factors as initial contributory causations, there were deeper, intrinsic issues associated with both accidents. The Piper Alpha investigation (Cullen, 1990) identified the initial event in the accident as an individual re-starting a pump that was under maintenance. This pump was fitted with a blank flange which was not leak tight and on being started, condensate leaked. This condensate then ignited within the module. The report further identified organisational failings related to the permit to work system, safety systems, training, and a poor inspection regime. In the case of the Texas City refinery explosion, the initial contributory factor was the violation by an individual of failing to institute liquid rundown from the tower, and the failure to take effective emergency action, resulting in the loss of containment that preceded the explosion (Mogford, 2005). However, the investigation found additional underlying causes including issues with culture in the company, a lack of awareness, and poor internal vertical communication.

In the shipping industry, the Herald of Free Enterprise accident investigation report (Sheen, 1987) also found that there were factors within the company and management structure that had contributed to the accident. An example of this finding is a statement from the investigation report that:

> '(the) Board of Directors down to the junior superintendents were guilty of fault in that all must be regarded as sharing responsibility for the failure of management' (Sheen, 1987, p 14).

These examples show that there is a need to fully understand accident causations and the related contributory factors which may not be readily apparent. Accidents and incidents which occur in modern, complex and technical systems require formalised, robust, and methodical investigative

techniques in order to identify not only the initial root cause, but all the related events which may be difficult to identify using traditional root causal investigation techniques. In many accidents, the root cause is identified as 'human error', and specifically for shipping, human error has been attributed to around 80% of accidents (Fotland, 2004). Therefore, if the contribution to accident causation by human error can be identified, then corrective and preventative actions can be put in place to prevent such accidents from occurring. Additionally, if near misses can be analysed in a similar manner to accidents and incidents, then the risk of near misses escalating into an incident or an accident can be minimised.

Studying the interaction between humans and other parts of a sociotechnical system has many benefits, importantly in this research, the ability to enhance the design for safe shipping operations (Hollnagel, 2015). Also, as highlighted by de Vries and Bligård (2019), it is important in safety-critical industries to ensure appropriate monitoring and control of the system are performed in order to ensure the design of the system is safe, and consequently the system is safe to operate. If monitoring and control of the system are not performed adequately, then there is a risk of policies and procedures not being followed, particularly when there is a complicated sub-system, as in the case of many complex and safety-critical industries including shipping. Further, Walker et al. (2008) consider that the sociotechnical approach is aimed at jointly optimising people, technology, organisations and other systemic elements, making this approach particularly suitable for the shipping industry due its complex relationships between and within the organisational structures, the complexity of managing ships and the technical challenges of operating the equipment.

The shipping industry sociotechnical system considered in this research consists of the regulatory bodies at the high level, and includes the shore and ship organisations and staff within the technical, organisational, regulatory and physical environments in which they operate. A holistic approach such as this is rare in shipping. Indeed, Underwood et al. (2013) suggest that a systemic perspective has generally not been adopted in practice in many similar industries. This research aims to fill this gap.

A change in attitudes to safety investigation and analysis can be difficult to promote within the shipping industry due to a number of factors. Shipping is a very traditional industry and historically the approach to improving safety in commercial shipping has been conservative and generally accident driven, particularly with respect to legislation. The industry is global, multi-national and multi-cultural, in many cases has a transient workforce, and a fragmented organisational structure due to the ships operating remotely from the shore organisation. The shipping industry lags behind other transport industries, such as the aviation and rail sectors, when considering advances in safety approaches and applying systemic methods to analysing accidents and safety performance. While there has been limited research in using systemic accident analysis methods in the industry, there has been several studies highlighting the importance of identifying human and organisational factors as contributory causations in shipping accidents (Hetherington, 2006 and Chauvin, 2013).

The limited research available relating to safety in the shipping industry has focused on applying techniques such as the Human Factor Analysis and Classification System (HFACS) to accident analysis of specific causations such as collisions (Chauvin et al., 2013), and using the same technique to analyse casualties (Chen et al., 2013) rather than having a holistic approach to reducing safety in the industry by using a sociotechnical systems approach. This research will therefore focus on considering ship operations as a complex system of systems and will apply a mixed method approach. This approach focuses on pragmatism and rejects the either-or paradigm found in singular methodological approaches. In other industries, the value of mixed method research approaches has been recognised, particularly in the heath sector where the system being analysed is also complex. Johnson et al. (2004) further define the mixed method approach as combining elements of qualitative and quantitative research for the purposes of breadth and depth of understanding.

1.2 - Research Aims and Objectives

This research aims to further the current understanding of accident causation in the shipping industry and propose measures for improving system safety in the industry by applying a human factors and complex systems approach to ship operations.

It will achieve this by:

- Assessing trends of accident causation by reviewing current reporting into shipping accident databases, and by identifying the main initial event that is submitted.

- Assess current practices related to safe operations and accident analysis in the industry by conducting a survey of shipping companies, and interviewing shipping professionals to understand the challenges of identifying and reducing human error in the industry.

- Identify any common contributory factors related to human error by examining a near miss programme, and using an accepted system methodology to examine an accident initial event causation.

- Assess an accident initial causation event using a systemic accident analysis technique and identify any common contributory trends. Additionally, consider ship operations as a complex adaptive sociotechnical system, and conduct an analysis of the previous studies using an established systemic accident analysis technique in order to assess its suitability for identifying system weaknesses in ship management and operations.

- Propose a number of strategies that can be used by the shipping industry that, applied correctly, can contribute to reducing human error onboard ships and in turn reduce the number of accidents and near misses.

1.3 - Original Contribution

This research is an important original contribution to accident investigation in the shipping industry. As noted, there is limited literature exploring accident investigation in the shipping industry, with multifaceted and bespoke investigation techniques being used to determine accident causation. This research adds to the literature concerning accident investigation by applying current investigative techniques to this important sector and proposing important modifications to the existing investigative practices in the shipping industry.

Further, the research engages in original research methodology never before applied to the shipping industry. As the system is frequently 'closed' to outside investigation for a variety of commercial and industrial reasons, the researcher was uniquely positioned to obtain important and meaningful data through the use of sequential research methods including surveys and interviews. Additionally, the industry experience of the researcher allows for a deeper understanding of the structure of the shipping industry as well as the unique challenges it faces.

Finally, the importance of the research findings in this thesis cannot be understated. The adoption of thorough and systemic investigation techniques regarding causal factors related to the human element in shipping accidents would minimise accidents, and ultimately fatalities, in this industry. The research provides evidence-based recommendations that will facilitate positive strategic decision making by key stakeholders in the industry which will impact safety performance and operations.

1.4 - Organisation of Thesis

Chapter 1: This introductory chapter outlines the background to the thesis, provides the aims and objectives of the research, discusses the original contribution of the research, presents the thesis structure, and confirms the ethical approval process.

Chapter 2: This chapter provides an overview of the commercial shipping industry as relevant to this research. It introduces the key

stakeholders, and then summaries the composition of the world fleet including the recent growth in the industry. Finally, it describes several recent shipping accidents and introduces the role of human error as a major contribution to accidents.

Chapter 3: This chapter considers the regulatory landscape in the industry, how legislation has evolved over the past years, and explains the prescriptive regime that has evolved. It describes major legislation that has affected how ships are managed, manned and operated. Finally, it summarises the role of the third party inspection in the industry and the effect it has had on safety in certain shipping sectors.

Chapter 4: An overview of the literature that creates the context for the research contained in the thesis is presented in this chapter. This includes literature concerning:

- Human error
- Human factors
- Theory of accident causation

The chapter will also relate previous research and its application to the shipping industry and identify any specific challenges.

Chapter 5: This first case study considers the availability of shipping accident databases and the quality of the information contained in them. After selecting an appropriate database, the information contained in that database will be reviewed and the accident data categorised in order to identify the causation factors of high incidence.

Chapter 6: This chapter consists of two related case studies. The first study considers quantitative data from a safety related survey focused on human factors in shipping operations administered to shipping companies. The second case study provides an analysis of qualitative semi-structured interview data with

shipping professionals who are involved in industry safety matters and ship operations.

The chapter concludes by synthesising both datasets in order to identify the major concerns in the shipping industry related to safe shipping.

Chapter 7: The case study contained within this chapter considers near misses in ship operations. It reviews data supplied by an international shipping company, applies an M-SCAT methodology to near miss data, and discusses the results and identifies trends found in the data.

Chapter 8: Using information obtained in Chapter 6 concerning major causations of accidents in the shipping industry, this chapter case study will analyse an accident causation type using AcciMap, a systemic accident analysis (SAA) technique.

The strength of this investigation technique in the shipping industry will be discussed, particularly in reference to identifying weaknesses in the relationship between ship and shore.

Chapter 9: This chapter case study initially applies a STAMP analysis to ship operations, followed by a STAMP analysis of ship design and construction organisation structures, and explains the constraints, the control of the organisation and the feedback within the system.

Finally, the STAMP ship operations control structure will be applied to the results of the previous chapter case studies, including near miss data and accident causation type.

Chapter 10: The chapter reflects on the research conducted and the findings of the case studies, with a focus on a systemic approach to the analysis of ship operations and accident causation in the industry. It discusses whether the current approach to safety in the industry is adequate, or if it could be improved by applying alternative techniques to the analysis of accidents, near misses

and to the relationship between the ship and shore organisations. Finally, options for further research are proposed.

Figure 1 provides a summary of the organisation of the thesis.

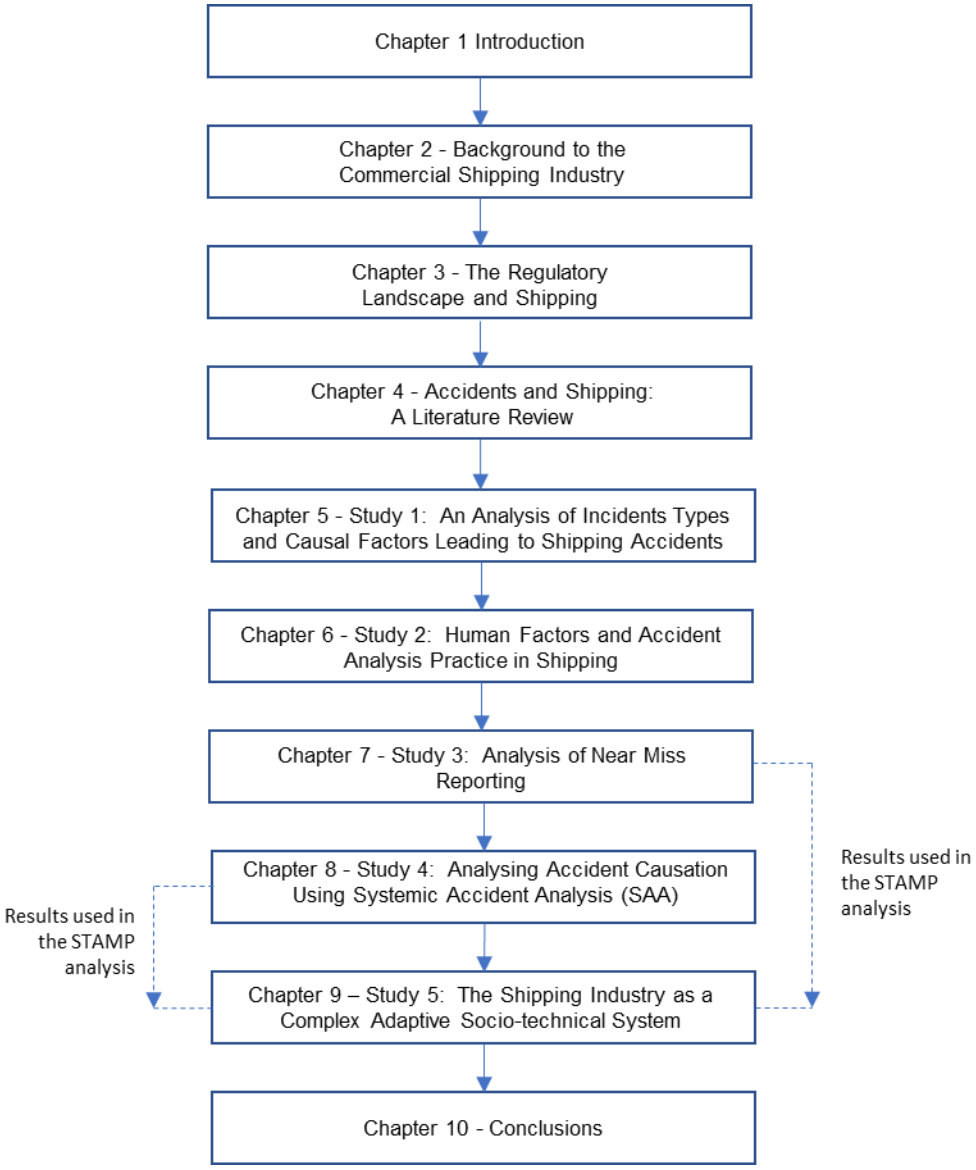

Figure 1 – Thesis Structure.

1.5 - Ethical Approval

This research was approved by the Loughborough University Ethics Committee. This ensured the studies complied with the university's 'Code of Practice on Investigations Involving Human Participants' and 'Data Protection Policy'.

2

Background to the Commercial Shipping Industry

Contents

2.1 - Introduction
2.2 - The World Fleet and the Growth of the Industry
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- 2.3.8 – International Maritime Organisation

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2.5 - Chapter Summary

2.1 - Introduction

This chapter will discuss the global nature of the shipping industry, explaining the demands on the industry to deliver the transport of cargoes safely and efficiently. It summarises the cyclical nature of the industry, which is an important safety factor. The bottom of the cycle may indirectly influence safety aspects of ship operations, as owners may reduce the number of crew onboard and operate different maintenance philosophies. The main stakeholders are described, noting that the management of one ship may have its stakeholders in many different countries, thus adding to the complexity of operation. Finally, the chapter gives an overview of the nature of accidents in the industry.

To the general public, shipping is a 'hidden' industry. Many people do not realise over 90% of world trade is carried by ships (International Chamber of Shipping, 2014), and as the global economy continues to expand this percentage may even increase. Ships deliver manufactured goods to Europe from the Far East, crude oil is transported from the Middle East to western economies and 'dry' cargoes, such as iron ore and grain, are transported from remote locations in Brazil and Australia to end users in Europe, North America and the Far East.

According to the International Chamber of Shipping, demand for maritime transport has actually increased by around 30% since 2008, with the annual volume of cargo carried by sea now exceeding 10 billion tonnes (International Chamber of Shipping, 2018). There are over 50,000 commercially trading ships (International Chamber of Shipping, 2014), with specific ship types satisfying various economic functions within the global economy. Cargo ships transport bulk liquids and solids, such as liquefied gases, oil and iron ore. They carry items in containers and they transport loose items, such as cars, on specialised ships dedicated to the carriage of this cargo. Passengers are transported on ferries and holidaymakers enjoy vacations on cruise ships. There are also specially designed ships working in the offshore industry, heavy lift ships which transport large items of equipment and ships that have large refrigeration plants in order to transport fruit and other perishables from where they are grown to the markets.

Ships are high value assets; liquefied gas carriers can cost around $200 million, sophisticated drillships around $600 million and the largest and most luxurious cruise ships around $1 billion each. However, the commercial market for shipping is notoriously cyclic, with charter rates at times being less than the operating costs at the bottom of the market, while rates at the peak of the market being extremely profitable for the ship owner. This cyclic nature gives additional problems to owners and operators. At the trough of the market there is a pressure to reduce operating costs and this may affect onboard maintenance. When rates are high, there is a tendency for ship ordering to increase which, when the ships are delivered, floods the market with excessive shipping capacity resulting in charter rates being put under pressure. The

resulting over capacity remains until the new ships are absorbed into the market or owners are forced to scrap their older ships. The market then returns to balance or gets tight and the charter rates then increase again.

Ships are registered in over 150 nations, and manned by over a million seafarers of almost every nationality (International Chamber of Shipping, 2014). Ships in some sectors are getting bigger; container ship capacity has increased by almost 1,500% in 50 years (Allianz, 2018), LNG ships have increased in capacity from around 75,000 m^3 in the 1970s to around 266,000 m^3 for ships built for a specialist trade in 2010. At the same time, there has been a reduction in crew numbers; ships in the 1970s had 40 to 50 seafarers onboard, while it is now common for the largest ships to only have between 15 and 25 seafarers, with the numbers of officers and ratings being determined by the type of ship, its size, complexity and trading area.

2.2 - The World Fleet and the Growth of the Industry

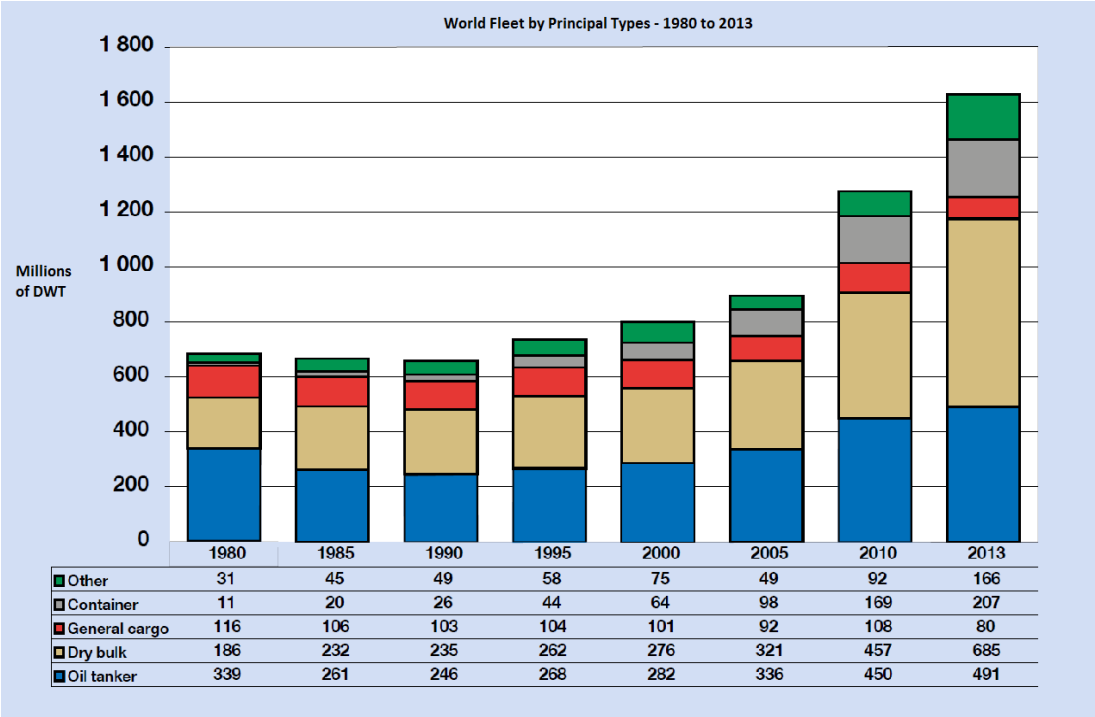
In 2012, over nine billion tonnes of goods were loaded onto ships world-wide (United Nations Conference on Trade and Development, 2013). Of the total volumes transported, dry cargo volumes accounted for approximately six billion tonnes with the remainder being tanker shipments, including crude oil, petroleum products and gas cargoes.

In addition, tonne-miles are increasing as the geography of world shipping changes and the need to diversify sources of supply increases. This particularly impacts the length of voyages being performed by the world shipping fleet and in turn requires more ships to execute the same number of voyages.

To cope with this demand for seaborne transport, the world's shipping fleet continues to grow. Since 2001, it has doubled in size and now totals over 1.63 billion deadweight (United Nations Conference on Trade and Development, 2013) in 2012.

The expansion of the shipping fleet, particularly since 2000, has not only placed enormous pressure on attracting and retaining experienced sea-going staff, but also on the recruitment of shore operational staff who are traditionally

from a senior seagoing position such as captain or chief engineer. These shore staff need to operate their ships in accordance with their company's management systems and legislation. As the experience pool of shore management staff decreases, the company's exposure to accidents, with organisational factors as a causation, may also increase.



	1980	1985	1990	1995	2000	2005	2010	2013
Other	31	45	49	58	75	49	92	166
Container	11	20	26	44	64	98	169	207
General cargo	116	106	103	104	101	92	108	80
Dry bulk	186	232	235	262	276	321	457	685
Oil tanker	339	261	246	268	282	336	450	491

Figure 2 – The Growth of the World Fleet 1990 to 2013. (United Nations Conference on Trade and Development, 2013).

Several studies have predicted shortages of sea-going manpower as the world fleet grows. One of the most comprehensive and respected studies is the BIMCO/ICS 2015 study which shows the worldwide supply of seafarers in 2015 was estimated to be 774,000 officers and 873,500 ratings, while the 2015 worldwide demand for seafarers was 790,500 officers and 754,500 ratings (Baltic and International Maritime Council and International Chamber of Shipping, 2016). The 2016 Report highlights that in the case of officers, while recruitment and training have increased and wastage and turnover rates reduced since the 2010 Report, this is not enough to reduce the current shortage of officers. Considering the supply-demand balance for officers in 2025, the Report forecasts a shortage of approximately 147,500 officers, meaning that the current retention levels of existing experienced officers has

to be maintained and efforts made to make seafaring an attractive career for the next generation.

To exacerbate the situation, 2014 saw the industry undergo a newbuilding ordering spree. For example, the current MR (Medium Range) tanker (40,000 to 54,999 dwt) order book was 20% of the existing fleet and the LR2 (Long Range) tanker (80,000 to 124,999 dwt) was 23% of the existing fleet (BraemarACM Ship Brokers, 2014).

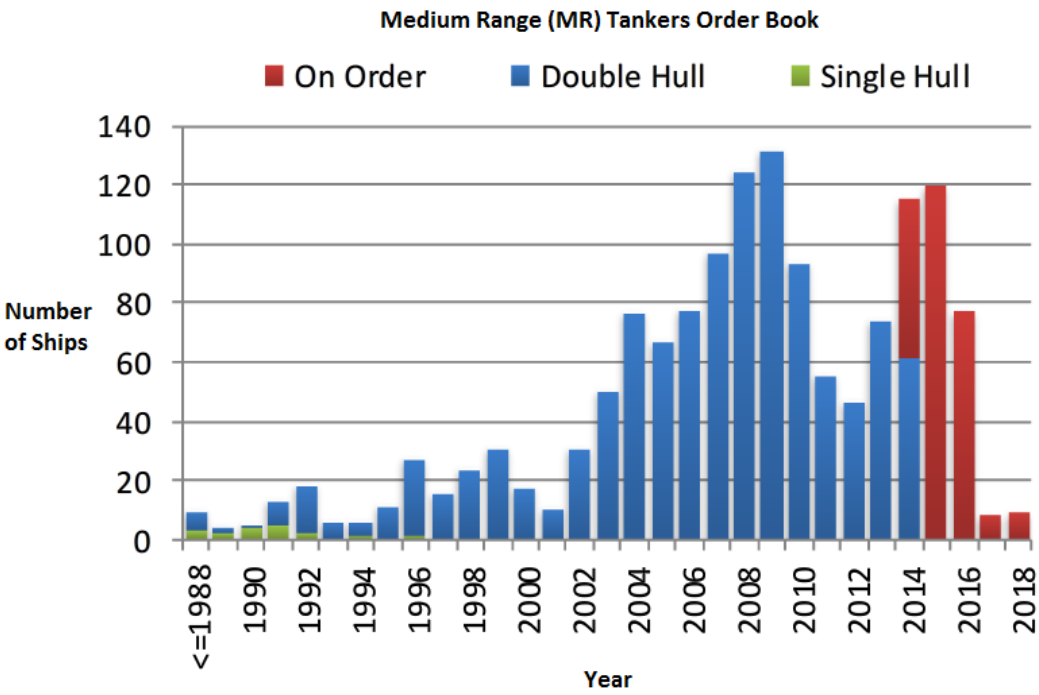


Figure 3 – Medium Range (MR) Tankers Order Book. (Braemar ACM Ship Brokers, 2014).

New ships will require fewer crew due to increased automation, a trend which began in the 1970s. However, this reduction in manpower onboard has not compensated for the increased demand for seafarers due to the continued growth in the world's shipping fleet. This is compounded by the increased share of specialised ships requiring to be crewed and, in particular, the officers manning these types of ships requiring further training in addition to the standard requirements of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) (International Maritime Organisation, 1978).

The continued growth in the world's shipping fleet has resulted in a greater number of inexperienced seafarers serving at sea, and has also given rapid promotion opportunities for officers, meaning their experience in rank becomes limited. These two main factors give increased concern with respect to the exposure for accidents during their time onboard. While the majority of accidents are categorised due to a physical cause such as grounding, fire or technical failure, shipping accident databases do not reflect causation due to human error. Human error is estimated to be responsible for the majority of marine accidents, with Allianz (Allianz Global Corporate and Specialty, 2012) estimating between 75%-96% of marine accidents are attributable to human error, and Perrow (1999) estimating that '80% of marine accidents are attributed to human error'. It is therefore extremely important that 'near misses' and underlying causes of human error are identified correctly, and corrective and preventative actions put in place to prevent further failures due to human error.

2.3 - The Stakeholders

The shipping industry has many different types of businesses that can be considered stakeholders in the industry. The stakeholders include investors, either private or public, that invest in the ships, companies that hire ships to transport products, legislators and insurance companies.

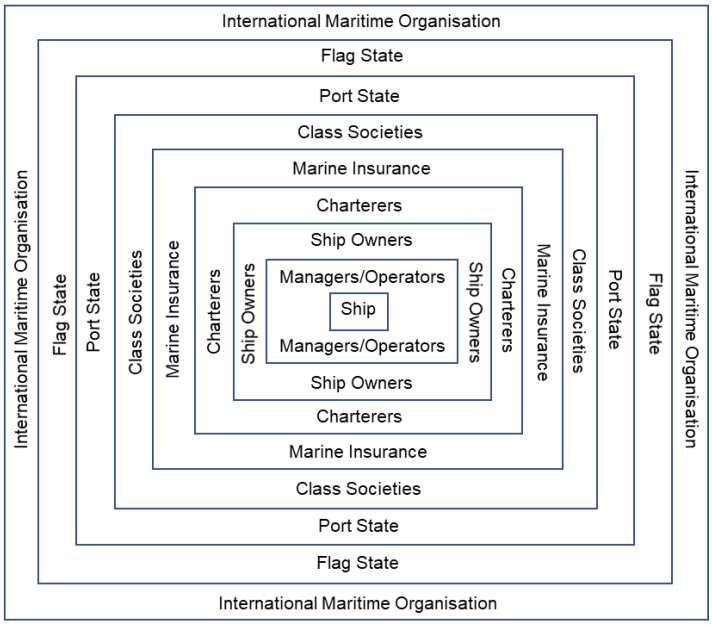


Figure 4 – Overview of the Stakeholders.

2.3.1 - Ship Managers/Operators

The operator of ships may or may not be the owners of the ships. In many cases, third parties operate ships on behalf of owners. These third party ship managers range from single ship managers to large companies having large diverse fleets operating in a number of different shipping sectors.

Ship owners who operate or manage their owned ships tend to be larger fleets where economies of scale are attractive to the owner in allowing the ships to be operated efficiently. It also allows the owner to bring their distinct culture to the shore employees and seafarers. Also, many traditional owners prefer to manage all aspects of their ship operations rather than hand the responsibilities over to a third party.

Third party ship management has become more prevalent in the shipping industry since the 1970s. There are many reasons for this including:

- The emergence of non-traditional ship owners, including financial institutions and charterers who do not want, nor have the capability, to operate ships themselves.

- The economies of scale which larger ship managers can provide.

- The ability of ship managers to manage diverse fleets.

Generally, a third party ship manager will arrange crewing, insurance, maintenance and repair, as well as ship inspections on behalf of the ship owner for a pre-determined fee.

The operator, whether it is the owner operating their own ships or a third party manager, is responsible for ensuring the ship complies with all the legislation as applicable to the type of ship. This includes the requirements of the International Maritime Organisation, the Flag State, the Class Society and any industry specific requirements.

2.3.2 - Ship Owners

As well as traditional ship owners which, in many cases, originated from a single family, there are family companies who have funded their fleet expansions by accessing equity or debt in the capital markets. An example of a company controlled by an individual family is the Angelicoussis Group which is Greece's biggest shipowner in terms of tonnage. An example of the latter is Tsakos which is a major Greek ship owning company listed on the New York Stock Exchange.

There are also commodity companies established as shipping companies and these companies have large volumes of products to shipped. In the oil and gas industry, names such as ExxonMobil, Shell and Chevron all have shipping assets ranging from small oil tankers to large LNG carriers. In the dry bulk market, mining companies such as Rio Tinto and Vale own ships moving their cargoes from the mines to the end users, such as production mills involved in the manufacture of steel.

Finally, there are diversified shipping companies such as Maersk. These companies operate a mixed fleet in different markets. Maersk, for example, owns container ships, oil tankers and specialised ships such as offshore drilling ships and semi-submersibles.

In addition to commercial investment in the industry, there are also some fleets controlled by governments operating in the nation state interest. This may be to provide shipping for a specified reason or in order to control the shipping in isolation to the markets and avoid exposure to the cyclic nature of the shipping industry. An example of this is Sovcomflot, a Russian company which owns 147 vessels with a combined deadweight of 12,732,069 tonnes (Sovcomflot, 2018). Sovcomflot owns mainly a mixed fleet of oil tankers and LNG carriers.

2.3.3 - Charterers

Companies or entities such as governments can hire charter ships. The majority of fixtures are between a ship owner and a third party wishing to hire a ship. In some cases, a ship can be chartered internally, for example between a ship owning company and the commercial department of the same company.

A charter hire period can be from several days to over the life of a ship (25 years or more) depending on the charterer's requirements. The charter is covered by a contract between the two companies. The type and terms of the contract are dependent on the type of ship being hired, the cargo being shipped and the period of hire.

There are voyage charters, period charters and contracts of affreightment (when the ship owner agrees to lift a pre-determined quantity of cargo over a certain period for the charterer, the shipowner may elect to use the same or an alternative ship to carry the cargo).

2.3.4 - Marine Insurance

Marine insurance is complex. For the shipowner, the two main types of insurance are Hull and Machinery (H & M) and Protection and Indemnity insurance (P & I).

Hull and Machinery insurance protects the shipowner's physical asset (both the hull and its associated equipment against total loss and damage) and is generally based on hull value. Protection and Indemnity insurance covers a shipowner against third party claims liabilities and expenses arising from owning ships or operating ships as principals (U.K. P & I Club, 2018). Examples of when a shipowner would claim under their P & I cover include:

- Personal injuries to crew members, passengers and stevedores
- Collision
- Pollution
- Cargo liabilities
- Fines associated with the claims above

There are also other insurances available to the shipowner:

- Loss of hire – Payable when the shipowner loses daily income due to physical damage to the ship.

- Freight, Demurrage and Defense (F, D & D) Insurance – covers claim assistance and legal costs in the event of disputes related to charter parties, ship building contracts, repair contracts and crew contracts, for example.

- War risks - Cover for losses caused by war or terrorism in respect of physical loss or damage to the ship.

2.3.5 - Class Societies

One aspect of rules and regulations which is unique to shipping is the role of the Classification Society. The first Classification Society was established in 1760 in order to give users of ships, such as merchants and underwriters, important and impartial information on the quality of their ships (International Association of Classification Societies, 2011). This information could then be presented to marine insurers prior to them covering the risk. A book titled the 'Register Book' was compiled and it included information on the quality of the ships inspected. Each ship was given a rating or 'class' after the structure and equipment of the ship had been inspected. The highest classification being 'A1' meaning 'first or highest class'. Since the formation of the first Classification Society, now called Lloyd's Register, other Classification Societies were established along similar principles.

2.3.6 - Port State

Inspections are carried out by the national state authority on foreign ships entering their ports. This is known as Port State Control (PSC). The inspections verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules (IMO, 2019). Port State inspections were originally intended as a back up to Flag State inspections, but now they ensure compliance with regulations relating to safety of life at sea, pollution by ships, and living and working conditions onboard ships (Paris MoU, 2014).

2.3.7 - Flag State

Each ship must have a nationality and a related identification sign; this is created when the owner of the ship registers the ship with a country or state. The ship is then allowed to fly the flag of that country or state. Once registered, the ship then comes under the jurisdiction of that country or state and must abide by its laws and regulations. If the country is a member state of the International Maritime Organisation (IMO), then the IMO laws and regulations form the basis of the Flag State's regulatory framework. However, they may also apply specific additional rules and regulations as they see fit.

2.3.8 – International Maritime Organisation

The International Maritime Organisation (IMO) is the United Nations specialised agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships (IMO, 2018). It was formed to provide an international framework for shipping legislation and met for the first time in 1959 (then known as Inter-Governmental Maritime Consultative Organisation, or IMCO until 1982). The framework that it works under has to be fair and effective and one that can be readily accepted, adopted and implemented universally.

2.4 - Accidents in the Shipping Industry

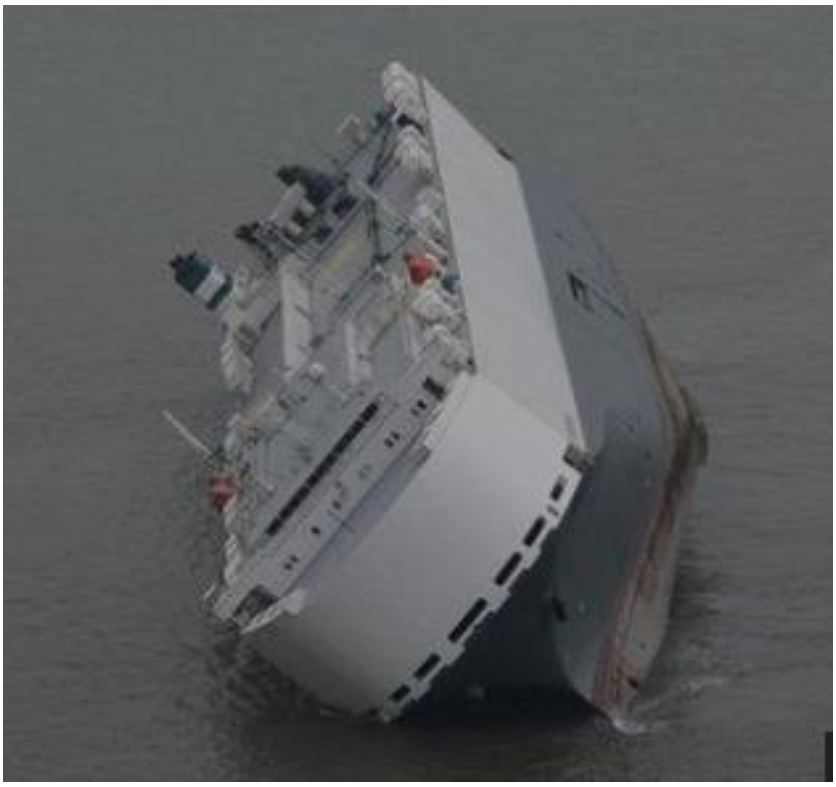
The shipping press publishes medium and high-profile incidents and accidents that may have an indirect impact on other areas of shipping or has a public interest angle. Examples include the Mediterranean Shipping Company container ship fire in 2012 (Tradewinds, 2018) which resulted in additional liabilities for the manufacturer of the chemicals, or the collision in 2018 between the Norwegian frigate and the Sola TS (Tradewinds, 2018).

However, many minor incidents go unreported. There are several reasons for this including the commercial sensitivity of publicising relatively minor incidents. This may then affect the trading ability of a company's fleet, not just the affected ship. Other reasons that incidents go unreported may be due to the relatively closed nature of the shipping industry and the global nature of the business. This means that experience sharing is difficult, and therefore

lessons learned are rarely passed directly between shipping companies. Some industry bodies do share experience, however this is usually kept within the members and may not even be passed to non-member operators of sister ships.

Baniela and Vinagre-Ríos (2013) concluded that there is a significant relationship between the safety standards and the severity of shipping accidents. Additionally, they found that this relationship showed that there was a tendency of substandard vessels to suffer more serious accidents than others. However, some of the more recent serious accidents include cruise ships and gas carriers, some of the more regulated shipping types.

Two accidents occurred in the first week of 2015, with both ships operating in areas of the United Kingdom, a jurisdiction with high safety standards and the regular inspection of ships calling at British ports. The first accident involved the Höegh Osaka built in 2000.



Höegh Osaka. (Höegh Autoliners, 2015).

While there were no fatalities, the ship grounded on the Bramble Bank outside the port of Southampton on 4th January and ultimately capsized in the busy

shipping channel (Höegh Autoliners, 2015). All 25 people onboard the ship were evacuated safely and the cause of the accident is to be investigated by the United Kingdom's Marine Accident Investigation Branch (MAIB). On 2nd January, the 1984 built cement carrier 'Cemfjord' sunk in the Pentland Firth with the loss of all 8 crew members. The ship sunk to the bottom of the North Sea and the hull may be recovered in the future in an effort to recover the bodies of those lost and to assist with the investigation. Again, the accident will be investigated by the MAIB (Press and Journal, 2015).

Cemfjord. (Royal National Lifeboat Institution, 2015).

Further, two recent, high profile, accidents underscore the part human error may play in accident causation:

> The Costa Concordia, a modern cruise ship built in 2006, sank in waters off the island of Giglio, Italy in 2012. Italian Defence Minister Giampaolo Di Paola, a former Italian navy admiral, blamed "gross human error" for the disaster in comments to Rai3 television on Sunday (Daily Telegraph, 2012).
>
> In 2014, the ferry 'Sewol' sank three hours from its destination in the southern resort island of Jeju, Republic of Korea. The ferry was carrying 475 people onboard at the time of the tragedy with approximately 270

> lost. Many of those that perished were school children on a class trip. South Korea's early response was to point to 'human error' and seek the arrest of the ferry's captain, first mate and another crew member (New York Times, 2014).

The part human error plays in accident causation is beginning to be recognised by industry bodies such as the International Maritime Organisation (IMO) and insurance companies, although legislation focusing on this aspect has not been forthcoming. In 2003, IMO updated their Human Element Vision, Principles and Goals (IMO, 2014) for the Organisation. This included two references to human error:

> In the process of developing regulations, it should be recognised that adequate safeguards must be in place to ensure that a "single person error" will not cause an accident through the application of these regulations.
>
> Consideration of human element matters should aim at decreasing the possibility of human error as far as possible.

In 2008, the Swedish Club in their newsletter (The Swedish Club, 2008) stated that 'It is also known that accidents due to human error are increasing' and 'Addressing the human side of shipping must be the most effective approach for increasing safety'.

As the world fleet grows and the pressure on the supply and training of experienced seafarers continues, the focus on preventing accidents increases. When accidents occur they are usually due to multiple causations, and in many cases, the chain of events has human involvement. Therefore, identifying human factor issues in both the shore and ship organisations prior to accidents occurring, such as in the case of near miss programmes, may prevent more serious incidents or accidents happening in the future. Lessons learned from identifying human factor issues can be formally introduced in the form of both corrective and preventative actions.

2.5 – Chapter Summary

This chapter provides necessary background concerning the nature of the global fleet including the contribution shipping makes to world trade and describes the recent growth of the world commercial shipping fleets. It also provides detail concerning key stakeholders in the industry as an overview of their roles in the shipping system. This information provides the foundational understanding of the shipping industry and the players involved.

Finally, it highlights two serious accidents which occurred, both with loss of life. These accidents had contributory factors related to human error, according to initial reports. However, despite the emerging attention human error in marine accident causation has received and continues to receive, published statistics and databases concerning accident investigations generally fail to account for the human factor element in marine accidents.

The next chapter will consider the regulatory landscape in the shipping industry, considering the requirements that ship operators have to comply with, and the players involved in ensuring compliance with the legislation. It will also discuss third party regimes in certain sectors of the industry.

3

The Regulatory Landscape and Shipping

Contents

3.1 - Introduction
3.2 - Legal Framework
3.3 - The International Convention for the Safety of Life at Sea (SOLAS)
3.4 - International Management Code for the Safe Operation of Ships and Pollution Prevention
3.5 - Flag State
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3.7 - The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)
3.8 - Safe Manning
3.9 - Port State
3.10 - International Convention for the Prevention of Pollution from Ships (MARPOL)
3.11 - Third Party Ship Inspection
3.12 - Legislative Timeline
3.13 - Chapter Summary

3.1 – Introduction

This chapter introduces the background to shipping legislation, highlighting that in many instances, legislation was retrospectively introduced after a serious accident. This is similar to many industries, particularly in the transport sectors. The main legislative regulations are explained, together with an assessment of the impact the legislation has on safety aspects of shipping operations. The role of Flag State, the Classification Societies and Port State

are described, together with the influence they have had on improving safety in the industry. Finally, the role that third parties have played in improving safety in certain sectors of shipping is described.

Shipping is truly a global industry, particularly with respect to legislative matters and owning operating structures. A ship may be owned in one country, the technical management may be carried out in another country, the crews may be supplied from several countries and the ship may be registered in a country which has no relationship with any of the other countries. This all makes for a set of complex requirements which ship owners and managers must comply with. It is additionally complicated when a fleet consists of ships owned and flagged in a number of countries, with different Classification Societies and different nationalities operating that fleet.

Traditionally, and with respect to regulation, shipping is a highly prescriptive industry. Flag State requirements, Classification Society Rules and Regulations and international maritime authorities' regulations are just some of the bodies that impose different requirements on the shipping industry. The requirements are broad in scope covering areas such as the design and construction of ships and the operation of the ships after delivery from the shipyard.

3.2 – Legal Framework

Historically, the introduction of new shipping legislation has followed an accident. This approach is not dissimilar to other industries approach to legislation. For example, the 'Piper Alpha' accident with the loss of 167 lives in 1998 resulted in a formal inquiry under Lord Cullen. The Formal Report (The Public Inquiry into the Piper Alpha Disaster, 1990) of this accident recommended fundamentally changing the regulatory system in the UK offshore sector from a prescriptive regime to one requiring a safety case in which the operator ensures that all hazards and major accident risks have been identified and measures have been, or will be, implemented to control those risks (Statutory Instrument No.3117, 2005). Moving to a 'safety case' legislative system effectively moved the UK offshore sector from a prescriptive to a proactive regime.

The Kings Cross underground station fire in 1987 resulted in 31 fatalities. The accident was investigated by the Department of Transport under Desmond Fennel OBE QC (Department of Transport, 1988). In addition to finding physical shortcomings with the fire prevention design of the station, including a lack of smoke detectors and only a manual water spray system, the inquiry also found that staff were poorly trained and unprepared for an emergency. The inquiry produced a total of 157 recommendations. These recommendations included requirements for inspection of hardware, minimum fire-fighting equipment installations, communications, emergency procedures, training of staff and, most importantly, the management and auditing of safety. Fennel also commented on the state of legislation with respect to fire certification and its applicability to underground stations. In 1989, The Fire Precautions (Sub-surface Railway Stations) Regulations (HMSO, 1989) were introduced and in addition, smoking was banned in all underground stations.

Both the accidents at Piper Alpha and Kings Cross occurred in what could be considered ‘mature’ industries, as the rail and offshore industries have both been well established for many years in the UK. Legislation in these industries has evolved over the years based on both operating experience and incorporating lessons learned after an accident. The safety practices of the companies involved have also evolved over the years, with further practices and culture developing as management systems mature. However this is not to say that either practices or culture improve over time, it simply changes when necessary.

The same challenges have faced the shipping industry with a growing world fleet, more sophisticated ships, many new entrants to the industry and also the cyclical nature of the industry, which may affect both investments and operating costs. Shipping legislation has been reactive, mainly due to high profile accidents which occur and are widely publicised by the press. Considering the history of the industry in comparison to other industries, there may indeed be a case for moving to a less prescriptive regime and using the safety case model of other industries.

3.3 - The International Convention for the Safety of Life at Sea (SOLAS)

An early example of shipping legislation being introduced after an accident relates to the Titanic in 1912. The British Wreck Commissioner's Inquiry (The Titanic Inquiry Project, 2014) found 'that the loss of the said ship was due to collision with an iceberg, brought about by the excessive speed at which the ship was being navigated'. After the tragedy, the first 'International Convention for the Safety of Life at Sea (SOLAS)' was signed in London in 1914 (IMO, 1974). Since the Titanic disaster, the Convention has been updated four times; in 1929, 1948, 1960 and 1974. In 1929, 18 countries attended a shipping safety conference in London. This conference covered areas including ship construction, lifesaving equipment, fire prevention and fire-fighting, wireless telegraphy equipment, navigation aids and rules to prevent collisions. In 1948, due to the 1929 SOLAS conventions being overtaken by technical developments, another conference was held in London which focused on a wider range of ships and also went into considerably more detail than the previous conferences.

IMO met for the first time in 1959 (then known as Inter-Governmental Maritime Consultative Organisation, or IMCO until 1982). It met in the following year of its formation to modernise the SOLAS regulations, taking into consideration the continued technical developments in the industry. The intention of IMCO after the 1960 conference was to issue regular updates to the SOLAS convention. However, it was found that, due to procedural requirements of the member states, it was impractical to do this within a reasonable timeframe. Therefore, at the 1974 conference, which was attended by 71 countries, the update included a 'tacit acceptance procedure' which in effect 'provides that an amendment shall enter into force on a specified date unless, before that date, objections to the amendment are received from an agreed number of Parties'. Due to this procedure, the Convention is now known as 'SOLAS, 1974 as amended' and forms the cornerstone of shipping safety legislation today.

More recently, in response to two tragedies relating to Ro-Ro ferries, the capsizing of the Herald of Free Enterprise in 1987 and the loss of the Estonia

in 1994, IMO adopted a series of amendments to the SOLAS regulations to ensure similar accidents do not occur again.

The Roll-on/Roll-off passenger ferry Herald of Free Enterprise was carrying 80 crew, 81 cars, 47 freight vehicles, three other vehicles and 459 passengers when it sailed from Zeebrugge on 6th March 1987. The ship capsized minutes after leaving the inner harbor and came to rest on a sandbank on its port side. More than 150 passengers and 38 crew members lost their lives. The formal investigation (Sheen, 1987) had a number of immediate recommendations affecting safety of the ship. These recommendations included installation of indicator lights and closed-circuit television, berth alterations, loading and stability improvements (including draught gauges, freight weights, weigh bridge certificates), and life-saving equipment upgrades (including emergency lighting, life-jackets, toughened glass, means of escape and movement facility in a ship on her beam ends). In addition, there were actions recommended for the near future including definitions, provision of stability information, growth of lightship and responsibility for stability during unloading/loading.

However, the official report also had eight longer term recommendations relating to design, calculation of stability in the damaged condition, the Inter-Governmental Maritime Consultative Organisation Regulations 1974 (IMCO, 1995) including; survivability in a seaway, ships built under the 1960 Convention and the 1965 Passenger Ship Construction (PSC) Rules, future design considerations, downflooding and air pipes and vehicle deck drainage. Due to the seriousness of the accident and the number of recommendations from the official report, the United Kingdom went to IMO in 1988 and subsequently, there were a number of amendments to SOLAS reflecting the recommendations culminating in the 'SOLAS 90' standard (IMO, 2014) relating to the stability of passenger ships in the damaged condition.

Spurred on by Lord Justice Sheen's criticism in his Formal Investigation report of the Herald of Free Enterprise, management failures by the shore organisation, which he described as 'the disease of sloppiness', IMO adopted Resolution A.647 (16) 'Guidelines on Management for the Safe Operation of Ships and for Pollution Prevention' in 1989 (IMO, 1989). However, the

guidelines were not compulsory nor enforced at this time. The purpose of the guidelines was to provide a framework for those involved in operating ships with respect to safe operations and pollution prevention, with an objective of the guidelines to 'ensure safety, to prevent human injury or loss of life and to avoid damage to the environment, in particular, the marine environment, and to property.

The Roll-on/Roll-off passenger ferry Estonia was carrying 989 onboard, of which 803 were passengers. The ferry left Tallin, Estonia, on the 27th September 1994 at 1915 hrs with a destination of Stockholm, Sweden. After just over six hours into the voyage, a first mayday call from the Estonia was received at 0122 hrs. Search and rescue efforts were immediately instigated from the Maritime Rescue Co-ordination Centre (MRCC) in Turku, Finland. The ship sank just one hour after the mayday call. A total of 138 people were rescued by helicopters and ships in the vicinity. The wreck was found in 80 metres of water with the ship's visor located about one nautical mile west of the wreck. (Joint Accident Investigation Commission, 1997)

Due to the impact on design and operations of new and existing ships, IMO set up a special panel commissioned to investigate all safety related aspects of Roll-on/Roll-off passenger ferry design and operations. In 1995, the SOLAS Conference adopted a number of amendments to the SOLAS 1974 Convention (Resolution MSC 46 (65) Adoption of Amendments to the International Convention for the Safety of Life at Sea) which entered into force on 1st July 1997 (IMO, 1995). The amendments were based on proposals put forward by the panel, with one of the most important concerning the requirements for the bow doors and the stability of Roll-on/Roll-off passenger ships. In addition, the Conference agreed to significantly upgrade the damage stability requirement to be applied to all existing Roll-on/Roll-off passenger ships.

Another relatively recent accident at sea which affected legislation was the fire onboard the Scandinavian Star which resulted in the loss of 159 lives in 1990. (Germanischer Lloyd, 2006). This tragedy resulted in IMO introducing and improving legislation aimed at fire protection and evacuation under the SOLAS

1992 Fire Safety Amendments. The amendments covered areas such as automatic sprinkler and smoke detection systems (similar to hotel requirements), and the upgrading of fire safety bulkheads to non-combustible materials and improved methods for assisting escaping persons, such as use of low location lighting (IMO, 2014). IMO recognised in this document that the existing SOLAS fire protection requirements had no support structure to review and approve novel designs and features, i.e. the prescriptive regulations to this date had not encompassed technical developments in the field of fire protection. Also, in the IMO history of SOLAS fire protection requirements, they highlight the lack of focus on the human element issue in previous legislation and amendments 'given that 80% of maritime casualties are attributed to human factors' (IMO, 2018).

As previously highlighted, the number of maritime casualties attributed to human factors by IMO above is an interesting figure as it correlates with other academic (Rothblum, 2000 and Perrow, 2011) and industry research (Allianz, 2018).

3.4 - International Management Code for the Safe Operation of Ships and Pollution Prevention

Following the three very serious accidents previously described, IMO reacted and adopted the previously introduced 'Guidelines on Management for the Safe Operation of Ships and for Pollution Prevention' as the International Management Code for the Safe Operation of Ships and Pollution Prevention, the ISM Code (Resolution A.741(18) International Management Code for the Safe Operation of Ships and for Pollution Prevention, International Safety Management (ISM) Code) (IMO, 1988). However it was not until 1st July 1998 that the ISM Code became mandatory.

Initially, the Code was applicable to passenger ships, including high speed passenger craft, oil tankers, chemical tankers, gas carriers, bulk carriers and high-speed craft of 500 gross tonnes or more (IMO,1993). In 2002, the application of the Code was extended to other cargo ships and mobile offshore drilling units (MODUs) of 500 gross tonnes or more (IMO, 2002).

The introduction of this piece of legislation was seen as a step change by both charterers and owner/operators of tonnage. The objectives of the Code were numerous; to ensure that there are provisions within the safety management system, to provide practices for safe working, and ensure there is a safe working environment onboard. The Code also established that there should also be provision for those operating ships to have the necessary tools in order to assess risks associated with the operation of the ship and related to the ships, personnel and the environment.

The system based on the Code should be dynamic, meaning mechanisms should be in place to continuously improve the system. Practically, this means the management system must be formally reviewed once per year, with other feedback mechanisms in place in order to improve or correct procedures for example.

Several studies of the ISM Code have been completed assessing its effectiveness. Very soon after the introduction of the Code relating to the second phase of ship types was implemented, Anderson (2002) asked the important question; 'are marine accidents reducing?'. Anderson's early research indicated that problems with the introduction of the Code were primarily due to the way the Code had been implemented by individual shipping companies; some had bought 'off the shelf' safety management systems and others had developed their own. A shipping company developing a system themselves may not have appreciated the complexities of introducing such a system. Conversely, buying a system 'off the shelf' may not have been totally suited to the company's needs.

Additionally, the perception of how the system was working between ship and shore differed between the parties actually using the system. Anderson also highlighted issues with general communications, although this was not specified in the summary of the research.

Another common issue concerned complaints from both shore and sea staff about how much paperwork the Code had unnecessarily introduced. This may have been the case when the systems were immature and companies introduced many procedures and checklists in order to meet the Code

requirements. However, with continuous improvement, systems have matured and seafarers now better understand the requirements for the formalisation of many of their practices. This has resulted in more focused systems.

When the Code was introduced, many ship owners and managers probably underestimated the education and training required for the seafarers. Indeed, Anderson found that due to a lack of training, there was probably a misconception of the impact of the Code on the seafarer.

Finally, Anderson comments on the different attitudes between seafarers from OECD and non-OECD countries, noting that seafarers from OECD countries had a more negative attitude than those from non-OECD countries to the introduction of the Code. Anderson suggests that this may be due to the OECD seafarers being older and less receptive to change as compared to the generally less-experienced non-OECD seafarers who are generally more positive.

A more recent study by Tzannatos and Kokotos (2009) analysed accidents in Greek shipping before and after the introduction of the ISM Code. This review used information submitted to the Hellenic Coast Guard for the purposes of conducting an official investigation. Ships under 500 deadweight tonnes were excluded due to the non-application of the ISM Code to these ships. After review of the data, the dataset considered 268 shipping accidents. After applying a classification tree algorithm to the accidents, the researchers concluded that the main initial benefit from the introduction of the Code was its positive impact upon the control of the human element in accident causation in tankers and Ro-Pax vessels; that is vessels that were considered the most vulnerable. Unfortunately, the results also showed that the Code had had little impact in the area of accident reduction where navigational location is a factor, particularly in restricted waters. This was applicable for both human and non-human sources of accidents which had navigational location as an influence.

However, this study has limitations. The age of some of the ships used for the study was not considered reflective of the world fleet. For example, the age of tankers used when considering the accident rate was very old (27+ years) and the age of container ships was also high (23 – 26 years). While this may have

been the average ages for the Greek fleet considered, the United Nations in their Review of Marine Transport (2009) reports average ages of tankers to be 17.5 years and for container ships 10.9 years for the world fleet. For developed countries, average ages of tankers is reported to be 14.2 years and for container ships 9.8 years. The sample size of ships considered was very low, and for some ship types such as container ships and Ro-Pax, the sample size was extremely low; 13 and 4 ships respectively. The sample set that was considered was based on the prerequisites for the Hellenic Coast Guard, meaning a Greek flagged vessel or an accident occurring in Greek territorial waters. Therefore, the geographical extent of the review is very limited.

IMO conducted a study into the effectiveness of the ISM Code between 2004 and 2005 (IMO, 2005). The parties contacted were of a similar nature to Anderson's study of 2002 and included seafarers, shore-based personnel, Administrations, Port State Control, the classification society association (IACS) and Protection and Indemnity Insurance Clubs. A total of 3,109 respondents participated in the survey. The group concluded that there are tangible benefits when the ISM Code is 'embraced as a positive step towards efficiency through a safety culture' (IMO, 2005, pp 2). Other conclusions focus on simplifying and reducing the administrative process and more use of technology to reduce the requirements for paper work, and the relationship between Port State Control and ISM compliance, which requires further study.

One of the recommendations from IMO's study was that a further study should be undertaken to consider several issues including whether changes to the ISM Code could make compliance easier and in turn give an improved safety culture onboard. However, to date, this further work has not been completed and therefore, there is scope for new research which would consider the effectiveness of a safety management system.

In 2008, Bhattacharya considered the effectiveness of the ISM Code from a qualitative perspective using a case study approach (Marine Policy, 2012). He concluded that while onshore managers see the ISM Code as legislation that is imposed on the ship for the benefit of safety and health, including its formalised practices and procedural requirements, seafarers saw it as

something they had to comply with as a piece of legislation, while at the same time restricting their ability to use their knowledge and experience to protect them from risks and hazards. However, he noted that the seafarers did comply with the Code, albeit seeing it as additional bureaucracy.

Apart from Bhattacharya's work, there has been little recent work published regarding the effectiveness of the ISM Code in practice. Anderson's work in 2002 remains one of the few to consider the various aspects of the Code, but in the years following the introduction of the Code, many factors affecting the effectiveness of the Code have changed, not least the number of seafarers recruited to the industry.

3.5 - Flag State

As described in Chapter 2, each ship must have a nationality and a related unique identification sign. The ship is then allowed to fly the flag of that country or state. Once registered, the ship then comes under the jurisdiction of that country or state and must abide by its laws and regulations.

Flag States usually appoint inspectors via a recognised organisation to check compliance with the rules and regulations by way of conducting the appropriate surveys of ships. These recognised organisations are often Classification Societies, such as Lloyd's Register, DNV GL, American Bureau of Shipping or Bureau Veritas. Flag States are also responsible for conducting accident investigations, as prescribed under SOLAS regulation I/21 and MARPOL articles 8 and 12 (IMO, 2014). This requires each Flag State to carry out an investigation into any shipping casualty under its administration. The Flag State then has a responsibility to supply IMO with any pertinent information relating to the accident. There is additional legislation contained within the United Nations Convention on the Law of the Sea (UNCLOS), article 94, on Duties of the Flag State (United Nations, 1982). This also requires the Flag State to hold an inquiry into any accident 'causing loss of life or serious injury to nationals of another State or serious damage to ships or installations of another State or to the marine environment'.

While every ship must have a nationality, this may or may not be the same state as the ship's owners. When the ship owner assigns a nationality to a

ship which is not the same as the owner's nationality, it is known as a 'Flag of Convenience' (FoC). Flags of Convenience have been used throughout the years, one of the main reasons being to avoid certain restrictions, such as the Spanish flag being used by British ships in the 16th century to overcome existing trade restrictions in the West Indies (Llácer, 2003). More recently, certain nations have been developed as 'open' registers. These are states that will accept vessels to be registered from other nations with virtually no restrictions (Alderton and Winchester, 2001). This development occurred between the two world wars, when some United States passenger ships were transferred to the Panamanian Flag to avoid prohibition laws and some European owners also re-flagged to Panama in order to decrease their operating costs (Alderton and Winchester, 2001).

Over the last 60 years, the adoption of FoCs has grown amongst ship owners and according to the International Transport Workers' Federation (ITF), over 22 per cent of the world's vessels sail under FoCs and over 51 per cent of the world's tonnage is registered under a FoC (International Transport Workers Federation, 2014). The International Transport Workers' Federation also highlights that 'over a third of the vessels lost at sea are FoCs' and a 'disproportionately high amount of the total tonnage lost at sea, almost half, is registered under a FoC' (International Transport Workers Federation, 2014).

The ITF defines and declares a FoC firstly by considering the number of non-national i.e. foreign ships that are registered to the state. In addition, a state's safety and environmental record is considered, its social record covering areas such as the enforcement of international labour conventions and the willingness of the Flag State to enforce international minimum social standards (including respect for human and trade union rights) (International Transport Workers Federation, 2014). The ITF declares a total of 34 countries as FoC.

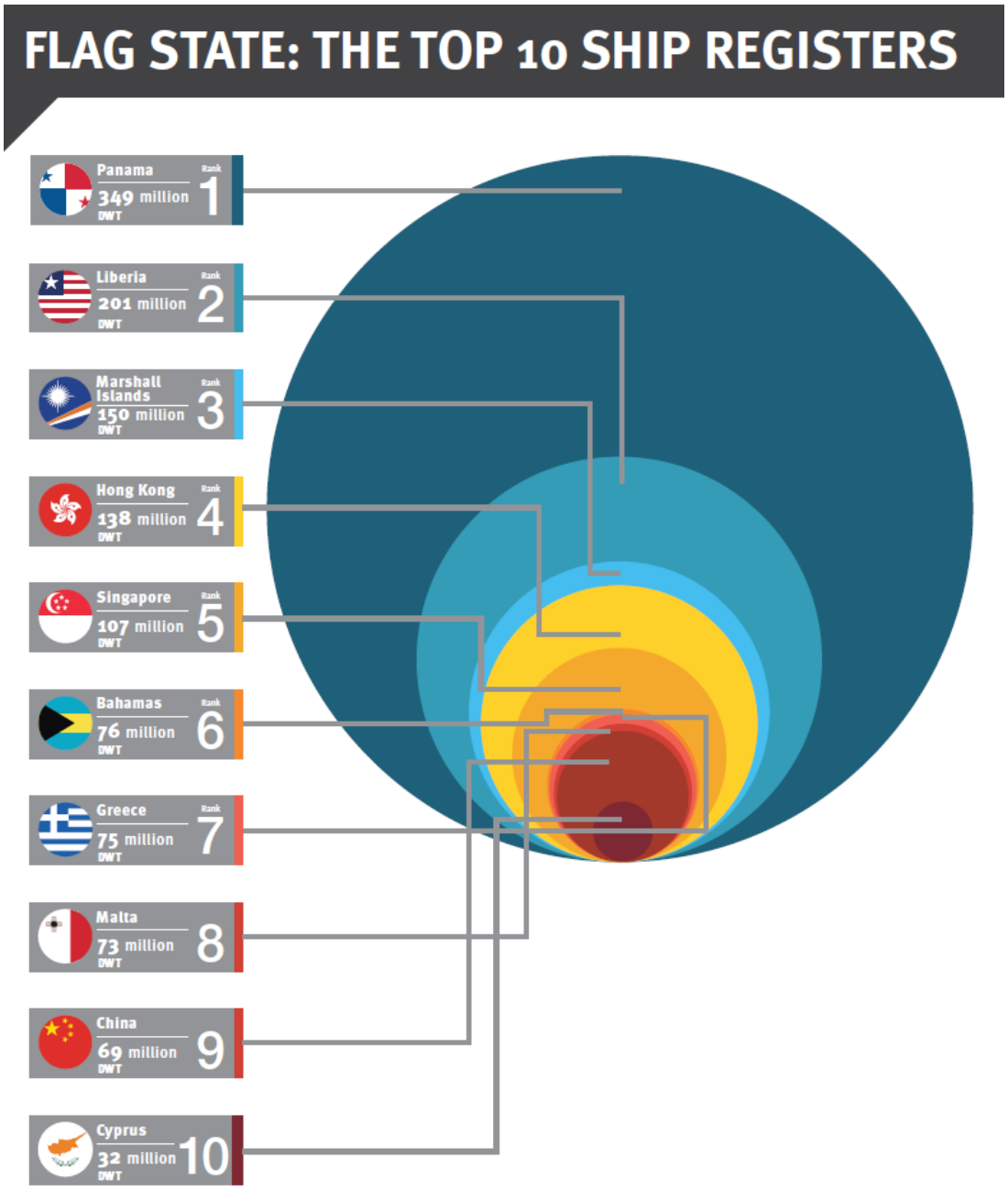

Figure 5 - The Top 10 Ship Registers by DWT. (Lloyd's List Intelligence, 2014).

The public perception, and that of some industry bodies such as the ITF, is that ships that are operated under FoCs are operated with poorly paid crew and with poor onboard conditions. As stated below, one of the reasons for the introduction of Port State Control was to monitor those Flags with relatively poor safety records. This, together with the introduction of Maritime Labour Convention (MLC), 2006 (International Labour Conference, 2006) should ensure that there is a uniform quality of ships trading and a minimum standard of conditions for the seafarers serving onboard.

Considering the top ten Flag States by deadweight as shown in Figure 5 and comparing it with the Flag States that have been declared Flags of Convenience by the International Transport Workers' Federation, the top 10 ship registers by deadweight include six states that are on the ITF list of Flags of Convenience; Panama, Liberia, Marshal Islands, Bahamas, Malta and Cyprus. These represent 881 million deadweight of a total world fleet of 1270 million deadweight or 69.4%.

In ongoing debates regarding the registration of ships, generally the discussion focuses between the traditional flags of maritime nations and flags of convenience. However, Alderton and Winchester (2001) also concluded that there are also distinct differences between Flags of Convenience, particularly between new entrants to the market and the established registers. One of the key differences cited by Alderton and Winchester (2001) is that new entrants to the industry, such as non-traditional ship owners and financial institutions, may have a resentment to the possibility of regulation, considering that regulation is a threat to their income generating powers.

Even though many Flag States are a member state of IMO and therefore IMO rules and regulations should be forming the basis of the Flag States regulatory framework, there are still wide differences in the performance of the Flag States, so much so that the International Chamber of Shipping produce an annual report on their performance (International Chamber of Shipping, 2014)). Six main criteria are used to assess the performance of Flag States:

- Port State Control - One of the simplest means of assessing a flags compliance and enforcement of international rules is to review the Port State Control records of ships flying a particular flag.

- Ratification of Major International Treaties - As an indicator of compliance with the international standards, the ratification of international maritime Conventions is considered. However, it should be noted that ratification does not mean enforcement.

- Use of recognised organisations complying with A.739 - As stated above, Flag States often appoint recognised organisations (ROs) to conduct survey works. In relation to this, IMO Resolution A.739(18) 'Guidelines for the Authorization of Organizations Acting on Behalf of the Administration' (IMO, 1993) requires Flag States to establish controls over such organisations. This will include ensuring the bodies have adequate resources for the tasks assigned to them.

- Age of Fleet - As a Flag State that has a younger age of ships is more likely to attract quality tonnage than a Flag State with an older age profile, this is seen as a positive indicator. However, a Flag State which does have an older fleet profile does not necessarily mean the fleet is sub-standard.

- Reporting Requirements – Flag States that have submitted compliance and practice reports as required by International Labour Organisation (ILO) is seen as a positive indicator.

- Attendance at IMO Meetings – As it is considered that Flag States that attend major IMO meetings have a higher regard and commitment to the implementation and enforcement of IMO rules, this is seen as a key indicator.

The IMO publishes a performance table annually. This allows ship owners and other interested parties to assess the performance of a particular Flag State and additionally, in the case of a ship owning entity, assist them to make a choice regarding the selection of a Flag. For example, the performance table for 2013/2014 shows Panama, the largest Flag of Convenience by deadweight, as having 15 out of 18 positive performance indicators. It shows Liberia and the Marshall Islands, the second and third largest, having all positive performance indicators. This is as good a performance as established national flags such as France, Greece, Japan, The Netherlands, Norway, the Russian Federation and the United Kingdom.

Flags of Convenience now have large energy majors as their customers (for example, Shell uses the Bahamas as their Flag on some of their gas carriers) and also they have sophisticated ship types such as offshore units and gas carriers operating under their jurisdiction. It may be said that in recent years the standard of Flags of Convenience has increased to that approaching that of national flags. Of course, there will always be sub-standard ships. Whether they have migrated to other Flags of Convenience with lower standards or operate in other areas with a lower commitment to legislation and safety matters, maintaining a consistent standard for all shipping remains difficult.

3.6 - Classification Societies

The remit of the Classification Society covers the design and construction of ships, and includes approval of the plans for the design of ships. Inspections or surveys are carried out by appointed surveyors of the Classification Society during construction to ensure the ship is built in accordance with its Rules. Once the ship has entered service and been given a classification, the Society's surveyors attend the ship to carry out periodical surveys in order to verify that the ship remains in compliance with its Rules. If an Owner becomes aware of any defects between surveys that may affect the Classification of the ship, then the Classification Society are to be informed. Their action will be dependent on the severity of the defect and may be noted (as a Memorandum on the Classification Certificate) or in more severe cases as a Condition of Class which requires rectification within a required time frame. It is extremely unusual for a Classification Certificate to be withdrawn as this then prohibits the ship owner from trading the ship.

Classification Society Rules are prescriptive and have evolved over the years. The Rules have been developed based on the Classification Societies experience in classing many ships over the years and in-service experience. Additional development of the Rules is by research into areas of technical change or development. An example of this would be the recent interest in the fuelling of ocean-going ships by Liquefied Natural Gas (LNG). Prior to the interest generated by this new development to replace liquid fuelled engines by gas fuelled or dual fuelled engines, there were no specific rules or

regulations applicable to such a design. They have however been recently developed and will evolve as the design of such ships develops. It is also important to note that the classification of a ship is based on the understanding that the ship owner loads the ship within its design limits, the ship is manned by competent and qualified crew, and operated and maintained in a proper manner. However, the safety of its seafarers and integrity of the ship always remains the responsibility of the ship owner.

To ensure uniformity, the International Association of Classification Societies (IACS) (2014) ensures that its 12 members apply consistent standards to their rules and regulations. Currently, over 90% of the world's cargo carrying commercial shipping is covered by classification design, construction and through-life compliance rules and standards.

It has been previously stated that shipping legislation is very prescriptive. However, one area that IMO has taken a new goal setting approach is in the case of a new regulatory framework for hull structures of oil tankers and bulk carriers (IACS, 2011). Within this framework, it is up to IACS members to establish the specific rule criteria to support the goals. This legislation will introduce a culture of bench-marking, backed by functional risk-based requirements.

3.7 - The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

Like the introduction of other shipping legislation, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) was introduced after several high-profile accidents, including the Torrey Canyon in 1967, to establish basic requirements on training, certification and watchkeeping for seafarers on an international level. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) was adopted in 1978, but did not enter force until 1984 (IMO, 1978). It was the first major legislation to consider human aspects of ship operations.

When introduced, the Convention focused on training, certification and watchkeeping duties for seafarers on an international level. Up to the

introduction of this Convention, these areas were the responsibility of individual governments. This resulted in differing standards being applied throughout the industry. One important requirement of the Convention applies to ships of non-party Convention states when visiting ports of states who are parties to the Convention. This scenario forced many ships to be compliant with the Convention soon after its introduction and by the year 2000, 135 parties had signed up to the Convention which represented 97.53% of the world's shipping tonnage (IMO, 2011). Specifically, the Convention considered basic principles to be observed when deck and engineering officers are holding a watch, minimum requirements for certification, additional training requirements for seafarers responsible for cargo on tankers, and it established the requirements governing the issuing of certificates in survival craft training.

The first amendment to the STCW was in 1991 and this applied to new technology relating to the introduction of the Global Maritime Distress and Safety System (GMDSS). This was followed by the next amendment in 1994 which was related to special training requirements for personnel on tankers. An additional 1995 amendment was a major revision in order to update the Convention and also to clarify some of the phrasing in the document to reduce ambiguity. Some of the more important amendments included enhanced procedures to allow a Port State to intervene in the event deficiencies are deemed to pose a danger to persons, property or the environment. For the first time, the 1995 amendment also included measures to prevent fatigue for watchkeeping personnel by requiring, establishing, and enforcing rest periods. New advances in training were recognised, and the usefulness of simulators, particularly in the use of radar and Automatic Radar Plotting Aids (ARPA), was established. As a result, simulator training became mandatory. The importance of seafarers' health was also recognised by IMO. The 1995 amendments introduced a requirement for all officers to meet stated fitness levels. Further, a certain level of professional competence at intervals not exceeding five years was required to be demonstrated. Other chapters in the 1995 amendments were updated, while some additional requirements were introduced including the requirement for special training and qualifications

relating to seafarers onboard RO-RO passenger ships, as well as training and proficiency related to survival craft.

The 1997 amendments focused on training and qualifications for personnel on passenger ships, with particular emphasis on safety aspects of ship operations. In 1998, amendments were introduced which were directed towards bulk carrier operations and improving the minimum standards of competence for seafarers sailing on them. The 2006 amendments introduced mandatory training and certification requirements for those seafarers appointed as the Ship Security Officer (SSO), and also additional training related to those operating fast rescue boats. The latest amendment was adopted in 2010 and again this was a major revision to the Convention. The amendments covered areas including the prevention of fraudulent practices in relation to officer certification, revised requirements relating to the hours of work and rest, additional training and certification requirements for specific ranks, some new training guidance relating to environmental awareness as well as specialised ships, and requirements for recently introduced equipment such as Electronic Chart Display and Information System (ECDIS).

IMO maintains a 'white list' of countries which are deemed to be giving 'full and complete' compliance to the revised STCW 95 Convention. To be placed on the white list, countries have had to meet certain requirements relating to the standard of education and training provided, controls relating to the licensing of seafarers, Flag State control and the validation and re-validation of certificates. If a seafarer has certification from a non-white list country then they can be rejected as part of the manning for a white listed ship. In addition, the seafarer's training and service onboard, as required for obtaining certification, may not be recognised.

Literature examining the effectiveness of STCW is very limited. However, at the 2002 Copenhagen Quality Shipping Conference, Session III on the Human Element, Andrew Winbow of IMO (IMO, 2002) stated that many of the accidents that continue to occur in the shipping industry may be prevented if seafarers had met the minimum standards required in the Convention, and if operators of ships had also fulfilled their obligations with respect to ensure all

seafarers are properly trained, experienced and competent to perform their duties. An ongoing problem relating to the Convention is ensuring fraudulent practices are not allowed to influence the issue and re-validation of certificates issued by countries. Two types of this type of practice are identified by Christodoulou-Varotsi and Pentsovby (2008). One relates to the standard of training in the establishments selected for seafarers, and the other relates to the forgery of certificates and other documents. Considering the standard of training, Helen Sampson of Cardiff University (2004) examined the effectiveness of the Convention as applied to standards in education and training of the seafarer. Three nations were considered; United Kingdom, Singapore and the Philippines. The review included visits to colleges and training centres and interviews with lecturers and trainers. This article was based on a year-long study which was funded by the British Academy. One of the conclusions of the work was that, even with legislation in place, investment in training was limited. It was highlighted that, in the past, the traditional maritime countries used to invest in training, however with the introduction of Flags of Convenience and seafarers coming from less developed countries, these resources have not been so forthcoming. Now, with the introduction of the latest STCW regulations, the seafarer is forced to educate themselves to the required minimum standard in order to obtain work onboard the international fleet or be sponsored by a shipping company or maritime training college.

Also, in the case of specialised ships, such as offshore, gas and chemical, additional qualifications are required, and while some ship owners may assist the seafarer with the costs, in other cases the seafarer has to bear the cost of the additional qualifications if he wants to sail on these types of ships. The reward for the seafarer is in the form of sailing on higher quality ships and better rates of pay and leave. For the shipping companies who operate in these sectors and are more reliant on having a pool of well trained and available seafarers, they are generally more reluctant to rely on the market forces to train and will either invest in the seafarer or attract trained seafarers from other shipping companies, usually by offering better conditions. When considering the issues of training, it also has to be remembered that the

shipping employment market is different to other employment sectors as its entire workforce works across many jurisdictions and they are also very mobile with respect to their employment. In conjunction with this, Sampson (2004) suggests that there is a failure on the part of labour supply countries to raise international standards of both training and competence due to reluctance to invest in facilities. It is likely that this is linked to the Flags of Convenience that are now well established in the industry. Prior to the acceptance of Flags of Convenience internationally, nations had training facilities to provide seafarers for the ships flying their national flag as seafarers would generally not sail on foreign nation ships.

Regarding the forgery of certificates, Winchester of the Seafarers' International Research Centre (2005) highlights that there is no centralised database that ship owners and other agencies can access in order to check the validity of certificates. Winchester also highlights that there is also a problem due to the large number of issuing institutions. This makes it difficult knowing what a particular qualification from a particular institute looks like. Of course, this risk exposure can be reduced by those wishing to check qualification validity by an audit procedure of the particular establishment, although this may become difficult when the supply of seafarers is through a number of agencies and sub-agencies and also different nationalities are involved. Nik Winchester does acknowledge that their research showed that checks are done, however this tends to be limited to institutions within one country or within government institutions.

3.8 - Safe Manning

In 1999, IMO adopted Resolution A.890(21), 'Principles of Safe Manning' (IMO, 1999). The Flag Administration is responsible for determining the 'safe manning' of a ship. This, in simple terms, means how many seafarers (numbers and qualifications) are required to operate a particular type of ship. The Resolution principles are directed at ensuring there is the capability to maintain a safe watch in all departments and to manage the safe operation of the ship at all times covering areas such as berthing/unberthing, preventing environmental damage, ensuring the safe carriage of cargo and maintaining

the structural integrity of the ship. The manning should also be capable of operating all the ship's machinery, have sufficient resources to operate emergency equipment as required, and be able to form and deploy a damage control party.

The Resolution also highlights the need for the Flag Administrations to consider other legislation issued by IMO, ILO, International Telecommunication Union (ITU) and the World Health Organisation (WHO) when dealing with the principles above, including:

- Watchkeeping
- Hours of work and rest
- Safety management
- Seafarer certification
- Occupational health and hygiene
- Crew accommodation

When considering the level of manning, the Flag Administration is required to be aware of the functions that have to be performed by the crew. These include training and the use of safety equipment, any specific crew training required for certain ship types, emergency duties and the supplying of provisions and water. The other areas that have to be considered by the Flag Administration when assessing the minimum manning level onboard are the hours of work and rest onboard during peak working to ensure there are enough qualified seafarers available to fulfill the onboard situations as they arise. Finally, consideration is given to the captain and crew complement to coordinate the activities necessary for the ship's safe operation and the protection of the marine environment.

3.9 - Port State

In addition to Flag State inspections, Port State inspections were introduced in 1978 (Federal Ministry of Transport and Digital Infrastructure, 2014). These were originally intended to back up Flag State inspections after it was considered that Flag States had not been rigorous enough in their duties related to certification and survey. The catalyst for the introduction of the inspections was the sinking of the Amoco Cadiz. The Amoco Cadiz ran aground in 1978 off the coast of Brittany (The International Tanker Owners Pollution Federation Limited, 2014). A total of 223,000 tonnes of cargo and 4,000 tonnes of fuel leaked from the ship. The resulting pollution contaminated 320 km of the French coastline and extended as far east as the Channel Islands.

Wreck of the Amoco Cadiz at Portsall. (Le Fevre, J. 2008).

In 1982, 14 European States formed the Paris Memorandum of Understanding (Paris MoU). This has since expanded to 27 maritime administrations (Paris MoU, 2014). The purpose of the MoU is to ensure that sub-standard ships do not operate in the waters of the relevant jurisdiction. Approximately 18,000 inspections take place annually on foreign ships and the inspections not only consider safety, security and environmental standards, but also the welfare of the crew, covering both their living and working conditions. In addition to the

European countries' membership of the Paris MoU agreement, Canada, Iceland and the Russian Federation are also members. One of the advantages that this gives is, with some coordination between the countries that a ship visits during its voyage, any defects or deficiencies can be closely monitored and followed up.

Since the introduction of the Paris MoU, IMO has encouraged the establishment of other regional Port State organisations and there are now nine agreements in place covering all of the world's oceans. The United States is not party to one of the MoU agreements however it operates independently and launched its own Port State control program in 1994 (United States Coast Guard, 2014). Despite this, the primary responsibility for ensuring ships meet the required standard remains with the Flag State, with the Port State acting as a backup to this inspection regime.

Several studies have assessed the effectiveness of Port State control. Cariou, Mejia Jr. and Wolff (2008) considered several aspects of the effectiveness of Port State control, finding that the majority of ships have a reduction in the reported deficiencies between earlier and subsequent inspections. However, one of the limitations of their study acknowledged by Cariou et al., is that their research did not take into consideration the seriousness of the deficiencies. Bang and Jang's (2012) research found that there are regional differences between the MoUs, and that this subsequently causes difficulties, particularly when a substandard ship avoids the stronger areas of Port State control and trades in a region where it is less likely to be targeted. Bang and Jang (2012) suggested that the MoUs and the IMO should work closely together and develop ways of tackling these ships that routinely avoid being in areas of strong Port State inspection. One such method may be a system which allows the stronger MoU regions to assist the less advanced regions with technical assistance.

3.10 - International Convention for the Prevention of Pollution from Ships (MARPOL)

After a number of large oil spills, including the Torrey Canyon incident, the International Convention for the Prevention of Pollution from Ships was

adopted in 1973 and updated in 1978 after further pollution incidents from oil tankers (IMO, 2015). The convention covers the prevention of oil pollution, not only during routine operations but also in the event of an accident. Both Flag State and Port State authorities have the authority to ensure ships are operating within the MARPOL convention.

Since the introduction of the initial legislation focusing on oil pollution, several annexes have been adopted. These annexes have added the Control of Pollution by Noxious Liquid Substances in Bulk (Annex II), Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (Annex III), Prevention of Pollution by Sewage from Ships (Annex IV), Prevention of Pollution by Garbage from Ships (Annex V) and, in 2005, Prevention of Air Pollution from Ships (Annex VI) (IMO, 2005).

There has been considerable research published on the effectiveness of MARPOL, mostly focusing on the first Annex relating to the prevention of oil pollution. Lagring et al. (2012) consider the decrease in oil pollution in the North Sea and conclude that there has been a significant reduction in the number of oil spills in the region, while shipping traffic in the region has increased. However, it is worth noting that the researchers also state that the legislation introduced cannot be solely attributed to the reduction in oil pollution. Additional measures such as other preventative, deterrent and enforcement measures at a regional, national and international level have also contributed.

3.11 - Third Party Ship Inspection

Within the shipping sector, in addition to shipping legislation, ship owners in specific sectors are subject to third party inspections by industry bodies who in turn share the results of these inspections with charterers or potential charterers of ships. Many of these inspections were brought into being in an effort for standards to be raised over and above that required by legislation and to ensure ships are being maintained and operated to a standard required by the charterers.

The most rigorous inspections are associated with the gas, oil and chemical tanker sectors. The Oil Companies International Marine Forum (OCIMF) is a

voluntary organisation (OCIMF, 2014) established in 1970 after the Torrey Canyon oil spill incident in 1967 which resulted in 120,000 tonnes of crude oil leaking from the ship (Centre of Documentation, Research and Experimentation on Accidental Water Pollution, 2014). Members of the Forum include National Oil Companies such as GazProm of Russia and Qatar Petroleum of Qatar. Other members are major energy companies such as BP and Shell. The Forum was formed in order to respond to the public's growing concern about oil pollution from oil tanker incidents. The Forum also provides expert advice to bodies such as IMO on the transportation and handling of hydrocarbons by sea.

One of the major incentives to improve safety standards on tankers was the introduction of the Ship Inspection Programme (SIRE) in 1993 by OCIMF (OCIMF, 2014). The programme has been developed as a risk assessment tool and considers a number of specific areas of ship maintenance and operation. Central to the inspection regime is the Vessel Inspection Questionnaire for Oil Tankers, Combination Carriers, Shuttle Tankers, Chemical Tankers and Gas Tankers. This document forms the basis of the physical inspection by an attending inspector. The inspection covers both hardware of the ship, including a general inspection, and also additional areas such as safety management, crew management, pollution prevention and certification. After the inspection, the report is uploaded to a database which can then be accessed by OCIMF members, companies which charter such ships as part of their normal business, bulk oil terminal operators and other designated authorities. There have been more than 18,000 inspection reports submitted to SIRE and currently there are over 22,500 reports on over 8,000 vessels for inspections conducted over the last 12 months (OCIMF, 2014). OCIMF considers that the SIRE inspection programme has created a level of transparency that is unique in the shipping industry and is a major source of technical and operational information. One of the areas that OCIMF has concentrated on is the quality of the attending inspector in order to ensure a uniform approach to the reporting of the conditions onboard. To support this, OCIMF have a very specific Ship Inspector Training and Accreditation Programme in place. Certainly, many shipping companies operating in these

sectors consider the number of observations received by the ship is a major performance indicator as to how the ship is being maintained and operated by its shore staff and seafarers. In 1998, due to requests from its members, OCIMF introduced the Offshore Vessel Inspection Database (OVID).

OCIMF has also introduced the Tanker Management and Self Assessment (TMSA) programme which encourages companies to assess their safety management systems (SMS) against key performance indicators (KPIs) and provides a minimum expectation (level 1) plus three levels of increasing best practice guidance (OCIMF, 2018). The TMSA is also used by the energy majors wishing to charter ships for medium and long-term periods to assess the quality of shipping companies' operations.

The Chemical Distribution Institute (CDI) was established by chemical companies to 'constantly improve the safety, security and quality performance of marine transportation and storage for the chemical industry' (Chemical Distribution Institute, 2014). The system is applicable to ships that transport bulk liquid, including liquid gas, chemical and petroleum product tankers. It works in a similar manner to OCIMF's SIRE programme in that it has a standard questionnaire considering the condition and maintenance of the ship together with the operational standards onboard. All inspectors are specially trained to ensure uniformity of reporting.

Generally, if a ship has not been inspected by one of the relevant inspection regimes as described above, then it will be unable to trade worldwide and certainly not for any of the participants of the schemes.

RightShip (Rightship, 2014)) was established in 2001 to improve the standard of dry bulk shipping. It was formed by BHP Billiton and Rio Tinto and combines their expertise in vetting to develop a 'Ship Vetting Information System (SVIS™). Cargill, a major commodity company, joined RightShip as an equal equity partner in 2006. RightShip works in a different manner to either SIRE or the CDI inspection. It takes information from a variety of sources, including market intelligence from established shipping databases, Port State control and terminal information. The system then uses an algorithm to consider risk factors such as casualty history, Flag and Class performance, age and

terminal performance to give a rating. The rating is from one star (highest risk) to five stars (lowest risk).

Some of the biggest ships currently trading in the world are container ships, in excess of 400 metres in length. These larger ships operate on 'liner' trades from east to west and back again. Yet currently there is no third party inspection regime for container ships. These ships can transport around 19,100 twenty-foot equivalent unit (TEU) containers. Additionally, they can carry onboard up to 11,000 m3 of fuel (some small oil tankers are not even this big) and therefore the pollution risk in the event of a grounding could be considerable. There are also many smaller sizes of container ships, including smaller feeder ships on intensive coastal trades. These ships are approximately 100 metres long and carry about 500 TEU containers. What is an important consideration for all sizes of container ships is that containers on board may be hazardous. While this may be marked on the ship's manifesto, the risk occurs when containers are either lost at sea or not identified as hazardous and there is an incident.

For passenger ships, from the smallest of ferries to the largest cruise ship, there is no third party inspection regime in place. However, many of the ships operate in high profile areas such as the English Channel or the east coast of the United States and it could be expected that authorities such as Port States have a more rigorous inspection regime themselves for ships carrying people. Unfortunately, many of the accidents in the industry occur on overloaded passenger carrying ships sailing in the more remote areas of the world.

3.12 - Legislative Timeline

The timeline shown in Figure 6 highlights the continuous main changes to shipping legislation since the 1960s.

As the legislation evolved, it focused initially on the physical aspects of ship design, being updated or revised in the event of a serious accident. However, more recent legislation has moved towards the human aspects of ship operation. Of particular note was the introduction of the ISM Code in 1998. This was legislation covering the safe management and operation of ships and pollution prevention. It formalised procedures to ensure a safe working

environment onboard, and also required measures to identify risks and ensure safeguards were put in place to protect against such risks. Finally, it required continuous improvement of safety management practices. At the time of introduction, the legislation was seen as a step change, particularly for ship owners who had not formalised their procedures. Considering this and the ongoing requirements, it is surprising that there has been limited work in assessing the effectiveness of the legislation.

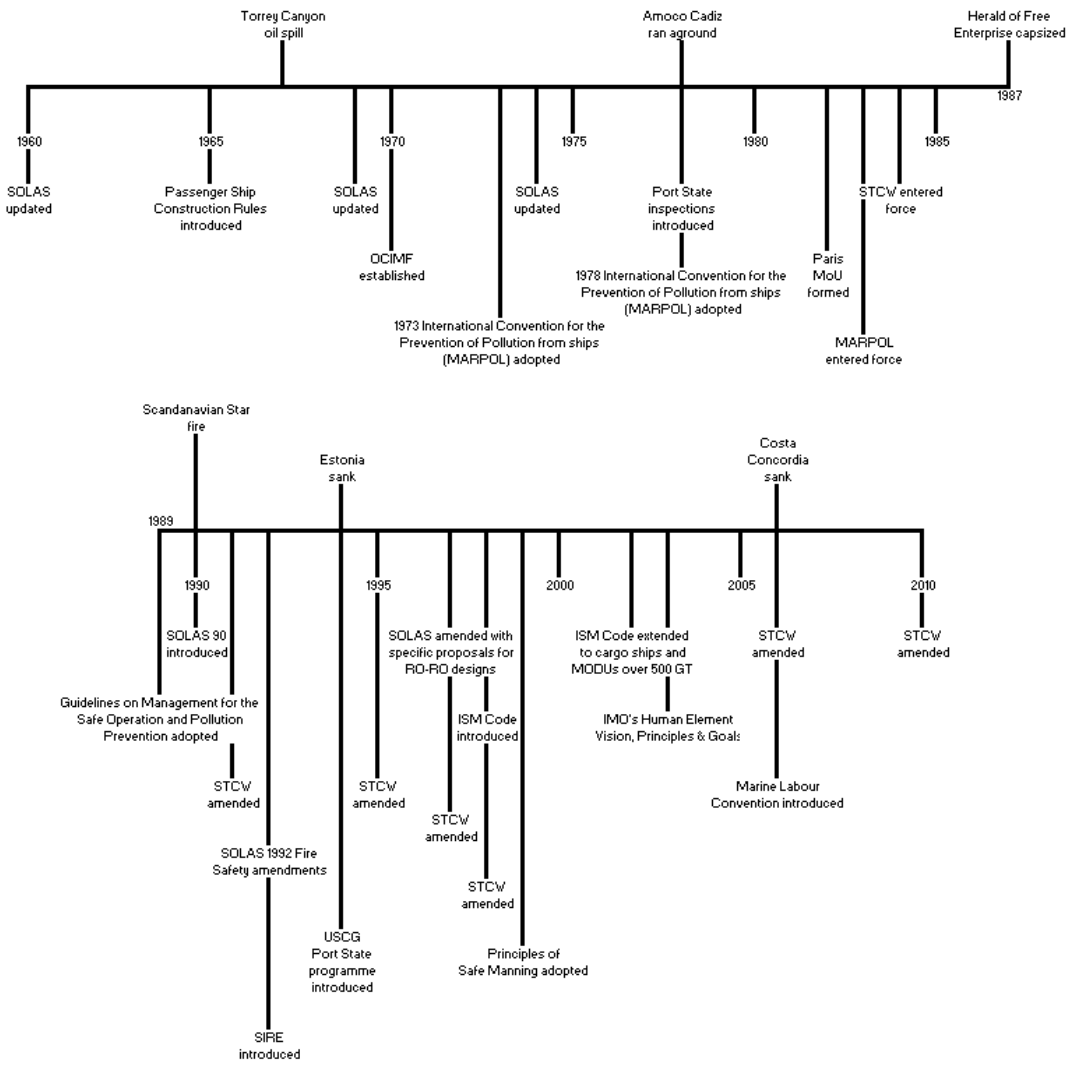

Figure 6 – Legislative Timetable; 1960 to 2010.

It may be considered that with modern design and construction practices, the safety factor for operating a ship within its parameters would be well established. However, the recent partial capsizing of the Hoegh Osaka shows that this may not be the case, certainly for specialised types of ships which

require careful operational procedures. After other capsizing accidents, such as the Herald of Free Enterprise, the legislation was changed in order to ensure the design of such ships was made more robust. In the case of the Heogh Osaka, there was no loss of life and no pollution. Therefore, this investigation may concentrate on operational aspects of this accident rather than implementing any design changes through legislation.

Of course, the physical aspects of ship design and construction are only one consideration. Once a ship is delivered from the shipyard, then other aspects of ship operations, including training and certification of the officers and crew, become the focus. The introduction of STCW requirements covered the 'soft' aspects of ship operation, including training and certification requirements. However, considering STCW is such an important piece of legislation for the industry, there is limited research on its effectiveness. The limited work that has been done has considered the change from national flags to Flags of Convenience and the effect this has had on the seafarer, including the onus on the seafarer to arrange and pay for the training and certification requirements.

3.13 – Chapter Summary

This chapter has considered the introduction and development of the main shipping legislation over the last 100 years. It has shown that shipping legislation has been heavily prescriptive and generally reactive. The chapter has also noted that many amendments to the international legislation take many years to enforce even after being ratified by the required number of countries. During this interim period, the opportunity for repeated exposure to the same risk remains high. International shipping legislation is driven by IMO which has evolved over time, taking into account serious accidents and their impact both on the design and operation of ships. Certainly, in the early 20th century, shipping legislation drove the design of ships, not necessarily driving innovation but rather ensuring best practices of design became the standard to ensure a minimum acceptable level of safety.

Additionally, reactive legislation and delays in implementation of the updates and amendments do have a negative impact on the industry, particularly in a

changing operational and technical environment. While IMO has started to introduce limited goal setting legislation, this has been limited to the physical aspects of oil tanker and bulk carrier hull construction, rather than looking at the human aspects of legislation. However, even with the introduction of the new legislation and continued revisions of existing legislation, including requirements for more formalised procedures (ISM Code) or additional seafarer training (STCW), incidents are still occurring in the industry.

There are also resource and training issues related to ensure legislation is complied with, and also that owners and managers are aware of new legislation before it is introduced in order to be properly prepared. Operating ships is complicated and requires substantial resources in terms of the number of shore and office staff. Staff are required to be aware of all legislation relating to the operation of ships, and they may also have to contend with additional local regulations, depending on the ship's trading area. They also need to be prepared for certification and operating procedures to be inspected and audited by the authorities at any time, in addition to having to comply with regular inspections for compliance with on-going legislation such as Classification Society surveys. In addition, in certain sectors such as the transportation of oil and gas, ship operators have to deal with the additional pressures of third party inspections.

In the tanker sector, many new initiatives related to safety are promoted by the energy majors. For example, Shell has its Maritime Partners in Safety programme. This programme aims to 'share best practice material in order to achieve a step-change in our safety performance' (Shell, 2018). However, this is only aimed at a relatively small number of the world's shipping fleet and is not widely implemented outwith the oil tanker sector and with the companies that Shell does business with.

There has been limited research considering the effectiveness of key legislation, particularly the International Safety Management (ISM) Code, which prescribes requirements related to the safety management of ship operations. Further, the current legislative frameworks described do not take into account the likelihood of accidents and incidents occurring due to issues

relating to human factors, and in turn the part human error plays as a contributory factor. The next chapter will consider the literature and the limited research related to human factors in the shipping industry.

4

Human Factors and Shipping: A Literature Review

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4.1 – Introduction

The first section of this chapter will provide an overview of the literature concerning error taxonomies and the different approaches used to assess the effect of human error on accident causation. The 'three human factor' model (HSE, 2004) is then described, followed by a discussion concerning the ages of safety. The final section of the chapter includes an application of the three human factor model to the shipping industry, as well as a discussion of the ages of safety as applied to the shipping sector.

In the previous chapter, the shipping legislation framework was discussed, with a focus on specific pieces of legislation that have had an important consequence to shipping safety. Much of the legislation in the shipping industry is very prescriptive and can be very slow to introduce. This is due to the long approval process, and in many cases, the ratification process as in the case of IMO legislation. However, in spite of new and updated legislation being introduced, accidents are still occurring in the shipping industry. Therefore, considering accident causation from a relatively new perspective may give several benefits, including the reduction of accidents and incidents in the industry.

The awareness of human error in accident causation in recent years has become more prominent in the public domain. Reason (1990) states that while there have always been accidents, as systems become more complex, the impact of errors committed can be wide ranging.

4.2 - Human Error

Human error can be difficult to define. Kirwan (1992) suggests that it can be defined as the failure to perform an action, or an inaction, if appropriate to the task being performed. Reason (1990) proposes a generic working definition of error in order to allow the term to be readily adaptable to different scenarios:

> 'Error will be taken as a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be

> attributed to the intervention of some chance agency' (Reason, J. Human Error. 1990. P 9. Cambridge University Press).

Over the years, significant research has been completed into the extent of human error as a contributor to accident causation, however this paradigm has not been consistently applied in the shipping industry. Heinrich (1931) was one of the first researchers to consider human error in accident causation. His review and re-classification of 12,000 insurance company accident claims found that 80-90% of accidents were due to human error. DuPont (1986) conducted a ten-year study and found that 96% of injuries resulted from unsafe acts by people, or from poor work practices. In the shipping sector, a study by Rothblum (2000) concluded that human error contributed to 84% to 88% of tanker accidents, 89% to 96% of collisions, and 75% of fires and explosions. It follows that focusing on this aspect of accident causation, and indeed incidents and near misses, should allow the accident and injury rate onboard to be reduced in order to produce a safer environment for the seafarer.

Human factors and human error are often considered to be synonymous in the shipping industry. While Rasmussen (1982) acknowledges that it is difficult to give a satisfactory definition of human error, he proposes that a useful point of view is to consider human error as an instance of man/task or man/machine misfits. He further considers that if the misfit is one that occurs frequently or is systematic, then the cause can be considered to be one of design. If the misfit occurs infrequently or occasionally, then it can be caused by variability on the part of the system or the man, and the instances are considered to be system failures or human errors respectively.

In the shipping industry, examples of different types of error can be as simple as a navigating officer not following procedures. This is human error as a direct causation. A consequence of human error could be an engineering officer leaving a tool in an engine that then causes the engine to catastrophically fail. Finally, an action or event can be considered as a human error, for example, a navigating officer forgetting to set manual inputs into an Electronic Chart Display and Information System (ECDIS), or even setting the incorrect ones (such as the settings for the anti-grounding cone). In this case, the

consequence may not be considered and the focus is on the human error as the event. This may constitute a near miss if a captain catches the error and it is corrected. Nonetheless, a human error occurred.

4.3 - Error Taxonomies

4.3.1 - Skill, Rule and Knowledge-based Errors

Human errors can be classified in a number of ways. One of the most widely accepted frameworks is Rasmussen's model of skill, rule and knowledge-based (SRK) behaviours (Rasmussen, 1982, 1986). This model groups and classifies errors and violations according to the level of performance at which they occurred (Reason, 1988).

Skill-based behaviours are gained over time and are carried out automatically by the operator. The behaviour relates to both sensory and motor aspects of bodily activity being carried out automatically and without conscious control. Skill-based behaviour is generally applied during familiar tasks that have been well practiced. Rule-based behaviour is evident in situations where the work is familiar to the operator and the operator applies a rule to the work. The rule is held in the operator's consciousness and is applied when the operator realises that rule is applicable to the task. In unfamiliar situations, the operator must analyse the situation at a conscious level. In this instance however, based on the conditions assessed by the operator (both environmental and the aims of the job to be completed), the operator will apply unique actions in order to complete the goal. This is defined as knowledge-based behaviour.

These types of behaviours are readily applicable to shipping operations. For example, the behaviour of a navigating officer on watch-keeping duty should be primarily rule-based using the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs) (IMO, 1972). Skill-based behaviour will be applied to manoeuvres that have been performed previously, hopefully improving the manoeuvre while complying with the Rules. In the case of an emergency situation, the officer will use his knowledge-based behaviour to apply actions in a timely manner in an attempt to avert a developing dangerous situation.

In addition, these behaviours are also applicable to other roles and responsibilities onboard ship. The officers are guided by operating manuals relevant to their job, but more importantly they have to comply with the company's safety management system. This covers operating procedures, company policies, responsibilities and authorities, management of change, risk assessment, incident investigation, and reliability and maintenance of the ship and equipment. Depending on the situation and task to be performed, the seafarer should apply the appropriate behaviour in order to complete the work correctly and, more importantly, safely.

4.3.2 - Active Failures and Latent Conditions

Reason (1987) considers an active failure relating to human error will have an immediate consequence and is usually made by operators carrying out the work. The failure will occur immediately before the accident and will be a direct cause. Turner (1992) alternatively considers the active failure as a trigger event which occurs after an incubation period of the system deviating from the normal parameters.

Reason (1987) defines a latent failure as a condition which, while not being immediately associated with an accident, is found to have contributed to the causation. Latent failures generally occur at the higher levels of organisations or departments which are not directly linked to the operational phase of the system (i.e. they can be considered organisational failures). Examples of when latent conditions may be introduced into a system are during the design or building phase of a project. They may also be introduced if a procedure is written incorrectly. It is therefore important to identify latent conditions because if they are not resolved, they may lie dormant within the system for many years before they combine with active failures and local triggers to create an accident opportunity.

4.3.3 - Slips and Lapses

Slips and lapses occur when a person fails to perform a simple task which they would normally succeed in completing. A slip is defined as 'an action not carried out as intended' (Reason, 1990). An example of this would be changing the port engine speed when the intention was to change the

starboard engine speed. Lapses are defined as a missed action or omission (Reason, 1990), and an example of this would be forgetting to complete a bridge checklist item. These types of errors are considered a cognitive failure by the person carrying out the task and can occur in everyday life to every age group.

Slips are made by an individual during the action phase of a process and therefore are likely to be separate from the activities of a team. However, lapses are more likely to be associated with group processes (Reason, 1990). Reason and Sasou (1999) further differentiate team errors into individual errors, when an individual alone makes the error without any participation of any of the other team members, and shared errors which are shared by some or all of the other team members whether or not they were in direct communication with each other. When identifying accident causations when a team is involved, such as a navigation incident in restricted waters, this differentiation is important.

Arslan and Er (2007) highlight the effect of fatigue on navigating officers committing slips and lapses. They use a strengths, weaknesses, opportunities, and threats (SWOT) methodology to conduct analysis on factors that influence fatigue and note that this should reduce the officers' risk to committing slips and lapses. Many of the ideas proposed to reduce fatigue are covered further in this text more fully, but include reducing workload, increasing team awareness, and having improved communication and nutrition onboard. They also found that weaknesses that could be contributing to fatigue onboard include commercial pressures, new technology onboard without adequate training, poor sleep quality, and formalised paperwork requirements.

4.3.4 - Violations

Reason et al. (1990) add an additional error classification, violations, when considering the human contribution to accidents. Violations occur when there is a deliberate deviation from those practices believed to be necessary to ensure the operation is being conducted safely. Further, Reason et al. (1990) differentiate between erroneous or unintended violations; when there was no

prior intention to commit the violation, and ‘an act of sabotage’ when there was a prior intention to commit the act.

Urğulu et al. (2018) used a modified version of HFACS to analyse passenger ship accidents. They considered violations under three sub-categories; violations of regulations, violations of procedures and abuse of authority. Considering violations of regulations, their findings found that noncompliance with Collision Regulations (COLREGS) and Standards of Training, Certification and Watchkeeping (STCW) were typical examples of this type of violation. Procedural violations were typically violations of company procedures which had been written to comply with national and international regulations, and operating practices such as navigation safety and watch handover procedures. An abuse of authority occurs when the violation is made intentionally and wilfully. An example of this type of violation highlighted by the authors is the case of the Costa Concordia when the Captain violated navigational safety procedures for the entertainment of the passengers.

Dahla et al. (2014) focused on procedural violations during their research of safety compliant behaviour onboard offshore service vessels. One of their findings showed that the more experienced worker was less safety compliant than the less experienced worker. It was suggested that this may be due to a different risk perception between the two groups. The authors also review the research of Snook (2000) which discusses the drift of established practices to local unapproved practices which become the ‘norm’ for the operators. This issue may also be applicable on ships, especially on ships trading with seafarers operating on a back to back basis and with deep sea voyages, characterised by relatively minimal port stay, making it more difficult for the shore organisation to monitor onboard practices and compliance with the company’s management system.

4.4 - Approaches to Human Error

4.4.1 - The Person Approach

Traditionally, the perspective to human error has been to consider it from a person approach. This focuses on the unsafe acts committed by people generally at the ‘coal face’ of operations. When using this approach, the

unsafe acts committed can be considered due to a large number of factors including negligence, poor motivation, forgetfulness and inattention. Reason (2008) highlights that the countermeasures associated with preventing these types of acts should be directed at reducing the variations in the human approach to the work being carried out.

The person approach has been used in many industries to assess blame as, according to this approach, staff who have directly contributed to the accident are capable of choosing between safe and unsafe modes of behaviour. Therefore, the consequence of their action is the resulting error. However, this approach has its weaknesses. Reason (2000) highlights that applying this approach disconnects the unsafe acts from any institutional responsibility. This may mean that errors within the system may not be readily identified and could lay dormant.

4.4.2 - The Systems Approach

The system approach considers that if humans are involved, then errors of some kind are inevitable. However, these errors are not seen as causes, rather they are consequences of systemic failures (Reason, 2000). Reason further considers that while we cannot change the human condition, the condition under which humans work can be changed. Therefore, a central premise of a systems approach is one of system defences. These defences can include barriers and safeguards to prevent the error occurring. The approach focuses on understanding why the defences failed allowing the accident to occur. For complex systems, this approach takes into account that while the behaviour of humans is difficult to change, by having a series of defences or barriers in place, the accident can be prevented. In the case of an accident, the focus is on the failure of the defences rather than the human failure.

Understanding complex systems and the environment they operate in can be difficult. Different aspects of the system have to be understood in order to assess the risk of system failure due to human error. This includes the design, construction, commissioning and operation phases. Unless these different phases are adequately assessed, then the system is at risk from both latent

and active failures. This is highlighted by Sheriden and Nadler (2006). They conducted an analysis of accidents in industries such as commercial aircraft, general transport systems, power generation systems and the medical industry, and found that the different causal factors studied were interdependent. They further highlighted that some industries have challenges of inadequate design in addition to the continual struggle to create the appropriate conditions for a positive safety culture.

Using a systems approach can assist in identifying the reason for failure within a complex system as, similar to the system being assessed, the reasons for failure can be complex. Cook (2000) describes several reasons why complex systems fail including:

- Complex systems are intrinsically hazardous systems.
- Complex systems are heavily and successfully defended against failure.
- Catastrophe requires multiple failures; single point failures are not enough.
- Complex systems contain changing mixtures of failures latent within them.
- Human operators have dual roles; as producers and as defenders against failure.

A systems approach to human error uses classification systems to both proactively anticipate errors that might occur, and retrospectively to classify and analyse errors that have occurred during accidents and incidents (Stanton and Salmon, 2009). This approach can therefore be used from the design phase to the operation and management phases to identify potential weaknesses in the system and also to analyse near misses, incidents and accidents.

4.5 - Definition of Human Factors

The International Ergonomics Association (IEA) defines human factors as 'the scientific discipline concerned with the understanding of interactions among humans and other elements of a system' (International Ergonomics Association, 2016).

Another simple definition of human factors is the interaction between man and machine (Mearns et al., 2001), or the interaction between the human and technology (Charness and Bosman, 1992). This definition has been expanded to cover more than just the seemingly direct relationship between man and machine to include other factors that influence this complicated relationship. It is this study of these additional factors used for identifying both accident causation, and for forming actions to prevent future accidents occurring, that has become paramount. The study of human factors is also called human engineering. It is related to the term 'ergonomics', however ergonomics is traditionally related more to the interface between the human and equipment in the workplace. Charness and Bosman (1992) also highlight that human factors is a discipline related to designing processes and products that enable humans to be able to complete tasks more efficiently and safely.

In the shipping industry, this approach to design and operation can be illustrated in the changes to bridge equipment that a navigating officer has to be familiar with in order to operate the ship safely and effectively. This new equipment includes advanced radars and Electronic Chart Display and Information Systems (ECDIS) for navigating. In addition, with the removal of the radio officer from the complement of the crew, the navigating officer also has to be familiar with the operation of all the communication equipment on the bridge, including satellite communications. This means that the study of human factors and the human computer interface becomes more important, particularly when considering the increased volume of information available to the navigating officer. In addition, as the bridge equipment may be supplied by different vendors, integration between the equipment can be lacking, giving the officer an additional workload to process the different interfaces. In a ship's engine room there are similar challenges for the engineering staff as more and

more information is brought into the control room from various items of equipment. This increases the cognitive demands on the engineer officer who now not only monitors the equipment from the control room, but also operates it remotely. There is also the issue that both navigating and engineering officers have to become familiar with a number of different interfaces as they sail on different ships with different vendors supplying the equipment.

4.6 - The Three Human Factor Model

Wilpert (1995) identified three human factors that are found to affect underlying safety. These include organisational, group and individual factors:

- The Organisation: How an organisation functions and interacts with its employees is paramount to ensuring that the right workplace culture is developed. The culture affects many interactions within the company and particularly affects the way safety is perceived within the company. Historically, the importance of organisational factors to safety has only come to the fore after major accidents. Reason (1991) highlights accidents such as the Herald of Free Enterprise capsizing and the King's Cross fire which had these factors as contributors to the failures within the system.

- Groups: Included in this are the role of middle managers, supervision and crew factors. How groups react internally and to other external parties are equally important when considering safety aspects of the system.

- The individual: This considers competences, skills, personality, attitude and importantly risk perception. Individual characteristics can influence behaviour in complex ways. Importantly, some individual characteristics are fixed, while some can be changed or improved.

More recently, The United Kingdom's Health and Safety Executive (HSE) (1999) noted 'Human Factors':

> 'refers to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety' (Health and Safety Executive, 2014).

Similarly to Wilpert (1995), the HSE (1999) also suggested three interrelated human factors that must be considered, including the organisation, the individual and the job. In this instance, the job factor considers the physical aspects of the task being carried out, including ergonomics, the environment the job is being conducted in, and the procedures that are associated with the job.

While the HSE model is beneficial to assessing safety, the peculiarities of the structure of shipping industry management companies pose unique difficulties at the organisational level. For example, there are particular difficulties involved with the management of fleets of ships in different locations remote from the office and its management. At the same time, ensuring that a satisfactory safety culture exists both ashore and onboard, while ensuring the safe operation of the ships is managed, is a unique challenge to the shipping sector.

The behaviour of groups has been well researched in other industries. In particular, the aviation industry has focused on this area considering flight crew interaction and performance (Helmreich and Foushee, 2010). Historically, the three-factor model of the determinants of group performance has been studied. Included in this model are input factors (considering characteristics of individuals, groups, organisations, and the operational environment), group process factors (considering the nature and quality of interactions among group members) and outcome factors (considering safety and efficiency of operations and secondary outcomes such as member satisfaction, motivation and attitudes). This model could be applied to the shipping industry. The aviation industry has also used a conceptual model called SHELL (software, hardware, environment, liveware) with each component representing a building block of human factors to consider relationships between the components (Aviation Knowledge, 2019). The model was first developed in 1972 by Edward and further refined by Hawkins and Orlady in 1984 and 1993

into a building block structure (Hawkins and Orlady, 1993). The human element at the centre of this model is considered the most critical and flexible component in the system, interacting directly with other system components. The model can be used as a framework for collecting data about human performance and contributory component mismatches during aviation incident/accident analysis or investigation. It could also be applied to other industries and similarly to other models in the assessment of operations from a human factors perspective.

Similarly, in this model the human factors review of individual factors will also include the job or task being conducted as they are interlinked and directly related to each other, both being influenced by the environment and the physical process.

4.7 - The Ages of Safety

The attitude to accident causation, including human factors considerations, and the scientific study relating to this area of research has developed over recent years. Initially, research considered physical means to prevent accidents. This included designing to prevent failures, safety guards, and alarm and shut down devices. Hale and Hovden (1998) consider that these technical measures form part of the first age of study relating to the science of safety. They further determine that this initial phase lasted from the end of the nineteenth century until after the Second World War. This period was characterised by a focus on technical failure and their associated causes.

According to Hale and Hovden (1998), the second age of safety study moved the focus from technical matters to the selection of staff, training of staff and motivational matters in an effort to prevent accidents occurring. Hale and Hovden (1998) also note that during the initial phase of this era of the 1960s and 1970s, the personnel approach was not connected to the technical measures from the first age. However, with the advent of probabilistic risk analysis and the influence of ergonomics in the approach to safety, the two methodologies came together. During this period, the study of human factors and related error came into its own, and together, these measures improved the research for the prevention of accidents at this time.

The third age of scientific study relating to safety moved towards safety management systems and their influence on operations. This was the start of a systems approach to the study of safety. This area was first developed in the 1990s, however literature on the impact and effectiveness of these systems is limited in the general research sphere, and in the shipping industry, the information is particularly sparse. It is recognised in the shipping industry however, that the implementation of formalised policies, procedures and continuous improvement can positively influence work place safety.

Hudson (2007) also considers that the approach to safety was sequential. However, he acknowledges that it developed through three waves; a technical wave, a systems wave and finally, a culture wave. An alternative view is that instead of being sequential, each phase of safety builds on the previous (Glendon et al., 2006). The advantage of this is that instead of new approaches being considered as independent processes, they use contributions from each prior age/wave, ensuring that lessons learned previously are not lost. Glendon et al. (2006) consider this coming together of the ages/waves as the fourth age of safety or the 'integration age'. The fourth age of safety allows for new ways of thinking, while at the same time allowing more complex perspectives to develop and evolve.

Borys, Else and Leggett (2009) take the concept further and introduce the fifth age of safety which they call the 'adaptive age'. According to Borys et al. (2009), the adaptive age transcends the other ages, however does not discount them. This age considers that occupational health and safety management systems have come to their limit regarding their influence on controlling behaviour relating to safety. This further means that the view of a formalised safety culture within the organisation, and staff working within those boundaries, has become outdated according to the authors. Rather, a key aspect of the fifth age is resilience engineering. Hollnagel et al. (2006) consider this new approach to be paramount to understanding accident causation, and it also provides a new approach to improving safety, particularly in complex systems. This approach means that instead of using the past in a retroactive way to consider solutions for the future, systems are designed to allow people to succeed when failure threatens. Hollnagel et al. (2006)

summarise their approach by saying it is time to move on from designers and operators considering reactive barriers and defences. Rather, safety can be improved by resilient processes which are proactive, and by their name, resilient to failure.

4.8 - Theory of Accident Causation

It is important to understand how and why accidents happen. Not only does this allow preventative actions to be taken, it is necessary to apply lessons learned from investigations in order to apply the corrective action to an accident cause. Accident causation theory and accident modelling have been around for many years. Initial theories considered single causations and events occurring one after the other culminating in the accident. More complex approaches were developed from these simple theories which considered multiple causations and their effects.

4.8.1 - Single Event Concept

The simplest approach, the single event concept, considers an accident and focuses on one event, and that is then considered the cause. If investigations are carried out, they only focus on the one event. Once the event has been established that is considered to be the root cause, preventative and corrective actions can be implemented based on that single event. With the single event approach, the focus can be on a single person's actions, and this can lead to a blame culture. Benner (1978) takes this further stating that this attitude to accident investigation can lead to scapegoats being identified in order to satisfy the victims quench for answers and blame.

4.8.2 - Sequential Accident Model

For a thorough analysis of accident causation, accidents cannot be considered single events. Analysis of real accidents shows that they are multi-causal and are caused by a number of different events and conditions (Hudson, 2014).

Heinrich (1931) was a pioneer in applying scientific principles to accident causation. He developed a set of theorems known as the 'axioms of industrial safety' (Heinrich et al., 1980). Using one of his axioms, Heinrich developed the domino theory; this implies that the accident occurs after a number of

events have progressed in a linear manner, commonly called a 'chain of events'. Heinrich et al. (1980) presented this model as a sequence of factors commencing with an injury itself being caused by the accident, the accident itself being due to an unsafe act and/or a hazard, and the act or hazard occurring due to the fault of a person.

Heinrich also tried to quantify the domino theory by use of the 'Iceberg' model. This shows that a number of unsafe conditions and practices will give a corresponding number of no-injury accidents, leading to a number of minor injuries, and finally to one major injury. This model has been adopted by many industries, however some safety practitioners (Hale, 2002) criticise the model as it can present different ratios between the levels. However, Hudson (2014) states the model remains appealing due to its ability to communicate that fixing small problems will solve big problems.

The 'Swiss Cheese' model (Reason, 1990) could also be considered a sequential accident model when there is a time base applied to the events. The model has defences between the hazard and the accident that, if they remain intact, will prevent the accident from occurring. These defences or barriers are not just physical attributes, such as alarms or automatic shutdowns, but they also include people who have been trained in a way so that they can prevent the defences failing. The model also includes procedures or other controls that again maintain the barriers in place. The barriers can fail either due to active failures or latent conditions.

One of the issues with this type of model is that accidents do not occur sequentially, rather they usually have a large number of events occurring simultaneously and only some of these events, or a combination of these events, will cause the accident to occur. Additionally, Hudson (2014) raises the issue that the model presented now has been reduced to a linear as well as a deterministic model, highlighting that more attention in analysis is being given to the final barriers rather than why the holes were appearing in the first place.

As previously stated above, accidents generally have a number of events culminating in the accident event and this can be difficult to depict, therefore

two other categories of related models have been developed. The first includes event trees, fault trees and cause trees. The differentiation between the trees is that the event tree analysis commences with a single initiating event and ends with a number of final events, whereas cause and fault trees begin with the accident and consider the possible combinations of events which could have led to the accident. Lehto and Salvendy (1991) consider that while the trees have different names, there are many similarities when used as a tool to model accidents. The other category of causation model developed is the network model. This model, unlike tree models, assign events to a timeline. As the analysis of accidents becomes more complicated due to the complexity of the systems that have failed, this model becomes difficult to apply and, in turn, to identify the causation of the accident.

4.8.3 - Epidemiological Theory

This theory is the study of patterns, the name being more normally associated with the cause and effects of disease on populations. However in this instance, it is applied to accident causation. Reason (1990) was one of the first to promote the multi-causality of accidents, and also considered the interaction between latent and active failures as a key contributor to accident causation.

Epidemiological theory relates latent conditions, such as management practices or the culture existing within an organisation, akin to resident pathogens which can lie within a system for a long time. Reason (1990) also highlights that if the system is complex, tightly-coupled and opaque, it is more likely a greater number of pathogens will be resident. Therefore, the potential for these latent conditions to fail is higher. Latent failures can remain dormant and, if not triggered by another event or condition, will continue to exist unknowingly within the system. Latent conditions and the effect of their failure will only become evident when they combine with an active failure, such as an unsafe act, which then causes the system to fail.

One of the advantages of this type of model is that it can show the influence of organisational factors on accident causation. However, they can be limited in that they are modelled in order to identify the root causes of the accident rather

than identifying the true causations of the accident, which may be remote from the initiating event and indeed the identified root cause.

4.8.4 - Human Factor Approach

Hudson (2014) also discusses the link between latent and active failures and suggests that poor designs, which can be error prone, together with inappropriate design standards and inadequate training programs are all types of latent failures that can remain dormant. These latent conditions are made by people remote from the accident, and therefore it is important that defences or barriers are created after these unsafe acts occur in order to prevent the accident from happening. Therefore, to investigate accident causation thoroughly, a human factors approach will link these two aspects in order to be able to identify the causation correctly.

Shappell and Wiegmann (2003) were one of the first research teams to consider this aspect. They adopted Reason's 'Swiss Cheese' model further, and expanded the definition of barriers in the model to develop the Human Factor Analysis and Classification System (HFACS) as a model for accident investigation and causation. This model was developed initially for the aviation industry. It has also been adapted for use in the investigation of accident causation in the shipping industry from an academic perspective, rather than being used by either formal investigators or shipping companies.

Using HFACS, together with a Fuzzy Analytic Hierarchy Process (FAHP) approach, Celik and Cebi (2009) approach accident causation in order to quantify human contributions to shipping accidents. While their results show that users of this approach apply the approach to reduce the probability of similar accidents, this is not considered a practical model for regular use in the shipping industry due to its complexity. A different approach is taken by Chen et al. (2013). They use an adapted HFACS framework for maritime accidents (HFACS-MA) and integrate it with a Why-Because-Graph (WBG) (Chen et al., 2013). Their results show that this integration can clearly show the causation amongst the factors, and can also reveal the adverse influences between the different levels. Again, and due to practical considerations in applying the

method, it seems that this is not a practical tool for accident investigators in the shipping industry.

A more practical approach using HFACS is shown by Chauvin et al. (2013). In this case, they focused on analysing collisions using a slightly modified HFACS tool; 'HFACS–Coll'. They also conducted a statistical analysis of their results. This was completed using specialised software not publicly available and therefore this part of the paper cannot be considered practical for everyday use. However, their results do show that HFACS as an analysis tool can be used with some minor adaptions for the shipping industry.

Energy Transfer Theory

Haddon (1973 and 1980) proposes a model that views an accident as the transfer of uncontrolled energy from a source, via a path, to the victim. Haddon further proposes ten basic strategies relating to preventing and reducing the energy in the loss that can prevent the accident. These are interventions aimed at the energy source, the path of energy being transferred, and the victim.

This theory is not often referenced when referring to accident causation modelling, rather it is highlighted for categorising the types of measures that can be put in place for accident prevention. Chua and Goh (2004) highlight that this theory, when considering accident or incident investigation and safety planning, does not provide a suitable feedback orientated framework.

Systemic Theory

This theory takes into account the role of the organisation and its systems into accident causation. Many researchers consider that only by taking this holistic view will all the factors contributing to the accident be identified. Therefore, in the research field and in many industries, this is the current approach to accident investigation.

Similar to human factor model theory for accident causation, systemic theory considers that the organisational factors that contribute to the accident are generally latent conditions. These conditions will only be triggered when an active failure occurs. This type of model considers multiple causation of

accidents when there is not a simple line of causation. Rather, there are numerous causations branching out from the trigger event which all need to be investigated.

There have been numerous systemic models developed since this theory was first considered. Examples include the Management Oversight Risk Tree (MORT) (Johnson, 1973), Contributing Factors in Accident Causation (CFAC) (Sanders and Shaw, 1988), and Accident Root Causes Tracing Model (ARCTM) (Abdelhamid and Everett, 2000). More recently, Leveson (2004) has proposed a new accident model (Systems-Theoretic Accident Model and Processes, STAMP) based on systems theory and tailored to changes in engineering and the way humans interact with systems. Leveson (2004) explains the background to proposing a new accident model:

- Technology is changing so fast in the modern world compared to previous generations and lessons learned from previous accident research may not be applicable or relevant.

- New types of failure modes which may change the nature of accidents are being introduced by the new age of digital technology.

- The digital age also gives unprecedented amounts of information at our disposal and this creates the potential for lost or incorrect data.

- The tolerance for single accidents, which harm increasingly large numbers of people, is decreasing.

- Systems are becoming increasingly complex with tight coupling. The effect of this is that understanding a system's behaviour is becoming increasing difficult, albeit for a number of specialists in their particular field.

- The relationship between humans and automation is becoming more complex. This relates to human error and individual factors contributing to accidents.

- The regulatory landscape is changing, with governments having to provide protection the public requires as individuals, and companies may not be able to control the risks.

The use of these systemic models are coming more to the fore, particularly in industries such as rail, offshore, and nuclear, which are highly complicated with a high potential for serious injuries. However, to date, there has only been very limited research in the shipping industry into accident causation using this approach.

4.9 - Human Factors and Shipping

As noted prior, there are particular features of shipping that make application of existing human factor theories problematic. This extends not only to shore based staff but to the shipboard staff as well.

Therefore, when relating the existing typology of human factors to the shipping industry, the following points must be recognised:

- Considering organisational factors, unlike many shore-based organisations, the ship is an organisation in itself. The captain is in effect a managing director of a small business. However, he also reports into another organisational structure remote from the day to day operation of the ship. In some ways, this could be considered in a similar way to a head office with regional offices. However, in reality, there are important differences. There are regular staff changes on the ship, not just of the captain, but of the whole crew over a relatively short period. These staff changes may be staggered or carried out in small numbers to ensure current knowledge of the shipboard operation is not lost. In addition, the seafarer may not return to the same ship and in this case, new relationships have to be forged as well adaption to the culture onboard if there is to be continued experience sharing and integration

of the seafarers onboard. This dynamic environment poses challenges with regards to leadership and culture.

- With respect to group factors, middle managers working ashore in shipping companies drive the various cultures, including safety and work, as directed by the board (see Figure 7). One of the ways this is achieved is by interfacing with the ship via staff directly responsible for the operation of the ship i.e. superintendents. Marine and technical superintendents are usually responsible for all aspects of the operation; crewing, maintenance and onboard training and drills for example. They are the direct link between the office management and the ship management.

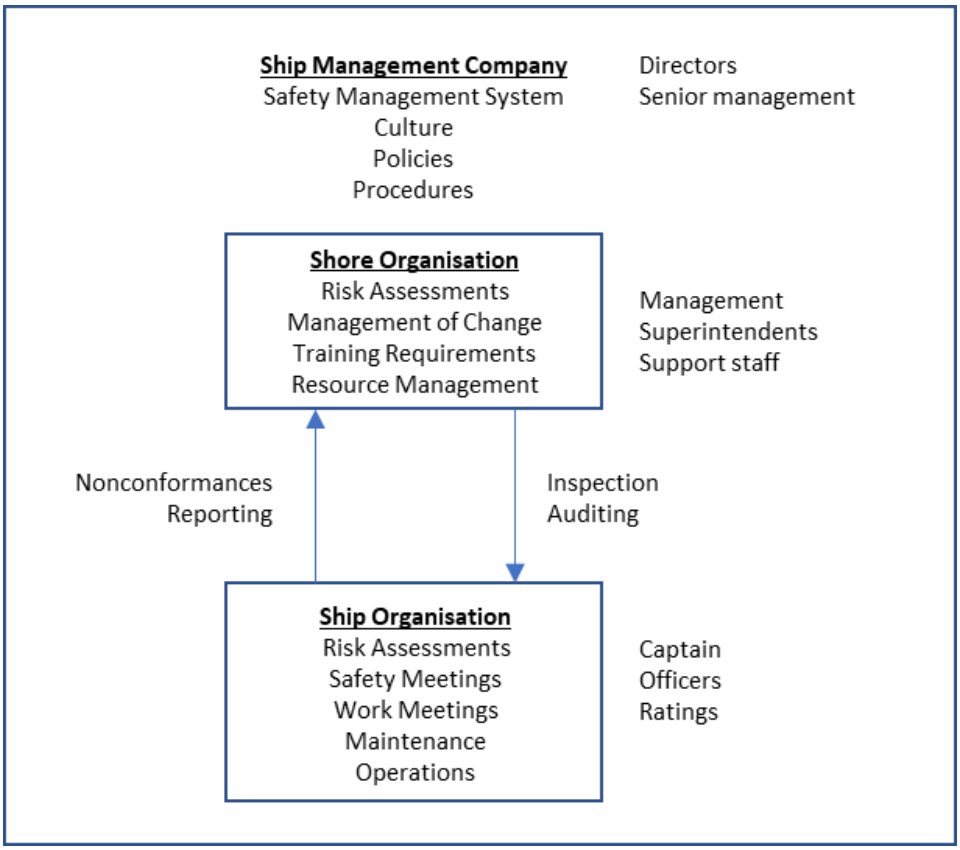

Figure 7 – The Ship Management Company.

- Concerning individual factors, the individuals onboard a ship have to become familiar with the equipment and the operating environment onboard very quickly after joining a ship. This situation provides its own challenges, especially when compared to a fixed plant installation such

as a power station or factory installation. In addition, on a ship which operates mostly away from land, and external communication is limited or difficult, attitudes are not only important during the work day, they are also important when off duty due to the confinement associated with working on a ship. Finally, while the jobs being conducted on ships may or may not be similar to those in a factory environment, other factors come to the fore, particularly the environment the job is being conducted in. The role of the individual within the shore organisation has also to be considered (see Figure 8). An individual may be responsible for a number of ships with different designs and capacities, and operating in different parts of the world with a number of different nationalities onboard the ships.

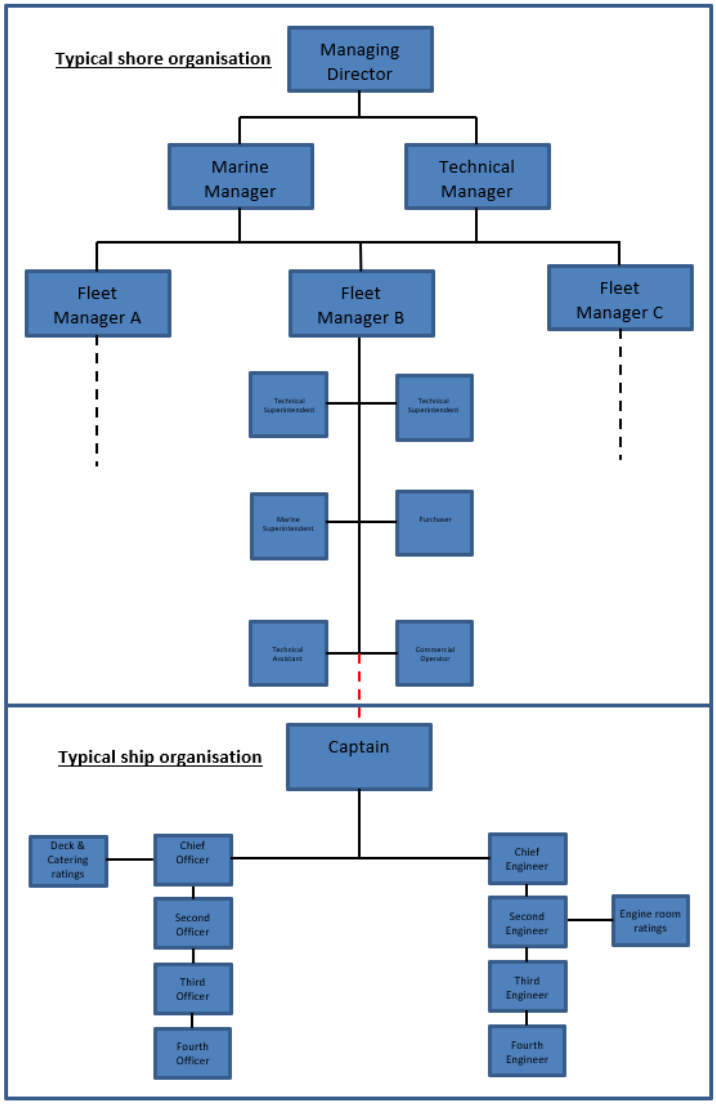

Figure 8 – The Shipping Company Organisation.

4.10 - The Three Factor Model and Shipping

As discussed in section 4.6, the three factor model identifies three human factors found to affect underlying safety; organisational factors, group factors, and individual factors. It was noted that applying this model to the shipping industry may be problematic due to the distinctiveness of the sector. However, derivatives of this model can be useful. The following discussion considers the three factor model by applying organisational, group and individual factors to shipping.

4.10.1 - Organisational Factors

Organisational factors have become more prevalent in recent years as researchers focused on human error using a sociotechnical approach. This approach considers that safety performance can be influenced by both internal factors (such as safety culture) as well as external factors (legislative factors) (Katsakiori et al., 2009).

The offshore industry is one industry that could be considered to have similar challenges to the shipping industry. Asset values and operating costs are high, platforms or offshore installations are remote from the head office, and a specialised work force is required to operate the facilities. The offshore industry is also exposed to cyclical world energy prices affecting capital investment and operating costs similar to the shipping industry. Considering the Piper Alpha disaster which occurred in 1988, human factors and their effect on the offshore industry came to the fore after the accident. Paté-Cornell (1993) concluded that the owning organisation had put short-term production goals ahead of other organisational priorities, including safety. These goals focused on reducing costs, which in turn affected other costs through the life-cycle chain from design to maintenance. In addition, even before the disaster, Paté-Cornell (1993) had identified factors that were endemic within the company, including the maintenance of equipment not being carried out in accordance with the proper procedures, and the climate of a poor safety culture.

The importance of proper organisational processes for the safety of complex operations is currently well recognised (Stroeve et al. 2007). Stroeve et al.

(2007) further discuss that the level of safety that can be achieved in an organisation is dependent on the middle managers who determine the working conditions of the staff at a lower level within an organisation who are directly controlling hazardous processes, in the case of shipping, the seafarers. Puisa et al. (2018) consider that by only considering the interactions between all the elements within the shipping system can causal factors of accidents be identified. Therefore, it is important to model the ship operations system accurately to represent the organisation and consider the contribution of each element in order to prevent accidents and other unwanted events. Importantly, from a sociotechnical approach, Puisa et al. (2018) concluded that the role of individual factors (human error and equipment failures) was marginal, giving way to organisational (contributing factors) and systemic causes. In shipping, the relationship between the shore and ship organisations is unlike other industries. While it is similar to industries like the construction industry with satellite sites and offices remote from the head office, shipping is different as the relationship between the shore and ship organisations can be difficult to maintain due to both internal and external factors. External factors include when there are periods of low oil price and low operating income, this may put pressure on technical shore staff to reduce operating costs. Internal factors may include a lack of presence by shore staff onboard due to the trading area of the ship and the limited time in port. This may affect the relationship between the shore and ship due to each being unfamiliar with each other's requirements and working practices. Indeed, they may have different cultures within the two organisations. Both external and internal factors can directly affect the relationship between the ship and shore organisations, which in turn can affect the safety culture both onboard and ashore.

There are several categories that constitutes organisational factors:

Safety Culture/Climate

A safety culture can be one part of an organisation's culture. Gordon et al., (2007) consider that the other sub-cultures making up part of the organisation's culture include; operational, professional, design, moral and ethical cultures.

It is also important to discuss the difference between the terms safety culture and safety climate. In common usage, sometimes these terms are interchanged. However, there has been extensive research to clarify and understand the differences between the two. One understanding is that safety climate precedes safety culture (Schein, 1992). A different view is proposed by Guldenmund (2000). He discusses that safety climate, when relating to an organisation, is a concept that underlies most events and processes within the organisation. However, this is now commonly used as a definition of safety culture within the organisation, and safety climate is the visible manifestation of a safety culture within an organisation.

Having a positive safety culture is one of the most important factors affecting safety performance. The culture of safety affects all levels within a company. While the senior management sets the stage for the safety culture within the company, it is the middle management who actually direct and nurture the safety culture within the organisation right down to the most junior of staff. In the case of a shipping company, it is the operational staff (technical and marine superintendents mainly) that interact directly and on a regular basis with the ships. Shore operational staff depend on the ship's captain, via his senior officers, to ensure the company's safety culture is passed from the management team onboard to the junior officers and ratings. There has been limited published research into safety culture in the shipping industry. Håvold (2005) found that there had not been any safety culture/climate research reported in the shipping sector and subsequent to this, there has only been limited work on assessing safety climate such as a program at the Lund University Centre for Risk Analysis and Risk Management, and a PhD thesis from the Norwegian University of Science and Technology (Soma, 2004).

Håvold (2005) completed some research into safety culture in a Norwegian shipping company from the seafarers' point of view using a safety culture questionnaire which is a common method of assessing culture in other industries (Pronovost, 2005). He highlights the nature of the shipping industry's unique challenges such as contracted working onboard, however he does not mention that the seafarer might not return to the same ship and the effect this may have on onboard safety culture. Håvold (2005) also suggested

that the factors influencing safety culture might exist across organisations and industries, highlighting that this confirms previous work in this field. He also comments on the finding that actual safety performance and safety culture may be linked empirically. One of the most interesting discussion points in the paper is regarding identifying the major influencer on safety culture; is it the shore management, the captain, officers or crew? Håvold (2005) concludes there should be further work to investigate this important factor.

Guldenmund (2010) also considers the relationship between safety culture and safety management and suggests the two go hand-in-hand in order to achieve the desired safety performance. He concludes that in order to enhance the safety culture of a company, a focus on the continued development of the safety management system, including the processes that can influence the organisational culture, is required. The safety management system should therefore truly reflect the processes that occur onboard ship and the procedures should be written to reflect this. One of the ways that a safety management system can be improved is by ensuring the management system is not just a bureaucracy of paper containing rules and regulations. However, this requires feedback from the end users of the system.

An added complication for the shipping industry related to the promulgation of a consistent safety culture is the multinational nature of the business. Not only can there be different nationalities working in the shore organisation, Berg (2013) highlights the challenges associated with ships manned by crews of different nationalities to establishing a safety culture. This can affect both communications onboard the ship and also between the ship and shore organisations. This situation has become even more prevalent in recent years. Until the 1970s, ships were manned by national flags and generally had one or two nationalities onboard (generally when two, it was the officers being one nationality and the ratings the other). However, the move to offshore companies and Flags of Convenience has meant that more nationalities sail together. It is therefore important that the management system specifies a working language, and that all seafarers show competency in that language. Communications at all levels of the organisation are now particularly important, especially between ship and shore as this can affect the implementation of the

safety culture. If the communication is not effective, this can lead to potential misunderstandings due to cultural differences. Horck (2005) recognises the challenges of multicultural manning while also highlighting the effect of the reduction of crew numbers onboard and relates these issues to less opportunity for social and work cohesion onboard. Further, the introduction of fully internet-enabled ships for crew use limits socialisation opportunities as seafarers tend to stay in their cabins communicating with family and downloading internet content when off duty rather than socialising with other crew members thereby enhancing the culture, including related to safety, onboard. This makes the only opportunity for social interaction at meal times when time is limited.

Assessment of safety culture within an organisation can be difficult. Measuring safety climate can be one way to assess the culture. One definition of safety climate is that it is a snapshot of an organisational safety culture at a particular point in time (Mearns, 2003). Hetherington et al. (2006) suggest that a robust measure of safety climate could be used as a predictive safety performance indicator. Many companies traditionally use lagging indicators (fatalities or Lost Time Injuries (LTI)) to assess their safety performance. However, Flin et al. (2000) consider the use of leading indicators, such as safety audits or measurements, as beneficial. One of the advantages of using leading indicators is that they are predictive measures which identify safety weaknesses rather than waiting for an accident to happen.

In other industries, increased research attention has been devoted to the impact of organisational factors on worker safety performance and negative outcomes, such as accidents and injuries in order to increase safety performance (Smith-Crowe, Burke, and Landis, 2003, and Zacharatos, Barling, and Iverson, 2005). Burke (2008) considers the following at the organisational level: management commitment to safety, the appropriateness of safety training interventions, and safety policies and procedures. These factors can give an indicator of the overall safety climate of the organisation.

While it is not peer reviewed research, recently the International Chamber of Shipping has produced a booklet ‘Implementing an Effective Safety Culture’

(ICS, 2013). This booklet covers the subject by giving advice for both the seafarer and shipping companies. It also highlights the fact that the ISM Code, while stating that one of its key objectives is to establish a 'safety culture' in shipping companies, does not give a definition of the term. Even though this is a 2013 document, it still emphasises the use of lagging indicators for assessing safety performance. One leading indicator it does propose is the use of 'near miss' reporting in order to identify areas of concern and put in place 'corrective actions'. Interestingly, it does not mention 'preventative actions', a common term now used in the industry. Correcting the problem is only part of the remedy. Putting in place actions to prevent recurrence is also necessary.

Safety Training

Generally, literature relating to safety training in the shipping sector has focused on the crew aspects of training, while keeping separate the requirements for shore staff. Only by ensuring both sub-organisation's safety training needs have common policies and goals can there be assurance that all parts of the organisation will be aligned and have the same attitude and goals towards safety.

In practice, this means delivering training with the same message and aims. For a shipping company with shore offices and a number of worldwide trading ships, this can be difficult due to the resources and time required to promulgate the message. Safety training not only covers equipment training and training to meet legislative requirements for qualifications, it is also important for both shore staff and seafarers to be given detailed training on management systems, covering the most important safety aspects including company policies and procedures, but also quality, environmental and energy conservation requirements of the management system. Sampson and Tang (2015) recognise some of the other difficulties regarding training for the various shipping sectors, including the need for training for new technologies being installed onboard, and also the cost of training which, in some circumstances, the seafarer has to pay for themselves.

Focusing on delivering safety training, there must be a visible commitment from the company with an ongoing programme in order to reinforce the safety message. The nature of the work force at sea, and increasingly the shore staff, is transient compared to other industries, and this creates challenges due to turnover and the introduction of new seafarers in the fleet. Theotokas and Progoulak (2007) found that the average employment length for foreign seafarers in the sampled fleet was less than one year for 27% of the officers. Therefore, to ensure a consistent delivery relating to safety training, constant enforcement of the message is vital. With manning offices all over the world, and usually being remote from the head office of ship operations, this is increasingly difficult to achieve with the limited resources that many shipping companies allocate to this function. Many shipping companies therefore rely either on the manning offices to deliver the training or invest in computer-based training.

However, if it can be accomplished, one of the advantages of training is that it can be delivered quickly to a company or department, meaning that as an intervention strategy, it is very attractive. This is especially true when compared to a design change of equipment or the upgrading of software (Drury, 1996), both of which can take time to implement considering a ship's trading pattern and the availability of personnel, such as service engineers, required to implement the change. Training can also be cost effective. In other industries with a low turnover of staff, it may only be required once. However, in the shipping industry, due to the high turnover of both shore and onboard staff and the number of players involved in the supply of the crews, it may be more of a continuous process and require considerable investment.

While resource management is discussed in more detail below, there are several opportunities to give training simultaneously to both shore staff and the crew. One way is to have shore staff participate in the resource management courses with the crew. Another option is to have specific training courses at seminars when both shore and ship staff are present.

Seafarer Contracting

The relationship between shipping companies and seafarers has changed since the 1970s. Until around that time, shipping companies were national fleets employing seafarers from the home nation or, in some cases, a related territory such as a Commonwealth Country in the case of the United Kingdom. The officers were contracted directly by the ship owner and were expected to remain with the same owner throughout their career. The ratings were also contracted and employed directly, or via 'a pool' controlled, in the case of the United Kingdom, by a national shipping federation (formed by the owners to counteract increased trade union activity).

Two factors have affected the recruitment of seafarers since the 1970s. The first was the rise of the 'foreign flag' or 'Flags of Convenience' as described in Chapter 3. This was due to the higher costs incurred by shipowners when employing seafarers from the traditional seafaring nations. The increase in foreign flagged shipping also meant that the relationship between the seafarer and the shipping companies changed and became more fluid, with contracts between the two parties lasting only one voyage. This meant that after one voyage, either the shipping company or the seafarer could choose to be re-employed, or the relationship ended. The seafarer then had to look for new work and the shipping company had to search for seafarers in an open market.

The second factor affecting recruitment was the introduction of ship management companies to operate ships. The management companies, acting on behalf of owners, may have diverse fleets, seafarers of different nationalities, and operate in different geographical areas of the world. These factors affect the relationship between the recruiting shipping company and seafarer as, in many cases, the managers want flexibility regarding their pool of seafarers as ships come in and out of management.

Currently, while some companies employ their seafarers on a rolling contract, the majority of seafarers are employed on a short-term basis. The length of the contract is generally to cover one voyage and in addition, the seafarer usually accrues leave pay whilst onboard. While this short-term contracting may have advantages for the ship operator by giving them flexibility with

regards to resources as the number of managed ships changes, from a seafarer's point of view this lack of perceived commitment may affect their working relationship with the company. Many of the issues raised by the short-term nature of the contracting of seafarers has already been discussed in the section on safety culture and climate.

There is limited literature on the effects of the different types of contracting in the shipping industry. Ruggunan (2011) considered the global labour market, specifically for Filipino and South African seafarers, by conducting interviews and conducting documentary research. It was found that South African crews had been replaced by seafarers from south east Asia, predominately Filipinos, as the main shipping company in South Africa, Safmarine, looked to reduce costs associated with crewing, as these can be around 50% of operating expenses. Filipino seafarers are employed either through a crew agency or by securing membership of a seafaring trade union. All of the Filipino seafarers interviewed for the research were either ratings or junior officers and it was found that contracts were rarely for more than 12 months, more commonly being for nine months. With short periods of vacation after having served onboard, there is further potential for researching the effects of the short-term contracting on the seafarer in terms of fatigue, attitude to culture and conditions onboard.

4.10.2 - Group Factors

The International Safety Management (ISM) Code (IMO, 1993) considered the management of ships by ensuring companies had in place safety and environmental policies. It also gave individuals certain responsibilities (the Captain and the Designated Person Ashore) and required the company to have procedures in place to cover operations, including accident investigations, evaluation and review. However, it was only in 2010, with the introduction of the revised International Convention on Standards, Training, Certification and Watchkeeping for Seafarers (STCW) 1978 (IMO, 2010), that human factors were considered. One of the items related to this was addressing communication issues between officers, with specific attention to Bridge Resource Management (BRM) training.

This human factor issue is further complicated by the attendance of third party staff onboard who not only have been trained to different standards, including different policies and procedures to the ship's crew, but may present with cultural and language difficulties. Of particular importance is the Captain/Pilot relationship. When the pilot comes onboard, he has to interact immediately with the bridge team and in many cases, this is the first time the captain and Pilot have met each other. This brings its own challenges with respect to communications and the interaction between the navigating team, especially when the ship is navigating in restricted waters and in bad weather. In a study conducted by the Canadian Transportation Board (1995), the relationship between the captain and pilot was considered and the findings suggested that more effort was required from both sides to ensure that the bridge team, including the pilot, works as a team.

Teamwork

Within all levels of a shipping company, teamwork is essential. There are several groups evident on a ship; the deck department, the engine department, the catering department, the engine and deck ratings, the management team, and of particular relevance in terms of safety is the safety committee. All these groups have certain responsibilities and specific duties. However, in all cases, the captain still has overall responsibility for all aspects of the ship.

In addition, when discussing teams and teamwork in the shipping environment, not only should teams be considered onboard the ship and the office individually, the operating team of the ship, which consists of some shore members and the senior officers of the ship, have to be considered as they regularly interact.

There are also several sub-teams within the ship's complement, all with their particular hierarchy. Sub-teams are evident on the bridge, in the engine room and the galley. On the bridge, and as a minimum, the navigating team consists of an officer and a rating acting as a lookout. The navigating department always operates a watch system. When at sea, the watch system is four hours on duty and eight hours off duty, and there is usually some additional work during the off duty period. In port, the watch can be even more arduous,

working six hours on and six hours off. Therefore, the individual watchkeeper is reliant on the preceding officer to 'hand over' the watch in a safe manner, ensuring that any potential difficulties or dangers that may endanger the safe navigation of the ship are highlighted. The watch change period is often cited by seafarers as one of high risk. Due to automation on many ships, the engineering officers generally work during the day, only working watches when required due to restricted waters, bad weather, or a technical issue. The engineering officers have the same challenges when working watches as navigating officers.

Whether it is the shore management arranging maintenance work, such as service engineers to attend the ship, or the ship's staff working together to complete a task, teamwork is essential in order to pre-plan the task and assess the risks. Failure to pre-plan will result in procedures not being followed and increase the risk of an accident. Flin et al. (2000) found that the supervisor's role in safety management has long been recognised, and the influence they have in setting the work atmosphere is particularly important regarding safety.

Onboard a ship, team-work and communications are closely linked together. There is limited literature available relating to this aspect of ship operations, however Baily et al. (2006) consider that it is not only the direct communication that is important, but also the contribution of team members making shared, interactional and perspective decisions. This is equally as important to ensure safe navigation. Baily et al. (2006) also consider the hierarchical aspects of the bridge team and the effect this has on teamwork, while acknowledging that merchant seaman are not civilians and have not been subject to the same discourse of discipline and control as those in the military service.

Resource Management

The first Crew Resource Management (CRM) programme was developed to fill a training void first identified by NASA in 1979 (Helmreich, 1999). The research found that the majority of air crashes were due to human error and failures of interpersonal communications, decision making, and leadership. As early as 1981, United Airlines introduced a training programme to address these issues. The initial focus of such training in the airline industry was to

make better use of the human resources on the flight deck and in doing so, pilot error would be reduced.

The equivalent of CRM training introduced to the airline industry and military aviation is Bridge Resource Management (BRM) training or Bridge Team Management (BTM) training in the shipping industry. This was first introduced to the shipping sector to improve the relationship between the captain and the pilot in the late 1990s (O'Connor, 2011). However, it rapidly expanded to also consider the human factor interactions between the officers.

Compared to aviation resource management, the literature relating to the effectiveness of BRM in the naval sector and shipping industry is mixed and limited. At the 23rd Conference of the European Association of Aviation Psychology, Byrdorf (1998) concluded that BRM training led to a decrease over a 4-year period in the number of nautical casualties from one per 30 ship years to one per 90 ship years. It was also found that insurance premiums had decreased over the same period by 15%. While not assessing the effectiveness of the training, Fonne and Fredrikson (1995) considered reactions by attendees to a BRM course. They found a positive reaction and attitude that was still evident six months after completion of the course. Brun et al. (2000) also evaluated a BRM training course and found that there was a positive reaction by the participants. More recently, O'Connor (2011) evaluated the U.S. Navy's BRM training and found that it is not having the impact on knowledge and attitudes that is reported in the CRM training literature. O'Connor suggests that this is due to the content of the training not being based on a needs assessment of the group being trained. He further concludes a course developed for one domain should not be applied to another without an assessment of that domain's needs.

Currently, many colleges conduct BRM training for commercial shipping companies. However, to date, there has been no research into either the content or the effectiveness of such courses. This is despite the requirement for such courses to be mandatory, with the latest amendments to the International Convention on Standards of Training, Certification and

Watchkeeping for Seafarers Convention (STCW) from 2012, and with full compliance required by 1st January 2017 (IMO, 2011).

The amendments to the STCW Convention are also applicable to engineering officers. While these types of courses have been available for engineering officers for some time, there has not been much focus on the human factors aspect of such training, rather the courses have focused on simulation training. In the public domain, there is no literature available assessing either the content of these courses or their effectiveness.

Authority Gradient

Also related to bridge management and the communication between the bridge team, Schröder-Hinrichs et al. (2012) consider the factor 'authority gradient' and its influence on decision making, as well as the imbalance of authority and power in a group or organisation. The authority gradient is related to the hierarchy within the team and can affect the established, or indeed the perceived, command and decision-making power with the team. Historically, the team onboard a ship would be considered a steep gradient with the captain having the concentration of power. Going forward, with the requirements for resource management and a more inclusive involvement of other officers, this should result in a shallower gradient. However, in all cases the captain retains the ultimate authority onboard.

While the authority gradient is rarely discussed in the shipping industry (it is a common phenomenon and the subject of research in the airline and healthcare industries), it has been mentioned indirectly in ship accident reports. For example, a recent report on a collision between a large oil tanker, in this case a Very Large Crude Carrier (VLCC), and a self-propelled jack-up barge found that the accident occurred when the bridge team of the oil tanker treated the barge as a normal power-driven vessel underway and expected it to maneuver in a certain way (Seaways, 2013). The assumption was that it should maneuver as the 'give way' vessel in a crossing situation (Collision Regulation, Rule 15). However, it did not as it actually had restricted maneuverability. The report highlighted the root cause/contributory factors as the bridge team management being ineffective. The report further stated that none of the

bridge team members challenged the captain's decisions or actions, reflecting a misapplied authority gradient.

4.10.3 - Individual/Job Factors

More than organisation or group human factors, there is much research available on the effect of the individual or job regarding human factors in the shipping industry. This is probably related to the historical precedent that the person is responsible for the failure, and therefore the individual or job becomes the focus of investigation.

In 2010, the United Kingdom's Stationary Office published 'The Human Element, a Guide to Human Behaviour in the Shipping Industry' (Gregory and Shanahan, 2010). This guide, while written for both seafarers and shore staff, focuses on individual human factors affecting the seafarer. The guide uses case studies to demonstrate particular circumstances when human error played a part in an incident or accident. There are sections covering areas such as communication, risk perception, decision making and mistakes, organisations and culture, fatigue and stress, education and some aspects of teamwork. The guide does not focus on the relationship between ship and shore or the responsibilities the shore organisation has with regard to ensuring compliance with regulations, procedures, and auditing requirements in order to reduce error onboard. However, it does give an insight into how organisations can influence mistakes made by individuals by discussing time pressures on individuals and workload, inadequate design, inadequate staffing and safety culture.

Automation

As automation has increased on ships, the number of seafarers onboard has been reduced. In particular, the two operational areas that automation has affected onboard are the navigation function and the monitoring and control of machinery. While the seafarer relies on the automation to assist with their dedicated role onboard, the seafarer cannot become remote from the environment outside of the navigating bridge or machinery control room. One of the problems with the increased automation is that there may be information overload. Lützhöft et al. (2011) highlight this scenario by suggesting that the

role of the deck officer changes from one of actively navigating a ship to passively monitoring semi-automatic systems. The same assertion can be applied to the engineering department. Before the introduction of automation and control systems, the engineer patrolled around an engine room at regular intervals physically assessing equipment. Currently however, the majority of on-duty time is spent monitoring information screens and operating equipment remotely. The prospect of the officer being de-skilled is also discussed by Lützhöft et al. (2011). Even with automation managing many of the tasks, the seafarer must be trained in the basic principles of his job to be able to use his experience as a cross-check of the automation, and also in the event the automation fails.

Another problem that may occur with automation doing many of the tasks is that the officer may suffer from 'out-of-the-loop' syndrome. This syndrome has been identified in the aviation sector as a factor in several accidents, including Air France AF 447 (Bureau d'enquétes et d'Analyses, 2012). Out-of-the-loop syndrome is a factor which is a sub-category of the situational awareness syndrome. It occurs when the automation process has taken over so many of the routine tasks that the human only intervenes if there is a problem. Wickens and Hollands (2012) consider that 'out-of-the-loop' syndrome can develop over time, with the operator becoming increasingly more complacent, tending to trust the automation more and more, which in turn means the operator monitors the situation less and less. Then, because the human is only taking over at critical times, he may not have the full picture of the situation and therefore might not make the correct decision at the required time in order to prevent an accident occurring.

There is one view that this increased automation increases the cognitive demands on the seafarer and contributes to human error in the accident statistics (Hetherington et al., 2006). However, Akhtar and Utne (2014) note that while bridge watchkeeping is a passive function, it demands cognition at all times from the watchkeepers to ensure awareness of the situation around them. Also, for a watchkeeper, the demand on his mental judgement can change greatly throughout a voyage and even during a watch.

Decision Making

Decision making is a continuous process and is affected by other factors such as fatigue and stress. Also, decisions that may seem minor at the time may have serious consequences as time progresses. History has shown that rarely does an accident occur due to a single system fault. There are usually multiple factors involved such as a human error or a bad decision taken. Cacciabue (1998) notes that when there are two factors such as a sequence of small, apparently minor events and crucial human errors, the accident becomes much worse.

In an emergency, the operator has to rely on his experience to make the correct decision as he only has a limited time. As part of management system requirements, shipping companies include an Emergency Preparedness and Training Manual (EPTM). This manual aids the ship captain's cognitive processes in the event of an emergency by providing checklists for pre-determined emergency situations such as collision and fire.

Many papers written about decision making in the shipping environment, and the effects of that process, do not differentiate between the officer and the ratings watchkeeping roles and their effect on decision making. The officer, in addition to making judgements on his own by monitoring the marine traffic and processing information received from the rating, has to ensure the ship complies with the collision regulations and keeps on its intended track. The deck rating is the continuous 'eyes' of the ship, monitoring the horizon and traffic and also alerting the officer of any developing situations. The demands on the ratings' cognitive processes are very dependent on the marine traffic in the area the ship is sailing.

In Chapter 2, the shortage of seafarers was discussed. This shortage may also have an impact on decision making onboard ships. If seafarers are not very experienced, and have also been promoted too fast due to shortages, then in certain circumstances, the decision-making process may move to the shore organisation. This has also been aided by the development of modern communications between ship and shore, thus allowing the ship to discuss scenarios with the shore organisation before deciding on a course of action.

Leadership

The captain has the ultimate responsibility for the safety of his crew and ship. This is embodied in international legislation, including the safety management system and specifically in the ISM Code, Section 5, Master's Responsibility and Authority (IMO, 2002). This, together with the vertical structure of the officers and crew, creates a necessarily steep authority gradient and hierarchal relationship onboard. The captain, and this also relates to his decision making, has to be commanding and self-confident, especially in times of stress or in an emergency situation. This makes the role autocratic, however there are at times occasions when the captain's decision and therefore leadership has to be questioned. One of the purposes of resource management training is to address the issue of the captain's ultimate authority and how junior officers can question his decisions.

There has been limited research to consider how leadership can affect the safety climate among seafarers. Borgersen et al. (2014) consider this relationship and highlight that even though there are a number of groups onboard such as the different departments, the captain's influence on individuals and their behaviour is extremely high. Borgeresen et al. (2012) used the Authentic Leadership Questionnaire (Walumbwa et al., 2008) as a basis for the research and concluded that authentic leadership (leadership based on self-concept and how self-concept relates to actions (Shamir and Eliam, 2005)) was positively and significantly related to seafarers' perceptions of safety climate. While this study only considered one nationality, Filipino, the autocratic power that a captain has onboard suggests that this would probably be applicable to other nationalities.

Onboard a ship, not only does the captain require to have leadership skills, head of departments and head of the ratings onboard also need to have these skills. Sometimes this is overlooked. Bhattacharya and Tang (2013) acknowledge that while upward communication from ratings is difficult due to the hierarchal structure onboard, they suggest that officers' leadership can contribute to improving occupational health and safety onboard by working alongside ratings and socialising with them. Certainly, leading by example,

showing good work practices, and having a positive attitude to safety can enhance attitudes onboard to safety. However, on many ships, officers socialising with ratings can be more difficult, especially when there are cultural differences between the officers and ratings that imply there is not an expectation to mix. Indeed, in some situations the opposite is true, and segregation is the normal behaviour when not on duty.

Competence

Due to the remoteness of the ships from the shore office, it is difficult to assess the competence of the seafarers once they have completed their qualifications. Recognising this difficulty, in 1996, the United States Coast Guard (USCG, 1996) considered the feasibility of interactive testing using a desk-top computer. This research focused on testing of seafarers' knowledge and application of the Rules of the Road (the ColRegs). The Coast Guard study also considered how an automatic scoring of such a test could be achieved. This approach is now common place onboard ships and is an integral part of competence testing of seafarers, with ship owners using onboard computer-based training (CBT) covering areas such as ECDIS, enclosed space entry training, as well as more core subjects such as the ColRegs and watchkeeping.

Flin et al. (2000) also highlights that in high reliability industries, such as aviation or offshore, there is an increasing emphasis on competence in non-technical skills, such as leadership and decision making. This is due to these skills contributing highly to safe operations in these industries. The shipping industry can be considered to have similar challenges to the aforementioned industries.

More recently, the introduction of Competence Management Systems (CMS) has become popular in many industries, with the shipping industry now starting to consider such systems. These computer-based systems can include learning tools and assessments, analysis of competencies, and skill gap analysis in order to provide better planning for training. To date in the shipping industry, there has been no literature relating to CMS and its effectiveness in the industry.

Situational Awareness (SA)

The lack of situational awareness is one factor mentioned in many shipping accidents. Baker and Seah (2004) of the American Bureau of Shipping (ABS) reviewed accident report data from the Canadian Transportation Safety Board (TSB), the UK's Marine Accident Investigation Branch (MAIB), and the Australian Transportation Safety Bureau (ATSB) and found that failures of situational awareness represented about 25% of accident causation for all the investigative bodies studied. In simple terms, situational awareness is knowing what is going on around you. A more formal definition of situational awareness 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' (Endsley, 1988).

Endsley (1988) further describes three levels of situational awareness. At level one, perception of cues is paramount. Without this, the odds of forming an incorrect picture dramatically increase. Level two encompasses how individuals combine, interpret, store and retain information. Level three is the highest level of situational awareness and allows individuals to forecast future events and dynamics, consider the implications of such events, and allow for timely decision making.

There has been some research into this aspect of human factors relating to the effect it has had on both shipping operations and accidents. From the navigating aspect, passage planning and the execution of the voyage is one of the most important aspects of sailing a ship. These tasks require different levels of situational awareness in order to successfully execute the voyage, from level one relating to the gathering of information and forming the initial situation, to level three during the voyage when the passage plan may have to change due to an increased situational awareness. This is confirmed by Koester (2003) who conducted a study onboard passenger and car ships over eight voyages to study the situational awareness of the crew members relating the communications on the bridge to the situational awareness of the bridge team. He found that the type of communication changed in parallel with the level of situational awareness required by the officers based on the situation,

from general communication at level one to actual and relevant communication at level three as they adapted to a more critical situation.

Fatigue

Fatigue and its effects on seafarers has been well recognised. Seafarers can work watches (for example, 4 hours on and 8 hours off), day work (meaning working normal business hours, such as 9 to 5), or a combination of both. The shift pattern, together with other factors such as the movement, noise and vibration on the ship, can make the consequences of fatigue, such as loss of concentration and poor performance, more prevalent than other industries. The Cardiff University Seafarers International Research Centre (Smith et al., 2006) also highlights longer term ill-health, and more concerning, a reduced life span due to the effects of fatigue.

Arslan and Er (2007) also focus on a SWOT analysis considering fatigue as well as their slips and lapses study mentioned previously. They discuss the probable opportunities for reducing fatigue onboard and propose shortening of seafarer's contracts as one measure to reduce fatigue. They also consider that new technologies and the application of ergonomic design would also assist in reducing fatigue. Finally, they discuss the introduction of new ships being built with improved manoeuvring capabilities. It is difficult to see how this initiative would reduce fatigue, because even if the manoeuvring times of the ships can be shorter, usually the control and timing of such operations is under the control of a pilot and the associated tugs, and therefore there is a limited opportunity for fatigue reduction. Regarding threats to increased fatigue, Arslan and Er (2007) highlight the continued increase in ship traffic, the decreasing number of seafarers onboard, environmental conditions, and changes to the periods in port for rest opportunities together with newer ports being located from built up areas allowing less opportunity for the seafarer to relax away from the ship.

However, there is legislation from both the ILO (1996) and the IMO (2010), which updated their requirements in 2010, in order to restrict work hours and give adequate rest periods. The ILO legislation limits the hours of work and rest for both within a 24-hour period and a 7-day period, while the IMO

legislation requires minimum periods of rest, again for both within a 24-hour period and a 7-day period. Hetherington (2006) recognises that while there is legislation, there are occasions when a seafarer does have to work hours in excess of those permitted, and apart from the general effects of fatigue, the seafarer can also suffer from health issues and also reduced performance. However, in spite of the legislation, Cardiff University (2006) found that as many as one in four watchkeepers reported having fallen asleep on watch and more than 50% of respondents reported having no opportunity to have six hours of uninterrupted sleep. Concerned by this, Nautilus (the shipping trade union and professional organisation) became part of 'Project Horizon' (Project Horizon Consortium, 2015), a research initiative to investigate the impact of sleeplessness on the cognitive performance of seafarers. The development of a maritime alertness regulation tool based on hours of work (MARTHA) came from this research. This is described in further detail below.

Third party inspectors now closely look at hours of work and rest and have the authority to stop a vessel from sailing if the seafarers are not rested enough. Therefore, management systems should incorporate procedures for dealing with the times when hours of work and rest are not complied with. Other industries have introduced a 'Fatigue Risk Management Plan'. This is a document that details how work and rest periods must be implemented and how they should be managed when they are not complied with. In March 2015, the Australian Maritime Safety Authority (AMSA, 2015) introduced such a plan for marine pilots and the requirement to comply as part of the license condition. Nautilus is also now campaigning for the adoption of fatigue management techniques to be adapted by the shipping industry.

There has been limited research into fatigue onboard ships. The Project Horizon project, MARTHA, is one recent example (Warsash Maritime Academy, 2016). This project considered fatigue at sea and related issues, such as stress and workload. The project was in three stages and used the following for data collection; questionnaires and interviews with managers and seafarers in four shipping companies, onboard diaries of volunteer seafarers from the four shipping companies over a tour of duty and actigraphy data from selected volunteers. The conclusions of the research highlighted that the

effects of both lack of sleep and fatigue are important factors for both ship and shore personnel wellbeing. Longer tours of duty were found to contribute to increased sleepiness, loss of sleep quality and reduced motivation, all factors that may reduce the seafarer's safety awareness and increase their risk of accidents. Additionally, it was found that seafarers who maintain night watches may be more at risk of falling asleep while on duty. As noted previously, the study proposed the introduction and development of a 'Fatigue Risk Management System'. This will be researched further in a later chapter as part of the survey of shipping companies. Finally, the study concludes with a proposal for further research into fatigue covering areas such as optimum time onboard for the seafarer and the adequacy of the recovery time available to the seafarer during their vacation.

Stress

Connected to fatigue is stress as the effects of this can affect sleep patterns and the length of sleep. McGrath (1976) defines stress as the interaction between three elements; a perceived demand by the operator, the operator's perceived ability to cope on a specific situation, and the perception of the importance of being able to cope with the demand. Stress can also affect the operator's attention, their memory function, their perceptual-motor performance and, most importantly, their judgement and decision making (Staal, 2004).

Therefore, the issue of stress at sea cannot be ignored, and while there has been much research into the effects of stress on human performance in other industries, particularly the medical and aerospace industries, surprisingly there has only been limited research into the effects of stress on seafarers. The Australian Maritime Safety Agency (1997) conducted a comparative study between an onshore population and seafarers where they found that the seafarers reported significantly higher levels of stress from sources of work pressure than the onshore group.

Health

The health of seafarers is something that can also affect other factors such as fatigue. Overweight or unfit individuals can tend to feel tired more quickly than

their fitter colleagues. The diet of seafarers onboard a ship is also important as lighter, more protein-based foods encourage wakeful alertness, unlike heavier carbohydrate foods. Other issues that can affect the health of the seafarer are smoking, drinking, and a lack of exercise. Shipping companies have started to recognise these issues and usually have controls to limit alcohol consumption onboard and offer smoking cessation programs. Also, many ships now have gyms installed in the accommodation. However, research concerning the links between seafarers, their health and their performance is limited and requires further investigation.

Many of the individual human factors are linked. Certainly, decision making is closely associated with fatigue, awareness, and the health of the individual performing the task. Therefore, when identifying and considering the impact of these factors, they should not be considered in isolation but the effect of one on the other also has to be considered.

4.11 - Shipping and the Ages of Safety

Shipping accident investigations have certainly followed the ages of safety, but to a point. Initially, accident causation investigations and the general approach to safety considered many physical factors as technological progress was rapid, and the influence of the human on improving safety performance was limited. Many early accidents at sea were due to poor material selection (or materials that were not fit for purpose, but used as that was all that was available at the time) or insufficient lifesaving equipment onboard, or inadequate firefighting detection and protection installed onboard.

In the 1960s and 1970s, limited training for seafarers was introduced. However, this training was not directed at the human side of ship operations, rather it was specific training on selected equipment focusing on the familiarisation and maintenance aspects of the equipment.

The real change was in 1998 when the International Management Code for the Safe Operation of Ships and for Pollution Prevention (International Safety Management (ISM) Code) (IMO, 2002) was introduced. From 2002, adherence to the Code has been mandatory for most types of ships. The introduction of this Code formalised many of the policies and operating

procedures required for operating a ship safely and also ensured shipping companies that had previously avoided a structured approach to safety were required to do so. Shipping companies are also required to prove that they comply with the Code through the use of internal audits. Finally, they are subject to external audits by an independent third party, usually a company appointed on behalf of the country whose jurisdiction the ship operates.

Chapter 3 considered research that has been carried out on the effectiveness of the ISM Code. However, it should be noted that such research has been very limited to date. There is an opportunity for further research taking into account recent changes in shipping, such as the rapid expansion of the fleet and the large influx of new and inexperienced seafarers into the industry.

Considering the fourth age of safety, while there is no research into this aspect of safety in shipping, experience is passed on in the hierarchal structure of shipping companies, both onshore and onboard the ships. Therefore, it could be considered that there has been a sequential adoption of the previous ages. This ensures experience gained over the years is not lost.

4.12 – Chapter Summary

This chapter has highlighted the role human error contributes to accidents and presented relevant literature. Only by considering human error in detail and then considering all the associated human factors that contribute to accidents can causations be correctly identified, especially in the shipping industry which faces unique challenges. Reducing the accident and incident rate can only be accomplished by considering the contributing factors together. This is particularly relevant in the shipping industry which has fragmented work places (the offices and the individual ships), each with their own organisation and structure, and also the transient nature of the workforce and the limited time they spend onboard.

While in the academic field and in some other industries there has been much research into applying the correct theoretical methods in order to identify accident causes, in the shipping industry there has only been very limited work. Only relatively recently has there been consideration of the influence organisational factors, external from the accident, have on the accident

causation. Therefore, there is an opportunity for more research to be completed in order to identify common causations in order to reduce the accident and incident rate, particularly when there is human error associated with the accident. For this to happen, the correct accident causation model, relevant to the shipping industry and its unique challenges has to be selected. This is one of the aims of this research.

The chapter has also considered some specific challenges related to human factors that the shipping industry faces. These include:

- Ships operating remotely from the main ship management office, with each ship having their own sub-culture onboard, driven by the captain and management team.

- The reliance on middle managers and superintendents to impart the company's culture to the ships and to ensure that the company's policies and procedures are being followed.

- The related challenges of increased automation onboard and the impact of the seafarer being 'out of the loop' when something goes wrong onboard.

Other individual factors that the industry faces include the health and well-being of the seafarer and ensuring adequate training of the seafarer in order to operate the ships safely. Many of these aspects will be explored further in Chapter 7 which considers human factors and accident analysis practice in shipping.

5

Study 1: An Analysis of Incident Types and Causal Factors Leading to Shipping Accidents

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5.1 - Introduction

In Chapter 4, the literature concerning human factors and human error was reviewed, providing background for the various approaches and theories for this research. The chapter then continued discussing the challenges of the various human factors in shipping and how they may affect safe operations. Finally, the theory of accident causation was discussed and, where applicable, was related to literature relevant to the shipping industry. This chapter will initially review the availability of shipping accident databases in the public

domain and consider their appropriateness in assessing trends in accident causation, including the role of human factors and human error.

There has been some prior work in this area by Baker and McCafferty (2005) in which they considered human element aspects of accident causations. Their study was initially limited to accidents associated with commercial vessels in US territorial waters as investigated by the United States Coast Guard (USCG). It was then further expanded to accidents which had been investigated by the United Kingdom's Marine Accident Investigation Branch (MAIB), the Australian Transport Safety Bureau (ATSB) and (TSB) Canada. The study concluded that 85% of all accidents are either directly initiated by human error or are associated with human error. This concurs with other studies discussed in previous chapters of this thesis. Of these accidents, about 50% of maritime accidents were initiated by human error, and another 30% were associated with human error. This study also found that management practices, failures of situational awareness, and risk taking/risk tolerance each represents about 25% of accident causation for each respective source. While this study was geographically limited, this research will review databases which are more representative of global commercial shipping.

Using the selected database, categorisation of the accident's initial event will be considered and the number of related accidents occurring over the years 1998 to 2014 will be trended, reviewing both the number of accidents, the number of accidents per categorisation with deaths, and the number of deaths per categorisation. Secondly, accident numbers in relation to the type of vessel will be considered. This review will allow a selected causation to be considered for further research, considering that there is an opportunity for applying human factor analysis techniques for the review of accidents. Using this approach, any common contributory factors will be identified in order to focus on these factors in subsequent chapters and consider preventative actions and recommendations.

5.2 – Methodology

Using accident databases for research purposes allows the researcher, in this case, to have access to a large quantity of accident data contributed by third parties who have been required to submit data to a central database, either due to a legislative requirement or for commercial purposes. Accident databases are used in other transport sector industries in order to share information between interested parties and to learn from past incidents and accidents. This is the most appropriate method to use in the shipping sector considering the legislative requirement to submit details of accidents to a central database, and in order to align accident investigation techniques in the shipping industry with other transport sector industries. Other data sources for the review of shipping accident data is extremely difficult to obtain due to commercial sensitivities and the reluctance of companies to share safety data.

This review considered disparate shipping industry datasets in order to synthesise the data and consider accident trends within the industry. Generally, datasets are not considered together due to different end user requirements for use of the data; data required for be submitted as part of a legal requirement may be used by legislators to focus on subsequent safety initiatives, while data submitted to commercial databases may be used by charterers to monitor ship safety performance, and therefore company performance, in order to assist with commercial decision making regarding the charter of ships.

As with all databases, accident databases have to fulfil two main functions:

- They have to reflect the true status of the information the database is designed to report.

- They have to be fully and correctly populated.

Considering the second point, Chung and Jefferson (1998) highlight that there is often an unwillingness for some companies to release data related to accidents as it may endanger their reputation. In shipping, there may also be a reluctance to release data to a third party, as there may be commercial implications. One way around this issue, also highlighted by Chung and

Jefferson (1998), is the use of anonymous reporting. The shipping industry does have an anonymous reporting system, The Mariners' Alerting and Reporting Scheme (MARS) (The Nautical Institute, 2019), administered by The Nautical Institute. This system, while being publicly available, does not formally investigate the causation of accidents, however it does consider lessons learned based on best practices.

As noted previously, accident databases are used throughout many industries, including the offshore and aviation industries, in order to share information between interested parties and to learn from past incidents and accidents. Generally, the databases include information about the accident cause, location, conditions at the time of the accident, and may also include information regarding social and economic impacts. The information held in accident databases can be used both at the regulatory level and also, when access is allowed, by end users in the industry as a means of risk management and assessment. In both cases, the information held in the databases can assist in identifying hazards associated with the accident and also ensure any hazards so identified are effectively mitigated.

In the public domain, there are generally two types of accident databases for the shipping industry; the first type is produced by regulatory bodies such as IMO and Flag States, and the second type is produced for commercial reasons. Both types of databases have the same functions; to categories accidents or near misses, to describe the ship and the scenario at the time of the accident or near miss, and to allow the database to be interrogated by the end user.

This thesis will consider not only the information held by official government shipping authorities, but will also review legislative bodies' databases as well as commercially available databases to expand the geographic scope of the analysis. All selected databases must be fully searchable, with the ability to export the data in order to interrogate it. Various reports will then be generated from the selected data sets and subsequently analysed. The data will be presented in tabular form in order to identify trends and also to quantify each causation factor.

5.3 - Rationale

This chapter will use information stored in shipping accident databases as the source for analysis. In this case, these databases are completed by third parties i.e. the information stored in the database is not populated by the researcher. The researcher is only accessing the information to use in their research.

The use of secondary data, such as third party populated databases, has both advantages and disadvantages. The main advantage is that the data has already been collected and can be leveraged to answer new research questions. Using secondary data is also cost effective. The third party may also have access to large amounts of data that a sole researcher may not be able to access due to confidentiality or commercial issues. Additionally, the uploading of data to a specified database may be a legislative requirement, for example as required by IMO's accident and casualty database described below. Further, in some cases the data collected usually is cleaned by a specialist working with the data collector. Disadvantages to using a third party database include verifying the data, and ensuring that the data collected is what the researcher actually requires. Additionally, there may be a cost associated with accessing a third party database, although the cost is likely lower than what the expense would be to create the same data set from scratch.

5.4 - Database Review

A number of available casualty databases were selected for review. As the United Nations appointed agency for the safety of shipping, the IMO's web site was reviewed and the database contents assessed. Further, as the entities responsible for implementing IMO's legislation, a number of Flag State's web sites were reviewed to assess if they had any relevant accident information. Also, being responsible for a large geographic area and having contributions from 28 states, two European shipping safety databases were assessed for their suitability for the purposes of this research. Finally, two commercial shipping databases were viewed to evaluate their relevance to this research. The results of the reviews and assessments follow.

5.4.1 - International Maritime Organisation (IMO)

IMO's 'Global Integrated Shipping Information System' (GISIS) contains a module on marine accidents and casualties (IMO, 2015). Under the Safety of Life at Sea (SOLAS) Regulations (IMO, 2015) and the International Convention for the Prevention of Pollution from Ships (MARPOL) articles 8 and 12 (IMO, 2015), each Flag Administration is required to conduct an investigation into a casualty which occurs on one of its flagged ships bound by these two conventions and report the results of the investigation to IMO as required by MSC-MEPC.3/Circ.3, Casualty-Related Matters, Reports On Marine Casualties and Incidents (IMO, 2008). In association with this circular and the requirements to submit a report, Flag States are requested to make full use of the electronic data exchange and reporting facilities available, which includes the GISIS database.

The information in this database is gathered from two different sources. The first, as stated on the web site, is 'factual data collected from various sources'. The various sources are not detailed. The second source is from reports submitted under the requirements of the circular on casualty related matters referred to above and is submitted by the Flag States.

The GISIS database categorises the accidents based on their severity, ranging from 'very serious casualties' when there has been loss of life, loss of the ship or major pollution, to 'marine incidents' which may be a hazardous incident or a near miss.

The database can be accessed via two types of search; basic and advanced. In the basic search, up to seven parameters can be specified such as 'Ship involved', 'Flag Administration', 'Type of Casualty' and 'Incident Date' being the most useful. The advanced search gives options to refine the search within 10 annexes (or sub-categories), each of which has a number of variable parameters. In addition, it is possible to analyse the report considering the causation. Interestingly, this option also specifically includes 'Contributing Factors' and 'Observations on the Human Element' as query options.

5.4.2 - Flag States

As required by IMO, Flag States investigate accidents on ships that are under their jurisdiction. There are many accident reports on Flag State web sites or the body that is tasked to investigate on the state's behalf, however not many have data on their sites that may be interrogated.

The Transportation Board of Canada (TSB) (Transportation Board of Canada, 2015) does have monthly and annual statistics available. These statistics give shipping accidents by type and also display the type of ship, whether it is a Canadian Flagged ship, the size of ship, any fatalities and the type of reportable accident. There is not a searchable database however.

The United States Coast Guard (USCG) has on their web site a searchable database named 'Online Incident Investigation Reports' (United States Coast Guard, 2015). The reports available are those that are required to be submitted under Section 4.05 of Title 46 of the Code of Federal Regulations. Reports are generally available from October 2002, although some additional reports from before this date may be made available. This database has a basic search function with seven parameters covering date of accident, type of ship, vessel name/organisation/facility, and includes the capability for a key word search.

The Hong Kong Flag State (The Government of Hong Kong Special Administrative Region, 2015) produces an Annual report, as do many other Flag States, showing accident statistics. Hong Kong's Annual report includes accidents within and outside of Hong Kong territorial waters, the type of accident, and any human loss or injuries.

Maritime New Zealand (Maritime New Zealand, 2015) did produce a monthly report detailing and summarising accidents for a given month. The summary detailed the ship's name, ship type, type of accident and where the accident occurred. Included in the report after the summary is the narrative of the report of the accident as submitted to the authorities. However, since January 2014, the publication of the reporting summaries is on hold due to privacy concerns.

The United Kingdom's Marine Accident Investigation Branch (MAIB) does not have a public database available (Department for Transport, 2015). However, the Chief Inspector's Annual Report to the Secretary of State includes statistics and is publically available.

The Australian Transport Safety Bureau (ATSB) vpublishes marine safety investigations and reports on its web site (Australian Government, 2015). The web site lists accident reports since 1982. The search tools for this database are in two parts, the first being a 'quick' search function using key words and the second being a detailed search using up to 14 parameters plus a date range.

As the largest Flag register, Panama could be expected to have a substantial amount of information relating to accidents, however there is none available on their web site (Panama Maritime Authority, 2015).

The Liberian Registry (The Liberian Registry, 2015) also does not display any accident information on their web site, apart from their requirements for the reporting of maritime accidents.

The Marshall Islands Flag web site (International Registries, 2015) has two accident reports available, however apart from these reports there is no further information relating to accident statistics available on the web site.

The Norwegian Maritime Authority does not have a database available on its web site (Norwegian Maritime Authority, 2015). However, the Strategic Safety Department has produced a document detailing marine casualties from 2000 to 2010 (Norwegian Maritime Directorate, 2011). In addition to accident statistics, the publication also provides feedback on inspections. This publication also categorises the accidents differently to other databases and reports; it particularly concentrates on occupational accidents (falls, contact with electricity, impact injuries, etc.) as a separate category, unlike other ship accidents are grouped based on the initial event such as groundings and fire/explosions.

5.4.3 - Equasis

The Equasis database (European Commission and the French Maritime Administration, 2014) was established in 1997 by the European Commission and the French Maritime Association. The goals of Equasis are to provide safety related information in order to reduce the number of substandard ships trading worldwide, to make the information publicly available, to encourage marine authorities to work together, and to provide information on ships and shipping companies.

Whilst this is not an accident database, it does give useful information on the owner and manager of the ship, the classification society and the insurance company of the ship, together with information relating to the Port State control status. However, in many instances, the information held in Equasis is used by charterers as an initial screening of a ship, particularly the Port State Control information.

5.4.4 - European Maritime Safety Agency (EMSA)

The European Maritime Safety Agency (EMSA) has developed a database (European Maritime Safety Agency, 2015) called the European Marine Casualty Information Platform (EMCIP). This database is in accordance with the requirements of the European Communities Regulation (EC)1406/2002 (2002). The Regulation requires cooperation between Member States and the Commission concerning investigations related to serious maritime accidents. In addition, the ECMIP allows the creation of statistics or any other data analysis relating to casualties.

Only Member States and EMSA have access to the data. EMSA was approached to give access to the database for this research, however this request was declined.

5.4.5 - IHS Sea-Web

The largest maritime database in the world, Sea-web™ (IHS Markit, 2015), is compiled by IHS Maritime and evolved from the Lloyd's Register of Ships which has been published since 1764. This commercial database is subscription only and is part of the IHS group. The casualty search page, top

menu, includes the 'Ship Name', 'LR/IMO Ship No' and 'Incident No' parameters. Further interrogation is available via a menu covering three additional parameters including 'Name, 'Ship' and 'Locations' with a sub-menu in each of these to select detailed search terms.

5.4.6 - Lloyd's List Intelligence

Lloyd's List Intelligence also has a commercial shipping casualty database. This database draws its data from a number of sources including the published paper 'Lloyd's List' and Lloyd's Casualty Service (Informa, 2015). Unfortunately, it was not possible to access this database as the subscription available only included access to the daily e-paper which included market data and information, and access to articles the day before they are published in the printed version of the Lloyd's List, but not the casualty service. Contact was made several times with Lloyd's List Intelligence via email regarding student access. Disappointingly, there was no reply.

However, an overview of recent accident trends by ship type is publicly available (Mandryk, 2011). The presentation to the International Maritime Statistics Forum gives an overview of marine casualty profiles covering areas such as total loss and serious casualty trending.

5.5 - Selection of database(s)

After review of the above databases, it was considered that the Flag State databases were too regionally focused and therefore not suitable for this study. Equasis did not fulfil the requirements of having a searchable database and EMSA's database was not made available.

For global information, IMO's Global Integrated Shipping Information System (GISIS) appears to have the right attributes; a fully searchable database populated from a number of sources. Access to this database is freely available. However, it was considered in addition to IMO's database that it would be beneficial to use a commercial database as a comparison to the publicly available database. As discussed previously, Lloyd's List was contacted regarding access for research purposes, however this was refused. Therefore, considering that the Lloyd's List Intelligence database was not

available, the only other commercial shipping database available for review was IHS's Sea-web™. Fortunately, professional access was obtained for a limited time in order to complete the review as part of this research.

5.6 – Comparison of the Sea-web™ and GISIS databases

IMO's GISIS database yielded disappointing results. The number of reported accidents per category and year is substantially lower than the numbers reported via Sea-web™. For the period 1998 to 2014, a total of 2,398 accidents were reported to the GISIS database, while 21,950 accidents were reported to the Sea-web™ database. The Sea-web™ database is well populated and allows searching using a large number of variables. The good quality of data is probably due to the number of professional contributors who are able to provide information. The data may be used to check a ship's casualty history or, as in this case, be used to consider a number of variables relating to the casualty or a number of casualties. The fields that were selected for review were filled out comprehensively and in a consistent manner across both databases. These fields are discussed in Section 6.6 of this chapter.

The total number of accidents per year is also more consistent over the period 1999 to 2014 in the Sea-web™ database, while the contributions to the GISIS database commence significantly only from 2003. This may be due to the applicability of the ISM Code to all ships from 2002 and the required reporting thereafter.

5.7 - Accident Trends in the Shipping Industry

Using the two databases, the database data will be interrogated in two ways. The first enquiry is to consider the initial event to an accident which is being reported in the database in order to analyse the number of accidents for each particular initial causation. The second enquiry will look at accident causation by ship type in order to consider if there are any specific types of ships with accident rates higher than other types. These two enquiries have been selected because it is the most comparable search device between the two datasets.

5.7.1 - Analysis by Causation

5.7.1.1 - All Accidents

The initial focus of accident causation is almost always on the 'visible' first event and this is what is usually reported in the first instance. For example, capsizing is a common category used in the shipping industry and an accident would be categorised as such. However, this does not take into account any contributory factor related to the human error element, such as incorrect ballasting of the ship by the ship's officers, or incorrect stability calculations resulting in an unstable ship that may have influenced the ship's behaviour culminating in the capsize, or a navigation error by the officers.

The review of accidents by causation uses each of the pre-determined categories within each database and while similar, there are slight differences in the definition of the categories between the databases. The differences are summarised within Figure 9.

Category	IHS Sea-web™	GISIS
Collision	✓	✓
Contact	✓	✓
Foundered	✓	
Fire/Explosion	✓	✓
Hull/Machinery Damage	✓	
Hull Failure		✓
Machinery Damage		✓
Damage to Ship or Equipment		✓
Capsized/Listing		✓
Missing	✓	✓
Wrecked/Stranded	✓	
Stranded/Grounding		✓
Misc.	✓	
Accidents with Life-Saving Appliances		✓

Figure 9 - Database Category Comparison.

Considering the differences between the categories of each database, there are similarities; for example 'foundered' and 'wrecked/stranded' in the IHS Sea-web™ database is closely related to 'stranded/grounded' in the GISIS database. Hull/machinery damage in the IHS Sea-web™ database is two distinct categories in the GISIS database, hull failure *and* machinery damage. The GISIS database has additional categories for 'damage to ship or

equipment' and 'accidents with life-saving appliances', while other causations are represented by the 'misc.' category in the IHS Sea-web™. Therefore, even though there are differences in the categories, the datasets can still be used comparatively for the purposes of this study.

IHS Sea-web™ Database Interrogation

Accessing the Sea-web™ database, the period reviewed was from 1998 to 2014. The category 'War Loss/Hostilities' was not included in the analysis due to war or hostilities not being considered an accident, but rather a pre-determined act rather than an unplanned event. Ships over 500 Gross Tonnage were included in the database query as the ISM Code applies to all commercial ships above this tonnage. This summary includes serious accidents and also accidents of a lesser nature which resulted in damage to the ship, another ship or persons onboard.

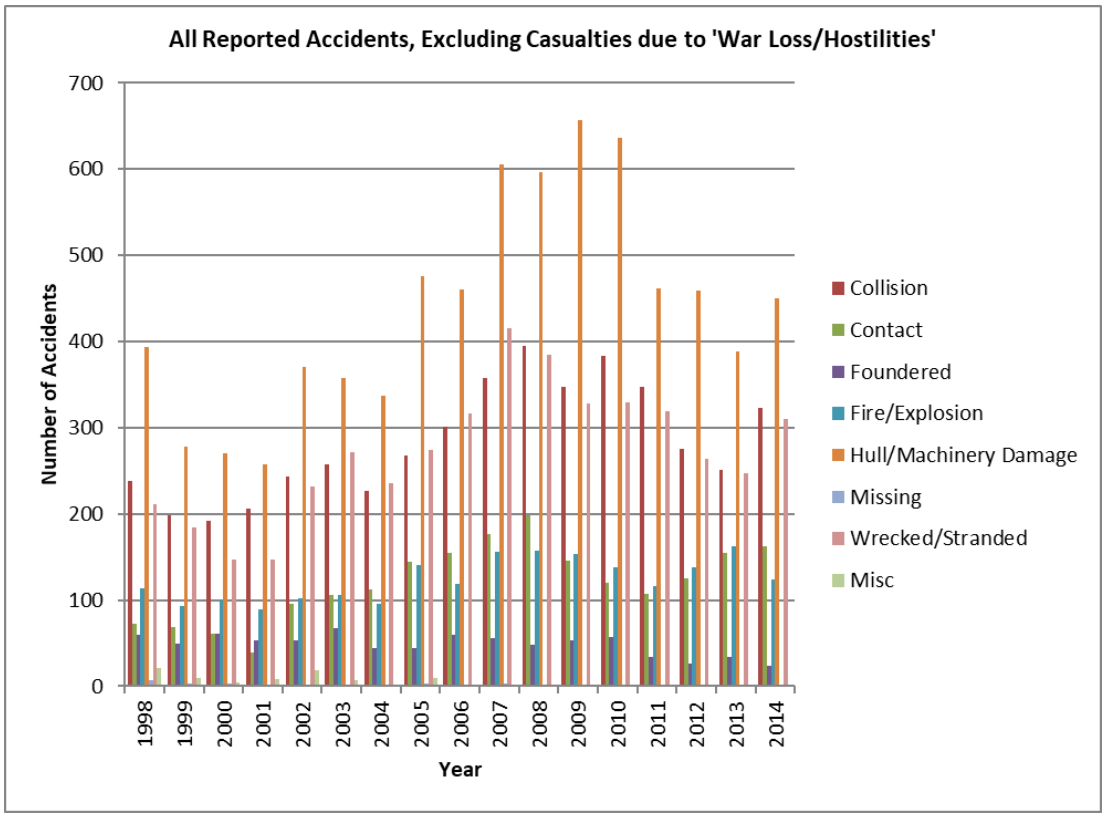

Figure 10 - Results of SeaWeb™ Interrogation for Accident Causation.

The overall trend in the result of the interrogation shows that there is an increase in the number of accidents from 2007 to 2010. This increase

corresponds to the newbuild ordering boom prior to the global financial crisis of 2008.

Global Integrated Shipping Information System Database Interrogation

IMO's Global Integrated Shipping Information System module on Marine Casualties and incidents uses similar categories to the Sea-web™ database as discussed previously, however war casualties are not included in the database as a separate category. Again, accidents with ships of 500 Gross Tonnage or more were included in the database search.

Compared to the Sea-web™ database, the number of results returned from the GISIS search was very low. The low number of reported accidents is particularly evident in the early years of the implementation of the ISM Code (1998 to 2002). Therefore, it was decided to further interrogate the Sea-web™ database only for this research.

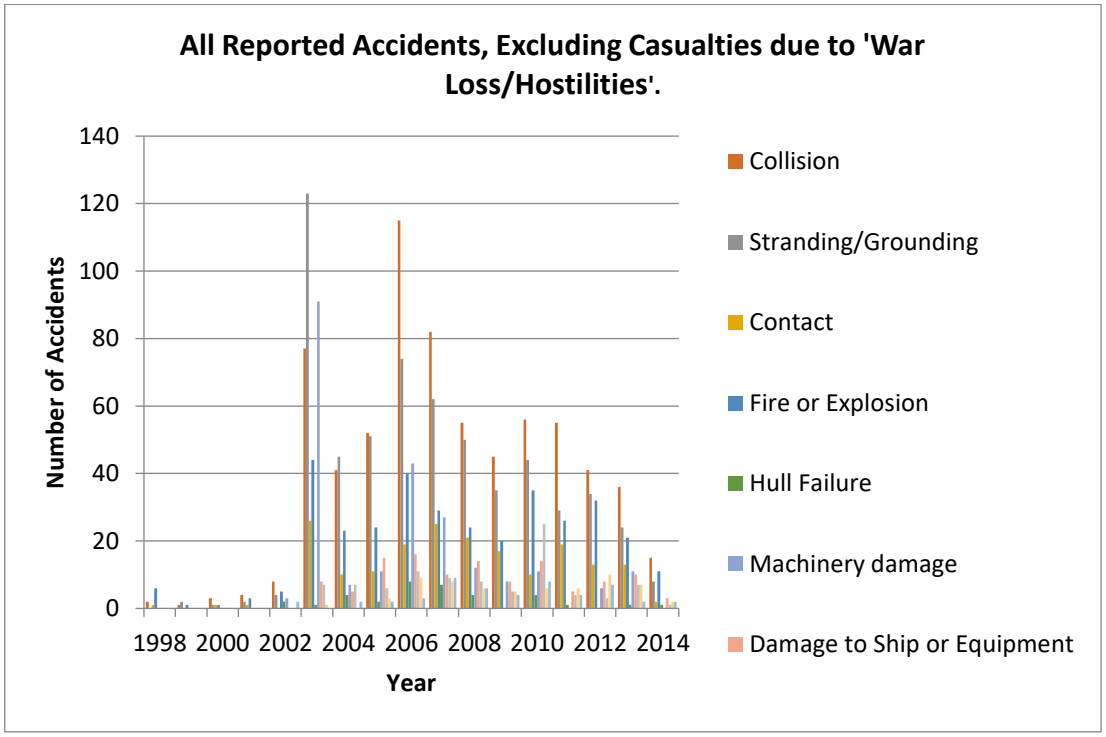

Figure 11 - Results of GISIS Interrogation for Accident Causation.

5.7.1.2 - Accidents with Lives Lost or Missing

The Sea-web™ database was further analysed to consider the number of more serious accidents which resulted in loss of life or missing persons.

Reviewing the results highlighted that three categories contribute to a large number of deaths with a relatively low number of accidents, namely 'Fire/Explosion', 'Foundered' and 'Collision'.

The introduction of the ISM Code between 1998 and 2002 appears to have had minimal effect on reducing the number of accidents attributed to collision. Details of the accidents within the database was limited, therefore it is difficult to assign further causation factors to the accidents without having access to the individual accident report.

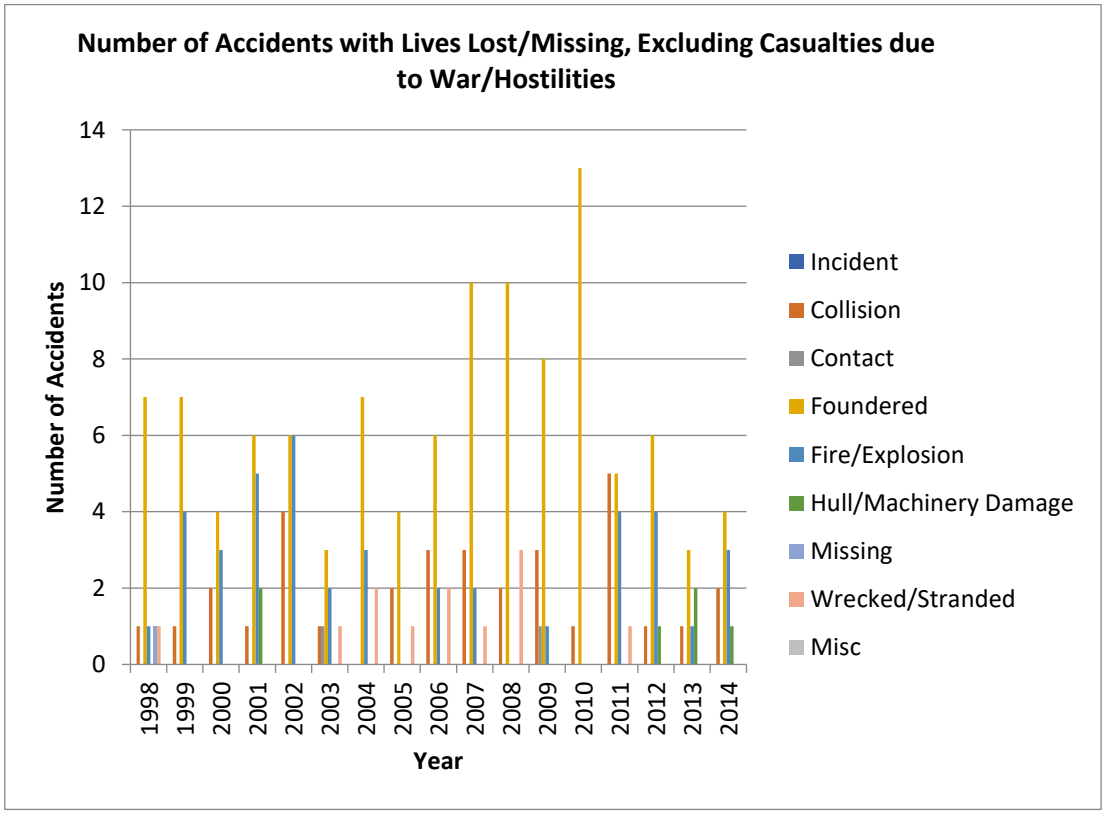

Figure 12 - Number of Accidents with Lives Lost/Missing, Excluding Casualties due to War/Hostilities.

Fire/Explosion

The details of the causations are limited within the database information, however further review of the 'Fire/Explosion' category may reveal what type of vessel had suffered damage and whether the accident had been initiated from the cargo area (an oil tanker cargo explosion, for example), in the engine room or in another area of the ship. This would give a clearer picture of the

root cause of the accident and also if any human error could be attributed to the accident causation

Fires and explosions are fortunately now relatively rare on ships. On oil tankers, after a number of high-profile accidents in the 1970s, the introduction of cargo tank inerting has substantially reduced accidents due to fire and explosion on all types of tankers. More recently, as container ships have increased in size and container capacity, there have been incidents with containers catching fire. A factor contributing to this is the incorrect declaration of the container contents and the subsequent positioning of the container on the ship. Generally, containers containing hazardous substances are stowed where there is access to the container and in a dedicated area of the ship, usually aft of the accommodation structure.

Fire or explosions within the machinery spaces may be due to mechanical failure of equipment or a failed part on a piece of equipment. An example of this type of failure is a diesel engine, which has had a catastrophic failure (a crankcase explosion) or the failure of a fuel pipe on a diesel engine resulting in a hydrocarbon leakage. Additionally, due to the relatively large stored and system inventories of fuel, lubricating and hydraulic oils in the engine, there is also the risk of hydrocarbon release in the engine room due to either pipe or valve failure, which in the event of impinging on a hot surface, may result in a fire. There is technology available, such as an atmospheric oil mist detection system, installed in areas of risk which will reduce the risk of such failures. However, this type of equipment is neither fitted as standard nor required by legislation.

Other areas on ships which may be susceptible to fire include laundries/drying rooms, seafarer’s cabins due to unauthorised electrical equipment being used or smoking regulations being ignored, electrical equipment rooms and chemical/lubricating oil storage areas.

Foundering and Collision

It was decided to consider the categories 'Foundered' and 'Collision' together due to the causations that may be common to both categories. Examples of these common causations include a lack of seaworthiness (covering areas such as design, loading distribution and engineering practices) or navigational aspects (such as navigational practices, human error and external factors).

A lack of seaworthiness can be attributed to latent defects, such as a design issue which has been undiscovered usually until the accident occurs. An example of this type of causation includes some of the factors that contributed to the Herald of Free Enterprise accident which has been discussed in an earlier chapter. Active factors that may contribute to a lack of seaworthiness include overloading the ship or officers not loading the ship correctly. This may be due to inexperience and lack of supervision or not checking that the ship is loaded in compliance with the regulations for stability and strength.

There are many navigation errors that can contribute to both foundering or collision. Group and individual factors, as discussed in Chapter 5, are contributing to these types of accidents, however organisational factors relating to training are also contributors. Fundamental to avoiding such accidents are compliance with the Collision Regulations (IMO, 1972) as previously discussed in Chapter 5.

5.7.1.3 - Loss of Life/Missing, by Category

The data was further analysed to consider the number of deaths per accident per category. It was found that twelve accidents distorted the data due to a very large loss of life (refer to Figure 13). This was due to the accidents involving Passenger/Ro-Ro Cargo/Ferry carrying a large number of passengers at the time of the accidents.

As these accidents may have other factors as causations outside the scope of this research, such as local influences and practices, it was decided to exclude them from the data being reviewed.

Collision 2013 - St. Thomas Of Aquinas excluded due to 137 lives lost or missing (Roro Cargo/Ferry)
Foundered 1998 - Princess of the Orient excluded due to 150 lives lost or missing (Passenger/Roro Cargo/Ferry)
Foundered 2002 - Le Joola excluded due to 970 lives lost or missing (Passenger/Roro Cargo/Ferry)
Foundered 2006 - Senopati Nusantara excluded due to 373 lives lost or missing (Roro Cargo/Ferry)
Foundered 2009 - Princess Ashika excluded due to 88 lives lost or missing (Ferry)
Foundered 2011 - Spice Islander I excluded due to 1573 lives lost or missing (Roro Cargo/Ferry)
Foundered 2014 - Sewol excluded due to 304 lives lost or missing (Passenger/Roro Cargo/Ferry)
Fire/Explosion 1999 - Da Shun excluded due to 282 lives lost or missing (Roro Cargo/Ferry)
Fire/Explosion 2002 - Maria Carmela excluded due to 73 lives lost or missing (Roro Cargo/Ferry)
Fire/Explosion 2006 - Al Salam Boccaccio 98 excluded due to 988 lives lost or missing (Passenger/Roro Cargo/Ferry)
Wrecked/Stranded 2000 - Express Samina excluded due to 83 lives lost (Passenger/Roro Cargo/Ferry)
Wrecked/Stranded 2008 - Princess of the Stars excluded due to 831 lives lost or missing (Passenger/Roro Cargo/Ferry)

Figure 13 – List of Passenger/Ro-Ro Ferry Accidents Excluded.

The revised findings are presented in Figure 14.

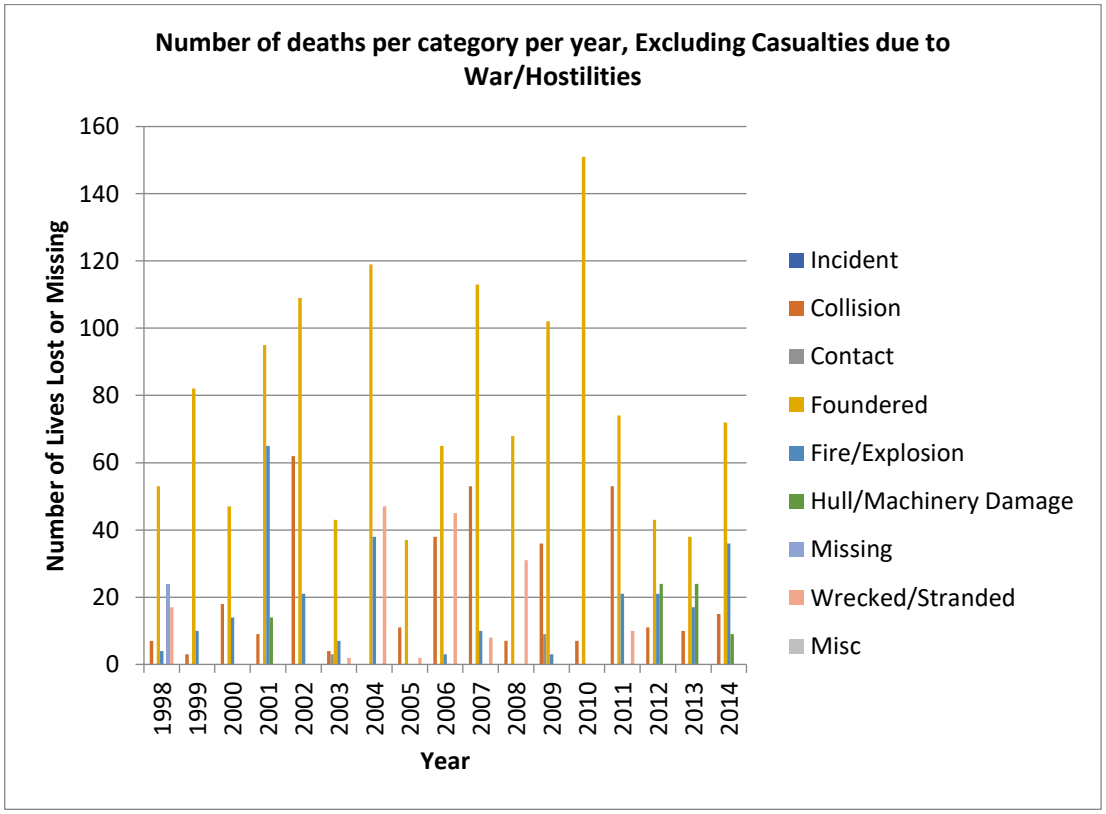

Figure 14 - Number of Deaths per Category per Year, Excluding Casualties due to War/Hostilities.

Considering the results presented in Figure 15, the category which has had the highest number of deaths is 'Foundered'. In addition, if this category is combined with 'Collision', 'Contact' and 'Wrecked/Stranded' due to likely causation similarities, then it appears that closer consideration should be given to these categories as a subgroup when considering the number of accidents with lives lost or missing.

When considering the fatalities associated with each category, the number of deaths per 'Fire/Explosion' accident is generally less than those attributed to a 'Foundered' and 'Collision' accident. This may be due to fire/explosions being more localised when they occur onboard and easier to contain. However when a ship has an accident relating to the other high incident categories, the loss of life is much higher due to the accident possibly affecting the integrity of the ship. When the integrity of a ship is compromised, then there is a possibility of having to abandon ship. As a result, in addition to possible casualties from the accident itself, there is the risk of more deaths occurring due to having to abandon ship.

5.7.2 - Analysis by Ship Type

Ships vary in size, propulsion type and are designed to carry specific cargoes. As discussed in Chapter 5, regulations vary between vessel types and, in addition, third party inspections are also applicable, depending on the cargo carried. Crew training requirements and qualifications also vary between vessel types. It could therefore be expected that these two factors, ship design and crew competence may affect casualty rates.

Mandryk (2011) of Lloyd's List considers serious casualties by ship type, 'Serious Casualties' are defined as:

- An incident resulting in human fatalities.

- Structural or machinery damage likely to result in a vessel being declared a Total Constructive Loss or damage rendering a vessel unseaworthy or requiring extensive repairs.

- Disablement or breakdown resulting in a vessel requiring the assistance of salvors or the abandonment of a voyage or the vessel being removed from service for a reasonable period for repairs.

- Any other incident resulting damage considered to be serious enough to prevent a ship from continuing in service.

Considering the different ship types detailed in Figure 15, Lloyds List Intelligence data for the years 2006 to 2010 (Mandryk, 2011) suggests that while there has been an overall reduction in serious casualties during the period, the trend is not seen to be moving in a continuous positive direction. While more recent data has not been available for this research, this trend should be taken in the context of the growth of the international fleet over the period.

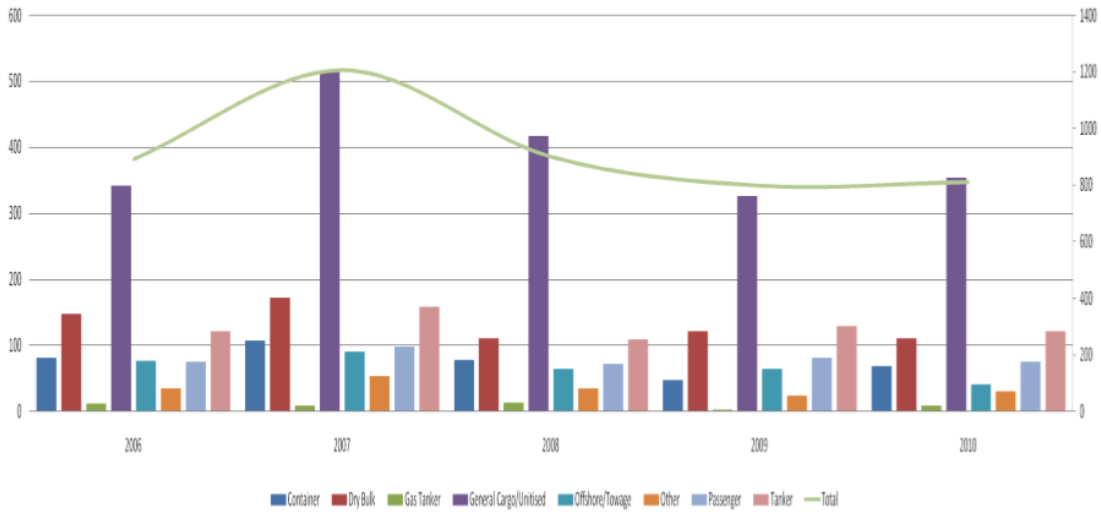

Figure 15 – Serious Casualties by Ship Type 2006 to 2010 (Lloyds List Intelligence, 2011).

Ship types detailed in Figure 16 include both LNG and LPG gas carriers. The dry bulk type relates to ships that carry grains, ores and coal loosely in holds. Tankers include ships that carry crude oils, chemicals and refined petroleum products. Offshore/Towage includes offshore support vessels as well dedicated towing vessels. Container ships include large ships on liner routes between the far east and Europe and also smaller container ships on feeder services.

Considering the individual shipping sectors, historically the gas tanker sector has always been highly regulated and this is reflected in the consistently low casualties throughout the period. This sector is also monitored closely by charterers. In addition to additional legislation, further regulation in the tanker sectors comes from energy majors and charterers of the tonnage. As discussed in Chapter 3, one of these initiatives is The Oil Companies International Marine Forum's (OCIMF, 2014) 'Ship Inspection Report Programme'. The industry introduced this programme to specifically address concerns regarding sub-standard shipping and applies to all tanker sectors. All registered users of the system can download reports on ships before they commit them for business while OCIMF members (mainly energy majors) can access reports on any ship in the system. This system has contributed to ensuring that tankers are operated in accordance with their company systems and managed to the highest standard at all times.

At the other end of the scale is general cargo/unitised tonnage. This sector has older tonnage and may also be operating in less regulated areas. These factors taken together with less monitoring than other shipping sectors results in the higher casualties as seen in the Lloyds List Intelligence data.

It may also be that authorities are assessing the various shipping sectors to different standards, depending on what they carry and where they trade. This could affect the safety standards onboard, as well as the seaworthiness of the ships operating in these areas.

5.8 – Chapter Summary

Accessing data in the public domain relating to safety in the shipping industry is difficult. Shipping companies do not publish safety data routinely as it may negatively affect commercial aspects of their company's trading ability. Therefore, unless shipping companies are willing to allow access to their safety data for research purposes, even if it is anonymised, it is very difficult to analyse statistics related to safety. In addition, there are databases produced by legislative bodies (IMO for example) and Flag States. However, as noted earlier in this chapter, information was limited in IMO's database and, in many cases, not fully completed.

Commercial databases relating to safety information in the shipping industry are also limited. Of the two databases considered in this chapter, one was not willing to allow access for research purposes and the other was accessed after subscribing, although the data contained within was only accessible for a limited time due to the type of subscription purchased.

The initial analysis of causal factors showed that there are two main types of accidents occurring in the industry, one is due to hull and machinery damage and the other is occurring at sea due to either collision, wrecked or stranded. When the number of accidents with lives lost or missing is analysed, ships that have foundered and have fatalities due to fire or explosion are still prominent. The data was further analysed to consider the number of deaths per accident per category. This showed that accidents due to foundering, collision and wrecked were the most prominent initial causes of accidents.

Finally, the number of serious casualties related to ship type was also analysed. This showed that general cargo ships have the highest incidence of serious casualties and that this is probably due to the relatively unregulated nature of this sector of the industry, especially when compared to the tanker sector which has a number of third party inspection regimes as described in Chapter 4.

The next chapter presents Study 2 by considering human factors and accident analysis practice in shipping by using a sequential mixed method approach. Initially a discussion of survey construction and distribution will be presented, followed by an analysis of the survey results. Then a series of semi-structured interviews with industry safety professionals will be presented.

6

Study 2: Human Factors and Accident Analysis Practice in Shipping

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6.1 - Introduction

This chapter will analyse quantitative data collected from an online survey as well as qualitative data collected through a series of semi-structured interviews with a number of selected shipping experts with particular expertise in the safe operation of commercial ships that trade worldwide. This is the first time a large number of ship owners and managers have been approached to consider their views on operating ships safely. The data contained in this chapter

compliments the analysis provided in Chapter 6 and provides a unique contribution to the study of human factors in shipping.

The analysis will also give a fuller insight into the current concerns of the industry relating to shipping safety, with a focus on human factor challenges within the shipping sector. The synthesis of information from both of these research tools will be used to formulate an approach for promoting how a reduction in human error can be achieved in the shipping industry.

6.2 – Methodology

This chapter extends the mixed method approach by using a sequential mixed method as defined by Carayon et al. (2015); the first sequence consists of a survey tool designed to produce quantitative data, and the second sequence utilises the analysis of the survey data collected to design semi-structured interview questions to produce rich qualitative data.

This sequential approach relates specifically to the survey and interview phases of this research, and describes when one type of data provides a basis for collection of another type of data, in this case combining the survey phase with the interview phase. The first phase is exploratory, generating its own inferences, and allows the second phase to emerge from the inferences of the first phase (Tashakkori and Teddlie, 2003). The final analysis confirms and synthesises the inferences from both phases. This is a hallmark of a mixed methods approach; the ability to generate meta-inferences beyond what qualitative and quantitative approaches could accomplish alone (Guetterman et al., 2017).

Other methods were considered as an alternative to a sequential approach, however this specific approach was chosen in order to ensure anonymity for the data being provided as other methods, such as focus groups, would compromise commercial interests. This is because of the relationships between both companies and personnel in the industry which restricts disclosure and openness amongst commercial competitors. Figure 9 shows the two phases contributing to the design of the sequential mixed model as applicable to the survey and interview research.

Using the mixed method approach in this instance allows the structure of the interviews to be aligned with the findings of the survey and facilitates the development of emergent themes which are of further interest to this research. Cameron (2009) notes that this approach is very apt to organisational research, where many disciplines meet, as in the case of the shipping industry.

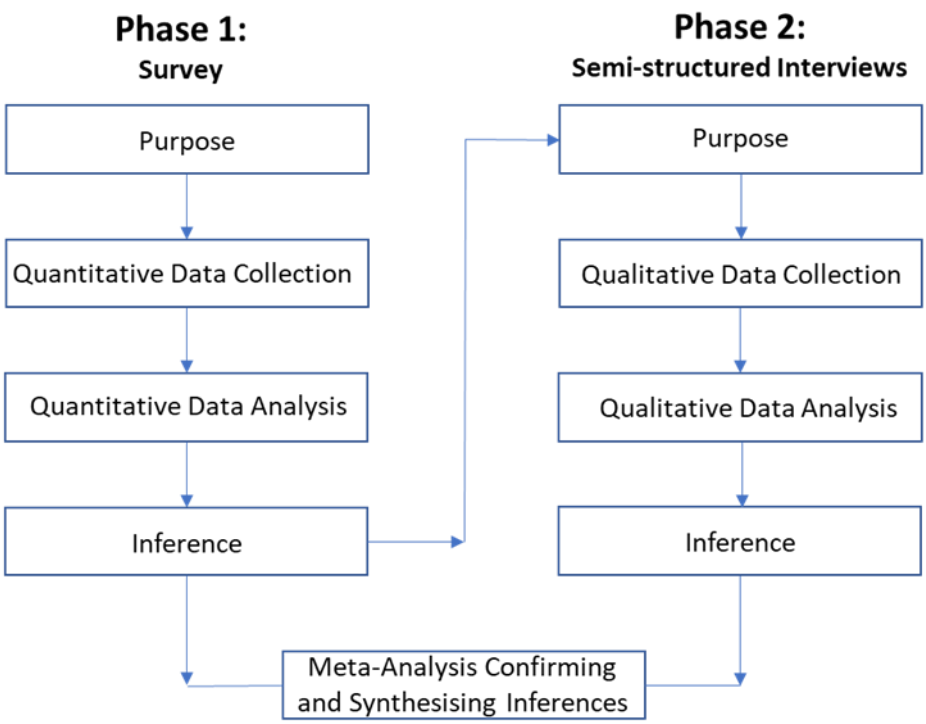

Figure 16 – Sequential Mixed Model Design of the Survey and Interview Phases.

6.2.1 - Part 1: The Survey

This part of the research used an initial quantitative approach to amalgamating basic data concerning safe operations and related human and organisational factors in order to identify factors that are important in identifying areas for further research. The survey forms a fundamental understanding of shipping as related to safe operations and allows for a unique insight by giving a broad overview of the challenges affecting safety as perceived by ship owners and managers of various types of commercial ships.

In other industries, there has been much research into applying a theoretical approach to identifying the causes of accidents, and also identifying human error when that was a contributory cause. However, in the shipping industry, there has only been limited work in applying theoretical models of human

factors to influence operational practice and to identify human factor contributions to accident causation. Therefore, the research examines four practical aspects of human factors within shipping companies, namely; organisational, group and individual factors together with accident investigation practices.

The following objectives were established to achieve this:

- To understand the current applicability of using each of the human factors elements in order to improve the safety of ship operations, with a focus on safety culture.

- To understand current accident investigation techniques in the industry and to consider if human factor elements are identified in order to focus on human error and reduce its effects.

- To understand the relationship between the shore and ship organisations and its effect on safe operations.

- To assess which accident and incident analysis techniques are used in the industry and to consider if Systemic Accident Analysis (SAA) methods could be applied to ship operations in order to identify common causations, for example occurring in near misses.

The initial approach to achieve these objectives was to target a wide number of shipping companies in various sectors using an online questionnaire. There are several advantages to using this method. Kapolowitz, Hadlock and Levine (2004) note that the anonymous environment of the internet prevents respondents from undue influence, thus enabling data accuracy. De Vaus (2002) adds that internet surveys are effective at obtaining representative samples of specific populations. The questionnaires can also be distributed easily (Couper and Miller, 2008).

6.2.2 - Part 2: Semi-structured Interviews

Further to the research conducted via the survey questionnaire, and in order to achieve the desired goal of having a framework while allowing a discussion

of the subject, a secondary sequential research method was introduced. The survey was used to formulate a sub group of respondents for the qualitative semi-structured interviews. The questionnaire provided respondents with an 'opt-in' option to be involved in further research. If respondents did 'opt in', semi-structured interviews were conducted only with those particular respondents. Using semi-structured interviews as part of a research methodology is an established tool. Advantages to this technique include the ability to explore respondents' opinions, clarify interesting and relevant issues, elicit complete information and explore sensitive topics within each interview (Barribell, 1994). While having a high level of items to discuss with the interviewee, the ability to digress and expand particular issues and areas of specialist knowledge, depending on the interviewees experience, ensures that their area of expertise is fully explored during the interview.

Using semi-structured interviews is one of the most commonly used qualitative methods. One of the main advantages of this method is that it allows an open response from the respondent in their own words (Turner, 2010). However, the interaction between the interviewer and interviewee is also important to ensure that the response is to be the most beneficial to the study. With semi-structured interviews, it is also most important to formulate the questions correctly; utilising closed questions does not allow the interviewee to share his knowledge of the topic. There is also a possibility that the interviewee will go off topic during the questioning rather than directly answering the question in a concise manner. This could provide unexpected yet important information.

The interviews were semi-structured in order to allow the participants to expand on their specific areas of expertise after introducing an initial question covering the main topics of interest to the research. Cachia and Millward (2011) discuss how the semi-structured interview is characterised by elements from both structured and unstructured interviews. Sequential questions are used as an interview guide, but additional questions can be introduced to facilitate further exploration of topics brought up by the interviewee, thus almost taking the form of a managed conversation. Most of the interviews were not conducted face-to-face primarily due to the wide geographical locations of the interviewees. However, this does give the advantage of the

interviewer's physical or emotional responses not influencing the participants responses. All the interviews were recorded and transcribed as is best practice.

One of the most challenging aspects of using semi-structured interviews as a qualitative method is analysis of the data. This is highlighted by Sofaer (2002), who states that it is important to ensure the data is not treated in a quantitative manner. It is also highlighted that the data obtained from qualitative means is often not conclusive, rather it is suggestive. This has to be considered when drawing conclusions from the interview process, however the combination of using initial questionnaires together with semi-structured interviews will give the fullest account of current practices relating to shipping companies approaches to human factors and safe operations.

While the bulk of interview participants were obtained from the online questionnaire, additional interview participants who are industry specialists were contacted through the researcher's professional network. This included ship owners and managers, regulatory bodies and insurance companies in order to ensure that an overview was obtained covering all aspects of safety practices and concerns in the industry. Finally, several respondents were contacted using LinkedIn and industry bodies such as Intertanko (members who are independent tanker owners and operators of oil, chemical and gas tankers) and SIGTTO (the Society of Gas Tanker and Terminal Operators).

This is the first-time industry wide interviews with shipping safety experts have been conducted. The experts had specialised experience in a number of different areas of shipping including; onshore ship management at a senior level (additionally with senior sea-going experience on different types of commercial ship), human factors, regulatory bodies (at the Flag State level and Classification Societies) and responsibilities for loss prevention at insurance companies. The thesis therefore provides a unique insight from experts, the majority of whom have sailed on ships and gained practical experience and knowledge and, later in their career, held senior positions in ship owner and management companies.

6.3 – Survey

As described in Chapter 5, the survey was designed to give an industry-wide overview of different approaches to safety in the shipping industry and, by approaching operators in the different sectors of the industry, will provide an overview of the different standards, processes and systems used in order to maintain safe shipping.

6.3.1 - Survey Question Design

The survey questions were designed to provide insight into the following areas of interest:

- The perception of safety culture within a company and how it is measured or determined by either lagging or leading indicators.

- Human Factors:

    - The influence and awareness of organisational, group and individual human factors in a company's safe operation of ships.

- Accident Investigation:

    - To consider current investigation methodology within a company.

    - To assess current accident investigative practices within shipping companies and the determination and reporting of accident causation in order to make ships safer and improve ship operations.

There has been very limited research related to shipping organisations and the effect of safety culture and other human factors on safe operations. To date, research has been more focused on individual factors, and has used questionnaires to ask only seafarers for their views on certain personal issues. For example, Hetherington et al. (2006) refers to a survey of seafarers by the National Union of Marine, Aviation and Shipping Transport Officers (NUMAST)

relating to fatigue, and an Australian Maritime Safety Agency (AMSA) survey of seafarers concerning stress. This survey also included questions on health issues.

This research questionnaire will consider human factors from a wider perspective, and accident investigation from shore-based shipping safety practitioners, to give an overview of current attitudes and practices in the industry.

As part of the survey piloting process, the survey was reviewed by a Marine Manager of a shipping company, a senior safety professional in a shipping company and a Master Mariner with extensive experience of sailing and onshore experience in ship operations.

6.3.2 - Questionnaire Participants

Several sources were used to identify possible survey participants, the first being a number of industry bodies:

- OCIMF (Oil Companies International Marine Forum, 2014): This body was formed after the Torrey Canyon incident in 1970 to counter the public's growing concern about marine pollution, particularly oil. It has consultative status at IMO.

- Intertanko (International Association of Independent Tanker Owners, 2017): Members of Intertanko are independent tanker owners and operators of oil, chemical and gas tankers.

- Intercargo (International Association of Dry Cargo Shipowners, 2017): This body represents shipowners, managers and operators of dry cargo vessels.

- SIGTTO (Society of International Gas Tanker and Terminal Operators Ltd, 2017): The Society was formed to promote shipping and terminal operations for liquefied gases.

- InterManager: This is the industry body associated with ship management. It was established to consider all aspects involved with the management and crewing of ships.

Additional potential survey respondents were contacted via 'The Motorship' magazine. This has a publicly available listing of owners, operators and managers of ships (The Motorship, 2016).

Finally, a comprehensive list of ship managers is available at Lloyd's List (Informa, 2016). This lists ship managers by country. There is a total of 7,105 listings, however many of the entries are service companies related to the shipping industry and not relevant to this study. Therefore, each listing was checked by accessing the related web site for the company, checking to confirm that they were operating commercial ships applicable to this study and had a current email for contact. After cross checking, a total of 905 companies were selected to be invited to participate in this research via the survey. In most cases, the contact email address was a general office email and the contact letter was modified to ensure that survey email was re-directed to the person responsible for onboard safety matters in the company.

6.3.3 - Distribution and Response Rate

The survey was deployed using online based survey software (SurveyMonkey). As a preliminary distribution, a targeted weblink email was sent via LinkedIn to 33 invitees from the researcher's professional network. This resulted in 16 surveys fully completed and three surveys partially completed. The main distribution of the survey occurred on 6th September 2016. An email containing an introductory letter and a link to the online survey was sent to 860 potential respondents, excluding the prior 33 invitees. Reminder emails were then sent to non-respondents on 13th September and 20th September in order to maximise the response rate.

Of the total 893 survey invites, 44 surveys were fully completed and eight partially completed. The response rate, considering partially and fully completed surveys, but excluding rejected and opt out was 5.8%. Partially completed surveys were included in this instance to maximise the data collection and collate all possible data. This is because a survey of this type

has never been conducted before. One reason for such a low response may be that contact information for staff responsible for safety in shipping companies is difficult to obtain. This suggests that the communication to safety departments is closely controlled internally, possibly due to commercial restrictions and/or concerns. Indeed, my experience with contacting safety departments within shipping companies via the only publicly available contact details was highly problematic.

6.3.4 - Survey Results

General Question Section

The majority of companies responding to the survey were operating ships directly as part of their company ship owning strategy, however third party ship managers also responded to the survey. These are companies that manage ships on behalf of a client who is usually a ship owner, but may also be a finance institution or other entity with an owning interest in the ships.

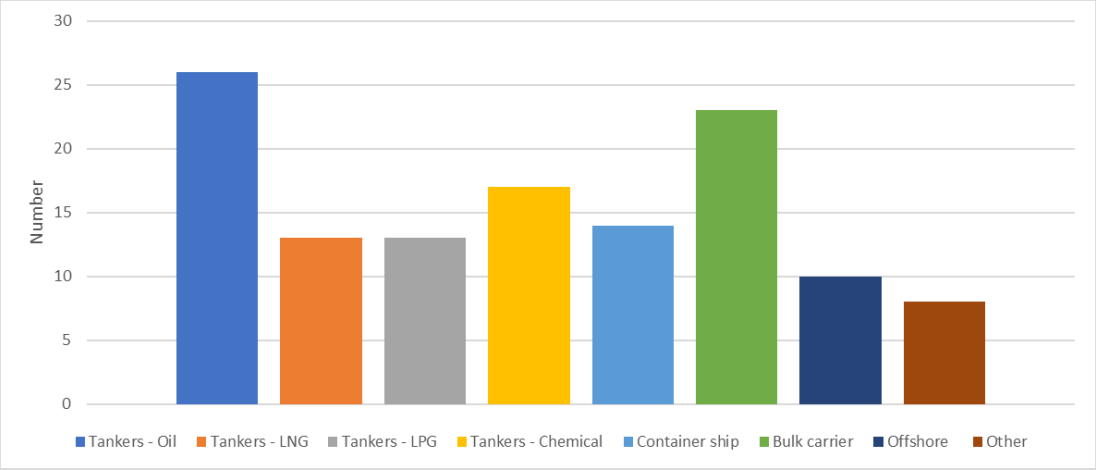

Figure 17 - Ship Types Operated by Survey Respondents.

As expected, due to the stringent operating standards in the sector and proactive approach to safety, the majority of respondents were operating tankers (oil/gas/chemical), however there was also a good response from bulk carrier and offshore operators. Other types of ships being operated by the respondents include cement carriers, car carriers and livestock carriers.

The majority of respondents operated up to 50 ships, however 12 responses were from large ship owner/operators, with six companies operating in excess

of 100 ships. Reflective of the large organisations that responded, 12 companies had more than 200 employees, however the majority of companies employed between 21 and 50 employees. This wide range of organisation size provides a good overview of different working practices, procedures and approaches related to safety in the industry.

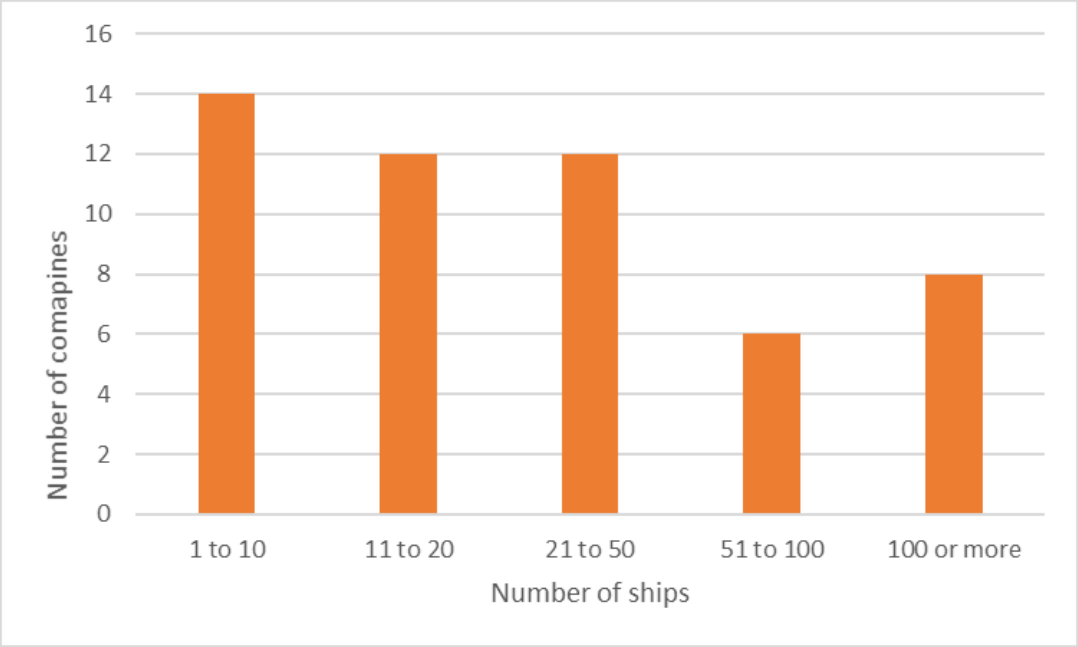

Figure 18 - Number of Ships Managed per Responding Company.

Risk Management

When the respondents were asked what, in their opinion, is the most significant factor that poses a risk to safe shipping, almost 80% of respondents considered human error to be a very significant risk and 20% of respondents considered human error to be a significant risk. Poor training of seafarers was also rated as a very significant factor by over 40% of the respondents, with respondents noting the difficulty in recruiting seafarers.

Interestingly, machinery failure was also considered a significant risk to safe shipping. This is surprising considering the development of more reliable machinery, the increased automation and the system redundancy onboard. Of less concern to the respondents was the gap between the procedures and practices onboard and their management system. This is something that could be expected due to the period that it has been required to have an approved

safety management system in order to operate ships, that being the introduction of the ISM Code in 2002.

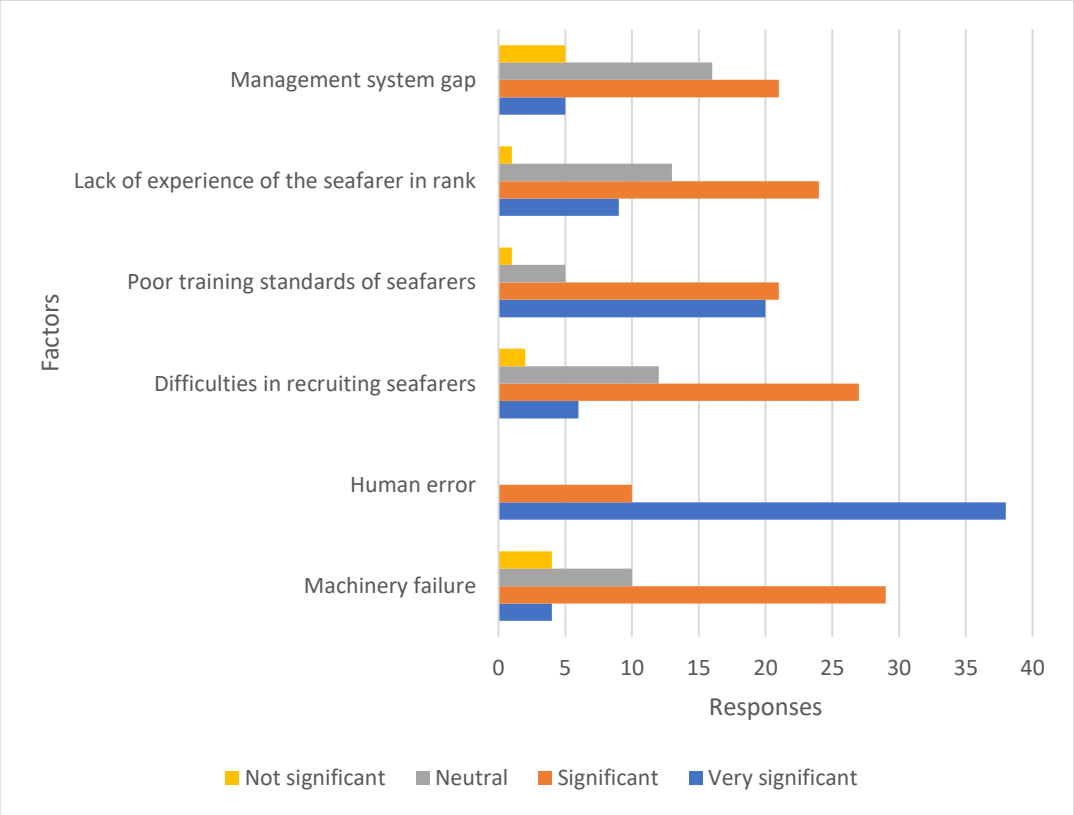

Figure 19 - Responses Regarding Factors Affecting Safe Shipping.

Safety Department

The majority of respondents have departments which are designated to monitor safe operations. The advantage of this organisational structure is that staff dealing with safety are not influenced by either operational or commercial pressures. The majority of companies responding employed both safety professionals and ex-seafarers in their safety departments.

Respondents noted that for employed safety professionals, there is a requirement for a qualification such as a National Examination Board in Occupational Safety and Health (NEBOSH) or similar, while seafarers employed in the safety departments are mainly senior officers, including captains and chief engineers. The majority of staff employed in safety departments are given additional training on joining the department such as accident investigation and risk assessment.

Organisational Factors: Safety Culture

The respondents were asked about their perception of safety culture in their organisation. The majority (over 40%) described their safety culture as 'just', meaning human error as a way for organisations and staff to learn and improve (Maritime and Coastguard Agency, 2014), with 30% describing their safety culture as 'reporting' meaning cultivating an atmosphere where people have confidence to report safety concerns without fear of blame (Air Safety Support International,) and 20% as 'no-blame' implying a blanket amnesty on all types of unsafe behaviour (Reason, 1998).

The majority of respondents stated that their company uses both lagging and leading indicators in order to measure safety performance. Industry standard lagging indicators were used such as fatalities, Lost Time Injury (LTI) and Total Recordable Case (TRC).

The majority of respondent organisations (more than 80%) indicated they had a safety awareness programme, however only 21 respondents gave a response about having a specific safety programme. The remainder provided an overview on the company's safety training such as computer-based training, training related to drills and incident/near miss feedback. Those that had a programme responded that the programmes were introduced between every three months and annually, although quarterly is the industry's best practice. While over 30% of respondent companies had their safety awareness programmes active for over five years, the majority of the respondent's companies only had them in place for between one and three years.

Only about half of respondents indicated that their company had measured the impact of their safety awareness programmes. This is an area that could be improved and would give valuable feedback to the operators of ships, particularly when leading indicators show particular areas of concern. Over 80% of respondents had a safety opportunity or safety reporting programme in place and all gave feedback from this programme to the ships. Most companies held seminars for officers, but not for ratings. While it is good to get a company's safety message across to the officers, it is also important to

stress the importance of safety to the ratings as they are carrying out most of the manual work onboard ship and may present the highest exposure to workplace injuries.

The survey also highlighted that the majority of companies required senior managers to visit ships that are in service. This practice is beneficial as it means that the seafarers hear the safety message directly from representatives who set the company's policies and monitor the safety performance of the company.

Companies also used additional means to promote safety within their organisations, these included:

- Seconding sea-going staff to the office in order to enhance the safety message when the seafarer goes back onboard.
- Onboard training team.
- Posters, newsletters and bulletins.
- Rewards or safety awards.

Organisational Factors: Safety Training

The majority of organisations that responded use a third party to supply their seafarers. Of these organisations, over half had officers and two thirds of ratings supplied by a third party. The remainder had mixed fleets consisting of some officers and ratings employed directly and the remainder by a third party.

Companies see the value of additional training over the STCW requirements (IMO, 1978) and the majority of companies assess the training needs of seafarers in their organisation with leadership, simulator, bridge resource management and risk assessment courses being examples of those being provided.

Group Factors: Teamwork

The majority of companies surveyed (80%) did not have any policy in order to restrict the number of nationalities onboard. An advantage of such a policy is that it gives the shipping company more flexibility when recruiting seafarers and also prevents one or more cultures becoming dominant onboard. However, from an operational viewpoint, it means there could be a communication issue between the seafarers, not only during normal working hours, but more crucially when the seafarer is in a stressful situation and may revert to their mother tongue. This could result in emergency orders being misunderstood or not being followed. Of the companies that did have policies, it was primarily due to local legislation requiring the ships to be locally manned or it was specified by the project that the ship was assigned to.

Apart from two respondents, the working language onboard was English. The majority of company's safety management systems included a reference to the IMO 'Standard Marine Communication Phrases' (IMO, 2017). These are useful because they include a number of key phrases, in English, that can be used to avoid any confusion or error and are simple and direct in their use. Future research might investigate how a company ensures that the working language is spoken and understood by all onboard.

Over three quarters of companies conduct resource management training. The focus is on bridge resource management training with over 90% of companies conducting such training and over 70% of companies conducting resource management training for engineer officers. Generally, ratings do not attend such training and in the majority of such courses, shore staff do not attend either. Additionally, the majority of companies did not assess the effectiveness of such training, however those that did used a variety of methods to assess the course contents. These methods included assessing feedback from the course attendees and shore staff assessing the performance of individuals on the course.

Individual Factors: Competence

All of the organisations that responded had an appraisal system in place for seafarers. This covered, in all cases, the officers performance, and the majority of companies also assessed the performance of their ratings.

Half of the companies that replied advised that they used some form of Competence Management System (CMS), however the extent of use is not known. Most of these systems were developed in-house and not provided by a third party. The majority of the systems included learning tools, a skill/gap analysis and an assessment section.

Individual Factors: Fatigue

As required by the STCW Convention (IMO,1978), hours of work and rest are monitored onboard, with three quarters of companies using software to assist with the monitoring. However, the majority of companies did not have a Fatigue Risk Management Plan (FRMP). Ships schedules and workloads are continuously changing and to ensure that hours of work and rest are adhered to, together with assisting the planning of rotas onboard, such a plan would be advantageous.

Individual Factors: Health

Both the MLC 2006 (International Labour Organisation, 2006) and the STCW Convention, (IMO, 1978), as amended, require a seafarer to be medically examined before attending onboard. This is to ensure the seafarer is healthy and fit for duty. However, some companies do not consider this medical as thorough enough and have commenced conducting an additional pre-boarding medical. Of our respondents, over 60% replied that they conduct this additional medical.

The majority of companies that responded to the survey (over 80%) supplied and maintained gym equipment onboard. This allows the seafarer to be able to maintain health while being onboard and restricted to exercise. The ship type of some of the respondents may not have enough space onboard for even a small gym, however the seafarers onboard these ships are likely to have a shorter onboard time.

Onboard welfare is extremely important and one of the main areas that is often criticised by seafarers is the quality of food. Considering this, over 40% of companies used a catering professional to review the onboard menus to ensure a healthy diet. Almost 60% of companies that responded banned the consumption of alcohol by seafarers onboard. Ships working in the offshore sector have for many years not allowed alcohol onboard, and more recently many tanker operators have also banned the consumption of alcohol onboard. This policy is not only intended to improve the health of the individual seafarer, but also to ensure that alcohol is not at any time influencing the seafarer's performance. Smoking has been and still is very common among seafarers. This may be due to the stress onboard and also due to the low cost of cigarettes onboard. Only 30% of respondents have a smoking cessation programme in place.

Accident Investigation

Over 85% of respondents advised that their company uses a standard method for accident investigation. The respondents who replied that they don't use a standard method were further asked what alternative method they used and were provided with an open-ended response option to elaborate. Comments included 'review and assessment of accident reports', 'internal fact finding' and 'professional committee'.

The respondents that used a third party to provide a system for accident analysis are summarised below:

Method	Number
Root Cause Analysis	3
Tripod	2
TapRoot	2
Incident Cause Analysis Method (ICAM)	1
Why tree & 5-whys	1
Kelvin TOP-SET	1
Investigating accidents and incidents – Health & Safety Executive Booklet HGS245	1
Informal method (in-house developed)	14

Figure 20 - Summary of Methods Used for Accident Investigation.

The third party systems, in most cases, were provided by Class Societies. One energy major had developed their own system for accident investigation.

According to the respondents, the majority of companies trained their staff in accident investigation. This not only included members of the safety department, onshore managers and other operational staff, but there was a high response rate showing that the officers onboard were also trained.

Regarding organisational and human factors being considered in the investigations, there was confirmation that these two factors were specifically considered. However, knowing that a standard method for investigations was not used, or without reviewing accident reports, there is a high likelihood that this was not conducted in a formal or structured manner. Despite the likelihood a lack of formal structure to the investigation, companies noted safety improvements were made. Figure 21 summarises the improvements that companies have made from the conclusions of accident investigations:

Improvement Type	Number
Additional procedures or procedural changes	17
Additional training or amended training	6
Physical change to machinery or surroundings	5
Culture improvement	5
PPE improvements	4
Change in reporting line/authority	2

Figure 21 - Improvements Arising from Accident Investigations.

While the large majority of respondents were aware of the accident reporting requirements of IMO, just over 10% had submitted anything to IMO's Global Integrated Information Shipping (Marine Casualties and Incidents) database. Only over a third of respondents had accessed the database for information purposes, however those that had found the information useful.

6.4 – Interviews

As noted in Chapter 5, this research employed a sequential research method that utilised survey data to inform the design of the semi-structured interviews. This method allows for greater accuracy in data collection and stronger ability to make accurate inferences. In this case, use of interviews had additional benefits:

- Considering the poor response rate of the survey, the interviews provided a supplement to the data already collected.

- The interviews were specifically targeted to professionals who have definite experience in the field of ship operations and safety, allowing practices and issues to be explored.

- Interviews were comparable.

- The nature of the interview process promotes clarity and accuracy in data as the likelihood of collaboration and outside influence is minimal.

To the author's knowledge, this is the first time that interviews have been conducted with safety shipping specialists who have detailed knowledge of the industry and are closely involved with ship operations and safety aspects affecting operations.

6.4.1 - Semi-Structured Questions

Following sequential research practices, survey results were used as a framework to structure the interview questions. The interview initially consisted of eight high-level questions considering aspects of culture, compliance, training and individual factors related to a shipping company's organisation and the onboard approach to safety. These questions included:

- The majority of respondents to the survey highlighted 'human error' as either a very significant or a significant risk to safe shipping. Why do you think this, as the industry has very prescriptive legislation from the ISM Code to the ColRegs and also qualified officers onboard?

- What could you do to improve the safety culture onboard ships and within companies?

- Is compliance with regulations/policies/procedures a problem onboard?

- Has automation taken the officers out of the loop? If so, how do you overcome this?

- Poor training was also a concern for many of the survey respondents. Why is this?

- Is there any additional training you think would be beneficial to the industry?

- What other means could be used to promote safety?

- Is incident/accident investigation adequate in the industry?

Not all participants were asked all of the questions; the questions were targeted based on the interviewees background. For example, some participants were not familiar with onboard operations due to their expertise being related to ship design at the new build stage at the shipyard, therefore the questions were more focused on this aspect of their expertise.

The sample included policy makers and managers for Flag States, specialists in loss prevention employed by marine insurance companies and senior management working for industry majors. The size of the companies represented ranged from a safety consultancy with one employee to major shipping companies/energy majors having offices around the world and operating large fleets of ships.

6.4.2 – Interview Participants

Potential interview participants were identified by an 'opt-in' process on the survey (see Chapter 5).

Owner/Manager:	8
Marine Insurance:	2
Class:	4
Flag:	2
Industry Body:	1
Consultancy:	3
Total:	**20**

Figure 22 – Summary of Participants by Company Type.

Of a total of 32 survey respondents who 'opted in', 20 agreed to be interviewed, resulting in a response rate of 62.5%.

There were a total of five different stakeholders involved in the interviews, with the largest stakeholder representing owner/managers, i.e. operators.

Loss prevention:	2
Ship operations:	10
Human factors:	5
Regulatory:	2
Industry Association:	1
Total:	**20**

Figure 23 - Summary of Participants by Discipline.

6.4.3 - Data Collection

The interviews were conducted between December 2016 and May 2017. The protracted nature of the interview schedule was due to a number of factors including internal company approvals and, due to the international nature of the business, it meant that some of the interviewees travelled regularly and therefore it was difficult to schedule the interviews. It is important to reiterate that this was the first time in the industry such interviews have taken place and therefore assurances had to be given specifically regarding confidentiality due to the nature of the questions being asked.

A combination of Skype audio (8), telephone (10), and face-to-face (2) communications were used to conduct the interviews, depending on what was most convenient for the interviewee. All the interviews were conducted by a single researcher and were recorded using MP3 Recorder software. The duration of the recordings ranged from 19 minutes to 50 minutes with an average of 31 minutes. The complete interview data set comprised 9 hours and 42 minutes of recorded interviews.

6.4.4 - Interview Results

The interviews were transcribed and NVivo used to code and analyse the interviews. Each interview was coded using organisation, group and individual factors as outlined in Chapter 5. This approach facilitates a greater

understanding of the respondent's views on culture, attitudes and challenges related to safety in the shipping industry.

As a framework, open coding was used to assign a theme to each sentence which was relevant to the main coding. The coding was then further expanded to a tree structure, grouping sub-themes for each factor under the main heading.

Human Factors

Further to the survey results highlighting that human error onboard ships was a concern for safe shipping, this question considered the reasons behind this response. Consistent across almost all of the replies was noncompliance with safety management systems policies and procedures.

Noncompliance was discussed in two aspects. The first discussion concerned when procedures are in place and reflect correctly the manner in which an operation should be conducted or equipment operated, but the seafarer does not follow the procedure. This may be due to poor or no training, or negligence. The second aspect of noncompliance is when procedures do not reflect the operating practice onboard the ship. This may be due to several reasons; new equipment introduced without due regard for the associated operating procedures, procedures initially incorrectly written or the procedure does not reflect the working practices onboard and has not been updated to reflect actual working practices.

The ship operator responses also linked noncompliance to safety management systems:

> *'it's a tick box exercise' (Respondents 8, 12, 16 and 20)*

and

> *'the captains and chief engineers now are doing far too much paperwork' (Respondent 6)*

When asked the reasons for this, the respondents working for ship operators, while considering that the introduction of safety management systems has been good for the industry, advised that in many cases the management

system has become cumbersome and bureaucratic. One of the respondents, working in marine human factors, summarised that the safety management system has become a paperwork exercise in two ways:

> *'more and more it's the value of having it on paper rather than the actual safety delivered' (Respondent 18)*

and

> *'we're designing a system which we track down thousands of pages of procedures…….and if they deviate from them we haul them over the coals.' (Respondent 18)*

The introduction of new ships with latent design issues was highlighted by several respondents. It is difficult for ship owners to influence design at the contract stage without incurring large costs due to the shipyards wanting to produce a series of ships with minimum design changes in order to reduce their costs of production. In many cases, the issues are not apparent until the ship is in operation. Further, many companies do not conduct detailed safety audits of new ships at the shipyard prior to entering service.

It was noted by one respondent that, in many cases, a management system written for one type and size of ship may not be suitable for other ships in the company's fleet because, while the ship may be physically similar, it may have equipment supplied by different vendors with different operating interfaces, making the procedures not applicable to the particular installed equipment.

Also, highlighted by respondents from ship operating companies was the impact of new legislation being introduced without proper training, or the opportunity to develop new procedures before the legislation is introduced. The introduction of Electronic Chart Display and Information Systems (ECDIS) and Ballast Water Treatment Systems (BWTS) were highlighted as equipment which required new procedures and training in a relatively short time frame. Without this training or the correct procedures in place, it was considered inevitable by the respondents that noncompliances will occur.

The culture of companies was also highlighted as having an effect on why human error is a factor in shipping accidents. Several of the ship operators

linked this aspect to safety management and the culture of the seafarers onboard preferring to have a prescriptive system onboard. Several respondents also noted that having different nationalities onboard can contribute to human error. This situation relates to ensuring equivalent standards of training across many countries by the many education providers.

Culture

Consistent responses from ship operators concerned the importance of the engagement of shore senior management with the seafarers in order to reinforce and improve culture both onboard the ships and within the company. Related to this response was the industry representative's response highlighting that communication needs to be improved between the ship and shore and that feedback from the seafarers is important.

> *'You can only have a good culture if you have a feedback system' (Respondent 13)*

There was also a consideration from several respondents that individuals have to take their own responsibility for ensuring they are part of the company's culture. However, this is more difficult in the shipping industry due to the low retention rate of seafarers, the challenges of turnover onboard when the seafarer completes his contract, and the third party contracting nature of the industry.

The introduction of culture change programmes was also proposed as an effective method of improving culture. These types of programmes have been used in other industries to engage staff, such as the nuclear and medical sectors. Carroll (1998) found that a correctly designed survey can be used to open culture dialogue between multiple levels of hierarchy and also between different groups of employees. This is something that could be used to overcome the culture barriers between ship and shore staff and also between the seafarers onboard. Surveys of this type can be administered retrospectively, however it is suggested that if such a programme was introduced, then periodic surveying of the effectiveness of such a programme would allow the management to assess issues raised and address any areas of concern.

Two respondents discussed the structure of the officers onboard, considering that effective leadership needs to be in place and that there has to be consideration in order to reduce the effects of hierarchy onboard. Both of these factors will have a positive influence on culture onboard and are also applicable to the shore organisation.

To try and improve safety culture amongst its seafarers, one respondent advised that they had used a cross company survey in order to obtain feedback from seafarers. However, one of the main issues that had become apparent from the survey responses was that there were communication issues with multi-national crews. They found that the use of a common language as required by many management systems was not as they had thought onboard, and while it was less of an issue for the senior officers, they also found that the communication issue relating to language was a problem for the junior officers and ratings:

> *'They can't read it, they don't understand perhaps some key words.' (Respondent 14)*

This communication issue can have a huge impact on safe operations.

The introduction of several programmes to improve culture were also discussed. Behaviour based safety programmes have commonly been used in the construction industry. This industry has similar challenges to the shipping industry, namely contracting of labour and a relatively high turnover of the workforce. Choudhry (2014) investigated the introduction of such a system in the construction industry and concluded that this bottom-up approach identified critical behaviours which were targeted for change. A similar approach could be used in shipping although the accessibility of the ships may be a barrier to the introduction of the system. This approach may also better assist in understanding the attitudes which affect culture within a company, a concern raised by a human factor respondent.

One respondent, who works for a ship operator, suggested that it may be beneficial to interact with the seafarer during their vacation period in order to maintain the relationship between the company and seafarer as this would assist in fostering the culture of the company.

Compliance

Compliance was identified as a major issue in shipping in the introductory interview questions. Using probing questions, further data was gathered to gain a better understanding of the issue during the interviews.

All the respondents had strong views on matters of noncompliance by seafarers. They considered this one of the major issues affecting safe operations and many linked the problem to safety management systems. Regarding the management systems, several respondents from different areas of the industry stated that the system had increased in both size and complexity making it difficult and unwieldy for the seafarers to know and understand.

Generally, the respondents indicated the main area of noncompliance from their experience was at the procedural level onboard. Examples discussed included procedures being too onerous, not correct for the system being operated or the procedure is inadequate for the intended operation. The respondents further noted this situation then creates shortcuts or 'work arounds' and the written procedure is ignored or only partially followed. This then becomes the normal practice onboard. It was also suggested that there may also be a related issue considering that the seafarers may not understand certain items of a procedure and this may be related to a lack of training.

If there is no system for changing or updating procedures within the management system, or if the seafarer considers their input to the system will not be recognised, then there may be a tendency for the seafarer to be noncompliant with the procedure or take shortcuts, as described by one of the respondents. Apart from not complying with the physical aspects of procedures, several respondents raised examples of excessive system administration such as having to fill in forms/checklists both in paper form and electronically and also having to electronically scan paper documents even though paper filing is in place.

The issue of complacency was discussed with the respondents and if this could also be linked to over confidence; when the seafarer becomes complacent due to their high level of familiarity, this then 'allows' them to cut corners without

due concern for their actions. None of the interview respondents directly linked noncompliance with inadequate training, however when specifically asked about training, concerns were raised regarding the quality of content and delivery. Time pressures (particularly perceived or real commercial pressures) may also be a factor in not complying with company requirements. This aspect was raised by several respondents involved in ship operations and also by a loss prevention respondent.

The introduction of new legislation (such as ECDIS or BWTS) was discussed by several respondents as this can contribute to noncompliance if the seafarer is not aware of the new legislation or has not been given adequate training in the new requirements.

Automation

As discussed in Chapter 5, automation onboard ships has been introduced gradually, initially focusing on ways to make the simpler, routine tasks automated. Examples of this include remote operation and indication of equipment in the engine room and, on the bridge, automatic radar plotting tools to aid the prevention of collisions. As a result of this, it was suggested by several respondents that there has been a loss of basic skills. Question 4 was designed to probe the extent of this situation, particularly concerning loss of seafarer skill related to lost perception or situational awareness due to automation. This loss of basic skills, both navigation and engineering, may make it difficult for the seafarer to recover from a potential accident situation, particularly when corrective action is required quickly.

This concern was expressed by a human factor specialist who noted the current level of automation onboard can disengage the officer both mentally and emotionally when on watch. This can manifest itself as boredom during the watch, making the officer fatigued as much as overwork can. The following was discussed by one respondent:

> *'is the automation applied to help the seafarer, or is it there to replace the seafarer?' (Respondent 1)*

It was also suggested by this respondent that when automation is applied to systems onboard, psychological or emotional aspects are not considered. Similar to this response, another respondent stated the following when describing the effects of automation on the navigating officers:

> *'They have become effectively passive observers of automation on the bridge during navigation, critical navigation passages.' (Respondent 8)*

A similar response from another respondent concerned the operation of ships:

> *'I do think automation has numbed people's natural sort of awareness.' (Respondent 11)*

Also highlighted by the respondents was the ability to maintain complex equipment which the officers are reliant on to operate the ship safely. According to the respondents, seafarers have to be specially trained in the maintenance of the new technologies onboard. Linked to this, one of the respondents working for a regulatory body described the issue of lack of redundancy and the inability of officers to recover in the event of a system failure.

A respondent from a ship operating company, while recognising the challenge of automation and the introduction of new technology onboard, commented on the issue of not reviewing the effect the technology has on operating procedures and management systems prior to their introduction. Therefore, according to the respondent, the effect of this is that the seafarer has additional equipment to operate while still following procedures which have not been revised, and therefore the outdated procedures becomes a 'tick box' exercise.

Training

Training is essential to ensure safe operations and further insight was sought during the interviews to explore why the shipping industry has an issue with the provision of training to fulfil both statutory requirements and also company specific training needs, such as management system and equipment training.

The standard of training was considered inadequate by several respondents, not only at the college level but also between the different countries and more

importantly, the lack of consistency regarding training as required by different Flag States was also raised as a concern.

Another concern discussed was that courses are not aligned with the technology onboard. It can be difficult for colleges to keep up with the modern equipment onboard as this requires a substantial investment by the provider and, from several respondent replies, this has not happened at many colleges with antiquated equipment still being used for training.

The lack of adequate training focusing on basic skills was a concern for many of the respondents, especially when considered with 'out of the loop' syndrome and the seafarer's inability to recover from situations which may put the ship in danger, and at the same time requiring an immediate response. The additional difficulty for the seafarer involved is that this occurs often during a stressful time which can also affect the decision-making process.

Several of the larger shipping company representatives that participated in the interview advised that their companies had developed their own training centres around the world in order to control the quality of both the training content and the course provider. However, in order to justify this investment, the number of seafarers using the facilities would require to be significant and therefore this approach is out of reach for many companies, especially when the cost of training is considered a major factor in the selection of training providers.

The use of simulators for training, while considered beneficial, was criticised by several respondents due to the lack of 'real' scenarios and also a disconnect was discussed regarding the equipment used in the simulators to that onboard. This is always a problem due to the many manufacturers supplying equipment to ships and difficult to overcome without a large investment by the training facilities.

Computer-based training (CBT) is now onboard many ships, however several respondents discussed the level of monitoring of this training which, due to the remote nature of the ships, is difficult to police.

> *'Effective monitoring of this type of training by the shore management needs to be in place' (Respondent 8)*

This is in order to ensure the training requirements are being followed. Also, a respondent suggested that while the use of CBT is a quick fix for the industry to meet additional requirements as it is relatively easy to deliver, it may not deliver the standard or depth of knowledge of training required.

One respondent, working for a ship operator, highlighted that training needs to be more focused to the needs of the individual seafarer, rather than applying generic training to everyone. The advantage of this approach to training is that the seafarer becomes engaged in the training and is likely to have a positive personal experience.

One aspect of training often overlooked but mentioned by several respondents is the lack of onboard mentoring of junior officers by senior officers. This may be due to the rapid expansion of the world's shipping fleet which has had the effect of seafarers being promoted rapidly through the ranks and not gaining enough experience in their former rank before being promoted. Because of this, it is likely the senior officer therefore does not have the confidence or experience to mentor the junior officers.

Additional Training

One respondent reiterated the need to focus on training in order to give the seafarer basic skills as discussed above. However, several respondents considered it would be beneficial, in addition to training on equipment and systems, to add training in 'soft' subjects such as human behaviours and resilience planning. Resilience planning would give the seafarer options to be flexible and adaptable when put under stress. This in turn gives the seafarer confidence in handling unexpected situations.

The improved use of simulators would also benefit the seafarer. Many training establishments have very modern simulator facilities, but as highlighted by several respondents, scenarios need to be improved in order to make the simulated experience more effective.

One ship operator respondent highlighted that, while bridge and engine resource management is very common in the industry and is now required by legislation, cargo resource management is not required and many companies do not consider it necessary. Considering that cargo operations on some ships are months apart, and a seafarer may only see one or two cargo operations during their time onboard, there is the possibility of lack of familiarisation with cargo operations.

Several respondents from ship operation companies also discussed the concept of reflective learning. In a group, the seafarers discuss an incident that one of the group has had recently and discuss corrective and preventative actions so that all the attendees can learn from the incident. This approach also starts a discussion between the seafarers and allows open dialogue in order to learn from their colleagues.

Safety promotion

The respondents were asked what, in their view, would be beneficial in promoting the safety message to seafarers.

The respondents that were involved with ship operations highlighted improving interactions between ship and shore and having a better focus with respect to safety with the seafarers. One respondent proposed that improved interaction can be accomplished by holding seminars at which both shore and seagoing staff attend. Regarding the latter, several respondents had used safety campaigns as a tool to promote safety and also used feedback from near miss reporting to highlight specific issues to seafarers. The representative from the industry body also discussed the advantages of improved dialogue with seafarers in order to learn from them as they are the ones that actually carry out the work and often have valuable feedback, especially if the shore staff have no experience of ship operations.

One respondent, also from ship operations, discussed their company's initiative to introduce reflective learning (learning from previous experiences). This initiative was introduced in an attempt to break down barriers and to share experiences of an incident that had occurred and learn from it in a positive

way. This approach to lessen onboard hierarchy was also highlighted by one of the respondents working in human factors.

Several respondents highlighted that safety has to be considered at an early stage of the design of a ship. Linked to this response was the comment from a human factors specialist:

> *'some of the interfaces are too much for one person, or two people' (Respondent 15)*

and

> *'control panels in the bridge information are not designed together, they're designed separately.' (Respondent 15)*

Improving this integration and the human /machine interface, it was suggested by the respondent, would directly affect safety onboard in a positive manner.

Both respondents from the loss prevention companies suggested that better onboard familiarisation with ships and systems would be of benefit to making operations safer, especially considering the number of interfaces onboard which are not fully integrated. Additionally, one respondent from a loss prevention company focused on the retention of seafarers noting this could be a way to promote safety. This could be accomplished by having seafarers onboard with intimate knowledge of the systems, including specialist training, who could break the continuous cycle of inexperienced seafarers joining ships and having to complete a detailed onboard familiarisation.

One of the respondents linked promoting safety to fostering culture and empowering individuals to think what could go wrong this time, even though they have carried out the same operation many times. This response is linked to the effect of complacency, particularly for the operations which may be perceived routine but have an inherent risk.

Accident Investigation

Accident investigation and reporting was part of the survey questionnaire and focused on the methodology used in shipping companies for conducting such

investigations. The related semi-structured interview question was designed to allow the respondents to discuss the effectiveness of such reporting.

Several respondents highlighted that while many of the companies have a 'no blame' culture when investigating accidents, it was still apparent that there are still implications for individuals when either reporting accidents or being investigated. It was suggested this may influence reporting or investigations negatively. The respondents from companies involved in human factors, who have the opportunity of being able to review different reports from a number of shipping companies, noted that their experience showed many companies' reports still having a culprit focus rather that a cause focus, and that many companies still identify immediate causes rather than considering organisational factors that may have contributed to the accident.

> *'there's still too much tendency to play the blame game and that discourages a robust root cause analysis' (Respondent 18)*

Respondents from the loss prevention companies, who are also able to have access to reports from different shipping companies, commented that the standard of investigative reports is very variable. They also commented that in some cases the report may be edited, prior to wider circulation, outwith the company in consideration of commercial pressures as the report in its 'raw' form may affect a ship or a company's commercial acceptance. The same respondents also found from their review of reports that many reports had a strong technical focus (for example, when considering equipment failure not considering the true root cause) as they were produced by staff involved in the technical operation of the ships and not safety professionals.

Again, as mentioned previously, respondents from both ship operations and human factor companies discussed the importance of considering the relationship between ship and shore, as this interaction may be an integral part of the factors contributing to the accident.

The respondent involved in regulatory aspects of the industry commented that when there are latent defects identified as contributory factors in company accident reports, it is very rarely that these are incorporated in ships at the

design stage or passed to third party shipping companies who may benefit from the findings.

It was also highlighted by one respondent involved in ship operations that timeframes for the distribution of formal accident reports are too long in their opinion and the process, especially for the case of major accidents, requires improvement.

Other factors discussed during the interviews

Contracting of seafarers

Generally, seafarers are only employed on a voyage contract, giving both the employing company and the seafarer the option to either be re-employed or to terminate the relationship after each voyage. This aspect of contracting was discussed with the respondents.

The consensus from the interviews was that a longer-term commitment from companies to the seafarers would be beneficial regarding culture, onboard familiarisation and commitment from the seafarer. This commitment also reduces the requirement for familiarisation training and allows the seafarer to become familiar with the company's management system, including policies and procedures.

One respondent highlighted the use of third party ship managers, noting that the short-term contracting of seafarers inherent in the industry has been driven by several factors; owners putting pressure on the managers relating to costs, owners wanting the flexibility to sell ships as the market changes, and also not having to employ seafarers directly and continuously.

The cost of seafarers was discussed by several respondents, with one commenting:

> *'The industry likes to cut costs. It optimises all costs and the ability to choose any crew to turn up at the lowest price and not invest in them in terms of whether it's the environment they work in or in the way they're managed or all of their training, all of that sends a clear message.' (Respondent 9)*

Safety Management Systems

The survey did not highlight any concern regarding issues with the structure of safety management systems and related issues with procedures and practices. However, after review of the survey questions, this was not a focus of the survey and therefore the interview questions had a section to discuss this important area in more detail. Therefore, all the respondents were asked for their opinion on the introduction of mandatory safety management systems in the industry and the effect it has had on safety.

The majority of respondents considered that the framework of the legislation is still very valid and an important contributor to safety onboard ships. There were concerns however in the way systems have been developed and implemented. Specific concerns were the size, applicability and administration of management systems.

Many respondents also considered that the administration of such systems was a burden on the ships' crew and may, in some instances, take away the focus of the seafarer from safe operations. A human factor respondent involved in the review of such systems highlighted that some systems have thousands of pages of procedures which have to be understood and acted upon by the seafarer. If there is found to be any deviation from the procedures, then the seafarer is held accountable.

Another response noted that some perceptions of the system gives more value to having the paperwork completed rather than the actual safety delivered. This was also discussed by another respondent who noted, from his experience, that there are many stakeholders in the industry wanting data from ships and this drives the demand for formalised procedures and checklists, especially in the event there is an incident when the shipping company will be required to provide evidence of management system compliance.

Other respondents gave examples of systems expanding over time, with procedures being constantly added, producing a large and unwieldy system which is difficult to follow and, in some cases, procedures which have been superseded in the system being retained. This can be compounded by the seafarer not being informed of any changes to the system.

Several respondents discussed the issue concerning the introduction of new equipment and the management system not being updated to reflect the new operating procedures required causing the seafarers to improvise. To counteract this, a respondent from the human factors sector considered that a strict 'management of change' procedure needs to be part of every management system.

One respondent had an interesting and contrasting view on management systems as having either a comprehensive set of procedures which would enable the shipping companies to use less trained and perhaps less experienced seafarers versus *'encouraging self-awareness and risk assessment so that the procedures are fit for purpose'*, therefore making the seafarer part of the system and encouraging them to think for themselves.

Following from this, one respondent from ship operations who has audited many safety management systems considered that, while the ISM Code has brought benefits to the industry, it has come at the cost of expertise of sea staff, especially younger and more inexperienced officers. This is due to these officers not being as adept as older officers, or having the experience to correct errors or mistakes. This may be related to the training standards of the younger officers. He also noted, from his experience, that younger officers adhere to procedures and checklists more than senior officers who may have the attitude that they don't need a piece of paper to guide them.

Finally, one respondent noted that some companies want to manage their risk to ensure the avoidance of accidents. In these cases, their policies and procedures are very stringent and, in addition to having a comprehensive management system, they train their seafarers in excess of the legislation.

Resource Management

Resource management training is well established for navigating officers and has been introduced relatively recently for engineering officers. However, several respondents commented that there is no similar training for officers conducting cargo operations.

Several respondents commented that while resource management is of benefit, the training is held in a simulator and the teams are only working together for the period of the course. To improve the training, it was suggested that this kind of training should be held onboard with the actual bridge team members participating, as well as the ratings involved in navigation, the bridge lookout, and the helmsman, two important participants of the team.

One respondent also discussed the importance of training as an officer progresses through the ranks from junior to senior positions. Currently, there is limited training in leadership and human behaviours which, according to the respondent, could benefit the officer as they progress through the ranks.

Nationality and Culture

It was highlighted by a respondent who had completed research into relationships between different nationalities onboard that there can be communication challenges between multi-national crews. They found that the use of a common language onboard, particularly between multi-national senior officers, is not as prevalent as they had thought. They also found that these verbal communication issues hindered understanding of written procedures, particularly if crew members have difficulty reading and understanding the procedures.

Authority Gradient

Most of the respondents had views on this, not only occurring onboard the ships, but also between the ship and shore organisation staff.

A respondent involved in human factors discussed when there is a traditional hierarchal management approach together with a cultural difference the gradient can be affected negatively i.e. becoming steeper. However, the respondent also stated that some of the leaders in the shipping industry are exemplary, and in the case of good leadership, the issues associated with a steep authority gradient can be negated.

Discussed by one of the respondents from a regulatory body was the issue of some nationalities and related cultures where authority is not questioned, which manifests itself as an extreme authority gradient onboard. The

respondent highlighted it is not a case of questioning the authority, rather it is challenging and seeking clarification on the decision making of the authority.

It was commented by one respondent involved in ship operations that autocratic senior officers don't get the same response out of their teams or have such a good safety performance as those officers who are less autocratic. They also discussed the opposite approach to leadership; when relationships are less formal and friendlier. It is important, according to the respondent, to get the balance right between having authority, leading the team and having respect from the more junior officers.

Fatigue

The limits on hours of work or rest onboard ships is regulated by two sets of legislation (ILO Convention 180 and the STCW convention) and therefore the effects of fatigue should be limited. However, two aspects of fatigue were discussed with the respondents.

a) Short term fatigue due to work patterns.

Several respondents involved in ship operations admitted that hours of work and rest were being breached and considered it unavoidable due to the schedule of ships, particularly on the approach to a port when extra manning is required, and also due to the intensity of loading and discharging ships with the pressure of having to complete the port operation within a certain time.

The two common watch patterns of four hours on watch/eight hours rest and six hours on watch/six hours rest were discussed with the respondents and options proposed such as a 12 on/12 off cycle such as that operating in the offshore sector. However, consideration of working for 12 hours in the ship environment was not considered a safe option by the majority of respondents.

The respondents that were involved in human factors considered that while it may be possible to work these watch patterns for a limited time, research was required into the effects of working these patterns for an extended period and the effect this has on an individual's fatigue.

One human factor respondent considered the link between fatigue and organisational culture, stating that a good organisational culture, with people

in a happy working environment, may reduce the effects of fatigue when compared with an authoritarian, belligerent type of culture.

Another factor discussed and not commonly taken into account was the burden for senior officers particularly in dealing with the paperwork requirements of management systems. There may be a requirement for these to be completed after an intense sea passage or a cargo operation and may compromise an officer's rest period.

One factor affecting short-term fatigue mentioned by a human factors respondent was the influence of the shore staff on the seafarers. The respondent highlighted that if the superintendents are not working reasonable hours, they may also be driving unreasonable working hours onboard. Associated with this, there may be issues of falsification of working hours on some ships in order to comply with the hours of work and rest legislation.

One respondent also described physical reasons why seafarers can't get adequate rest on a ship. These included sleeping spaces being too noisy due to either poor design or inadequate insulation, and seafarers being noisy when off duty seafarers are resting.

b) Long term fatigue due to onboard contract length

The effects of working onboard for a long period of time (up to nine months onboard for some seafarers) and considering the required watch pattern for this period was discussed.

The majority of respondents considered that, with the very short turnaround of ships in port, these extended periods onboard are neither healthy nor conducive to safe working practices. A typical response when discussing this was:

> *'maybe being onboard for six to nine months for the ratings is an issue in terms of their output and their motivation.' (Respondent 1)*

Also, and not generally considered but highlighted by the human factor respondents, was the length of vacation after working these types of watch patterns for months, and if individuals recovered adequately before returning onboard. This is particularly relevant to ratings who can work onboard for up

to nine months, but are only at home after completing their contract, for as little as two months.

One human factor respondent also discussed the impact of the type of trade the ship is on and the effect that has on a seafarer, stating that a short sea passage trade with intense port activities may have a more adverse impact on a seafarer who has been onboard a ship for a longer period of time but with a less intense trading route.

Another factor that was highlighted by one loss prevention respondent was the issue that for some nationalities, their preference was for longer voyage lengths in order to maximise their earnings with an intention to retire early.

The industry body representative advised that project Martha (Warsash Maritime Academy, 2016) had shown that seafarers being onboard for longer periods was not an issue. What was more of an issue was the seafarer not being able to leave the ship at the end of his contract (this may be due to a ship's trading pattern or the unavailability of a relief seafarer). The effect of this can cause fatigue, complacency and a lack of motivation. However, two respondents working with human factors discussed the increase in accidents during the end of tours of duty. This aspect may be difficult to attribute to fatigue and needs to be researched further.

Considering the above discussion about short and long-term fatigue, one respondent working for a human factors company proposed a link between the two. He explained that there may be a sleep deprivation link to poor health and also a poor mental state. Therefore, it was suggested the effects of fatigue go beyond tiredness, and that the lack of sleep causes depression. Further, he described the effects of the senior officers onboard all being sleep deprived and perhaps depressed. This could be reflected in the rest of the crew and the potential for human error may increase.

Welfare

Many respondents commented on the lack of social cohesion onboard and this was mainly due to the seafarers not using the room in the accommodation area provided for such interaction. Reasons for this were twofold according to the

respondents; the banning of alcohol onboard ships and the provision of the internet in cabins. The effect of these two factors is that there is no reason to engage with other crew members onboard socially. Also, as highlighted by several respondents, having multi-national crews onboard may also contribute to the reduced social interaction onboard.

Respondents from ship operations companies discussed the need to provide internet access onboard for crew use as a condition of employment and, if it is not provided, it can be a reason for not joining a particular company.

Also, several respondents considered that the provision of the internet could be contributing to fatigue. This is due to the seafarer, after his working hours, sitting in front of the computer speaking to families and watching movies rather than getting the rest required. This has become such an issue on some ships that, according to one respondent, some shipping companies are:

> *'rationing access to the net and reducing the bandwidth as, so they can't stream videos' (Respondent 8)*

One respondent also commented on the sites that seafarers may access which could become abused, such as gambling sites. Not only can they contribute to a seafarer's fatigue, but can increase stress and cause a distraction from their work.

Health

One respondent from a ship operations company discussed the extra measures their company is taking to ensure the health of their seafarers whilst onboard. This consisted of blood pressure and urine tests with a report being sent to the company each month for review, with any concerns discussed with a doctor. This was the only company where the respondent detailed this higher level of medical monitoring. All the other ship operators had a basic pre-joining medical as required by legislation.

One respondent from a loss prevention company stated that a study that they had conducted about the health of seafarers had shown the diets and mental well-being of the seafarer were not being well served, and that it was a low

priority issue for shipping companies as they do not appreciate the benefit of being proactive with respect to the health of their seafarers.

Stress

Stress can take various forms, sometimes being work-related and sometimes linked to the effect of being away from home, as in the case of some seafarers. On a ship, these two aspects are very much interrelated. One comment regarding this from a respondent from a regulatory company was:

> *'stress was very much relieved by the ships themselves being a much more social environment' (Respondent 2)*

The availability of internet onboard affecting the stress of a seafarer in relation to family matters was also highlighted by several respondents. For example, the seafarer can now be in constant contact with their family at home. One respondent highlighted the issue when there is bad news from home and the negative effect this can have on the seafarer. This knowledge, together with knowing that they can't return home to deal with the situation, will increase stress and anxiety.

According to one respondent, there is also an external pressure on the officers that contributes to their stress. This pressure is coming from charterers, the company's commercial department, and agents who may be requesting a steady flow of information from the ship about its port activities.

6.5 - Discussion

The survey results confirmed that the risk to safe shipping due to human error is one of the main concerns to ship operators. Related to this was the difficulty of both recruiting enough seafarers with the right experience and the quality of training seafarers.

From the survey results, many companies had developed departments within their organisation which focused exclusively on the safety of the ships. These departments are responsible for management system compliance, developing new and modified procedures and updating the management system. The survey also confirmed that companies had developed both lagging and leading indicators to monitor their safety performance. Companies participating in the

survey had also developed additional tools to enhance culture within their organisations such as safety awareness programmes. However, the results from the interviews highlighted that one of the most effective ways to enhance safety culture was to have senior management and members of the shore organisation engage with the ships in a direct manner, either by attending onboard, or by attending seminars that officers attend. From the survey feedback, while it was confirmed that many of the companies arrange seminars for officers, this is not extended to ratings who can make up around 50% of a ship's crew complement and are the seafarers actually carrying out much of the physical work onboard a ship thereby presenting the biggest exposure to accidents. Additionally, if senior management attends seminars, it shows their commitment to the company's culture directly to the attending seafarers.

From the survey responses, the majority of participating shipping companies used third party crew providers, usually in the domiciled country of the seafarer, to provide their training requirements. However, many of the interview respondents considered that the standard of basic training was inadequate and considered that this may be linked to shipping companies outsourcing such an important function. Due to the training providers being remote from the offices, it is difficult to ensure the quality of the delivery of the training.

A common theme from many of the participants was the loss of basic skills and lack of understanding of the systems which are installed onboard. In order to counteract this, both improved basic training and more specialised training needs to be implemented in the industry. Also, more validation of officer's competence on a regular basis is considered necessary, particularly with the continuous introduction of new technology. This new technology requires officers to continuously update their knowledge and be trained on the new equipment.

Providing modern equipment to train on, and keeping up with technology changes onboard ships with respect to providing training, is challenging for colleges. Modern engine room equipment is expensive and difficult to procure

due to its physical size and also due to the associated systems which are required to operate them. Historically, colleges were near shipyards or other heavy industries and there was a collaboration between the industries to invest in the colleges by providing training facilities, and in turn the industries had facilities to train their apprentices. However, colleges are now not near areas of ship construction or repair making it very difficult for companies to provide the up to date training required on modern equipment.

6.6 – Chapter Summary

In this chapter, through an analysis of survey data and semi-structured interview data, it has been determined that the major concerns in the shipping industry related to safe shipping are:

- Noncompliance:

  This is generally related to the application and administration of safety management systems.

  Generally, there has been a lack of research in the industry regarding this topic. However there is research data available to the author (near misses) over a 12 month period for different types of ships; oil tankers, bulk carriers, container ships and gas carriers.

- Recruitment, training and retention of seafarers:

  Companies have different standards for recruitment and training. Basic training is covered by legislation. Retention depends on a number of factors including individual company terms and conditions.

- Fatigue:

  This is due to excessive work hours and not enough rest, even though there is legislation to protect the seafarer from working too many hours. Additionally, there was particular concern regarding internet usage during hours of rest instead of sleeping. The use of the internet has also impacted the social interaction onboard ships.

There has been research in to this topic, for example from Cardiff University (2006).

- The relationship between the ship and shore organisations:

  This particularly affects the safety culture onboard which can be difficult to sustain.

  Generally, there is a lack of research in the industry regarding this topic and may be difficult to research due to limited accessibility to company operating structures.

- Lack of standardisation in shipping company accident investigation techniques:

  The survey confirms there are many different accident investigation techniques being used. In the case of formal investigations, the time frame for the findings to be disseminated to the industry is, in many cases, too long. It is difficult to assess further as data is not easy to access due to company confidentiality.

Considering the findings in more detail, the issue of noncompliance in the industry will be researched further in the next chapter using near miss data from an established shipping company operating a mixed fleet, including oil tankers, container ships and LPG and LNG carriers. Noncompliance with management system procedures in the shipping industry has not been widely researched within the academic literature, although there have been some studies considering environmental protection compliance (Gunningham et al., 2005). Other transport industries, particularly road (Figliozzi and Tipagornwong, 2016), rail (Salmon et al., 2013) and aviation (Degani and Wiener, 1997), have studied the effect of noncompliance on accident causation and the reasons why procedures are not complied with or existing procedures are modified without approval.

Due to the confidentiality associated with company terms and contracts, the issues associated with recruitment and retention of seafarers will not be progressed further within this research. In a competitive market for seafarers, terms such as basic salary, pension benefits and other conditions are very

sensitive in order to either maintain an existing seafarer pool or to attract new seafarers. While there are crew benchmarking studies of conditions conducted annually, for example the Precious International Tanker Officer Benchmarking Survey (Precious, 2017), the data is kept anonymous and the results are only distributed to the participants. However, the training issues highlighted will be researched in the next chapter as related to analysing contributory factors within the near miss data.

Fatigue, particularly the effects of fatigue on the cognitive performance of maritime watch-keepers under different watch patterns, has been studied (Warsash, 2016) and also the longer-term effects of working excessive hours and the problems associated with voyage length and recovery time have all been the subject of research (Smith et al., 2006). Therefore, detailed research into this topic will not be conducted, however the role of fatigue in near misses will be assessed as part of the next chapter's analysis.

An important factor when considering organisational factors as contributory factors to accident causation, and also as a factor in ensuring safe operations, is the relationship between the ship and shore. This issue was highlighted during the interviews mainly by the interviewees involved in ship operations. Traditionally, the shore organisation is comprised of ex-seafarers who, after gaining their qualifications and onboard experience, have wanted to move ashore due to several reasons, including a wish to be closer to family and the promotion prospects ashore. However, this has changed in many companies recently, with shore organisation recruitment focused on graduates qualified in related subjects such as marine operations or naval architects. The AcciMap analysis that will be conducted in Chapter 9 will highlight some of the issues which can affect the relationship between the ship and shore organisations, including an inadequate management system which affects both the policies and procedures of both organisations within the company, and the shore culture which can influence ship culture, both in a positive and negative manner. The next chapter, using a root cause analysis technique, will review the near misses and consider if the shore organisation has had any influence on the ship near miss.

As discussed earlier, the survey concluded that shipping companies use a number of different accident analysis tools; some use an analysis method developed in-house and others use a proprietary method. However, due to company confidentiality and the sensitivity of accident and near miss data, it is not possible to assess the techniques companies use for accident analysis and related data as part of this research.

The next chapter will use near miss data from a shipping company to assess causal factors that may be a precursor to accidents and also to identify the personal factors and job/system factors within the near miss reporting data by using a similar technique to that which was used by the companies replying to the survey to analyse accidents.

7

Study 3: Analysis of Near Miss Reporting

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7.1 – Introduction

As discussed in Chapter 5, this study will use anonymised near miss data from a shipping company operating a mixed fleet of oil tankers, bulk carriers and container ships. Then, using a causation analysis technique identified by survey respondents, the study will review the data to identify any common causations or trends that may be used together with the previous studies to propose measures to reduce human error in shipping. It is important to highlight that while the company has provided their near miss data, other sensitive details have been withheld from this research.

The majority of shipping companies have a near miss programme. In some companies, it has been renamed 'safety opportunity' programme in order to promote a more positive influence on the seafarer as, in some cases, a near miss has a negative connotation regarding safety performance. The requirement for near miss programmes is driven by several factors; it may be introduced as a lagging indicator of safety performance, which can then be used to focus on areas of concern, and secondly, charterer's may require a specific number of key performance indicators that the company must comply with of which a near miss programme is one. If there is noncompliance with the agreed KPIs, the charterer may have an option to terminate the charter within a pre-determined period if the performance is not rectified with the contract terms.

7.2 – Methodology

In Chapter 5, it was highlighted that shipping companies are reluctant to share their accident data as it may have commercial implications. Similarly, shipping companies do not share near miss data for the same reasons; a high number of near misses or several near misses with similar causal factors may cause a charterer or a potential charterer concerns with respect to the standard of the safety within the shipping company. This research is in a unique position to have access to a large near miss data set and to assess the data using a human factor approach, which is not routinely considered in the industry or even in individual shipping companies.

The use of near miss data has been used in a number of different industries in order to improve safety as it is considered that accidents and near misses have similar causation factors, the only difference between them being the consequence due to opportunity factors which belong to random variation (Greenberg, 2009).

The United Kingdom's Health and Safety Executive (HSE, 2004) defines a near miss as:

> 'An event not causing harm, but (one that) has the potential to cause injury or ill health.'

Near misses can provide a warning that an accident may occur. The near miss itself may be due to either an unsafe act or an unsafe condition that affects the work being carried out in such a manner that continuing with the act or condition may cause an accident. Near miss events occur much more often than adverse events such as incidents or accidents. This makes the analysis of near miss data an important opportunity to improve management systems and associated procedures in order to avoid incidents or accidents that may have otherwise occurred. In view of this, shipping companies have recognised the value of near miss data analysis and have introduced processes and key performance indicators (KPIs) for monitoring such data.

The value of near miss reporting has been identified in many industries, including nuclear, petrochemical and health. Tjerk (1991) describes three ways that using near miss data can be of benefit; they can give a qualitative insight into how relatively minor events can develop into near misses and in some cases, into actual accidents; they can give a quantitative insight into the occurrence of factors, or combination of factors, that may give rise to accidents; and they can promote a certain level of alertness to danger, especially when the rates of actual injuries and accidents are already considered low within an organisation.

Many companies have a near miss reporting programme which requires a minimum number of unsafe acts or conditions to be reported within a specified timeframe. The near misses are then analysed and lessons can be learned without having to suffer the consequences of a full accident. Jones et al. (1999) considers that focusing on the reduction of actual near miss occurrences will reduce the frequency of accidents. However, it is also suggested by Jones et al. (1999) that the rate of near miss reporting is an important numerical indicator of an industry's safety awareness.

It is also important to recognise that the near miss approach, as well having a structured system of analysing the near misses, must also lead to safety interventions that address the accident precursors identified, disseminate the information gained from such a programme and finally, monitor the effectiveness of the safety solutions implemented (Gnoni and Saleh, 2017).

There can be disadvantages associated with a near miss programme, especially those with a requirement to report a specific number within a specific timeframe. This may lead to near misses being reported that may not be true near misses, rather they may be fulfilling the company's requirement to report. Therefore, submitted near misses have to be carefully assessed to ensure they comply with the company's required definition of a near miss and not artificially distort the results and conclusions of the near miss reporting.

In the shipping industry, many shipping companies have near miss programmes in order to raise safety awareness in the company, especially in ship operations and onboard ships, where the risk is higher than in other areas of the company. Analysing near miss data has been used specifically to identify inadequate safety management systems, including the policies and procedures contained within the system. In addition, and as discussed above, the data can also be used to introduce corrective and preventative actions to ensure identified weaknesses are not repeated. This study will use anonymised near miss data from a shipping company operating a mixed fleet of oil tankers, bulk carriers and container ships and will apply a causation analysis technique that will review the data to identify any common causations or trends that may be used together with the previous studies to identify common factors relating to human error in shipping.

The survey conducted in Chapter 8 will identify several systematic cause analysis techniques most commonly used by shipping companies to identify root causes in accidents and incidents. Therefore, it was considered that in order to provide a basis for comparison with accident investigation methodologies, a systematic cause analysis technique should be selected for the analysis of the near miss data. Systematic cause analysis techniques were originally based on an idea developed by Frank Bird Jr. (DNV·GL, 2015) to assist with the training of accident investigators and to be used as a tool to assist in investigations. A systematic analysis of near miss data in the shipping industry such as this has not been published prior to this research. The data set is reflective of a typical mixed fleet shipping company, operating worldwide with multinational crewing, and thus serves as an insight into unsafe acts and conditions at the operating level of the company i.e. the seafarers. This thesis

therefore provides unique access to an industry leader's data not otherwise available for research purposes.

Kontogiannis et al. (2000) highlighted that using systematic analysis to review near misses can also give useful information with respect to why the near miss did not continue to become an accident. This information can then be used as described above, as a feedback loop to improve management systems and also to alert the seafarer to any specific dangers arising from, for example, the use of specific equipment. There are other techniques available, however it was decided that the categorisation of near miss data should use the same taxonomy as that used to identify the root causes of accidents and incidents in the shipping industry.

There are several proprietary systematic cause analysis techniques used in industry, in the case of the shipping industry, developed by Classification Societies and other commercial enterprises. The survey further identified that the most common tool used by shipping companies who participated in the survey was supplied by the Classification society 'DNV·GL' and therefore their technique 'Marine Systematic Cause Analysis Technique' (M-SCAT) flow chart was used to categorise the near miss data. The chart cannot be included in this thesis due to a licensing restriction.

7.3 - Company Profile

The company providing the data is privately owned and was established in the 1970s and initially managed a number of dry cargo ships. Since then, the company has expanded to operate a mixed fleet of oil tankers, bulk carriers and container ships.

7.3.1 - Trading Pattern

All of the fleet operates worldwide. The oil tankers transport crude oil, and while many of the smaller oil tankers trade in the Mediterranean and the Black Sea, the larger tankers load from terminals in the middle east and deliver to receivers in the far east, Europe and the United States primarily. The bulk carriers also trade worldwide. They can load different cargoes such as iron ore, coal and grains. Principal routes for the bulk carriers are Australia to

China carrying iron ore or coal, and Brazil to China carrying commodities such as soybeans. The container ships, due to their smaller size, are generally employed on feeder services supporting the distribution of containers from the larger inter-region container ships.

7.3.2 - Seafarers

The shipping company uses in-house crewing agents to source and manage both their officers and crew. Training of the seafarers is carried out using a mixture of in-house courses and third party training providers. Extensive use is made of computer-based training, covering all mandatory training requirements and additional courses, such as hazardous cargo endorsements, in the case of oil tanker regulatory requirements.

Officers

The shipping company uses three different nationalities of officers on their ships (Greek, Bulgarian and Filipino). The company has no policy on the number of officer nationalities that may serve together onboard (see Figure 24). The officers are initially nominated to one type of ship, but there is a tendency for the officers from the bulk carriers and container ships to request to be cross-trained in order to be able to sail on oil tankers. This is due to higher wages and the improved employability associated with this type of ship.

Number of ships with one nationality onboard:	45
Number of ships with two nationalities onboard:	16
Number of ships with three nationalities onboard:	10

Figure 24 – Number of Nationalities Onboard.

As shown in Figure 25, the company does not have a policy on restricting the number of senior officers that can sail onboard together.

Number of ships with one nationality of Senior Officers onboard:	68
Number of ships with two nationalities of Senior Officers onboard:	3
Number of ships with three nationalities of Senior officers:	0

Figure 25 – Number of Nationalities of Senior Officers.

While there is natural wastage and turnover of officers due to external factors, such as age/health requirements and the competitive nature of the industry, the company has a very high retention of officers.

Ratings

The ratings employed on the company's mixed fleet are all of Filipino nationality. Generally, they are retained by the company and are employed within the mixed fleet and can be allocated at any time, depending on the company's requirements.

7.4 - Raw Data Set

The near miss data reflected a period of 12 months covering from 1st January 2016 to 31st December 2016. The raw data set consisted of a total of 71 ships as seen in Figure 26, with 1,694 reported near misses.

Oil Tankers:	49
Bulk Carriers:	19
Containers:	3

Figure 26 – Fleet by Ship Type.

The age of the ships used for the research is shown in Figure 27.

Average age of ships sampled:	8 years
Minimum age of ship sampled:	<1 year
Maximum age of ship sampled:	16 years

Figure 27 – Age Profile of Ships.

Details of the data available for analysis was initially summarised showing the near misses issued for the fleet and then for each ship type. This data is presented in Figure 28. As expected, due to the large number of oil tankers, those ships produced the greatest number of near misses. Many companies, as part of their management policy to improve safety, have a minimum number of near misses each ship should submit on a monthly basis. Positively, this encourages the seafarer to have a safety awareness, in order to report the required number. Conversely, it may generate false or inappropriate near misses in order to fulfil the company's requirements. It is very difficult to

differentiate between genuine near misses and near misses that may have been submitted in order to meet the company's performance indication. For this research, it was not possible to identify any such near misses and therefore it was presumed that the near misses submitted for the research had already been vetted by the company's safety department for validity as they were used in the safety performance statistics for the fleet.

	Total near misses:	1694
	Average per ship:	24
Range	Min:	8
	Max:	51
Oil Tankers		
	Total:	1289
	Average:	26
Range	Min:	9
	Max:	51
Bulk Carriers		
	Total:	341
	Average:	18
Range	Min:	8
	Max:	34
Containers		
	Total:	64
	Average:	21
Range	Min:	18
	Max:	24

Figure 28 – Near Miss Summary - Total and By Ship Type/Year.

As seen in Figure 29, the near misses can also be differentiated according to where they occur, with the majority occurring at sea.

At Sea:	1136
In Port:	555
Not Reported:	3

Figure 29 – Near Miss: By Location.

Also reported within the raw data set is the operation that was being conducted when the near miss occurred.

Bunkering:	32
Berthed:	130
Discharging:	78
Congested Waters or Straits:	48
Mooring/Unmooring:	120
Ship to Ship:	29
Anchored:	328
Loading:	52
Open Sea:	882
SBM Conv. Buoy:	21
Dry-Dock:	23
Purging/Gas-free:	5
Anchoring:	53

Figure 30 – Near Miss: By Operation.

As seen in Figure 30, the majority of reported near misses occurred during operations in the open sea i.e. when the ship was sailing from one port to another.

7.5 - Data Analysis

As discussed in Chapter 5, the analysis of this company's specific near miss data is conducted using a proprietary M-SCAT flow chart. To reiterate, this method was chosen based on the survey responses. Considering each near miss individually, after reviewing the high-level type of loss (if applicable), the type of event is considered and an immediate cause is assigned (substandard act or condition) to the incident or near miss being evaluated. Subsequent to this, basic causes are assigned to the event. These include personal factors such as inadequate mental/physical capability and job/system factors such as inadequate leadership and inadequate maintenance/inspection. The basic

causes are then sub-categorised to give further analysis into the causation of the near miss. The results of the analysis are then summarised.

In order to gain familiarity with the categorisation process, an initial trial analysis was carried out using the M-SCAT methodology on the near miss data for four ships. In this trial, a total of 101 near misses were analysed successfully. Subsequent to this trial, the larger cohort of 1,694 near miss incidents provided by the company was sorted using a random integer generator to construct a representative and statistically significant random sample of 443 near miss cases at a 95% confidence level, with a confidence interval of +/- 4 cases, and an average of 6.34 near misses per vessel.

7.6 – Results

As seen in Figure 31, the highest number of near misses occurred, by a considerable margin, when the ships were in the open sea. This may be due to the seafarers who are reporting the near misses having more time to observe and report such events, or that there is actually more near misses occurring during this period. Alternatively, for the seafarer, it may be the easiest time in order to report the required number of near misses to meet the company's performance indicator. Unfortunately, due to lack of detailed information within the near miss data set, it is hard to analyse further the circumstances of the near miss occurrence.

Bunkering:	8
Berthed:	36
Discharging:	18
Congested Waters or Straits:	10
Mooring/Unmooring:	26
Ship to Ship:	5
Anchored:	80
Loading:	13
Open Sea:	236
SBM Conv. Buoy:	4
Dry-Dock:	8
Purging/Gas-free:	1
Anchoring:	19

Figure 31 – Summary of Analysed Near Misses Occurrence.

A large number of near misses were also reported when the ship was at anchor. This is usually when the ship is at its most idle, so it is possible that it is again a convenient time to observe near misses, or alternatively they are genuine near misses. In the case of genuine near misses, this may be contributable to complacency or a lack of leadership/supervision by the officer of the seafarer carrying out the work.

The period at the berth or terminal when cargo operations are taking place may also be considered a high-risk time for ship operations. At berths, particularly when the ship does not call frequently, near misses may occur more frequently. However, particularly for tankers, the operation is highly controlled and therefore the opportunity for near misses to occur may be minimised. There were a total of 36 near misses reported while berthed in port. While the ship's procedures may be controlled and applicable to the ship and its type of operation, there is also the issue of interfacing with the terminal and its staff which may not have similar procedures or work instructions. However, the analysis showed that of the 36 near misses occurring whilst berthed, only two were due to the behaviour of attending third party personnel. In both cases, the third party did not comply with the ship's personal protective equipment matrix as required by the shipping company's management system.

Generally recognised by shipping companies, mooring operations including anchoring are considered high risk and therefore specific procedures are in place to minimise the risk to the seafarer. There were a total of 45 near misses associated with these operations. On review of these near misses, a total of 15 are considered high risk i.e., risk of death or seafarer serious injury; parting of mooring rope/wire, passing over a mooring rope/wire under tension, poor rigging and poor operation of mooring equipment. Analysing the data further showed that the majority of substandard acts occurred when the seafarer did not follow procedures or instructions as directed. The majority of substandard conditions were attributed to either defective tool/equipment or poor housekeeping onboard. Also, prevalent when considering the job/system factors was the issue of inadequate leadership and supervision. Mooring and anchoring operations are conducted by a supervising officer and if the officer is not adequately trained, then the risk of a near miss is likely to increase.

Additionally, as further shown by analysis of the personal factors, the seafarers carrying out the physical operation of mooring and anchoring may lack competence in the safe method of conducting such operations.

7.6.1 - Immediate Causes

Analysis of the immediate causes of the near misses resulted in 60% (267) being categorised as substandard acts and 40% (176) as substandard conditions. Subsequent to either a substandard act or substandard condition being assigned to the near miss, a further more defined immediate cause was considered for each near miss.

Substandard Acts

A seafarer commits a substandard (or unsafe) act when there is a deviation from a normal working practice or a variance from a standard method of completing a job. By committing such an act, the seafarer increases the risk of an accident occurring.

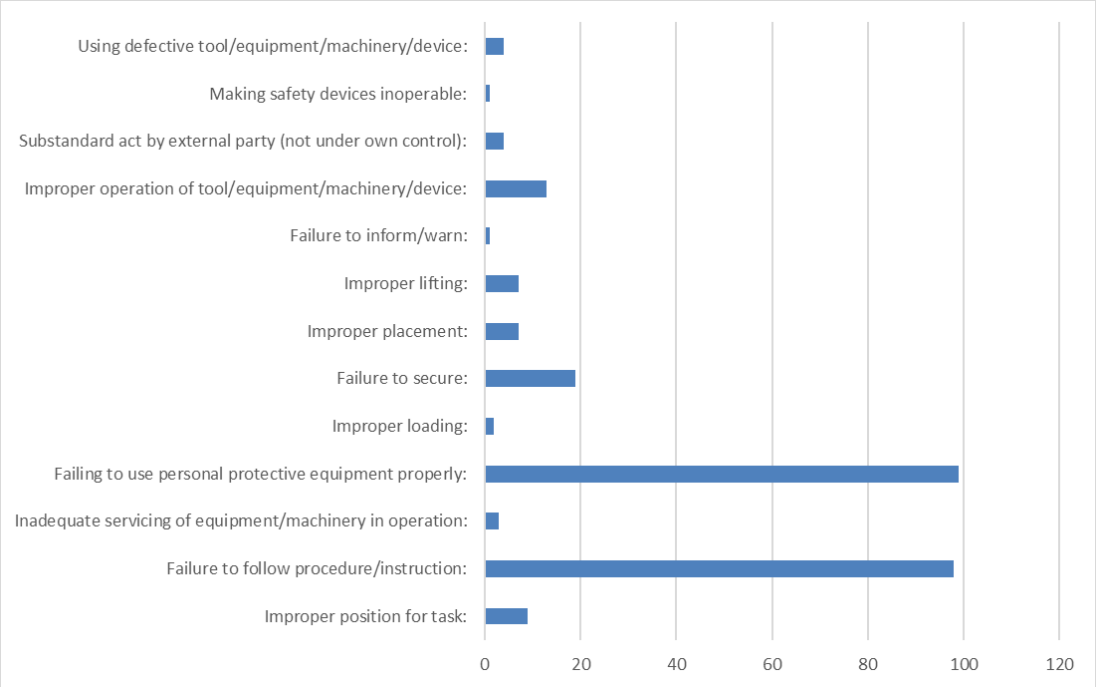

Figure 32 – Near Miss Analysis – Substandard Acts.

Many of the near misses analysed in Figure 32 relate to very basic seamanship practices, such as ‘failing to secure’ and training issues such as ‘improper operation of tool/equipment/machinery device’. However, two categories of

substandard act were reported substantially more often than the other categories.

The failure to use personal protective equipment properly can be due to a number of factors. The company providing the data had, within its safety management system, a matrix detailing the type of protection that should be used for a particular job. The failure to use personal protective equipment as found in this data set may be due to a lack of availability of the equipment, a lack of enforcement of the company's requirements regarding the wearing of the equipment, or it may be due to the lack of training in the use of the equipment.

The other category of substandard acts reported more often was the seafarer failing to follow the company's procedures or instructions. This may be attributable to a poor culture of compliance onboard or other reasons, such as a lack of supervision, or the procedures and instructions may not reflect adequately the work being carried out or the operational requirements of the specific ship type.

Substandard Conditions

A substandard (or unsafe) condition occurs when there is an unsatisfactory physical condition in the workplace that may contribute to an accident.

As seen in Figure 33, two conditions were prominent. Poor housekeeping/order is basic seamanship, however it can be easily overlooked or neglected, especially if there is limited supervision. It is very important on a ship to ensure equipment and other loose items are stored correctly and areas kept clean and tidy. If equipment is not stored correctly and if the ship is in bad weather, there is a risk of equipment causing damage, both to the ship structure and also to personnel. Additionally, the equipment itself may be damaged. Finally, if good housekeeping practices are not maintained onboard, there may be a fire or slipping hazard which could be potentially serious.

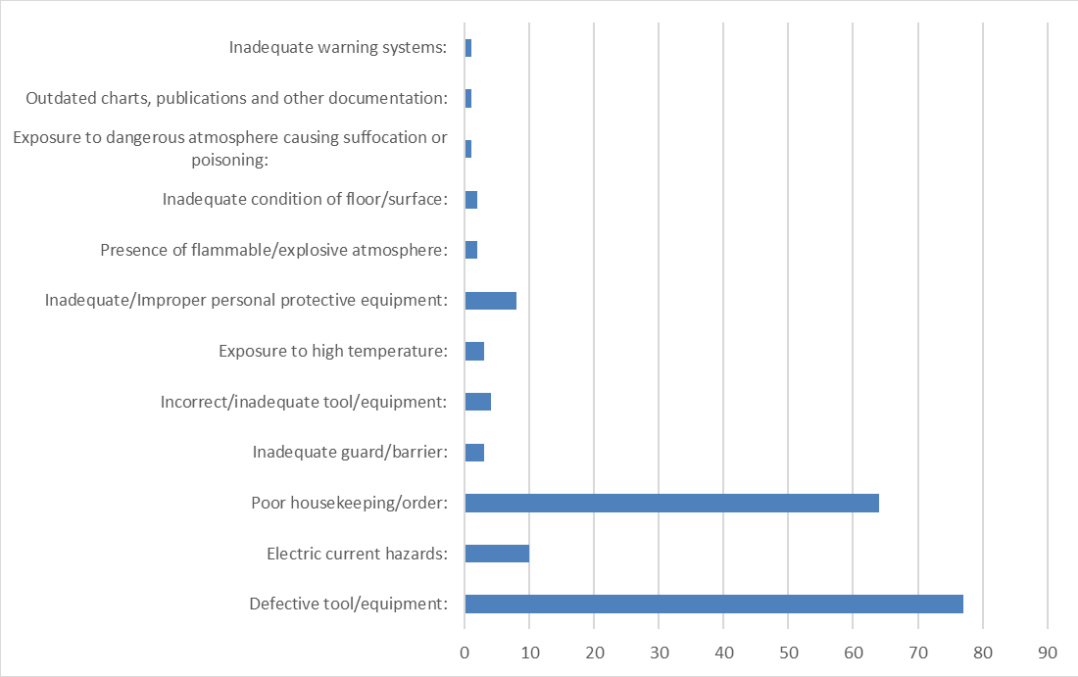

Figure 33 - Near Miss Analysis – Substandard Conditions.

Defective tool/equipment relates to two separate areas of near miss. The first, defective tools, occurs when a seafarer commences the work using a defective tool which should have been identified by the last user or by the seafarer before work is commenced. The second refers to defective equipment and while much of the equipment onboard ships is generally covered by a maintenance system, many of the near misses reported in this case referred to failures such as defective lights and relatively minor equipment not covered by maintenance procedures.

7.6.2 – Basic Causes

Further to the initial analysis of the immediate causes, each near miss was also categorised by basic causes. Basic causes are comprised of two categories, 'personal factors' and 'job/system factors'. A total of 53% (235) were categorised as job/system factors and 47% (208) as personal factors.

Job/System Factors

Near misses associated with 'job/system factors' relate to an occurrence which may be linked to a company level failure and which is outside the seafarer's responsibility. This includes the failure to be supervised.

During the analysis, it was very difficult to separate the 'inadequate supervision/coaching' and 'inadequate leadership' categories due to similarities in the description. If they were combined, then they would be by far, the largest category identified in this section. Relating to inadequate leadership and supervision, while seafarers have formalised training requirements, due to the steep authority gradient onboard ships, there is still a need for strong supervision and leadership qualities of the officers onboard in order to ensure basic seamanship practices are observed and management system requirements are followed.

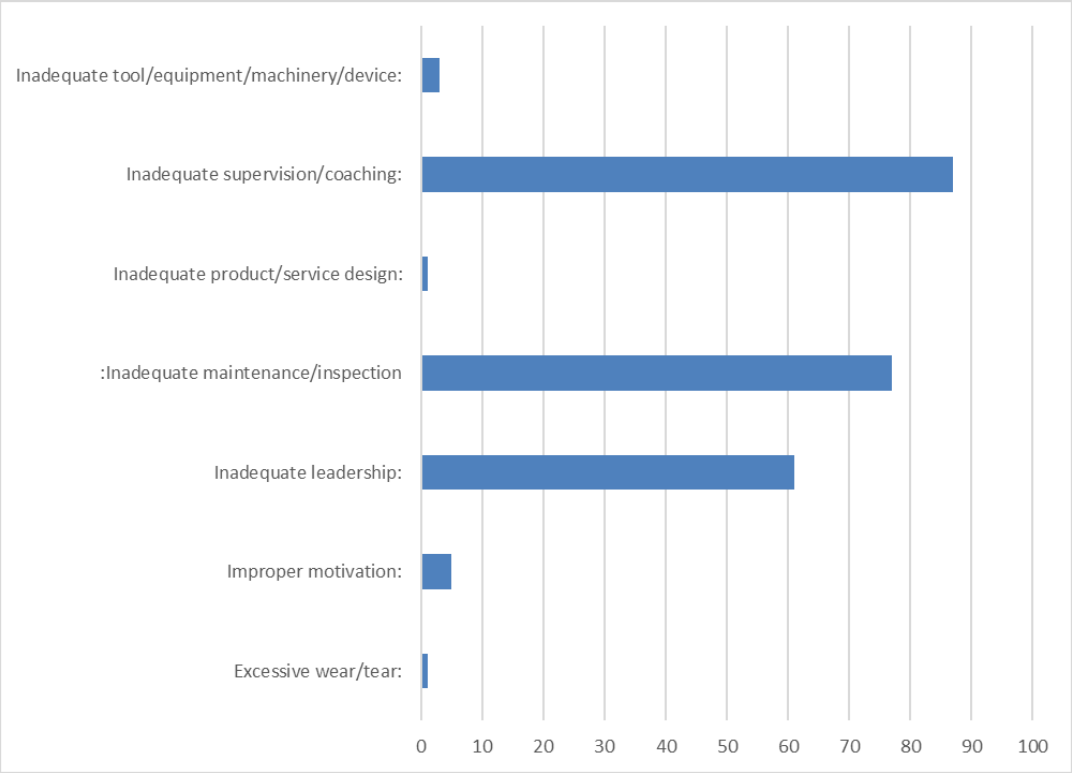

Figure 34 – Near Miss Analysis – Job/System Factors.

The other category which was highlighted in this analysis was 'inadequate maintenance/inspection'. As all the ships in this study have planned maintenance systems, this is a surprising finding, especially when the inadequate maintenance was related to items such as lifeboats, main engines and diesel generators in some of the near misses reported. However, the near misses may be attributed to equipment such as hand and machine tools that are not part of this company's planned maintenance system.

Personal Factors

Near misses are categorised as personal factors when an individual's performance impacts the work being completed. Personal factors may be related to psychological factors which may be prevalent in the shipping industry due to the working conditions.

The analysis showed that the majority of near misses assessed under this category were due a lack of competence by the seafarer. These near misses were generally basic tasks, but nevertheless important to the safety of the ship. These types of near misses could be due to a lack of basic training, however this is considered unlikely due to the training matrix the company has in place. Therefore, there may be other underlying reasons, including psychological reasons, which the near miss reporting data does not assess.

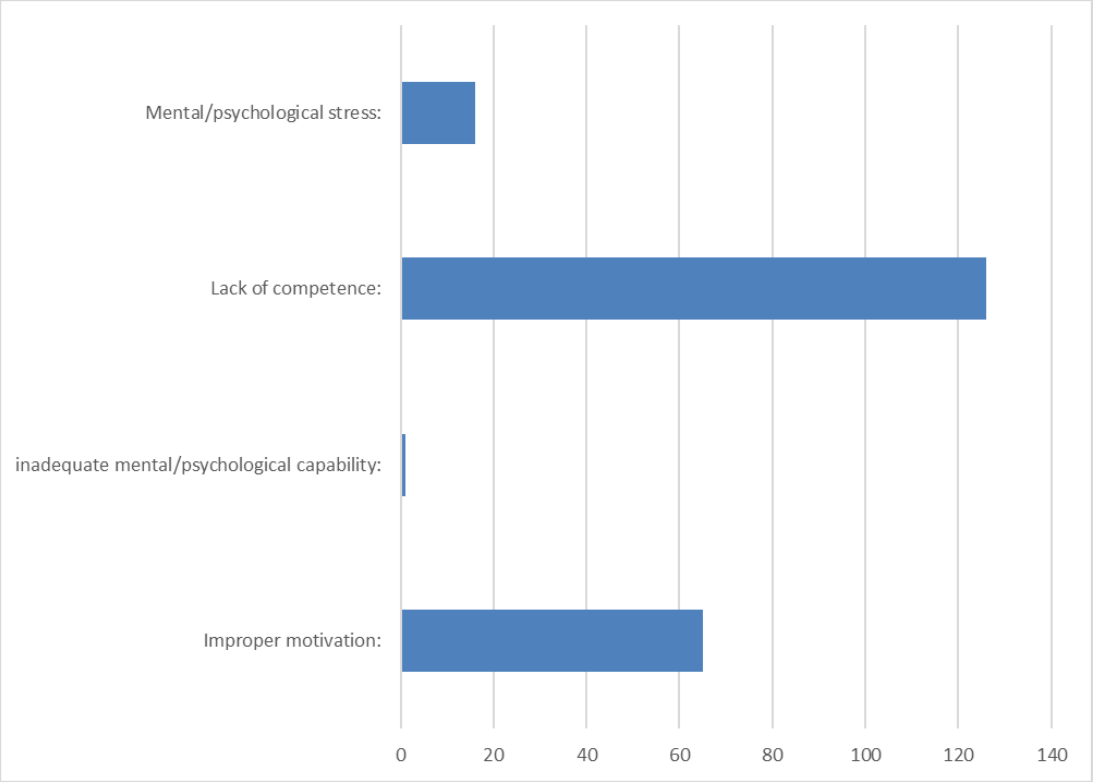

Figure 35– Near Miss Analysis – Personal Factors.

Improper motivation is when the seafarer considers that there is a 'short cut' which may save time completing the job or assist in avoiding discomfort. However, the impact of these short cuts may increase the risk of an accident or injury to the seafarer.

Associated with the substandard acts, there were 179 of these categorised as being due to personal factors and 88 were due to job/system factors. Similarly, associated with substandard conditions, they were 29 categorised as being due to personal factors and 147 job/system factors.

7.7 - Further Analysis Using M-SCAT

From the above charts summarising the substandard acts and substandard conditions, the two most prominent categories of each immediate cause were analysed further using M-SCAT to better understand the causation relating to the categories.

Substandard Act: Failure to use personal protective equipment properly

The majority of near misses associated with the failure to use personal protective equipment properly were found to be due to personal factors. Further analysis of this identified that, in the majority of cases, a lack of competence as a basic cause linked to lack of situational awareness/risk perception/risk awareness, and was likely a prominent cause of failing to use personal protective equipment properly. Examples of this include working outboard of the ship and working aloft without a safety harness, despite the company's safety management system clearly stating that it is a requirement. This could also be considered a training issue or a lack of supervision issue.

Job/System or Personal Factors	Basic Cause 1	Number	Basic Cause 2	Number
Job/System Factors	Improper motivation		Improper attempt to save time/effort	1
Job/System Factors	Inadequate leadership	3	Inadequate communication/implementation of policy/procedure/practice	9
Job/System Factors	Inadequate supervision/coaching		Inadequate supervision/orientation/training	16
Personal Factors	Improper motivation		Improper attempt to avoid discomfort	6
Personal Factors	Improper motivation		Improper attempt to save time/effort	16
Personal Factors	Improper motivation		Improper cost reduction incentive	1
Personal Factors	Lack of competence		Inadequate experience	1
Personal Factors	Improper motivation		Inadequate discipline	3
Personal Factors	Lack of competence	11	Inadequate initial training	6
Personal Factors	Lack of competence		Inadequate orientation/induction	1
Personal Factors	Lack of competence		Inadequate practice	2
Personal Factors	Lack of competence		Inadequate update/refresher training	7
Personal Factors	Lack of competence		Lack of situational awareness/risk perception/risk awareness	29
Personal Factors	Mental/psychological stress		Routine/monotony/boredom/overly routine tasks	1

Figure 36 – Analysis of Failing to Use Personal Protective Equipment Properly.

Additionally, the analysis showed that the seafarer was improperly motivated in many cases, mainly by trying to save time or effort by, for example, rushing to start a job without having put on the appropriate personal protective equipment. Improper motivation was also attributed when the seafarer tried to avoid discomfort, for example when the personal protective equipment worn was not the correct size for the user. The analysis also showed that a high

number of near misses occurred due to a job/system factor, and analysing this further highlighted inadequate supervision or training of the seafarer conducting the work.

Summarising, either directly or indirectly, a prominent factor in the seafarer failing to use personal protective equipment properly was due to a lack of supervision of the seafarer carrying out the work. However, there is also a training issue due to the seafarers being identified as not being familiar with the risks associated with work requiring the use of personal protective equipment.

Substandard Act: Failure to follow procedure/instruction

Analysing the near miss causation associated with the failure to follow procedures or instructions identified two main contributing job/system factors. At the basic cause, these were attributable to inadequate leadership and inadequate supervision. Further assignment of the basic causes showed there was inadequate communication/implementation of the procedures and inadequate instruction or training. Reviewing the details reported in the near miss report showed that the majority of these failures occurred when the person in charge failed to monitor the seafarer carrying out the task.

Under the personal factors, similarly to the failure to use personal protective equipment properly, there was a lack of competence by the seafarer in assessing the risk, and a lack of situational awareness.

Job/System or Personal Factors	Basic Cause 1	Number	Basic Cause 2	Number
Job/System Factors	Improper motivation	4	Improper attempt to save time/effort	2
Job/System Factors	Inadequate leadership		Inadequate communication/implementation of policy/procedure/practice	16
Job/System Factors	Inadequate leadership		Inadequate work/process planning/programming	1
Job/System Factors	Inadequate supervision/coaching		Inadequate instruction/orientation/training	15
Personal Factors	Improper motivation	15	Improper attempt to save time/effort	12
Personal Factors	Improper motivation		Inadequate discipline	4
Personal Factors	Improper motivation		Lack of incentive	1
Personal Factors	Improper motivation		Misuse	1
Personal Factors	Inadequate mental/psychological capability		Memory failure/lapse	1
Personal Factors	Lack of competence		Inadequate experience	2
Personal Factors	Lack of competence		Inadequate initial instruction/skill training	4
Personal Factors	Lack of competence		Inadequate initial training	6
Personal Factors	Lack of competence		Inadequate orientation/induction	2
Personal Factors	Lack of competence		Inadequate practice	2
Personal Factors	Lack of competence		Inadequate update/refresher training	4
Personal Factors	Lack of competence		Lack of situational awareness/risk perception/risk awareness	10
Personal Factors	Lack of competence		Misunderstood instruction/information	6
Personal Factors	Mental/psychological stress		Frustration	1
Personal Factors	Mental/psychological stress		Routine/monotony/boredom/overly routine tasks	8

Figure 37 – Analysis of Failing to Follow Procedure/Instruction.

Considering the training given prior to joining a company ship, the seafarer is required to be trained in accordance with the International Maritime Organisation's Convention on Standards of Training, Certification and

Watchkeeping for Seafarers (IMO, 1978) and, on joining a ship, familiarisation training should be given with a focus on the management system and ship specific equipment and procedures. Both these initiatives should ensure that the seafarer is trained adequately in the company's procedures. However, the analysis shows that supervision ensuring that the seafarer follows procedures is inadequate and that the risk awareness of a job should be highlighted to the seafarer, prior to the work commencing..

Substandard Condition: Poor housekeeping/order

The identified causation from the near miss analysis showed that poor housekeeping/order were due to two job/system factors; firstly, due to a lack of supervision/coaching from the person in charge of the seafarer carrying out the job and the other due to inadequate communication/implementation of procedures by the onboard leadership.

Job/System Factors	Improper motivation	8	Improper attempt to save time/effort	2
Job/System Factors	Inadequate leadership		Inadequate communication/implementation of policy/procedure/practice	12
Job/System Factors	Inadequate leadership		Inadequate work/process planning/programming	1
Job/System Factors	Inadequate maintenance/inspection		Inadequate adjustment/assembly	1
Job/System Factors	Inadequate maintenance/inspection		Inadequate assessment of preventative maintenance needs	1
Job/System Factors	Inadequate maintenance/inspection		Inadequate inspection method/interval	2
Job/System Factors	Inadequate supervision/coaching		Inadequate instruction/orientation/training	30
Job/System Factors	Inadequate tool/equipment/machinery/device		inadequate assessment of needs and risks	1
Personal Factors	Improper motivation	4	Improper attempt to save time/effort	2
Personal Factors	Improper motivation		Inadequate discipline	1
Personal Factors	Lack of competence		Inadequate experience	4
Personal Factors	Lack of competence		Inadequate update/refresher training	3
Personal Factors	Lack of competence		Lack of situational awareness/risk perception/risk awareness	2
Personal Factors	Mental/psychological stress		Routine/monotony/boredom/overly routine tasks	2

Figure 38 – Analysis of Poor Housekeeping Order.

Substandard Condition: Defective tool/equipment

The analysis showed that defective tools/equipment were an issue due to maintenance and inspection issues at the job/system factors level.

Job/System Factors	Excessive wear/tear	10	Inadequate inspection/monitoring	1
Job/System Factors	Inadequate leadership		Inadequate communication/implementation of policy/procedure/practice	8
Job/System Factors	Inadequate maintenance/inspection		Inadequate adjustment/assembly	3
Job/System Factors	Inadequate maintenance/inspection		Inadequate assessment of preventative maintenance needs	23
Job/System Factors	Inadequate maintenance/inspection		Inadequate inspection method/interval	29
Job/System Factors	Inadequate maintenance/inspection		Inadequate parts substitution/replacement	1
Job/System Factors	Inadequate maintenance/inspection		Unable to inspect	2
Job/System Factors	Inadequate product/service design		Inadequate product/service design/development	1
Job/System Factors	Inadequate supervision/coaching		Inadequate instruction/orientation/training	4
Job/System Factors	Inadequate tool/equipment/machinery/device		Inadequate inspection/repair/maintenance	1
Personal Factors	Improper motivation	4	Improper attempt to save time/effort	1
Personal Factors	Improper motivation		Misuse (unintentionally)	1
Personal Factors	Lack of competence		Inadequate experience	1
Personal Factors	Mental/psychological stress		Routine/monotony/boredom/overly routine tasks	1

Figure 39 – Analysis of Defective Tool/Equipment

Generally, for equipment, the ships have planned maintenance systems and it is possible that they are not comprehensive enough or the maintenance interval is not correctly specified. However, tools are generally not covered by a maintenance scheme and failures are only identified when the tool does not

function, either prior or during use. Therefore, prior to use they should be correctly inspected and seafarers have to be trained and supervised on this aspect of using tools.

7.8 - Chapter Summary

Near misses can give an insight into how effective a company's safety policies and procedures are. If they are analysed correctly, the results can be used to improve the safety management system and feedback given to the seafarers. However, many companies also have specific targets (as part of the company's key performance indicators) for ships reporting a number of near misses per month (seven is a common number) in order to encourage reporting, but this requirement may encourage seafarers to 'meet' targets by reporting non-relevant near misses. Therefore, it is important that the seafarers are educated regarding near miss reporting and use the system correctly.

Using the M-SCAT approach allowed the near miss to be categorised effectively, especially at the higher level when determining the immediate cause. In some cases, the sub-categories were difficult to assign, for example differentiating between lack of supervision and lack of leadership was difficult, particularly with the limited information contained in the near miss reports.

However, when considering personal factors, while a near miss can be categorised using the M-SCAT chart, in many cases it is difficult to know the real causation such as fatigue, or a physiological incapability as the near miss reports do not record such data. It is also more difficult however to assign the basic causes without knowing the full details of the event. Therefore, based on this research, near miss reporting forms could be designed in order to capture the additional factors that may have influenced the person to not follow procedures, for example. Additions to reports could include hours of work/rest, any seafarer physical factors (height, weight, fitness relevant to the job being conducted), identify any training requirements, any specific recommendations regarding procedures and any psychological factors affecting the seafarer's ability to complete the job safely.

To reduce the number of substandard acts occurring in an organisation there must be defined training in basic skills required for the seafarer to safely complete the task assigned. This must be supplemented by additional training for the specific role. The seafarer also has to be supervised onboard in order to ensure that the company's procedures are being followed. It is also important to recognise the value of refresher training in order to reinforce the company's culture and requirement to follow company procedures. Finally, the quality of training may, in many cases, be substandard or not delivering a programme which is suitable for the company's needs or the seafarer experience.

Additionally, supervising officers themselves need to be trained in the correct work procedures and ensure they monitor the work being carried out by their junior officers and ratings. This also applies to substandard conditions, for example, officers themselves must be aware of correct housekeeping practices in order to guide and direct ratings accordingly.

The next chapter uses one of the initial accident causation events identified in Chapter 6 and applies a systemic accident analysis technique to a number of published formal reports to identify any common factors between the accident and to consider the relationship between the ship and shore organisations.

8

Study 4: Analysing Accident Causation Using Systemic Accident Analysis (SAA)

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8.1 – Introduction
8.2 - Methodology
8.3 - Accident Sample
8.4 - Analysis of the Selected Accidents
8.5 - Summary of the Analysis
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8.1 - Introduction

The study in Chapter 6 identified collisions and other similar causations such as foundering as major initial causations of accidents in the shipping industry. Using reports published by a Flag State or a marine accident bureau, a number of accidents with collision as the initial causation factor will be assessed in order to identify any common factors in this type of accident. The identification of such factors will allow preventative measures to be proposed in order to minimise the future occurrence of such accidents with similar causal factors.

The systemic accident analysis technique, AcciMap, will be used to analyse the accidents. AcciMap was chosen as it has been used in related transport industries as well as in shipping. AcciMap presents the results of the analysis in a graphical manner and can be used in both accident and incident investigation, as well as the analysis of near misses. For shipping, with its

remote offices, the graphical presentation of AcciMap is useful in determining the relationship between the shore organisation and the ships. This is something which, in many cases, is not taken into account in current shipping accident investigations.

8.2 – Methodology

A systems approach is used to understand common factors when considering one accident causation, in this case, collisions. This approach can provide important lessons about safety and how future occurrences of similar accident causations can be avoided by considering the system as a whole entity (Underwood et al., 2013). Using a systemic technique to analyse accidents in complex systems allows causal and contributory factors to be assessed at all levels of the system being considered. In the case of shipping, this includes the regulatory influences at the upper levels, to the shore organisation and then to the ship organisation which includes the seafarers responsible for operating the ships safely.

Accident analysis techniques used in many industries focus on the sequential understanding of accident causation (Underwood et al., 2013) with the investigation reports focusing on 'sharp end' factors (Cedergren and Petersen, 2011) i.e. where the work is being carried out, in the case of shipping, by the seafarers onboard the ship. While it is important to find the true root cause to any accident, it is also important to know when to conclude an investigation. Rasmussen (1997) describes three stop rules; when information is missing and the causal path can no longer be followed, when a familiar, abnormal event is found to be a reasonable explanation and when a cure is available. Using a Systemic Accident Analysis (SAA) technique allows the investigation to be concluded when a causation, based on agreed stop rules, has been identified and can be used to make recommendations or implement new requirements in order to correct and/or prevent similar causations in future operations.

There are several systemic accident analysis techniques (SAA) such as Functional Resonance Analysis Method (FRAM) (Hollnagel, 2004) and causal loop diagrams (Goh et al., 2010), these all use a systems thinking approach, but for this study, the SAA technique AcciMap was selected to analyse the

accidents. AcciMap was chosen as it has been used in related transport industries as well as in shipping (Tabibzadeh and Meshkati, 2015 and Lee et al., 2017). For example, Kee et al. (2017) used AcciMap to analyse the sinking and subsequent rescue operation of the Sewol. AcciMap presents the results of the analysis in a graphical manner and can be used in both accident and incident investigation as well as the analysis of near misses. For shipping with its remote offices, the graphical presentation of AcciMap is useful in determining the relationship between the shore organisation and the ships. This geographical issue is something which, in many cases, is not taken into account. Using this technique, this study will consider the human factors influencing the relationship between the ship and shore, which can affect safe operations at every level within a shipping company organisation.

This application of the AcciMap technique was modified to allow the four accidents to be displayed on one AcciMap. This allowed the common contributory factors of the accident causations to be identified and mapped at the relevant level of the socio-technical system (Kee et al., 2017).

8.3 - Accident Sample

Using the official published reports from four collisions with loss of life, each accident was analysed using AcciMap. These accidents were chosen because they had similar characteristics; two ships involved in the collisions were ocean-going on specified courses instead of near ports, and the accidents occurred under calm or mild weather conditions.

The first accident occurred in 2000 between a container ship and a tanker (The Swedish Maritime Administration, 2000). The container ship was heading north in restricted visibility, and the tanker was heading south on a near counter course, passing close by. The two ships collided at an angle of approximately 35° and the tanker was cut in two just forward of the bridge. The after part of the tanker sunk soon after the collision while the forward portion remained afloat for about four hours before sinking. Five people lost their lives. The container ship only incurred slight damage and was able to continue with its voyage.

The second accident occurred in 2007 between a cargo ship and a bulk carrier (The Hong Kong Special Administrative Region, 2007). The cargo ship struck the bulk carrier, in way of number three cargo hold, in good weather conditions with a moderate sea and good visibility. After the collision, the cargo ship suffered damage to its bow and the bulk carrier sank with the loss of 17 lives.

The third accident occurred in 2011 between a ferry and a general cargo ship (Hellenic Bureau for Marine Casualties Investigation, 2015). The ferry was proceeding west and the general cargo ship was on a northerly course. The collision occurred in the Adriatic Sea off Port Durres. After the collision, the general cargo ship sank with the loss of eight lives. At the time of the collision, the weather conditions were calm with good visibility. The ferry did not suffer any serious structural damages and was able to assist with the search and rescue operation. After being released from the search and rescue operation, the ferry continued to its intended port to disembark its passengers and to discharge its cargo.

The final accident considered occurred in 2013 between a general cargo ship and a dry cargo ship (Republic of Turkey, Ministry of Transport, Maritime Affairs and Communications, 2012). The two ships collided at the south west end of the Peloponnese in Greece. Weather conditions were described as good, however it was still dark at the time of the accident. The cargo ship penetrated the dry cargo ship's hull causing it to list and sink quickly after the initial impact. Ten people lost their lives in the accident. Figure 40 summarises of the accidents.

Year	Geographical Area	Ship Type	Collided with	Flag	Casualties	Remarks
2000	Hogana Peninsula	Tanker	Container	Liberia	5	Poor visibililty
2007	Langgang Islands	General Cargo	Bulk carrier	Hong Kong	17	Strong winds/Fog
2011	Adriatic Sea	General Cargo	Ro-Ro/Passenger Ship	Malta	8	22 miles off land
2013	Mediterranean Sea	General Cargo	General cargo	Cook Islands	10	100 miles off land

Figure 40 – Summary of Selected Accidents for Analysis.

8.4 - Analysis of the Selected Accidents

Figure 41 shows a combined AcciMap of the four collisions. Considering each AcciMap level in detail, at the Ship Physical/Actor Events Processes and Conditions level various contributory factors were identified. From the

analysis, these factors can be grouped into three types. The first contributory type is equipment-based which relates to installed navigational equipment, such as radar, which is not in use or used incorrectly. These types of navigational aids are fundamental to safe navigation, and using them correctly is a basic requirement for navigation officers. The second contributory type relates to prescriptive regulations which are clearly not followed constituting noncompliance. These include regulations to avoid collisions and also regulations specifying the standard of navigating watch (COLREG) that must be conducted onboard (for example, watch arrangements and the requirements for lookouts). The analysis showed that in six instances, the COLREGs were not complied with. These noncompliances included failing to proceed at safe speed, failing to take action to avoid a collision in ample time and not following the regulations in a crossing situation.

Finally, the third type of contributory factor identified in the analysis relates to safety management systems and the operating company's management system being inadequate, or officers not following the company's safety management system policies and procedures. Examples of this type of factor include lack of onboard familiarisation for newly appointed officers, procedures not applicable to the onboard equipment or work processes, and issues related to communication, both onboard the ship and also between the ships involved in the collision.

At the Shore Operations/Management level, various factors contributed to the collisions; the lack of auditing of the ship's officers by the shore staff, and lack of seafarer training are key contributory factors. Auditing of the ships by shore staff allows the operating company to ascertain if the seafarers are following the regulations and the company's policies and procedures. The ISM Code (IMO, 2002) clearly states that companies should carry out internal safety audits onboard and ashore at intervals not exceeding twelve months to verify whether safety and pollution-prevention activities onboard comply with their safety management system. Additionally, at this level, it was found that there were inadequate policies for recruitment and training. This also relates to the company's management system being inadequate as shown. These policies

should dictate minimum requirements for qualifications, experience and training of the seafarer.

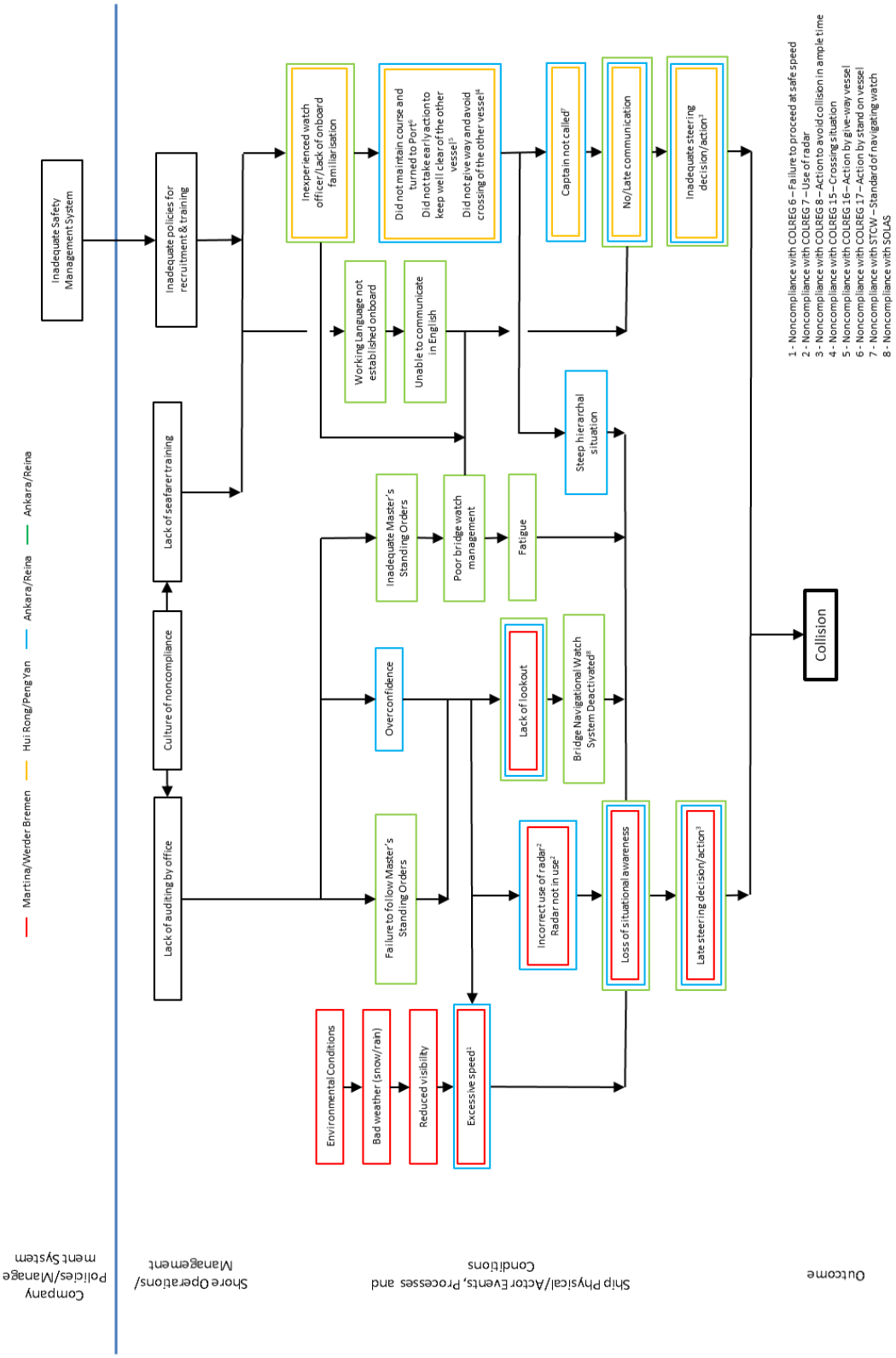

Figure 41 – AcciMap of Selected Accidents.

At the Company Policies/Management System level, the analysis showed that several companies had an inadequate safety management system, particularly with respect to policies regarding recruitment and training. One company had not established that their seafarers could communicate adequately in the English language, and several companies had either inadequate or had implemented minimum standards for watchkeepers, nor had established training requirements, particularly relating to onboard familiarisation.

At the Regulatory Bodies and Associations level, no failure was identified in the investigation reports.

8.5 - Summary of the Analysis

The outcomes from using the AcciMap output demonstrated that there was a culture of noncompliance in both the shore and ship organisations. Onboard, the analysis highlighted that a total of eight regulations fundamental to safe navigation and safe watchkeeping were not being complied with, and best seamanship practices were also not being followed. While ashore, there was noncompliance with the ISM Code. Safety management systems in the shipping industry are generally based on Dekker's (2006) 'model 1' of safety rules, and as stated by Hale and Borys (2013), this is the model in which violations of rules are identified which contribute to the accident, something which has occurred in all four of these collisions. The AcciMap also identified inadequate policies and procedures for recruitment and training as being contributory factors. If training is inadequate or poorly delivered, both the shore staff and the seafarers may not be fully aware of company policies and procedures resulting in noncompliance in different areas of the company as revealed in the application of AcciMap. Therefore, it is important that both the shore and seagoing staff are trained regularly and to the same standard.

Figure 42 shows the relationship between the actors involved, including regulatory organisations and the ship and shore organisations. Due to the nature of ships operating remotely from the shore offices, it is important to establish a relationship between the shipboard officers and shore staff to ensure that a consistent company safety culture is promulgated throughout the shore organisation and to the ships. The shore organisation can be

fragmented, having multiple offices and different departments which all need to be aligned with respect to the company's safety culture. This can be challenging. Additionally, seafarers in many instances are a transient workforce, contracted for relatively short periods and they may also be supplied by a third party. These issues can make it difficult not only to promote a safety culture at all levels within a company, but also to ensure the safety culture remains consistent over time as seafarers end their contract and their replacement joins the ship.

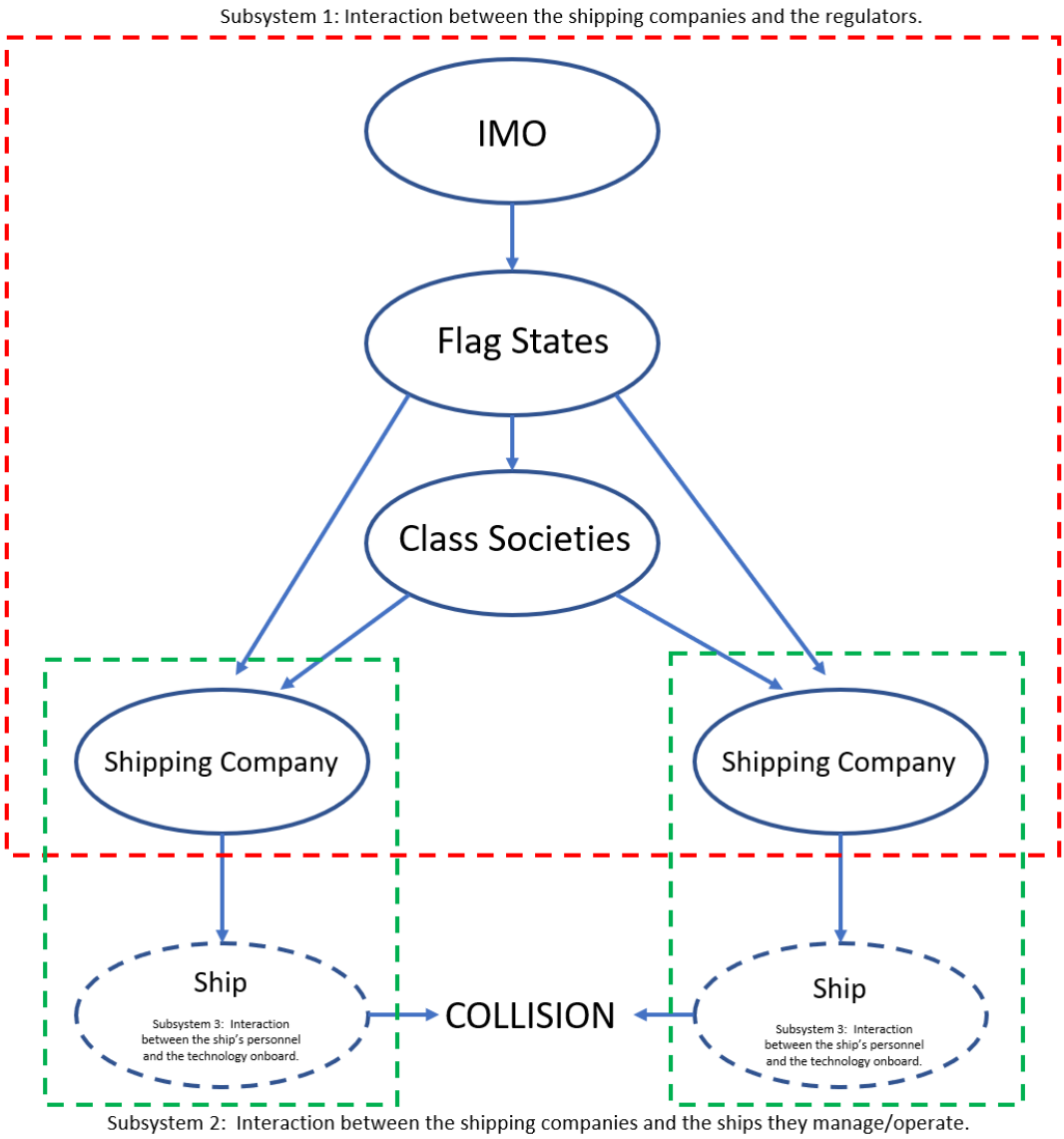

Figure 42 – Relationships Between the Organisations.

For all four accident reports reviewed, the AcciMap output did allow the contributory factors to be identified at all levels and every factor in the accident reports was able to be classified. The analysis was also able to identify

contributory factors across different actors and also within different levels of the shipping company organisation; both onshore staff and the seafarers. This result is not inconsequential. Due to the complex organisational structure of shipping companies, traditional methods of analysing accidents at sea are unlikely to identify the relationships between ship and shore. It was also possible to clearly see from the AcciMap output multiple contributing factors to each of the collisions. This aligns with Reason's (1990) theory that the causation of accidents is linked to the interaction of both latent and active failures within the system. The AcciMap output clearly shows both types of failure, while many of the latent failures are not considered in the investigative techniques used in the accident reports that were reviewed.

None of the reports identified the shore influence on the operation and safe navigation of the ships. For example, it is important that a company's safety management system is verified to ensure continued compliance with the legislation, auditing of the system (which is required by the ISM Code to be conducted both ashore and onboard) is completed, and the role and responsibilities of the shore-based staff are confirmed. It should also be ensured that once an officer has been trained, his standard of navigation is re-assessed and any re-training requirements that are identified are completed as necessary.

8.6 – Chapter Summary

This chapter used a systemic accident analysis technique (AcciMap) to identify common causal factors associated with the initial event of one type of accident. The analysis showed there was a culture of noncompliance or violations of fundamental shipping legislation identified as contributory factors. The noncompliance included not adhering to the Collision Regulations, STCW and SOLAS requirements. The analysis also showed that there was a lack of monitoring and supervision by the shore organisation, which resulted in the noncompliances not being identified, and therefore becoming dormant (i.e. latent) until other active causal factors were present and also contributed to the accident.

The importance of this application in this research is significant. AcciMap is not commonly used when investigating shipping accidents. As a result, certain causal factors may be overlooked, thereby reducing the likelihood that he potential for an accident can be minimised or eliminated altogether. The strength of AcciMap in identifying both latent and active failures in the system, as well as considering the relationship between onshore staff and seafarers, could be utilised to improve safety in the shipping industry.

After applying a STAMP analysis to both the ship operation and the process of design and construction of new ships, the next chapter uses the findings from the previous studies and applies them to the ship operation control structure to identify any common factors within the studies that may be used to make recommendations in order to improve safety onboard ships, enhance the relationship between the ship and shore organisations, and finally propose methods to promote the safety culture within shipping companies.

9

Study 5: The Shipping Industry as a Complex Adaptive Sociotechnical System

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9.1 – Introduction
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9.4 - Ship Design and Construction Control Structure
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9.6 - Chapter Summary

9.1 – Introduction

As discussed in Chapter 5, this chapter will initially consider the ship operations and ship design processes by applying a STAMP analysis to the ship management and ship new construction organisations. It will also consider any external factors that have influence on these organisations. Then, using the STAMP ship operations control structure, the conclusions from the studies carried out in the previous chapters will be analysed in order to consider any common causations and other factors affecting the operation of ships safely. The results of the analysis will then be reviewed and common factors identified for further discussion.

9.2 – Methodology

The previous studies have attempted to identify causal factors in the shipping industry which contribute to accidents by considering the factors after the event. In identifying them, corrective and preventative actions can be implemented at different levels within the organisational structure. The disadvantage of this approach is that corrective and preventative actions can only be determined after the issue has been identified i.e. there are lagging indicators in an organisation's safety management activity (Hopkins, 2009). The techniques applied to the studies in the previous chapters will consider lagging indicators when identifying the causal factors such as near miss reporting and trending of accident and incident data. Similarly, an analysis technique such as AcciMap can only consider causal and contributory factors after an accident occurs.

Leveson (2015) suggests that by considering leading indicators as identified in the petrochemical industry, it can presage an accident. However, differentiating between lagging and leading indicators can be difficult to distinguish. Baker (2007) differentiates the two; lagging indicators, he says, are generated by a process of reactive monitoring, while leading indicators are the outcome of active monitoring. Further, reactive monitoring allows an organisation to identify and correct safety related deficiencies in response to specific incidents or trends, while active monitoring can evaluate the current state of an organisation or facility through the routine and systematic inspection of systems and equipment.

Leading indicators, if identified correctly, can influence future behaviour and performance. Common metrics which have been used as leading indicators in the petrochemical industry include maintenance performance indicators, failure rates of equipment, and analysis of incidents such as leaks or similar process integrity failures.

An alternative approach to using physical metrics is to consider the operation as a complex system in a similar manner to accident investigation analysis. Using an accident investigation technique to assess safety is not unusual as it can help analysts understand the factors that can threaten safety (Kazaras et

al., 2014). Salmon et al. (2012) discuss three accident causation models that are established and used within the human factors literature:

- Human Factors Analysis and Classification System (HFACS) which is inspired by Reason's swiss cheese model and uses a taxonomy-based aviation accident analysis approach (Wiegmann and Shappell, 2003).

- Accimap is a generic approach used to identify and link contributory failures across six sociotechnical system levels, accompanies Rasmussen's risk management framework. An Accimap analysis is applied to a number of accidents, with a similar initial causation, in Chapter 9.

- The STAMP model uses control theory and systems dynamics methods to describe the systemic control failures involved in accidents. STAMP was selected for the method to be used for this study due to its generic nature which allows it to be readily applied to different domains. It has also been used frequently in other transport sectors, such as the rail industry. However, Salmon et al. (2012) highlight that, while this method is comprehensive, it is reliant on the initial control structure diagram being accurate with all control loops identified. This may make it difficult to be applied to systems where the system structure is unfamiliar.

The STAMP model will give an overview of the safety function of the ship management company as a complex sociotechnical system. Using such a model to analyse and control safety management in a complex system such as shipping may allow any deficiencies in the system to be identified, and corrective and preventative measures to be applied in order to improve the system.

Additionally, it will increase the ability to learn from experience and particularly deal with the complexity from the interaction among diverse system components (Leveson, 2011). Using STAMP, the analysis focuses on the control or enforcement of constraints related to safe operations and the

management of ships. The system is depicted as a hierarchical structure, with each level imposing constraints on the activity of the level beneath it (Leveson, 2011), whether it is controlled by regulations, procedures or inspection and auditing. The organisation of shipping companies is traditionally very hierarchical, and therefore considering the constraints between the levels and the control of such constraints will allow the assessment of the system with respect to safe management in a proactive manner.

The application of STAMP has been limited within the shipping industry. It has previously been applied to the analysis of safety adaptive management of the maritime spatial planning at the Gulf of Finland (Aps et al., 2015, 2016) and the analysis of the Sewol Ferry accident in South Korea (Kim et al., 2016; Lee et al., 2017). Osiris et al. (2018) uses a STAMP-based approach to design a safety management system for the maritime industry, however it is for the design of a vessel traffic service (VTS) which can govern and guide the functioning of a VTS centre, rather than a ship management company.

STAMP Overview

STAMP considers the system as a continuous control task with constraints imposed in order to limit the behaviour of the system to safe changes and adaptions (Leveson, 2004), rather than considering events as a single failure or a sequential chain of events to prevent failure events when relating the use of the technique to safety management. When assessing safety management performance, STAMP uses three elements to determine why the system is ineffective or failing, namely; constraints, control structures and process models.

When STAMP is applied to a complex system, such as ship operations, safety and performance can be monitored to ensure the system is meeting the required performance as determined by the setting of goals within the system. When considering the safety of a system, the STAMP analysis focuses on inadequate control or the enforcement of constraints on the system design, operation and maintenance of the system being analysed.

Constraints

In STAMP, the concept of the constraint is fundamental as, in systems theory, control is always associated with the imposition of constraints. In the case of the shipping system and safe management, the constraints will ensure the system will perform within pre-determined boundaries and safety performance criteria will be enforced by a control structure. The constraints that are decided, which in some cases are a legislative requirement, have to be relevant to ensure that risks are controlled. Constraints can be either passive, such as a physical barrier, or active requiring an action to ensure compliance within the system. Examples of active constraints in this application are auditing, inspection and measurement against metrics.

Control Loops

The control structure of a STAMP analysis has different levels within the organisation being considered. Between these levels are classic feedback loops (Leveson, 2015). The controllers within the levels provide controls to keep the system in equilibrium. In the case of a safety management analysis, safety constraints ensure the processes involved behave as expected. The processes which are being controlled in turn give feedback to ensure the process is providing appropriate and effective control of the system at that level.

In the case of STAMP assessing a system control, in addition to physical controls, the control is provided by policies, procedures, audits and other aspects which make up an organisation's culture and, applicable in this case when considering safety management aspects, the safety culture of an organisation. An example of control in ship operations is; ranks have specific assigned responsibilities as written in the safety management system, the Chief Officer is responsible for creating an entry permit for an enclosed space, the Second Officer has responsibility for ensuring the equipment for entry is working and available and the shipboard management team has responsibility for ensuring the activity is carried out safely and properly. The Class Society, acting on behalf of the Flag State, is responsible for ensuring that safe practices and appropriate equipment are being used.

Process Models and Levels of Control

In order to ensure an effective model, it is important the process is modelled accurately and reflects the different levels and relationships within the company. Leveson (2015) stresses the importance of the effectiveness of the control structure is greatly dependant on the accuracy of the information the controller has related to the state of the controlled system. Additionally, performance metrics provide feedback and can provide a means for measuring the risk in the process and the control structure. Specifically, when the STAMP model is used as a leading indicator programme, it is particularly important that the operational, organisational, and societal control structure reflects and works as designed to ensure that the safety requirements are complied with and the controllers are also complying with their responsibilities in accordance with the safety management system requirements.

Within the control structure, there are hierarchal levels, each with a controller who can influence the system by complying with the requirements of their sub-system that is their responsibility. The controllers receive feedback from the level below and, with this information, they have to maintain their part of the system within the constraints that are applicable to their level. In the STAMP analysis, communication is necessary in both directions between the levels in order for the system to maintain its equilibrium. While the system is considered dynamic, in the case of the ship operations control structure, there are invariably delays, particularly more so near the higher levels of the control structure. This is due to several reasons including the remoteness of the ships from the offices, as even with modern communications there is not a constant flow of information. For example, the performance indicators are not calculated continuously, and on occasions there may also be delays in reporting nonconformances and minutes of relevant meetings, such as the shipboard safety meeting minutes.

Application of STAMP

After constructing a ship operation and a ship design control structure using the STAMP methodology, the operations control structure will be used to analyse the results from the previous studies of this research and consider if

there are any common factors that the STAMP analysis can identify. Using this information will enhance the understanding of the complexity of the shipping industry, particularly the relationship between the shore and ship organisations, and allow the concluding chapter to propose measures for improving the understanding of human factors, as related to human error, in the shipping industry specifically with regards to accident causation and improving the safety of ship operations.

9.3 - Ship Operations Control Structure

The initial STAMP analysis was applied to a typical ship operations group structure. Generally, it follows the organisational structure of a company and the safety management processes with additional details included, such as feedback loops, responsibilities and control actions. The ship operations control group not only includes the company structure of management, operations and the ships, but also includes external influences on the operation of the ships, such as regulatory and third parties, which can influence safe operations. For the purpose of this analysis, the ship was considered as one part of the ship operations group, with its own internal constraints and controls. Also, as part of the system overview, and to consider the constraints and associated controls, a generic safety management system was incorporated into the analysis. As discussed in previous chapters, the International Safety Management Code (ISM Code) requires a safety management system (SMS) to be established by 'the Company', which is defined as the owner or any other organisation or person who has taken the responsibility to operate the ship (IMO, 1993). The typical hierarchal structure of such a system is shown in Figure 43.

At the highest level are the company policies. These are set by management and are the guiding documents for the management system. In addition to the company's safety policy, there will be a drug and alcohol policy, a quality policy, an environmental policy and, in many cases, an energy policy. These policies form the basis for writing and implementing the procedures. Procedures will include the following; management responsibilities, safe navigation, engineering practices, human resource/crewing requirements,

deck and cargo operations and other procedures to ensure the safe and efficient operation of the ship, together with the responsibilities of the shore organisation, in order to ensure compliance with the management system.

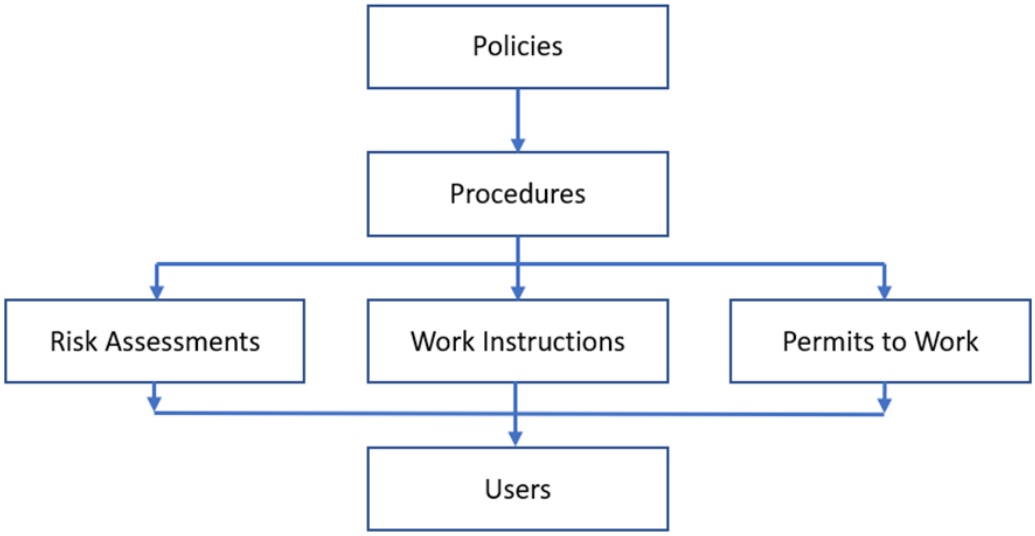

Figure 43 – Generic Safety Management System Structure.

At the level below the procedures, specific requirements are incorporated in the system. Generally, these requirements detail specific work procedures to the end users. Examples of these requirements include:

- Risk assessments - These are specific job reviews to ensure that any risks associated with the work being considered are assessed, reduced if possible and if not, mitigated by taking specific measures to reduce the risk.

- Work instructions to ensure jobs are completed safely and in accordance with the manufacturer's requirements and permits to work.

- To control recognised hazardous jobs - Examples of this include when permits to work are required for working with electrical equipment, working outboard of the ship's hull envelope, working aloft and entry into enclosed spaces.

The control structure in Figure 44 shows the constraints applied between the levels and the associated feedback to ensure control of the specific level.

Constraints within the system from external levels are regulations, rules, physical surveys and auditing from legislative bodies, with feedback from reporting and nonconformances. Other external constraints at both the company and the ship's level are third party inspections. Third party inspections include both physical inspections and audits at the ship and company management level. Feedback is provided by observations raised by the third party. Finally, Port States attend ships in port in order to carry out inspections. In this case, the feedback is provided by nonconformances.

The control structure within the various levels of the company follows the hierarchal structure of the company, and many of the constraints and feedback form part of the safety management procedures and reporting requirements as defined in the system. Using the safety management system as a guideline for the STAMP analysis is appropriate as this reflects the policies and processes promoted by the senior management within the company to ensure safety of the operations. The performance indicators of the safety management are also formalised within the system and can be used as part of the feedback of the system at the management level of the company.

Also, within the company, but external to the ship operations group, the crew department works between the management level and the officers and ratings. In addition to ensuring compliance with regulations, the crewing department ensures the ships are manned in accordance with the company's manning policy. Between the crewing department and the ship, the department supplies certified and qualified officers and ratings in accordance with the constraints of specific manning requirements, and the feedback from the ship is the reporting from the captain on each officer and rating.

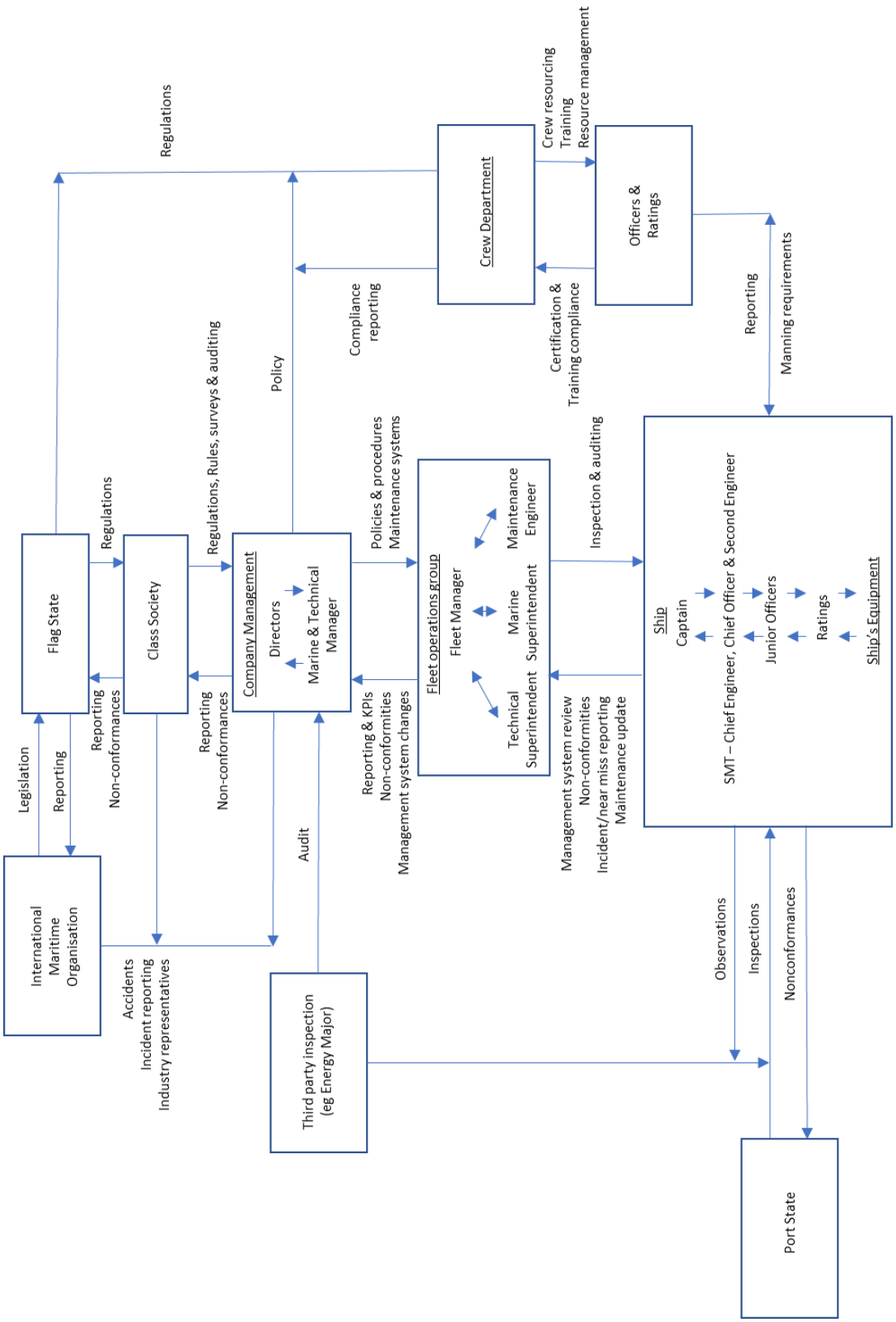

Figure 44 – STAMP Ship Operations Control Structure.

Onboard the ship, there is a control structure with its ship specific constraints and feedback. The constraints are part of the company's formalised safety

management system and include procedures, risk assessments, management of change, and the requirements of the planned maintenance system. The feedback onboard, which also forms part of the feedback into the shore operations group, includes minutes from safety meetings, nonconformances generated from auditing of the safety management system, and the company's key performance indicators.

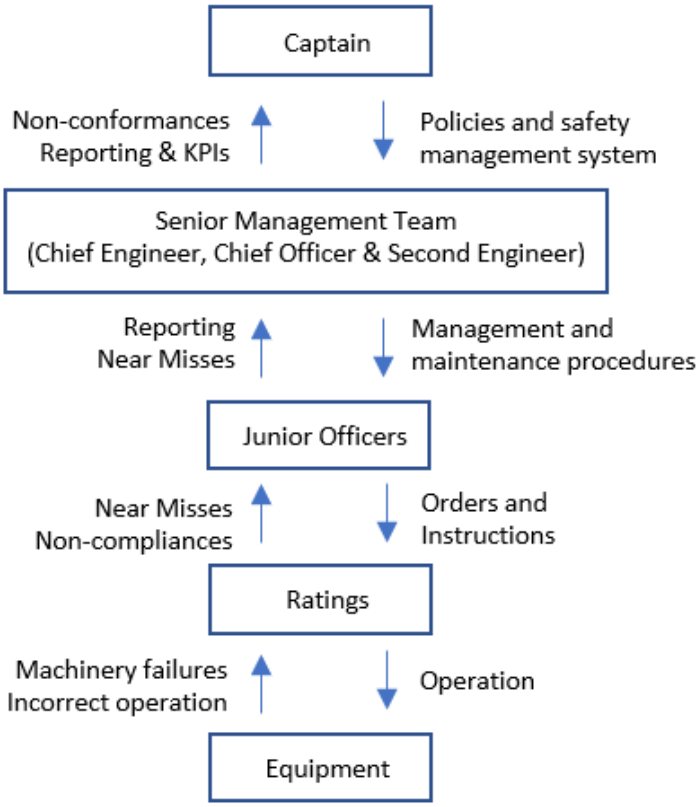

Figure 45 – STAMP Ship Control Structure.

In order to be representative of the ship management company and its function to operate ships safely, both the ship operations group and the detailed ship control structure should be considered as one entity as the constraints from the fleet operations group and the associated feedback from the ship structure will influence the model as constructed.

The captain is the company's representative onboard the ship and has absolute authority. As the company's representative, the company's policies and all other elements of the safety management system are required to be implemented. This is done via the senior management team of the ship,

namely the Chief Engineer, Chief Officer and Second Engineer as they are responsible for the day to day running of the ship. The captain receives feedback via nonconformances of the system, an assessment of the performance indicators as related to safe operations, and reporting from the senior management team, such as the minutes of the safety meeting.

The senior management team implements the management system and the maintenance procedures. This includes safety procedures as well as environmental, health, quality and energy requirements. Specific safety procedures include risk assessments, permits to work and work instructions which are all formalised in the safety management system and which should be strictly followed. Maintenance will be in accordance with the planned maintenance system and also any conditioning monitoring systems that the company may use to assess the health of certain systems. Feedback to the team will be via various maintenance reporting, minutes of meetings and near miss reporting. The senior management team will supervise and lead the junior officers in accordance with the requirements of the safety management system. The junior officers carry out much of the work instructions and complete the work permits and risk assessments for approval by the senior management team. Further, they give specific orders and instructions to the ratings, who should then be supervised by the junior officers. The feedback at this level is reflected in near misses onboard and noncompliance with the system's procedures.

The ratings are responsible for carrying out much of the physical work onboard and supporting the officers as required. Much of this work is specified and detailed in the management system, and the feedback to the junior officers are near misses and their noncompliance with the safety management system. This may include not wearing personal protective equipment or not complying with specific procedures or work processes. When the ratings operate the equipment there is only negative reporting; either the machinery fails or there is incorrect operation of the machinery. In both cases, the feedback is reported back to the junior officer supervising.

9.4 - Ship Design and Construction Control Structure

The design control structure is modelled hierarchically in a similar manner to the operations control structure (see Figure 46). At the higher levels, there is also similar legislation regarding the design of the ship, however in many cases, the lower level structure is not bounded by a safety management system. Rather, there may be a quality system with associated procedures relating to the company's requirements for the new construction process that must be followed by the stakeholders and project management team members.

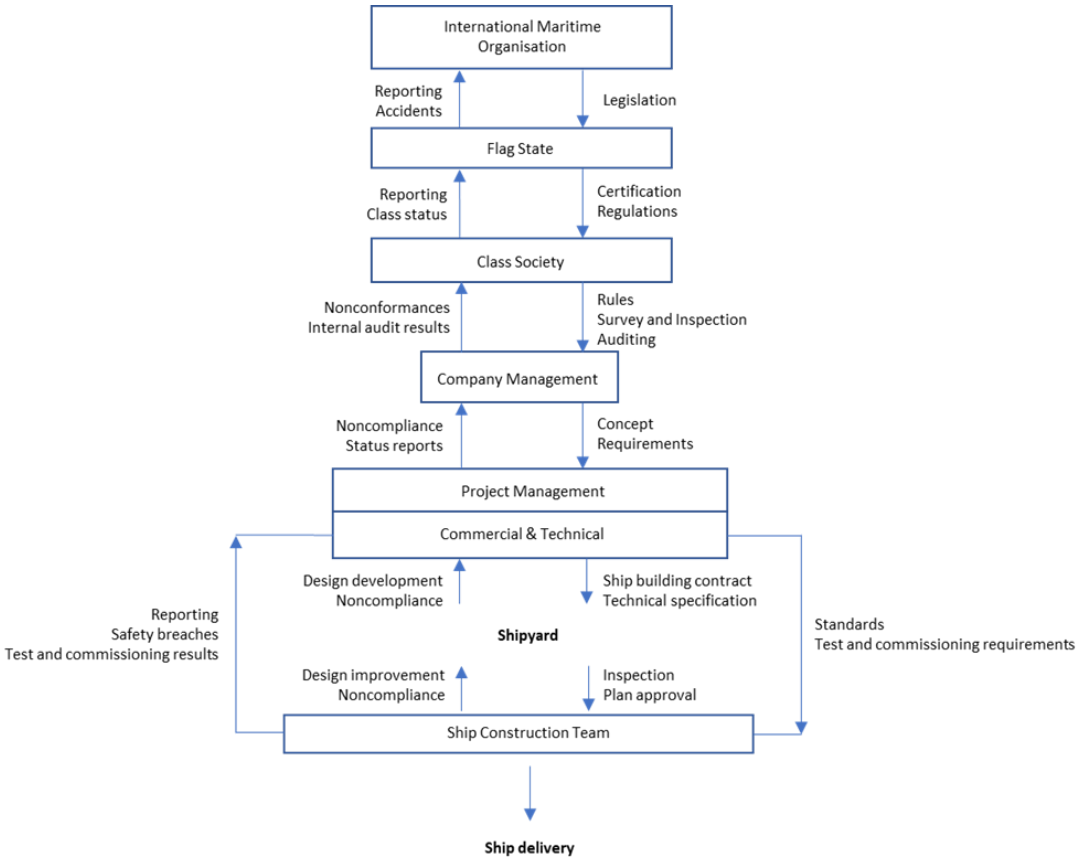

Figure 46 – STAMP Ship Design and Construction Control Structure.

The basic concept for a new addition to a company's trading fleet will be decided by the company's senior management and will be related to the strategy of the company. Generally, shipping companies will specialise in certain sectors, for example the oil tanker sector, the chemical tanker sector, the containership sector or the bulk sector. There may be some crossover in the liquid tanker sectors, while larger companies may have a diversified fleet

covering several sectors. Once a ship concept has been decided that will fulfill the company's commercial requirements, the information will be given to a project management team with both commercial and technical specialists. The project management team will either shortlist a number of shipyards as part of a tender process, or will select a shipyard to work with on the project and then, working together, the company and shipyard will develop a detailed technical specification that will be used to design and construct the ship specified, while also complying with the required legislation. The technical specification will form part of the ship building contract between the two parties. The other details in the contract cover areas such as the capital cost of the ship, the financial payment terms, the delivery schedule and other clauses for items such as warranties and default.

External constraints within the system throughout the process are from the higher levels to ensure compliance with regulations and rules relating to the construction of new ships, physical surveys and auditing from legislative bodies, with feedback from reporting and nonconformances. The company's internal constraints commence, in the case of a requirement for the construction of new tonnage, by determining the concept of the ship required for service. This will cover basic items such as service speed of the ship, range, cargo carrying capacity and possibly the cargo type, depending on the company's strategy. The project management team within the company will then work in parallel, developing commercial terms and a basic specification that a shipyard can price in order for the company to assess.

After assessment and recommendations to the company's management, the management will make a decision and, if the project proceeds, a detailed technical specification will be developed which must be able to meet the applicable legislation and the company's design requirements. At this time, a team consisting of legislators and company representatives with design and construction experience will assess the shipyard's drawing prior to production to ensure the design continues to comply with the required rules and regulations, and additionally, the company's detailed requirements. The legislators and company representatives will also be on site, monitoring the

shipyard construction team and ensuring continued compliance throughout the construction phase until the ship is delivered to the owner.

The ship construction team, in attendance at the shipyard, has two main functions; to monitor the shipyard progress during construction and to witness commissioning and testing before delivery of the ship. The ship construction team is constrained by the requirement to advise the shipyard of any design improvements that may be applicable during the construction and commissioning phase, and secondly, by issuing progress reports, advising the company of safety breaches, and finally by providing the project management team with the test and commissioning results.

Only when all parties are satisfied with the quality of construction, compliance with rules and regulations during the construction, and the commissioning phase has been completed satisfactorily, will the ship owner be notified that the ship is ready for delivery and its first voyage.

9.5 - Applying STAMP to the Studies of Near Misses and Accident Causation

The STAMP ship operations control structure was used to evaluate the results of the previous studies, near misses and accident causation, contained within this research to show how a systems approach can be used to identify failings within the organisation, consider where the failings are within the structure and provide guidance on corrective actions.

9.5.1 – An Example of a STAMP Analysis of the Near Miss Study

The near miss analysis highlighted that two categories of unsafe acts were prominent; the first being failure to use personal protective equipment properly, and failing to follow the company's procedures or instructions. Both of these unsafe acts are similar in nature. As shown in the ship operations control structure, policies and procedures are part of a company's control action from the company management level and, in turn, the policies and procedures also form part of the control actions from the fleet operations group directly to the ships being managed. Additional control actions between the shore and hip structures are the inspection and auditing of the ship against the policies and

procedures. The control actions provided by the policies, procedures, inspection, and auditing are complemented by the feedback from nonconformities from inspections and audits back to the higher level of the fleet operations group. In the case of the unsafe acts identified, each level, control action and feedback relevant to the unsafe act, will have to be considered individually, and when a system failure is identified, corrective and preventative actions can be applied. The control loop on the ship will also have to be considered as part of the analysis as the safety management policy and procedures together with nonconformances form part of the control actions and feedback onboard.

For the unsafe acts identified, the system failure may be inadequate policies or procedures, incorrect policies or inadequate enforcement of the policies and procedures. Examples include the personal protective equipment matrix (included as part of the safety management system), procedures not correctly written for the work being undertaken and the enforcement of such procedures being inadequate.

Similarly, when considering near misses attributable to job/system factors, inadequate leadership/supervision was identified as a contributory causal factor. Using the operations control structure, and considering each level, including the control structure and the associated constraints, the weaknesses in the system can be identified. The weaknesses may be identified at the ship level between the senior and junior officers or, alternatively, there may be an issue with the adequacy of training of seafarers who are in positions of responsibility. This may lead to the recognition that the company's recruitment or promotion criteria is ineffective, or for the established seafarer, resource management training is not delivering the results required and the training may need to be modified or re-focused.

9.5.2 - An Example of a STAMP Analysis of the Accident Causation Study

The findings of the official reports of the four collisions that were studied in Chapter 9 can also be mapped using the STAMP control structure. Additionally, if the reports identified latent defects from the design and

construction phase, these could also be mapped within the STAMP design and construction control structure linked to the operations control structure.

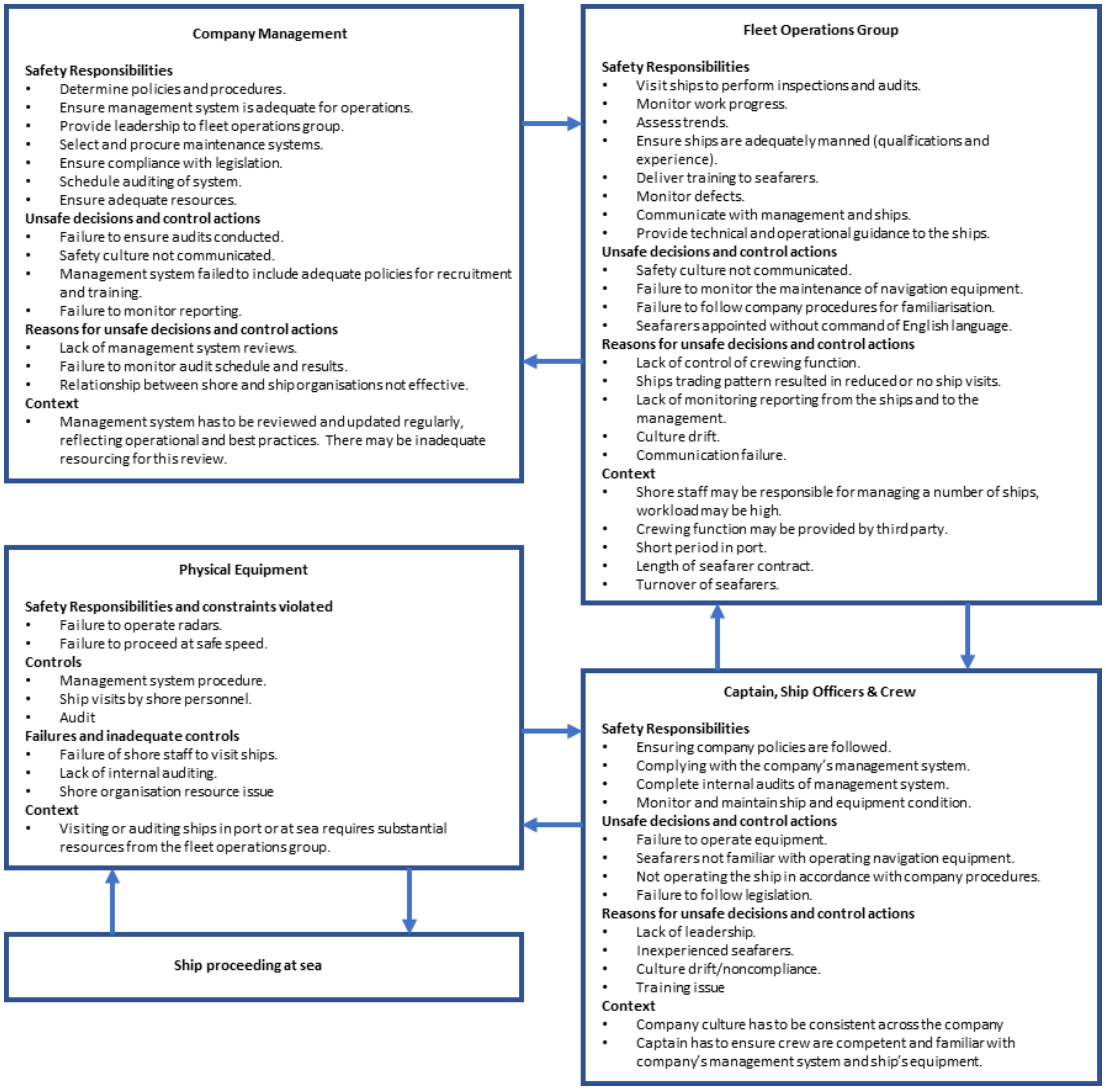

Figure 47 – Analysis of the Collisions Using the STAMP Ship Operational Control Structure.

The analysis shows the failure of the link between the company management and the fleet operations group, with the company management failing to ensure the management system and the required controls and resources were in place to ensure safe operations. The fleet operations group failed to give adequate feedback to the company management on the adequacy of the ship operation, particularly with respect to monitoring and auditing. Similarly, the analysis shows issues with the links between the fleet operations group and the ship personnel by not ensuring the organisation on the ships followed the company's management system policies and procedures. The captain, as the

company's representative onboard, also has responsibilities under the management system to ensure his crew operate the ship safely and to the company's requirements, as well as reporting as specified by the management system.

Further, an example of how the STAMP analysis could identify system weaknesses which otherwise may not have been identified despite the official report highlighting a contributory factor, relates to one of the findings from the official report of the collision between the Consouth and the Pirireis (Hellenic Bureau for Marine Casualties Investigation, 2015). The report highlights that the working language on the ships was English as stated in the official records of the ship. However, the investigators found that the Second Officer had a very poor level of English, and a translator was required during his interview. While this was identified, no further investigation was carried out to understand the reasons why this occurred. Using a STAMP analysis similar to the ship operations control structure previously described, although with more detail regarding the controls and feedback within the crew resourcing, familiarisation and training functions, the contributory factors could be readily identified, and recommendations made within the official report to prevent the company employing seafarers with limited understanding of English as required by their policies.

In the official report of the collision of the Ankara and the Reina (Ministry of Transport, 2012), the conclusions identify that both of the ships (the captain from one ship and the navigating officer of the watch on the other ship) did not comply with the established Collision Regulations (IMO, 2018). Using the STAMP ship operations control structure (modified to reflect the actual operating company's structures), contributory factors could have been identified and, similar to the example above, preventative measures could have been included in the report's recommendations. Examples of factors that may have been identified include training deficiencies, issues with onboard resource management, and lack of auditing of the navigation function by the shore organisation. The official report gave no such recommendations in this case.

9.6 – Chapter Summary

This study has shown that the STAMP methodology can be used to represent both the ship operations system and a ship design structure. In the case of ship operations, a generic safety management system was modelled, together with external factors which can also influence the safety of ship operations. The adoption of the technique fitted well with the vertical hierarchy of the shipping industry and also allowed for the remote operation of the ships to be taken in consideration. The ship design structure, while not bounded by a safety management system, was modelled showing the control loops and constraints at the different levels. The structure could also be expanded to include additional stakeholders, such as vendors and other third parties involved in the construction of the ship, to ensure all the risks are assessed and controlled adequately.

Practically, in the case of ship operations, the methodology could be used as a reference when developing or improving an existing safety management system for ship operations, or alternatively as an audit tool for an existing safety management system. In the former, using a STAMP analysis of the proposed safety management system will allow the requirements and constraints which can govern and guide the functioning of the system while ensuring regulatory compliance. Secondly, using STAMP as an audit tool could be effective. In Chapter 8, when considering near misses and associated job/system factors, the analysis of the near misses showed that one of the major failings onboard was the failure to adequately supervise. There was also inadequate leadership identified. Using a STAMP analysis of the system may have shown this deficiency, identified it, and allowed corrective and preventative actions to be taken in order to avoid the near misses occurring. In the case of ship design, the technique could be used to ensure all the legislative and company requirements are managed correctly, and all the associated risks are assessed and managed appropriately.

The first example of applying STAMP to the near miss study shows that the methodology can be used within ship operations to identify weaknesses within the organisation and ensure that both corrective and preventative actions are

implemented in order to avoid further violations of the policies and procedures. The second example showed that using STAMP can assist accident investigators to identify system contributory factors and make recommendations including preventative actions, rather than focus on the initial causation and the individual factors which precluded the accident. Application of STAMP in these situations can be an important addition to accident investigation techniques in the shipping industry.

10

Conclusions

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10.1 – Introduction

This thesis has considered the complex nature of the shipping industry in relation to ship operations with a focus on accident causation. In particular, the research has focused on applying a more structured approach to accident investigation, as well as near misses, through consideration of accident causation and human error. The impetus for this research stems from the fact that shipping accidents still occur at an alarming rate, despite extensive

attempts to introduce new legislation to improve safety. Within this analysis, there have been five main research aims.

The first aim was to assess trends of accident causation by reviewing current reporting into shipping accident databases, and to identify the main initial event that is submitted. It was found that shipping companies do not publish safety data routinely, and data entered into official databases was, in many cases, incomplete. Despite the limitations concerning data quality, it was found that the primary initial causes in shipping accidents included ‘foundering, ‘collision’ and ‘wrecked’, and that general cargo ships have the highest incidence of serious causalities.

The second aim of the research was to assess current practices related to safe operations and accident analysis in the shipping industry, and determine the challenges of identifying and reducing human error. This was accomplished by conducting a survey of shipping companies, as well as a series of semi-structured interviews with shipping professionals, an approach never before used in the sector. The findings highlighted major areas of concern in the shipping industry relating to safe shipping, including noncompliance, the recruitment, training and retention of seafarers, fatigue, the relationship between the ship and shore organisation, and lack of standardisation in shipping accident investigation techniques.

The third aim of the research was to identify common contributory factors related to human error by examining near miss data supplied by an internationally trading shipping company. This analysis was conducted using a proprietary M-SCAT flow chart as this was identified during the survey and interview research as the most common technique used in the industry. While this technique was effective at categorising near misses, it was found that the near misses reported failed to consider personal factors as causations. It was suggested that additional factors need to be captured in the near miss reporting forms to fully reflect all the potential contributory factors.

The fourth aim considered ship operations as a complex adaptive sociotechnical system and applied AcciMap, an established systemic accident analysis technique, to four specific accidents selected due to their similarities.

It was found that this technique is particularly strong in highlighting relationships between the shore staff and ship staff, thereby identifying areas of concern in that relationship, as well as weaknesses within the shore organisation. Further, applying a System-Theoretic Accident Model and Processes approach (STAMP) to a ship management organisation, the research found this approach fitted well with the hierarchical structure of the shipping industry by also including and considering the remote operations of ships. It was found that the most productive applications could occur when developing or improving an existing safety management system for ship operations, or alternatively as an audit tool for existing safety management systems. Importantly, and unique to this research, when applying STAMP to the ship operations structure it was found that STAMP was useful in identifying weaknesses in an organisation. It could also be used to assist investigators in identifying contributory factors to an accident.

The final aim of the research was to propose a number of strategies that can contribute to reducing human error in shipping accidents and, in turn, reduce the number of accidents and near misses. These proposals will be presented in this concluding chapter. Further, this chapter will reflect on the research and case studies. Together with the findings, it will consider the feedback from companies and safety practitioners in the industry, and the contributory factors identified in the accident causation study, and the validity and advantages of applying a human factor and complex systems approach to improving safe ship operations. The organisational structure of shipping companies is considered, with a particular focus on the relationship between the ship and shore organisations and the challenges relating to this unique aspect of the shipping industry including employment, training and retention of seafarers. The insights of this thesis will be summarised and drawn together in a final discussion of the application of complex systems being used to improve safety in the shipping industry.

10.2 – Summary of Thesis Findings

10.2.1 – Proposed Legislation

Chapter 3 discussed the regulatory landscape, the history behind the key legislation and, similar to other mature transport industries, concluded that much of the prescriptive shipping safety legislation in place has been introduced after a major accident. This reactive approach to legislation, which in many cases is due to the bureaucratic and prolonged nature of introducing new legislation, provides a window of opportunity for repeated exposure to the same risk for which the legislation is trying to prevent. As the shipping system becomes more complex due to the continued introduction of new technology and the pressure of recruiting and training seafarers to operate the systems onboard becomes more difficult, it is logical that the industry considers transitioning to another legislative framework. After the Piper Alpha tragedy in 1988, Lord Cullen's Official Report (1990) highlighted the conditions that make the offshore industry unique, including the living conditions being close to the plant and that evacuation may be difficult in certain weather conditions, both very similar to the challenges faced by the shipping industry. Cullen further stated that these particular conditions underline the need for an adequate management of safety and the requirement for a suitably rigorous regime that ensures this is maintained. Cullen concluded that the future regulatory approach of the offshore industry should be goal setting with appropriate objectives rather than being a series of prescriptive requirements. To accomplish this, Cullen recommended the introduction of a safety case for each offshore installation operating in the UK sector. In 1991, the requirement for a formalised safety case to be submitted to the HSE was legislated. Part of the safety case requirements is to have in place a safety management system, something which the shipping industry already has and is required to do so as part of the ISM Code (IMO, 1988). Other requirements of The Offshore Installations (Safety Case) Regulations 2005 include establishing adequate arrangements for audit and for production of reports, ensuring all hazards with the potential to cause a major accident have been identified, all major accident risks have been evaluated, and measures have been, or will

be, taken to control those risks to ensure that the relevant statutory provisions will be complied with (Statutory Instrument No.3117, 2005).

Under this proposed legislation for the shipping industry, it is envisaged that while the IMO would still be the United Nations agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships, responsibility for ensuring each ship operator complies fully with the safety case regulations would fall to the Flag State. The advantage of this proposed framework is that it allows the shipping company to be proactive with respect to new legislation, ensuring compliance in a timely manner, and also would ensure the introduction of new technology under controlled conditions. Additionally, it will allow the ship owner to tailor the management system and other safety case requirements specifically for different ship types and for the different equipment that can be installed onboard, even on sister ships. One of the main aspects of the safety case regime is the requirement for systematic assessment of the adequacy of the management system to be carried out by persons who are sufficiently independent of the system to ensure that such assessment is objective. This assessment is to ensure the management system is complying with relevant statutory provisions and the satisfactory management of arrangements with contractors and sub-contractors (Statutory Instrument No.3117, 2005). While many ship operators in certain shipping industry sectors such as oil and gas are being driven towards this type of compliance by the energy majors (The Tanker Management Self Assessment programme, for example), the majority of the industry works to the prescriptive regime in place.

10.2.2 – Safety Management Systems

Chapter 3 identified the lack of research into the effectiveness of safety management systems in the shipping industry since their introduction in 1998 (IMO, 1998). The introduction of this legislation was a step change for the industry, formalising the management of safety as related to ship operations. It required ship management companies to have safety policies and procedures in place to ensure safe working onboard. However, the results of the interviews highlighted a number of concerns with the current application of

the ISM Code. These concerns include systems which have become cumbersome and bureaucratic placing excessive demands on the seafarer and the systems becoming administrative burdens rather than focusing on ensuring safe working practices via appropriate procedures to the task being conducted. Other concerns included procedures not being written for specific equipment installed on the ships, but rather generic procedures provided within the management system. For example, the issue of new equipment, such as ECDIS and BWTS, being installed without operating procedures being written and included in the management system prior to the seafarer being required to operate the systems. This also impacts training of the seafarer in both the operation and maintenance of the equipment.

10.2.3 – Industry Accident Database

The first study in Chapter 6 considered what type of accidents are prevalent in the industry by using a commercial shipping accident reporting database to analyse the initial reported causation. The analysis showed that there are two main initial causations reported into the databases; 'hull and machinery damage', and accidents occurring at sea due to either 'collision', 'wrecked' or 'stranded'. Further analysis showed that the highest death rate was also related to accidents with initial causations due to 'collision', 'wrecked' or 'stranded'. This information was used to select a related causation type (collisions) to further investigate a number of official accident reports by using a systemic accident analysis technique to determine if the technique is firstly appropriate to identifying the human factors contributing to such accidents, and secondly to identify any common contributory factors with the shipping organisations. The Chapter also reviewed a database showing the number of serious casualties related to the ship type. The analysis showed that the general cargo ship type had the highest incidence of serious accidents. A factor contributing to this is the relatively low regulation of this particular sector by third parties. This is unlike the oil and gas shipping sectors which have had a number of initiatives introduced, primarily by the energy majors, to ensure their cargo is carried on ships maintained and operated to a high standard. Chapter 4 explains some of these initiatives that have been introduced and how they could be adopted by other shipping sectors.

This research also identified that IMO's database, which requires accident information to be submitted to it as part of shipping legislation, was lacking in accident submissions and those that were submitted lacked consistent details. This is an area that could be addressed by IMO making the database a practical tool for identifying trends in accident causation as part of determining areas to focus on in future legislation.

10.2.4 – The Shipping Company Organisation

A systemic accident analysis technique (AcciMap) was used in study 4, Chapter 9, to analyse four accidents to determine any common factors as contributing factors to the accidents. The accidents were collisions and official reports were used as the basis for the study. In all of the accidents, there was noncompliance with at least one regulation related to safe navigation. All of the noncompliances were related to very specific areas of legislation covering basic navigation principles such as 'rules of the road', as well as legislation intended to prevent excess hours of working and standards related to watchkeeping. This was further analysed at the shore/operations management level and it was identified that there was a lack of auditing by the shore organisation of the ships management system procedures in three of the accidents, and training issues in two of the accidents which also relates to the shore management. This lack of monitoring and supervision by the shore organisation resulted in the noncompliances not being identified and therefore, they became dormant (i.e. latent) until other active causal factors were present and also contributed to the accident.

The final study in Chapter 10 initially used STAMP to consider both the ship operations organisation (including both the shore and ship organisations) and the ship design and construction organisation. The ship organisation's control structure detailed the complicated nature of operating ships and also the reliance on the shore and ship relationship to ensure there are safe operations. As previously discussed, the fleet operations group of a shipping company has to ensure the ship understands the company's safety culture and assist in promoting the culture onboard by ship visits and auditing of the seafarers against the safety management system. The culture can also be reinforced by

the crewing department by ensuring the company's safety policy and requirements are delivered to each seafarer prior to boarding the ship. However, this may be complicated and difficult to deliver due to the employment of seafarers via a third party. Additionally, the company can arrange safety seminars for groups of seafarers to reinforce their safety message further. Similarly, the ship's staff have to give feedback to the shore organisation regarding the effectiveness of the management system by reporting any system nonconformances, meeting minutes, near misses, maintenance updates and the results of internal audits.

The STAMP ship operations control structure also details the sub-organisation onboard the ship and the controls and feedback within that system. In order for the ship sub-organisation to be effective, there has to be adequate supervision and enforcement of the company's policies and procedures onboard. In the near miss study, the lack of supervision was identified as a contributory factor to the near misses occurring and therefore, this is an important factor which needs to be considered by company management in order to avoid a number of near misses and possible incidents. Improving supervision onboard can be addressed by employing experienced officers who mentor and supervise other crew members and by leadership training of selected individuals.

The STAMP ship design control structure is modelled in a similar manner to the ship operations structure. Depending on the company's philosophy for the shipyard supervising team, the personnel monitoring the construction at the shipyard may or may not be direct employees of the company. In the event they are not, there may be issues with ensuring that the ship is constructed to the company's specific requirements. In either case, it is the responsibility of the project management team to ensure the ship is specified and constructed to the company's requirements and to have feedback from staff involved in operating the type of ship contracted with the shipyard. This is one area that, in many cases, is not considered.

The ship operations control structure was used to evaluate the results of the near miss study. The failure of the seafarers to follow procedures, including

failing to use personal protective equipment, showed that while the captain and senior officers have a primary duty to ensure seafarers wear personal protective equipment in accordance with company policy, the shore organisation also failed in their requirement to ensure the seafarers were wearing the correct equipment by conducting inspections and audits. The analysis also showed weaknesses at the ship level between the senior and junior officers, and also an issue with the training of seafarers who may be in positions of responsibility. However, as discussed in the chapter, the number of near misses associated with the failure to use personal protective equipment may be related to the company's requirement to report a certain number of near misses and therefore this aspect should be researched further.

The four collisions used in the AcciMap analysis were also analysed using the STAMP operations structure. The analysis was also expanded and focused on the three sub-groups within the company; the company management, the fleet operations group and the ship personnel, together with the physical equipment in operation at the time. The evaluation considered the safety responsibilities of the sub-groups, the unsafe decisions made, the associated control actions and the reasons for the decision making. The STAMP showed that the links between both the company management and the fleet operations group were inadequate, and also the relationship between the shore and ship organisations were ineffective.

Using STAMP to model an actual ship operating structure, showing the different levels of responsibility, control actions and associated feedback and then analysing the processes, allowed the analysis to identify system weaknesses and, in the case of a proactive approach to safety within a shipping company, the analysis will allow corrective and preventative actions to be implemented in order to improve safety performance.

10.2.5 - Relationship between Ship and Shore Organisations

A recurring theme throughout several chapters is the importance of the relationship between the ship and shore organisations. The senior management are reliant primarily on the shore employees, who are responsible for manging the ships on a daily basis to direct, encourage and

monitor the safety performance of the ship's staff. One of the interview respondent's highlighted that there can be an authority gradient, not only within the ship organisation, but also between the shore and ship staff, and this can negatively the safety performance of the company. It is therefore essential that the organisation's safety culture is consistent across the company and the ship's organisation aligns itself with the company's culture and policies. A culture of non-compliance in the shore organisation may be reflected in the safety performance of the ship organisation.

Traditionally, the shore personnel responsible for maintaining the relationship between the shore and ship organisations were ex-seafarers and, due to the shore personnel understanding the demands and challenges of the seafarer, there was mutual respect between the shore and ship personnel. More recently, staff without sea-going qualifications and experience have been employed in the role and therefore this benefit of employing ex-seafarers in this role may be lost. Therefore, it may be of benefit for a shipping company to encourage more senior seafarers to be willing to be employed in the shore organisation. Not only will this benefit the relationship between shore and ship, it will also lead to a better understanding within the shore organisation of the challenges in operating ships.

An additional means of encouraging an improved relationship between the shore and ship organisations include shore seminars, which most of the companies who participated in the survey already organise for officers. Seminars for the ratings could also be arranged in order to promote the company's safety culture. This may be particularly beneficial as ratings generally have less involvement with the shore organisation.

Additionally, if ex-seafarers are not employed in the shore organisation, an understanding of the shipboard operation and challenges could benefit the relationship if the shore employees were onboard a ship for training and familiarisation of the ship processes and the environment. From a safety perspective, the shore staff having an understanding of the ship operation would aid their understanding of accident investigation, the continuous improvement of the management system and work processes.

10.2.6 - Noncompliance

Noncompliance was identified in several chapters as a major factor negatively impacting safety performance in the industry. A common theme recurring from the interview discussions on noncompliance was that the complexity of safety management systems can contribute to making the system difficult to understand and use correctly onboard. The complexity of such systems also impacts the training and familiarisation of seafarers in procedures and in other requirements such as permits to work and risk assessments. One of the main methods a shipping company assesses the effectiveness of their safety management system and compliance with the procedures contained in it is by the use of onboard auditing. With modern technology allowing improved communications between the ship and shore, there may be an opportunity for using real-time auditing onboard using video calling, complemented by additional onboard audits by shore staff. This may also improve the relationship between the ship and shore staff due to increased familiarisation between the players involved.

As well as noncompliance in the ship organisation, noncompliance issues within the shore organisation were also found to be contributory factors to the collisions reviewed in Chapter 8. Therefore, it would be of benefit conducting further research into this aspect as it is important that the shore organisation also follows the company's requirements to ensure safe operations and to understand the reasons for deviations from the procedures within the safety management system. There may be a number of reasons for the noncompliance, for example it may be due to a training issue, a lack of experience or a workload problem relating to the demands of the safety management system.

Finally, the review of near misses in Chapter 7 identified many issues of noncompliance at the procedural level. These noncompliances are either seafarers not following the safety management system requirements, for example failure to wear personal protective equipment, or failing to follow specific procedures. This research identified that, in the examples of near misses studied, there was not enough information contained within the near

miss data submitted from the ships to identify the root causes. Therefore, working with a shipping company, further research could be conducted to assess real-time near miss data, conduct analysis of the data and then using feedback from the reports to analyse the reports further with the seafarer. This would allow the near miss reporting to be improved and become a useful tool in identifying organisational, team or individual contributory factors to near misses and allow both corrective and preventative actions to be implemented rather than just an indicator of safety performance.

10.2.7 – Safety Culture

The second study in Chapter 7 consisted of two parts; an initial survey of commercial shipping companies trading worldwide and a semi-structured interview of a number of shipping safety professionals. One of the survey's initial questions was related to the respondent's perception of what they considered to be the most significant factor that poses a risk to safe shipping. Almost 80% of the respondents considered human error to be a very significant risk and 20% of respondents considered human error to be a significant risk. This response highlights the concerns that many shipping companies have relating to preventing human error, particularly as increased sociotechnical influences impact on ensuring ships are safely operated. The survey responses were used to construct a number of questions that formed the basis of the semi-structured interviews.

As seen in Figure 48, the influence diagram relates the findings of the survey and interviews, showing the relationships and interconnections between the various items identified from the study. Many of the findings are interlinked, and this is expected in the complex system that is the operation of ships. Therefore, considering the findings in isolation will not give an overall analysis of any problems that may be either latent or active within the system.

Returning to the three factor model discussed in Chapter 4, there are different approaches to improving safety. For example, using the organisational factors described previously, a 'top down' safety approach is promoted by many researchers, especially when assessing complex systems, as accidents often

result from interaction among perfectly functioning components (Leveson et al., 2004).

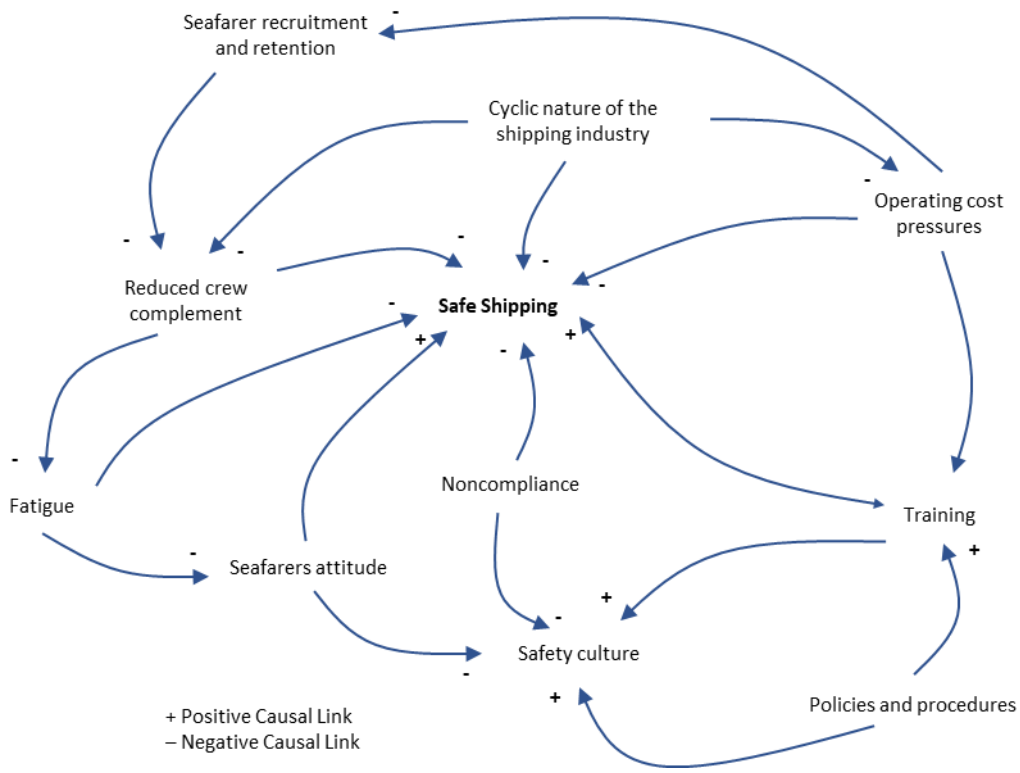

Figure 48 - Influence Diagram of the Factors Affecting Safe Shipping

The top down approach will focus on the safety culture of the company and is reliant on the safety management system policies and procedures being reflective of the working practices and operation of the specific equipment onboard the ship being operated. It is also dependant on training being effective and continuously refreshed to ensure that the seafarer continues to be updated with the requirements of the management system. Considering a 'bottom up' approach to improving safety, one example is to adopt a behaviour-based safety technique as discussed in Chapter 7. This approach has been used in other industries, but only a limited number of shipping companies have introduced it as a safety initiative. A behaviour-based approach differs to a traditional approach in several ways; the first is its concentration on observable safety behaviour, rather than unobservable attitudes toward safety, and the second is its emphasis on the encouragement of safe behaviour rather than the punishment for unsafe behaviour (Choudhry, 2014).

Both the top down and bottom up approaches to safety described are reliant on information being communicated between the ship and shore organisations. The challenges related to good communication were highlighted by the respondents of the interviews who discussed the challenges of a hierarchy gradient between the ship and shore organisations which can inhibit the exchange of information, and specifically the company's culture to the ships and feedback from the ships to the shore organisation regarding the safety management system.

10.2.8 - Contracting of Seafarers

The survey identified that almost three quarters of seafarers are contracted from third party crew managers to shipping companies. The remaining quarter are directly employed by the shipping companies. Whether or not the seafarer is contracted directly or via a third party, the term of the employment contract between the seafarer and company is, in the majority of cases, only for one ship voyage, with vacation monies due paid whilst onboard. Therefore, at the end of their time onboard, there is no requirement to continue the working relationship from either the seafarer or employing company.

The advantage to many shipping companies that use these types of contracts is that it gives them greater flexibility, particularly if there is a down turn in the market or if ships are sold, there is then no forward commitment to the seafarer regarding their future employment. It does also give the seafarer some flexibility regarding their work pattern onboard ships, however it also comes with employment uncertainty.

The lack of permanent contract may also negatively impact the relationship between the seafarer and the employing company because it may be perceived by the seafarer that the company is not committing to the employee. This may affect the attitude of the seafarer in respect of culture, commitment to safety and the team onboard.

It was concluded therefore that a change to the current contracting system could be beneficial regarding culture, onboard familiarisation and commitment from the seafarer. It could also reduce training costs, improve retention and

allow improved planning regarding the seafarers rotations onboard company ships.

10.2.9 – Near Miss Programme

The third study in Chapter 8 considered near misses over a twelve-month period for a mixed fleet of ships operated by several different nationalities of seafarers. Using an industry standard systematic cause analysis technique, the near misses were categorised at the high level into job/system and personal factors. Two similar job/system factor categories, inadequate supervision/coaching and inadequate leadership, were the highest when combined, this relating to inadequate oversight onboard the ship. As discussed in the Chapter, this may be due to the steep hierarchal gradient onboard, requiring the crew carrying out the work to be directed and supervised at all times to ensure policies and procedures are followed to avoid noncompliance being introduced to the ship organisation. The study also showed that a lack of competence was a contributory factor. This was even identified for basic tasks, which was surprising as the company had their training requirements detailed in a matrix. Therefore, there may be other underlying reasons, including psychological reasons, which the near miss reporting did not identify.

The analysis also categorised the near misses into substandard acts and substandard conditions. Two categories of substandard acts were prominent, failure to use personal protective equipment properly and failure to follow procedure/instruction. These categories could both be considered noncompliance by the seafarers of the company's management system. It may also be attributable to a lack of supervision by the officer in charge of the work being carried out. The two categories of substandard condition identified, poor housekeeping/order and defective tool/equipment, could also be attributed to poor supervision or poor training of the supervisors in managing and supervising staff.

It was concluded from the analysis of the near miss data that such a programme can enhance a company's safety culture if the near misses are categorised correctly and the reporting of near misses is from genuine

instances, rather than reporting to meet a near miss target. Using the analysis of the near misses may also give an insight into areas where the management system needs to be improved by, for example, reviewing procedures or requirements which might not reflect the work being carried out and adopting them to the correct work procedure or requirement. The analysis of the near misses also shows that this particular programme reporting of near misses could be improved to include additional human factors which may have had an influence on the near miss occurring. These could include hours of work/rest, any seafarer physical factor (i.e. height, weight, fitness), identify any training requirements, any specific recommendations regarding procedures and any psychological factors affecting the seafarer's ability to complete the job safely.

10.2.10- Resource Management

As discussed in Chapter 4, the requirement for both deck and engineer officers to receive resource management training is now a legislative requirement. While there has been no research into the effectiveness of resource management training in the shipping industry, the interviewees expressed the positive nature of introducing resource training albeit in a simulator scenario.

It was highlighted that resource training could be expanded to include cargo operations. In many cases, cargo operations are only conducted infrequently and after long voyages (during their contract, on some ships, seafarers may only conduct one loading and one discharge operation), and therefore resource management training based around cargo scenarios could be of benefit, particularly on ships with more complicated cargo systems and which have limited opportunity for working as a team during cargo operations.

Other areas which could be considered for improvement, and as discussed during the interviews, include having ratings (the helmsmen and lookout) to participate in the resource management training as they are a fundamental part of the navigating team. Finally, rather than holding the resource management training each time in a simulator, options could include monitoring of the team on the bridge as they navigate the ship and also the ship's marine superintendent participating in the resource training of the navigation team in real-time scenarios.

10.2.11 - Inadequate Leadership/Supervision

The analysis of the near miss data identified a lack of leadership/supervision as a causal factor contributing to the near miss. In the case of the near miss analysis, the lack of leadership/supervision is attributable to the officers who direct the ratings to carry out physical work and to follow procedures. However, lack of leadership/supervision can also be apparent at other levels within both the shore and ship organisations, including for example, lack of leadership/supervision by senior officers of junior officers and ashore between the shore ship operating team and the ship senior management team.

Several interviewees discussed the lack of mentoring by senior officers of junior officers. They advised several reasons for this including officers not having enough experience in rank, before being promoted, although they may have the required certification to be promoted. This minimum experience in rank may contribute to a failure to lead and supervise adequately.

The rapid promotion through the ranks is symptomatic of the demand for qualified seafarers due to the rapid expansion of the world's shipping fleet and the issue of attracting seafarers for a career at sea. Fundamentally, to address lack of experience in rank and, as the fleet continues to grow requiring ever more seafarers, either more seafarers have to be recruited (which is already proving difficult for ship owners and managers), or the increased use of automation on ships needs to be advanced to reduce the complement onboard while at the same time increasing the education level and training requirements for the remaining seafarers onboard, in addition to improving the quality of the training courses. The additional investment in automation and training would be offset by the reduced number of crew onboard; crew costs being the highest category of operating costs for ship owners and managers.

10.2.12 – Fatigue

The effect of fatigue as related to work and rest hours has already been legislated for by the introduction of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers by IMO (IMO,1978) and there has been some research into the effects of fatigue on the seafarer by the Cardiff University Seafarers International Research Centre.

From a practical aspect, and in accordance with the regulations, both Port State surveyors and third party inspectors routinely review records of hours work and rest during their inspections and therefore this aspect of fatigue can be considered adequately addressed, notwithstanding there is a possibility of falsification of records.

However, this research concluded that there is no legislation restricting the period that a seafarer can be onboard. While officers generally complete tours from two to four or five months, ratings may be onboard for six to nine months and more. As it is the ratings that carry out the physical work, then ensuring they are not impacted by long-term fatigue is an important factor to improving their safety while onboard. The effects of long term fatigue may also affect officers who are working long hours over an extended period when a ship is intensively trading with short sea passages and short periods in port. Considering this aspect of fatigue, the Project Horizon project, MARTHA, assessed the effects of being onboard ships for longer periods and found it contributes to increased sleepiness, loss of sleep quality and reduced motivation.

Therefore, considering that the effects of fatigue due to excessive working hours and inadequate rest periods has been legislated, a logical next step would be to introduce legislation to limit the period that a seafarer can remain onboard a ship without being relieved in order to allow adequate rest and recovery.

10.3 - Discussion

Noncompliance onboard ships was identified to be a contributing factor in the analysis of the collisions and also found to be a factor in the near miss study. The analysis of the collisions showed that the link between the shore and ship is paramount to ensuring compliance with a company's policies and procedures. On a ship, with its own sub-organisation remote from the ship operating office, unless there is a strong monitoring regime of the onboard practices, there is a possibility of the compliance onboard drifting from the company's requirements and expectations. The reasons for this noncompliance may be many, including complacency with respect to the

safety management system due lack of enforcement, procedures not reflecting the work being carried out, or the procedures not being reflective of the ship's design and equipment.

Linked to the above, a lack of management oversight could contribute to the noncompliance. In the data provided, the near miss analysis showed that there was a lack of leadership and/or supervision. This lack of management oversight may be linked to several factors including culture drift, inexperienced supervising officers, and inadequate or ineffective initial and/or refresher training. Due to the contracting nature of the industry, retention of seafarers is therefore very important, as is ensuring training is effective and delivered to the end user in order to improve safety onboard.

The difficulty of visiting the ships and policing the management system has been discussed. The nature of the industry and commercial pressures only allow limited time in port to conduct inspections and audits, and as resources in shipping organisations are limited, both in the shore organisation and onboard, it makes it difficult to fully monitor a ship's compliance with the company's policies and procedures. The oil and gas shipping sector has, in effect, policed itself by the introduction of third party inspection of both the ships and the shore organisation. This approach could be extended to other sectors in shipping, particularly those with poor safety records.

10.4 - Human Factors and the Shipping Industry

To date, the role of human factors in shipping has been limited. A more coordinated and integrated strategy would be of benefit, particularly if systemic analysis methods were more commonly adopted for the investigation of causal factors in accidents. Ideally, this would be driven by the legislators.

Ensuring a more standard approach to human factors within shipping would allow specific causal factors to be identified. As discussed in the thesis, collisions continue to occur even with all the technology and automation onboard. Therefore, it is possible that there are common causal factors occurring. Adopting a standard methodology, which includes specifically identifying organisational factors may be of benefit, especially if the results of the analysis are shared and used by the legislators to improve the safe

operation of ships. Standard practices are used in other transport sectors. It is not unreasonable for this structure to be applied in the shipping industry.

10.5 – Challenges and Limitations

As discussed in Chapter 4, the literature regarding applying a systems approach to improving safety in the shipping industry is limited. There has been limited research in specific causations, such as collisions, and more recently Puisa et al. (2018) has considered the shipping system using a causal analysis of the operations structure. This research concluded that safety management system deficiencies were the most frequently contributing causes behind accidents and incidents, but did not investigate the reasons why the deficiencies occurred. However, this research (Puisa's et al., 2018) did not have access to shipping company data, and only used accident investigation reports. This thesis therefore is an important corrective to the literature.

The issue of obtaining data to use in this research was challenging. In Study 1, Chapter 6, the main source of data was a subscription only database. The other databases reviewed had only limited data (Flag State) or were not fully populated (GISIS). Due to the subscription nature of the database used, once the initial analysis had been completed, it was difficult to revisit the data for further analysis. This potentially limited the rigour of the analysis, although highlighted the disparity of quality in the range of data sets available.

While this research did have limited access to near miss data, access to the data was agreed only on the condition of anonymity. This is relatively common in the shipping industry due to the commercial risks of allowing safety data to be in the public domain. Much research is therefore completed using Flag States official accident reports and, while this is a useful source of information, in many cases there is limited consideration of human factors as contributory factors to accidents.

There are challenges regarding the survey in this research. A common criticism of internet based surveys is that they are unrepresentative and cannot be generalised due to data collection from non-probability samples (Wright, 2005). However, recent evidence suggests the existence of bias is not as significant as some would imagine, and that internet surveys produce

representative samples with reliable and valid data, particularly when coupled in a mixed methods paradigm (Hesse-Biber and Griffin, 2013). As noted in Chapter 5, De Vaus (2002) indicates that while internet surveys may not be representative of the general population, they are very useful at obtaining representative samples of specific populations, in this case shipping industry professionals. Further, as Couper and Miller (2008) note, ensuring a high level of transparency regarding methodology when conducting internet based surveys is critical in ensuring overall quality and mediates issues concerning sampling bias. This is because transparency promotes open evaluation of research findings.

Response rates to internet-based surveys are problematic. Indeed, as noted in Chapter 7, the response rate to this survey was only 5.8%. There are several possible reasons that impact response rates, including survey presentation, sponsorship and topic (Fan and Yan, 2010). What is particularly salient to this research is the issue of topic, as sensitive survey topics negatively impact response rates (Cook et al., 2000). Providing data concerning safe shipping practices and accident investigation procedures could potentially expose a shipping company to negative consequences in the competitive commercial shipping environment. Shipping companies and shipping professionals are likely to be reticent to participate in research that could be harmful to their financial results. Further, as this was the first survey conducted of shipping safety practitioners, it is unsurprising that the response rate was low. Certainly the data obtained from the survey is useful, however further research and interaction with this subgroup is likely to yield better results.

Recruiting participants to the semi-structured interview was also challenging. The reasons for this are similar to the survey response rate challenge, although in participating in a semi-structured interview could be even more revealing for the participant due to the depth and nature of the method. Interview recruitment processes are not extensively considered in the literature concerning qualitative methods (Kristensen et al., 2015). As a result, this research relied on an existing subset of participants derived from the survey sample. Further, the researcher acted as mediator by using his position and relationships to

facilitate contact with potential participants. These existing relationships likely went some way to quelling participant concerns regarding confidentiality and sensitive content, thereby increasing the pool of interview participants. Certainly, the researcher's extensive experience in the industry was an advantage and provides findings that may not otherwise have been accessible.

In Chapter 9, there were difficulties obtaining reports of the accidents with similar initial causations and comparable conditions when the accident occurred. These difficulties related to the availability of the reports in the public domain.

10.6 – Future Work

One of the challenges to researching and completing this body of work was access to data. Sharing data for research is not common in the shipping industry, especially information related to safety performance as this may have commercial implications. This reluctance to engage was reflected in the survey response. Therefore, this research was limited to the database analysis, the survey, views of shore safety professionals and limited near miss data from one shipping company.

Considering the survey, while the response rate was poor, it has to be considered that this was the first time such a survey had been undertaken for the industry. Going forward, the introduction of such a survey at regular intervals and with a human factors focus, together with feedback to the participating companies may be of benefit particularly relating to safety initiatives. To gain acceptability by the industry, the introduction of such a survey could be introduced by a regulator or an independent body acting on behalf of a regulator, for example.

Future work, with the assistance and in collaboration with one or more shipping companies, could consider the actual work processes onboard a ship from a human factors aspect, preferably across several shipping companies and assess areas of weakness, particularly within the onboard organisation and also the seafarers relationships with the shore organisation. An alternative to working with one shipping company would be to engage with an industry body which has access to a number of different shipping companies.

There has been limited research assessing the impact of the ISM Code after it has been in force after its initial introduction over 20 years ago. New research could be conducted on the effectiveness of the Code and whether it now needs a new approach or if it is still fit for purpose. Ideally, this research would be conducted with the legislative bodies' involvement due to the difficulty of accessing shipping company's management systems. Of particular focus could be the suitability of the Code and its prescriptive approach as ships become more reliant on automation and as the number of seafarers onboard reduce in number. It is considered that research involving the various aspects of ship operations and the safety management system is a high priority due to the many areas affected by the issues raised in this research including safety culture, training, noncompliance and leadership/supervision.

There are many niche topics related to this research that have emerged as potential research avenues. These can be categorised into three overarching subgroups including:

- Seafarer/ratings issues: As noted in Chapter 10, ratings are responsible for carrying out much of the physical work onboard, as well as supporting the officers as required. Ensuring they are operating effectively is an important factor in ensuring safe ship operations. Several potential issues emerged that could impede the quality of a seafarer's work. These are worthy of further investigation: the performance link between a seafarer's health and their performance, the effects of the short term contracting system on a seafarer's health, and adaptation to a company's culture, including the recruitment, training and retention of seafarers.

- Impact: Measuring the effectiveness of any programme is key to ensuring those programmes are operating efficiently and producing the correct and expected results. It was surprising to discover that many of the safety and training programmes implemented in the shipping industry are not measured. Several programmes in particular seem good candidates for further research, for example measuring the effectiveness and impact of any programmes related specifically to

safety awareness and the safe operation of ships including Resource Management Training and Computer Based Training programmes.

- Safety culture: In Chapter 4 and Chapter 7, the importance of a cohesive safety culture within a company organisation was highlighted. However, assessing who constitutes the most important influencer on a safety culture in a shipping organisation (i.e. shore management, the captain, the officers or the crew) is not clear. As a consistent safety message is essential to maintain safe ship operations, unpacking the hierarchy concerning safety influencers could go some way to understanding how a culture is formed and maintained within a shipping organisation.

10.7 – Conclusions

The shipping industry is a complex system of systems involving many interrelated actors and processes. Only by understanding the ship operation and modelling it accurately can the true impact of human factors on the safe operation of shipping be fully analysed. Using a sociotechnical approach as applied in this thesis allows all the actors and processes to be considered, as well as the interactions between them. In the shipping industry particularly, this is complicated by the remoteness of the ships from the operating office and the contracting nature of the workforce.

This research has shown that systemic accident analysis investigation techniques can not only be used to investigate accidents, they can also be used to analyse operating practices in order to provide corrective and protective accidents before near misses or accidents occur. This is in line with Safety II thinking (Hollnagel et al., 2015); only by ensuring that ‘as many things as possible go right’ will safety improve in complex systems. This also relates to the system’s ability to succeed under varying conditions. This approach is very relevant to the shipping industry due to the dynamics involved in the complexity and interdependent shipping system. This includes different ship designs, the relationships between the company’s sub-organisations (which in the case of ships is remote to the main operating office and difficult to access)

and the challenges of crew resourcing, including the specific challenges of retention and training.

The prevalence of noncompliance within the industry was identified in this research and this may be linked to factors discussed such as a lack of oversight by the shore organisation, ineffective training and the turnover of seafarers within companies. This research has found that shipping companies will have to focus on the relationship between the shore and ship organisations to ensure that the culture is consistent within all levels of the company and onboard ships.

By adopting a systemic approach to both accident investigation and ship operations as discussed in this thesis, the safety performance of shipping companies will be enhanced and, importantly, the risk to seafarers operating ships will be reduced.

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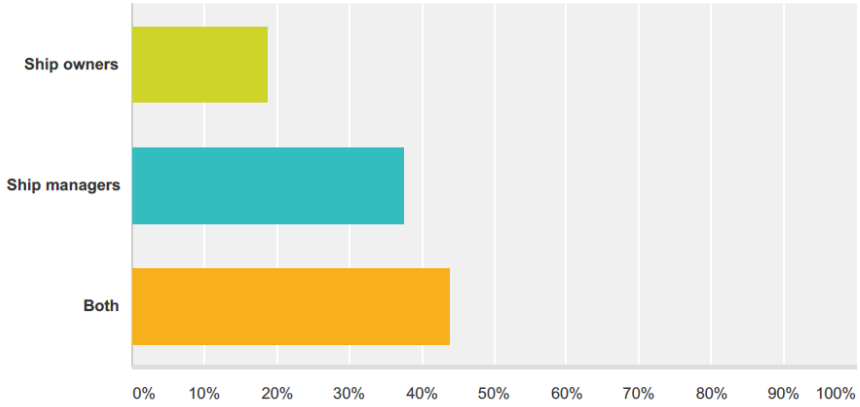
Appendices

Appendix 1 – Survey Questions and Responses

Q1 Is your organisation ship owners or ship managers?

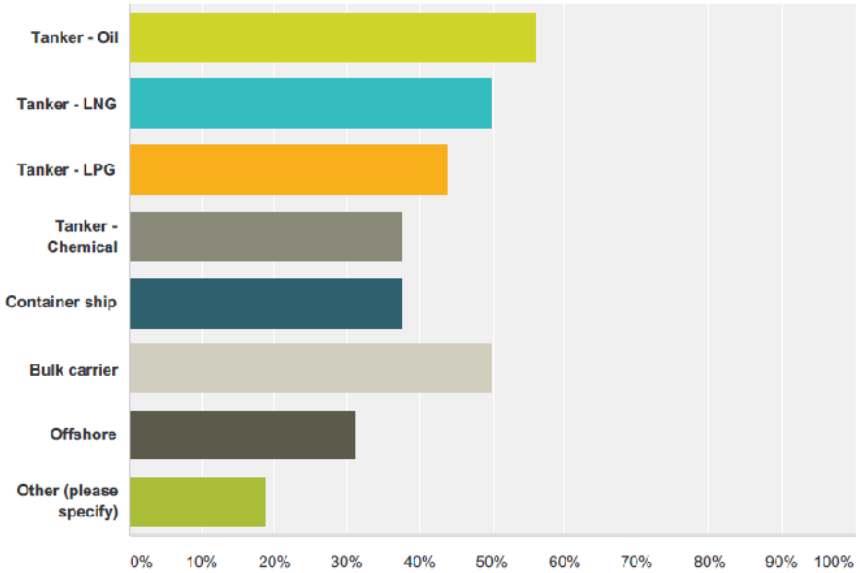
Answered: 16 Skipped: 0



Answer Choices	Responses	
Ship owners	18.75%	3
Ship managers	37.50%	6
Both	43.75%	7
Total		16

Q2 What type of ships does your organisation operate? Please select all that apply.

Answered: 16 Skipped: 0

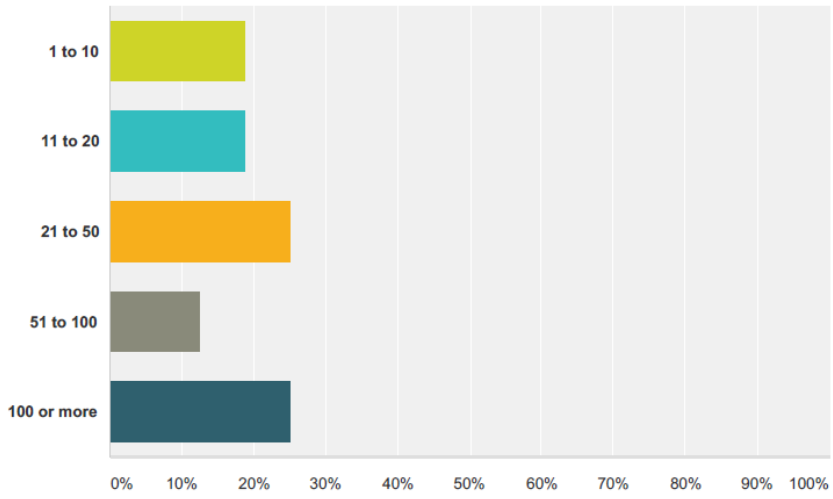


Answer Choices	Responses	
Tanker - Oil	56.25%	9
Tanker - LNG	50.00%	8
Tanker - LPG	43.75%	7
Tanker - Chemical	37.50%	6
Container ship	37.50%	6
Bulk carrier	50.00%	8
Offshore	31.25%	5
Other (please specify)	18.75%	3
Total Respondents: 16		

#	Other (please specify)	Date
1	PCC & ROPAX	7/25/2016 6:32 PM
2	Cement	7/25/2016 12:40 PM
3	Ice breaker, ATB, Research, Harbour services	7/13/2016 1:32 PM

Q3 How many ships does your organisation manage?

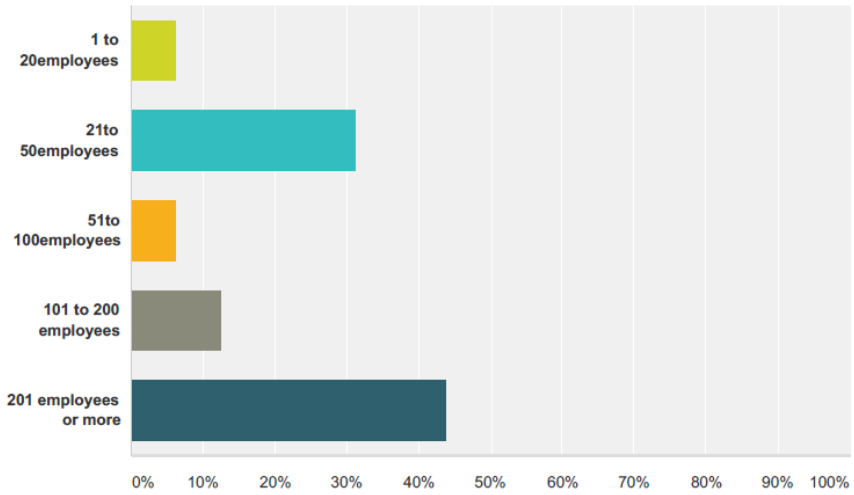
Answered: 16 Skipped: 0



Answer Choices	Responses	
1 to 10	18.75%	3
11 to 20	18.75%	3
21 to 50	25.00%	4
51 to 100	12.50%	2
100 or more	25.00%	4
Total		16

Q4 What is the size of your shipping organisation ashore?

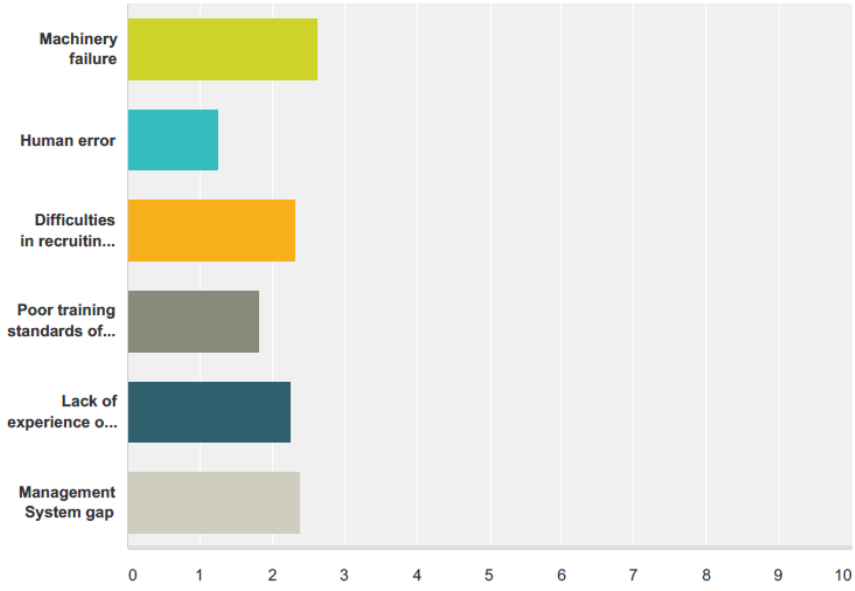
Answered: 16 Skipped: 0



Answer Choices	Responses	
1 to 20employees	6.25%	1
21to 50employees	31.25%	5
51to 100employees	6.25%	1
101 to 200 employees	12.50%	2
201 employees or more	43.75%	7
Total		**16**

Q5 In your opinion, what is the most significant factor that poses a risk to safe shipping?

Answered: 16 Skipped: 0

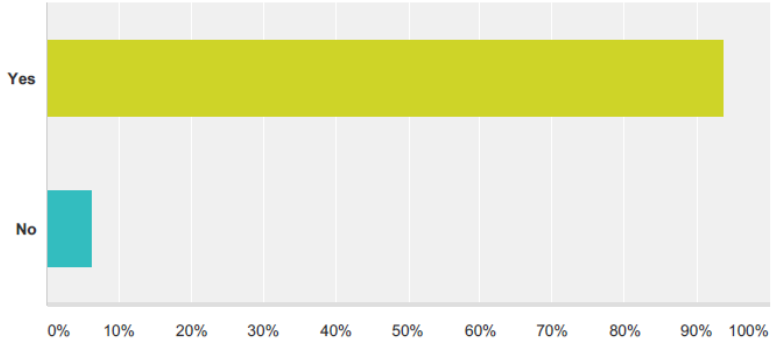


	Very significant	Significant	Neutral	Not significant	Not at allsignificant	Total	Weighted Average
Machinery failure	**0.00%** 0	**56.25%** 9	**25.00%** 4	**18.75%** 3	**0.00%** 0	16	2.63
Human error	**75.00%** 12	**25.00%** 4	**0.00%** 0	**0.00%** 0	**0.00%** 0	16	1.25
Difficulties in recruiting seafarers	**12.50%** 2	**43.75%** 7	**43.75%** 7	**0.00%** 0	**0.00%** 0	16	2.31
Poor training standards of seafarers	**43.75%** 7	**37.50%** 6	**12.50%** 2	**6.25%** 1	**0.00%** 0	16	1.81
Lack of experience of the seafarer in rank	**18.75%** 3	**43.75%** 7	**31.25%** 5	**6.25%** 1	**0.00%** 0	16	2.25
Management System gap	**6.25%** 1	**62.50%** 10	**18.75%** 3	**12.50%** 2	**0.00%** 0	16	2.38

#	Other (please specify)	Date
1	Commercial pressure	7/24/2016 2:57 PM

Q6 Does your organisation have a designated safety department?

Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	**93.75%**	15
No	**6.25%**	1
Total		**16**

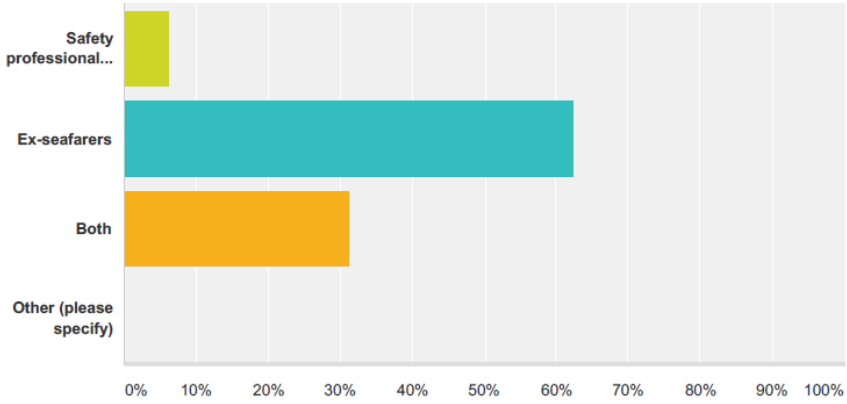
Q7 What department deals with safety issues in your organisation?

Answered: 1 Skipped: 15

#	Responses	Date
1	Fleet Department	7/14/2016 6:43 AM

Q8 Are thestaff responsible for safetyin your organisation safety professionals or ex-seafarers?

Answered: 16 Skipped: 0

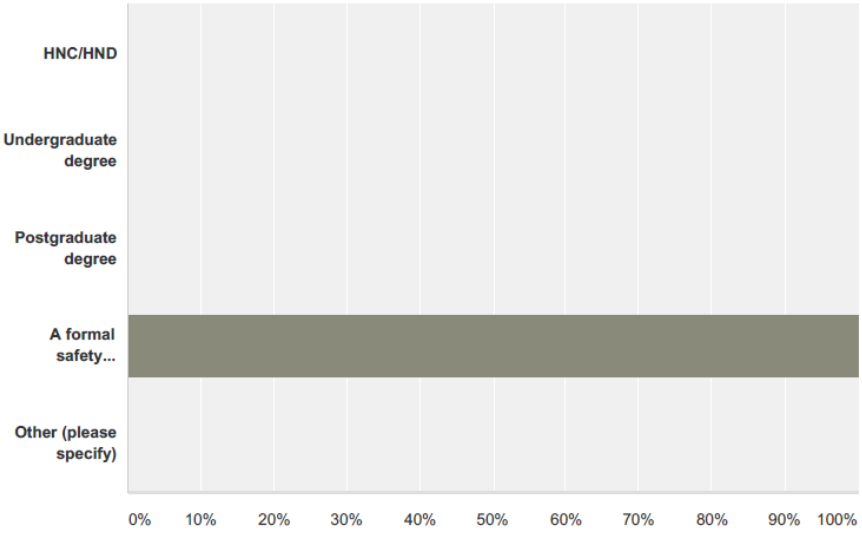


Answer Choices	Responses	
Safety professionals (Certified Safety Professional/NEBOSH or similar)	**6.25%**	1
Ex-seafarers	**62.50%**	10
Both	**31.25%**	5
Other (please specify)	**0.00%**	0
Total		**16**

#	Other (please specify)	Date
	There are no responses.	

Q9 What is the minimum qualification your organisation requires to be a member of the department responsible for safety?

Answered: 1 Skipped: 15

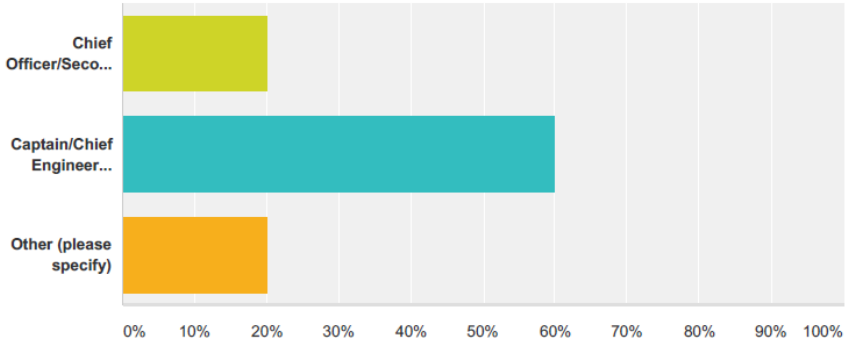


Answer Choices	Responses	
HNC/HND	0.00%	0
Undergraduate degree	0.00%	0
Postgraduate degree	0.00%	0
A formal safety qualification(Certified Safety Professional/NEBOSH or similar)	100.00%	1
Other (please specify)	0.00%	0
Total		**1**

#	Other (please specify)	Date
	There are no responses.	

Q10 What is the minimum qualification your organisation requires for an ex-seafarer in order to be considered for a position in the department responsible for safety?

Answered: 10 Skipped: 6

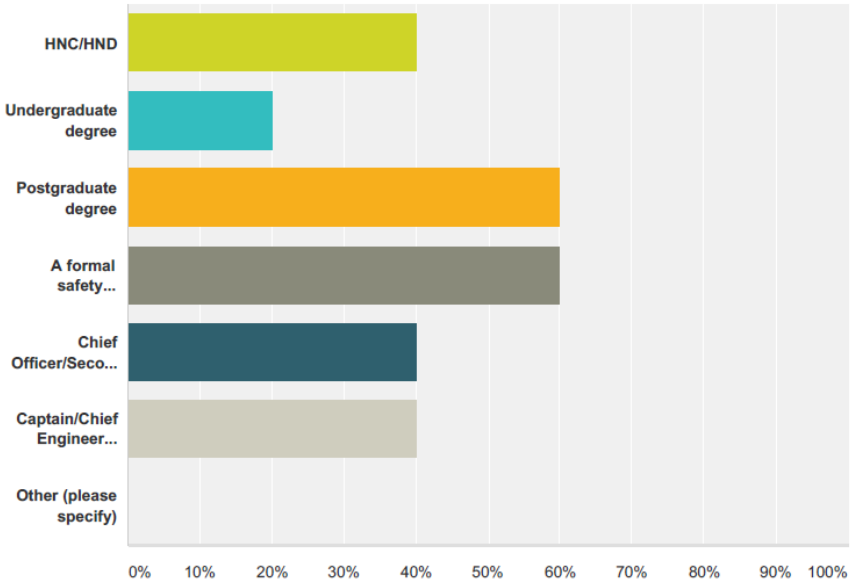


Answer Choices	Responses	
Chief Officer/Second Engineer certificate(Class II)	20.00%	2
Captain/Chief Engineer certificate (Class I)	60.00%	6
Other (please specify)	20.00%	2
Total		**10**

#	Other (please specify)	Date
1	Bachelor's Degree or its equivalent in a Maritime/ shipping Industry, Marine Engineering or Science discipline,Ten year relevant experience including four year in oil and gas shipping industry,3 year experience in Occupational Health & Safety role	7/26/2016 10:09 AM
2	Safety experience as deemed	7/25/2016 12:41 PM

Q11 What is the minimum qualification your organisation requires to be a member of the department responsible for safety. Please select all that apply.

Answered: 5 Skipped: 11

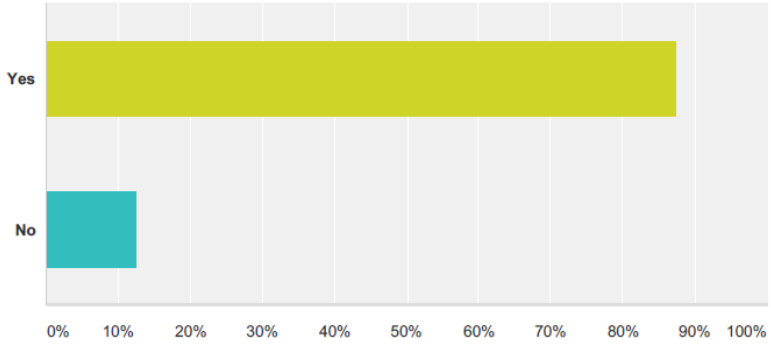


Answer Choices	Responses	
HNC/HND	40.00%	2
Undergraduate degree	20.00%	1
Postgraduate degree	60.00%	3
A formal safety qualification(Certified Safety Professional/NEBOSH or similar)	60.00%	3
Chief Officer/Second Engineer certificate (Class II)	40.00%	2
Captain/Chief Engineer certificate (Class I)	40.00%	2
Other (please specify)	0.00%	0
Total Respondents: 5		

#	Other (please specify)	Date
	There are no responses.	

Q12 Are staff responsible for safety in your organisation given professional safety training when joining, e.g. accident investigation?

Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	87.50%	14
No	12.50%	2
Total		16

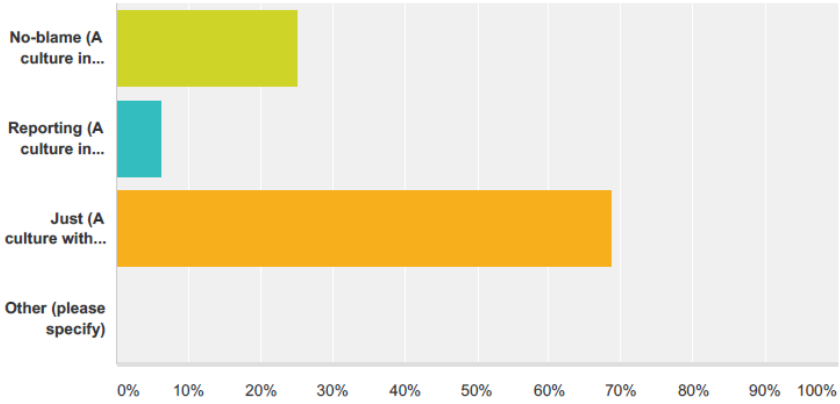
Q13 Whattraining is given to new members of the safety department in your organisation?

Answered: 14 Skipped: 2

#	Responses	Date
1	onboarding with processes	8/2/2016 6:03 PM
2	Lead Auditing, Training, Investigation	7/26/2016 6:59 PM
3	DPA Training Course, Incident Investigation Course, CSO Course, Risk Management, ISM Internal Auditor Course, ISPS Internal Auditor Course	7/26/2016 2:53 PM
4	Lead Auditor's training, Security, SMS, Incident investigation, Risk Assessment, Emergency Response, Coaching	7/26/2016 10:12 AM
5	Taproot, Risk Assessment, OHSAS18001 TRAINING	7/25/2016 6:54 PM
6	Safety awareness, induction, auditor	7/25/2016 12:42 PM
7	On job training, courses, seminar, mentoring	7/24/2016 2:59 PM
8	TRA, OHSAS, ISM, ISPS	7/22/2016 7:03 PM
9	Accident investigation, Root cause analysis, Loss prevention, Case studies and access to E-library of industry docs, pubs, circulars	7/15/2016 5:05 AM
10	Kelvin TopSet Investigation techniques, DNV MSCAT, auditing	7/14/2016 11:34 AM
11	Lead Auditor, Safety Training and Inductions	7/13/2016 11:55 PM
12	Risk Assessment and Management, Incident Investigation, regulatory requirements, etc.	7/13/2016 1:57 PM
13	DPA training, Accident investigation, Auditor training CSO training, MLC familiarisation, managemetn system training	7/13/2016 1:30 PM
14	Safety Induction, Root Cause Analysis and Incident Investigation	7/13/2016 11:07 AM

Q14 How would you describe the safety culture within your organisation?

Answered: 16 Skipped: 0

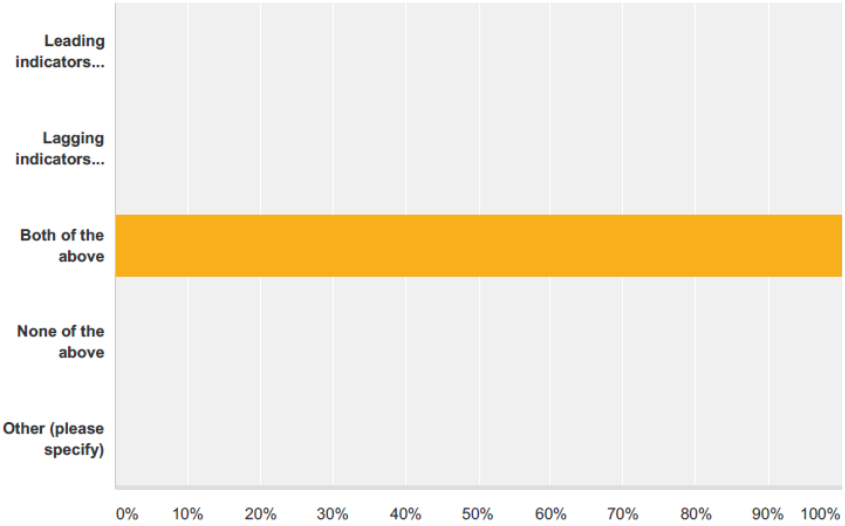


Answer Choices	Responses	
No-blame (A culture in which all unsafe acts are considered as 'honest errors' and therefore there is limited remedial or preventative actions.)	25.00%	4
Reporting (A culture in which people are prepared to report their errors and near-misses.)	6.25%	1
Just (A culture with an atmosphere of trust in which people are encouraged to provide essential safety-related information, while knowing the line is drawn between acceptable and unacceptable behavior.)	68.75%	11
Other (please specify)	0.00%	0
Total		**16**

#	Other (please specify)	Date
	There are no responses.	

Q15 How do you measure safety performance in your organisation?

Answered: 16 Skipped: 0



Answer Choices	Responses	
Leading indicators (e.g. safety audits or other measurements)	0.00%	0
Lagging indicators (e.g. Fatalities/Lost Time Injuries(LTIs)/Total Recordable Cases(TRCs))	0.00%	0
Both of the above	100.00%	16
None of the above	0.00%	0
Other (please specify)	0.00%	0
Total		**16**

#	Other (please specify)	Date
	There are no responses.	

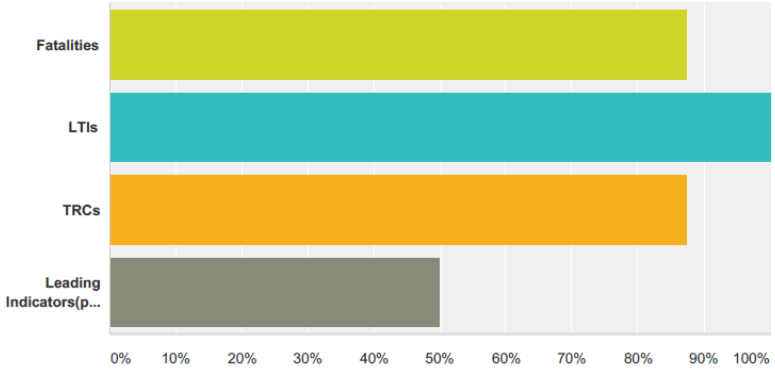
Q16 Please describe the leading indicators used:

Answered: 0 Skipped: 16

#	Responses	Date
	There are no responses.	

Q17 Please indicate all that apply:

Answered: 16 Skipped: 0



Answer Choices	Responses	
Fatalities	87.50%	14
LTIs	100.00%	16
TRCs	87.50%	14
Leading Indicators(please specify)	50.00%	8
Total Respondents: 16		

#	Leading Indicators(please specify)	Date
1	Audits, Inspections	8/2/2016 6:04 PM
2	audit and inspection results	7/26/2016 3:01 PM
3	Audits/Inspection/Ship visit/Safety meeting	7/26/2016 10:16 AM
4	Safety opportunities (near misses), Audit results, PSC concentrated inspection campaigns, Ship Manager inspection results,	7/25/2016 7:00 PM
5	audits, ship visits by safety reps and senior management, BBS/ near miss reporting & trend analysis	7/15/2016 5:08 AM
6	Inspection and audit findings	7/14/2016 11:35 AM
7	ZERO Harm 5 year Initiative	7/13/2016 11:57 PM
8	Near Miss Reports, safety committee meeting issues, Master's system review ideas, feedback, audits, case studies	7/13/2016 1:33 PM

Q18 Please indicate the lagging indicators used (Please indicate all that apply):

Answered: 0 Skipped: 16

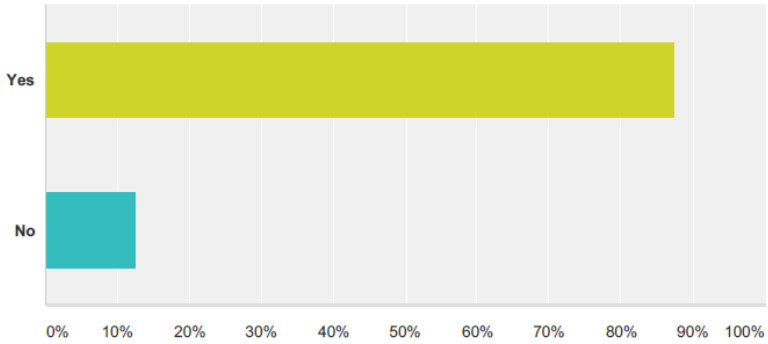
! No matching responses.

Answer Choices	Responses	
Fatalities	0.00%	0
LTIs	0.00%	0
TRCs	0.00%	0
Other (please specify)	0.00%	0
Total Respondents: 0		

#	Other (please specify)	Date
	There are no responses.	

Q19 Does your organisation currently have a safety awareness programme (ie a campaign targeting or focusing on safety issues)?

Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	87.50%	14
No	12.50%	2
Total		16

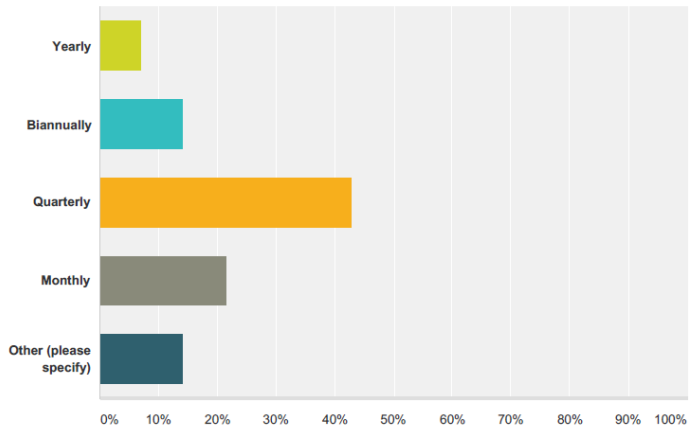
Q20 Please briefly describe your safety awareness programme

Answered: 14 Skipped: 2

#	Responses	Date
1	Reflective learning and Learning Engagement Tool	8/2/2016 6:05 PM
2	Safety Days, Safety Awards, LFI, Reflecitve	7/26/2016 7:02 PM
3	every quarter a new safety campaign is conducted	7/26/2016 3:02 PM
4	In Safe Hands - Unsafe Acts/Conditions Awareness programme where crews are encouraged to report openly. An incentive scheme is in place to acknowledge positive contributions and interventions. Besides company run safety awareness program on specific subject to create awareness.	7/26/2016 10:22 AM
5	We use the Shell Learning from Incidents program. Currently Mooring incidents.	7/25/2016 7:05 PM
6	Company Focuses each year on specific common items	7/25/2016 12:43 PM
7	Safety sampling, Safety Campaign, Focused Campaign	7/24/2016 6:22 PM
8	INCIDENT & INJURY FREE leadership programme	7/22/2016 7:05 PM
9	Incidents are shared with the fleet and personal encouraged to discuss, think and reflect (what went wrong?, why? How?) collect the thoughts and report. Later a comprehensive analysis is shared to align the thoughts and actions with industry expections and safety aspects. This is designed to promote a safety culture and bring about behavioral change in personnel.	7/15/2016 5:14 AM
10	Campaigns in six weeks intervals, BBS, Shell LFI / LET	7/14/2016 11:37 AM
11	ZERO Harm 5 year safety initiatives focusing on personal behaviours	7/13/2016 11:58 PM
12	Various Safety Campaigns. Also lessons learned and best practices are circulated to entire fleet.	7/13/2016 1:59 PM
13	Monthly safety flashes, safety stand downs from technical for relevant issues.	7/13/2016 1:35 PM
14	Think - Life Saving Rules	7/13/2016 1:33 PM

Q21 Is the safety awareness programme in your organisation introduced:

Answered: 14 Skipped: 2

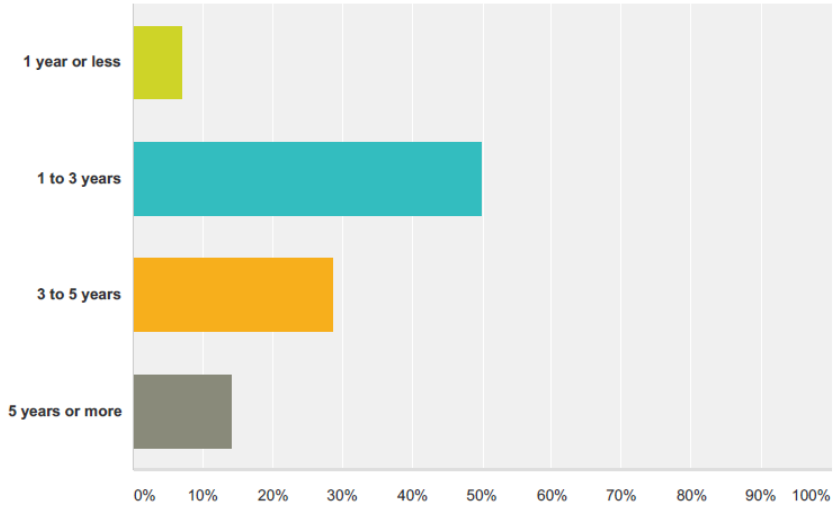


Answer Choices	Responses	
Yearly	7.14%	1
Biannually	14.29%	2
Quarterly	42.86%	6
Monthly	21.43%	3
Other (please specify)	14.29%	2
Total		14

#	Other (please specify)	Date
1	an on going scheme. Besides, safety awareness program runs on specific subject biannually.	7/26/2016 10:23 AM
2	Integrated and Continuous	7/13/2016 1:33 PM

Q22 How many years has asafety awareness programme in your organisation been in place?

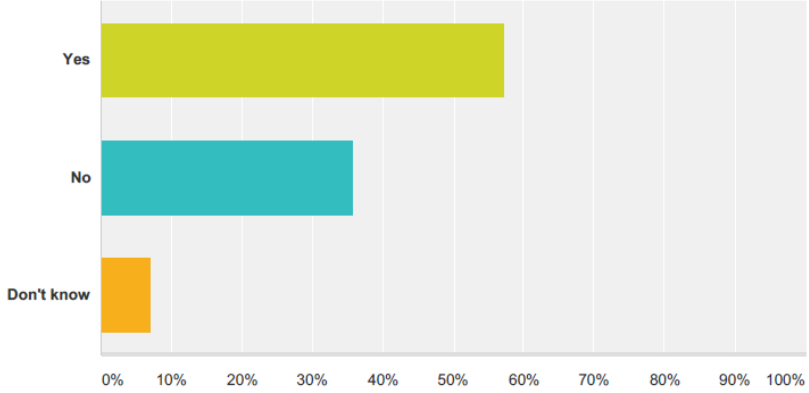
Answered: 14 Skipped: 2



Answer Choices	Responses	
1 year or less	7.14%	1
1 to 3 years	50.00%	7
3 to 5 years	28.57%	4
5 years or more	14.29%	2
Total		14

Q23 Has your organisation measured the impact of the safety awareness programme?

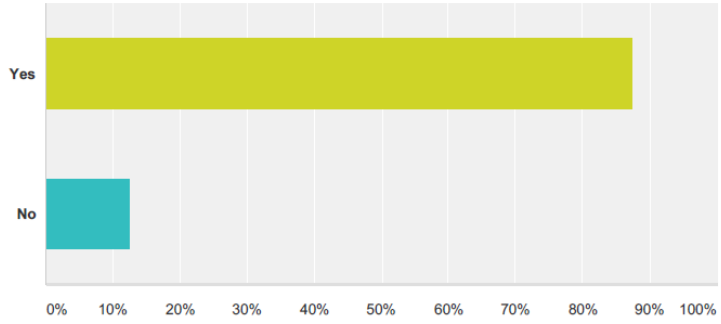
Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	57.14%	8
No	35.71%	5
Don't know	7.14%	1
Total		14

Q24 Are there any leading indicators from the safety awareness programme in your organisation?

Answered: 8 Skipped: 8



Answer Choices	Responses	
Yes	**87.50%**	7
No	**12.50%**	1
Total		**8**

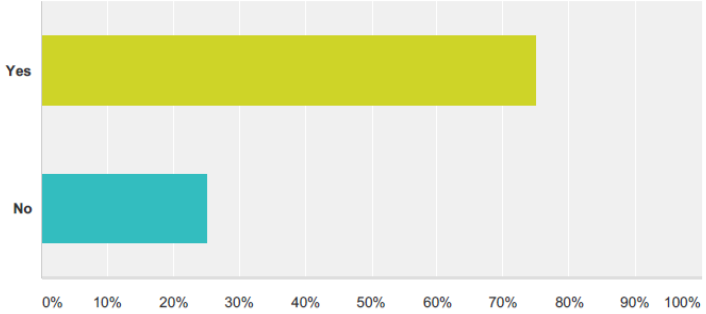
Q25 Please give brief descriptionsof the indicators:

Answered: 6 Skipped: 10

#	Responses	Date
1	The amount of engagement on the 3 actions that are part of the program	8/2/2016 6:06 PM
2	Company observed a trend of minor injury reported on manual handling and using portable tool on board	7/26/2016 10:27 AM
3	Annual review and publication of results	7/25/2016 12:44 PM
4	Safety audit scores, Safety inspection	7/24/2016 6:26 PM
5	impacting approach	7/22/2016 7:06 PM
6	Near miss reports number and type, safety training superintendent ship visits on board safety training, office inductions communication skills and seminars	7/14/2016 12:03 AM

Q26 Do you have a safety opportunity/reporting/sampling programme in your organisation?

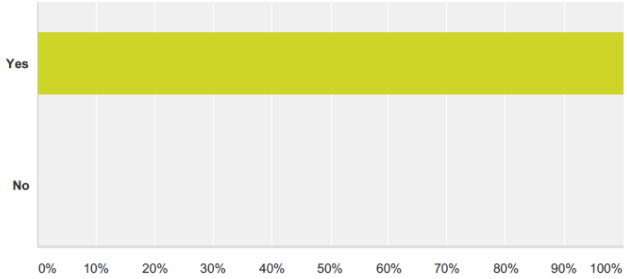
Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	**75.00%**	12
No	**25.00%**	4
Total		**16**

Q27 Do you give feedback to the fleet from issues arising from thesafety opportunity/reporting/sampling programme

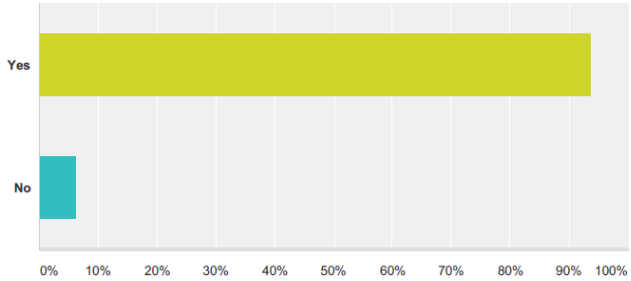
Answered: 12 Skipped: 4



Answer Choices	Responses	
Yes	100.00%	12
No	0.00%	0
Total		12

Q28 Does your organisation hold seminars for officers?

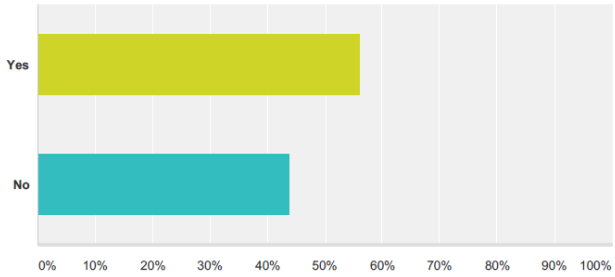
Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	93.75%	15
No	6.25%	1
Total		16

Q29 Does your organisation hold seminars for ratings?

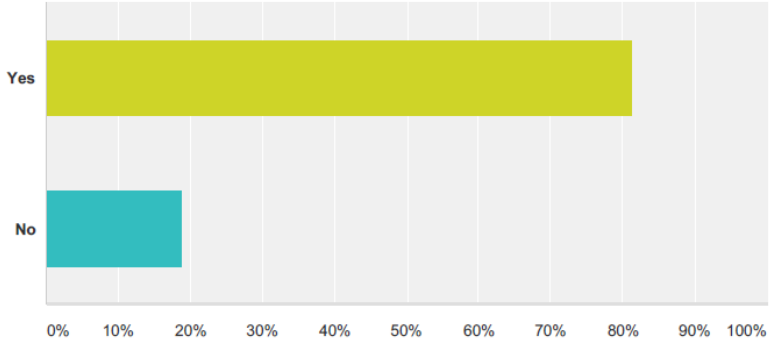
Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	56.25%	9
No	43.75%	7
Total		16

Q30 Does yourorganisation's management system require senior managers to visit the ships operated? (Senior management for this purpose is defined as General Manager/Technical Manager/Marine Manager/Chief Operating Officer/Director or similar)

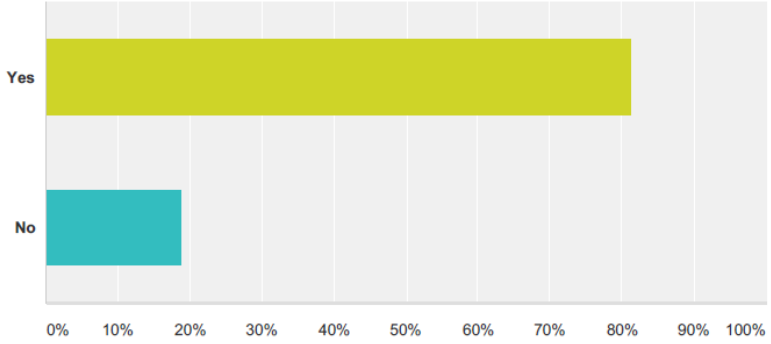
Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	81.25%	13
No	18.75%	3
Total		16

Q31 Does your organisation use any other means to promote safety within the organisation?

Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	81.25%	13
No	18.75%	3
Total		16

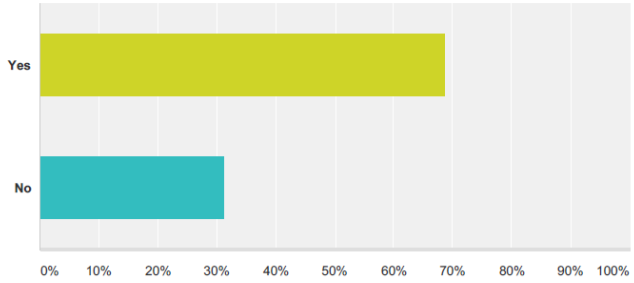
Q32 Please describe the other means used to promote safety within your organisation:

Answered: 12 Skipped: 4

#	Responses	Date
1	Bulletins, Video messages, organisational based social media (Yammer)	8/2/2016 6:07 PM
2	On board Training team formed by ex-Masters	7/26/2016 7:04 PM
3	e.g. circulars, briefings, feedback	7/26/2016 3:04 PM
4	Supt and/or GM has an onboard HSSE meeting during ship visit.	7/25/2016 7:11 PM
5	Circulars, Training Master visits	7/25/2016 12:45 PM
6	Situational awareness, decision making	7/24/2016 6:28 PM
7	Shell reflective learning	7/22/2016 7:08 PM
8	regular and personal engagement with the seafarers and the shore team	7/15/2016 5:17 AM
9	Bulletins, internal Safety Magazine, Safety days	7/14/2016 11:39 AM
10	Marine Summary and Shared Learning publications	7/14/2016 12:04 AM
11	Safety News letters, circulars, frequent communication relating to safety reporting	7/13/2016 1:35 PM
12	Tool box talks, Risk assessment, Safety Bulletins, Safety campaigns,	7/13/2016 11:10 AM

Q33 Are seafarers in your organisation supplied by a third party?

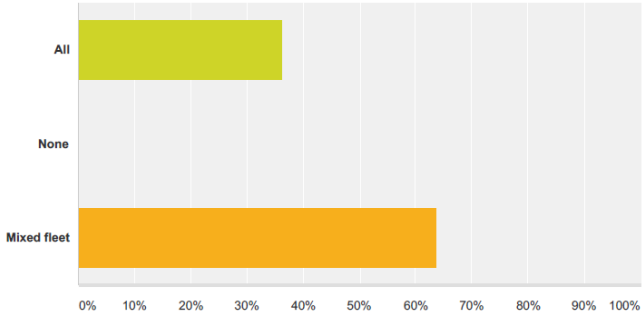
Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	68.75%	11
No	31.25%	5
Total		16

Q34 Are the officers in your organisation supplied by a third party?

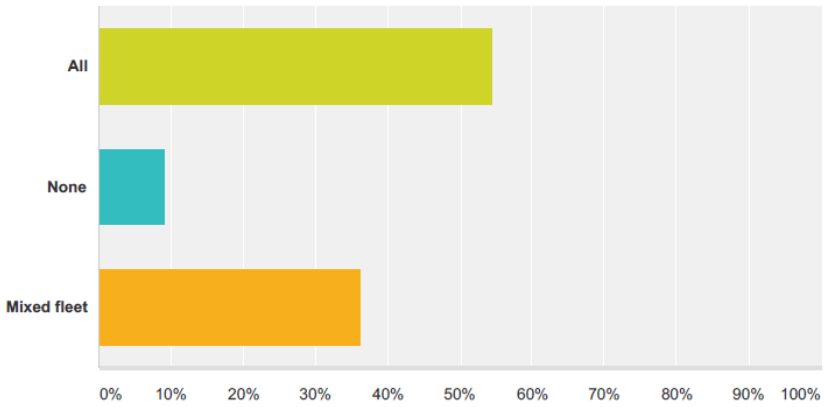
Answered: 11 Skipped: 5



Answer Choices	Responses	
All	36.36%	4
None	0.00%	0
Mixed fleet	63.64%	7
Total		11

Q35 Are the ratings in your organisation supplied by a third party?

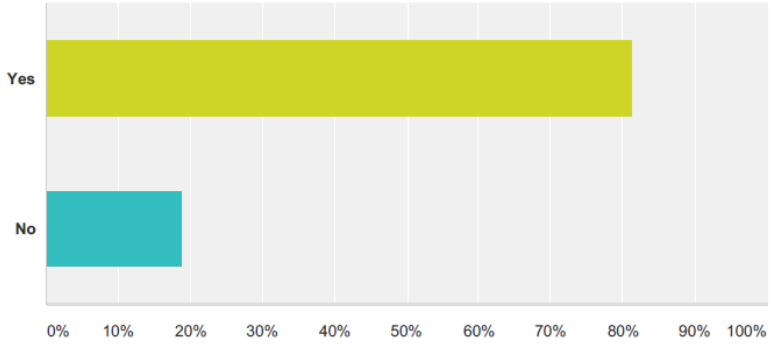
Answered: 11 Skipped: 5



Answer Choices	Responses	
All	54.55%	6
None	9.09%	1
Mixed fleet	36.36%	4
Total		11

Q36 Does your organisation conduct any specific training above STCW requirements?

Answered: 16 Skipped: 0



Answer Choices	Responses	
Yes	81.25%	13
No	18.75%	3
Total		16

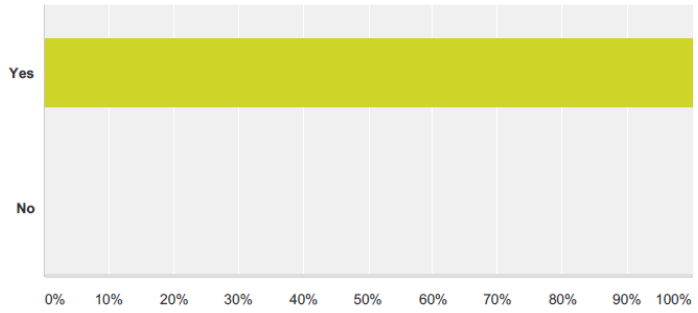
Q37 Please provide a brief descriptionof the additional training your organisation provides above STCW requirements:

Answered: 11 Skipped: 5

#	Responses	Date
1	List of Companys mandatory & other optional, class rooms, trainign centers and CBT	7/26/2016 7:06 PM
2	BTM renewal every 5 years, ship handling course for master, STS course for master, safety officer for jr officers, survival craft and adv FF for all crew, medical care for 2/O, adv oil and chem tanker for all jr officers, FRAMO courses for officers, basic arc-welding for 3Eng	7/26/2016 3:12 PM
3	Risk Assessment, Incident investigation, Safety Offcier, Human relations, high voltage etc	7/26/2016 10:33 AM
4	Crowd control (Ropax), ISO 14001 & 18001, Taproot (Root cause analysis), In-house Risk assessment training, In-house Company SMS training,	7/25/2016 7:19 PM
5	ECDIS, safety and security, Engine specific.PSC.	7/25/2016 12:47 PM
6	ISM, ISPS, BTM< BRM, ECDIS, High voltage, Liquid simulator	7/24/2016 6:29 PM
7	BTM, NSAP & ESAP	7/22/2016 7:09 PM
8	Loss prevention course, BRM, BTM, Risk assessment, Hazardour cargo, Safety & Environmental officer training, various value added courses	7/15/2016 5:19 AM
9	BBS, safety culture, induction to SMS, junior officer course, simulator training	7/14/2016 11:41 AM
10	Hours of rest training and MCL 2006 training	7/14/2016 12:05 AM
11	Almost all	7/13/2016 1:37 PM

Q38 Are the training needs of individual seafarers assessed in your organisation?

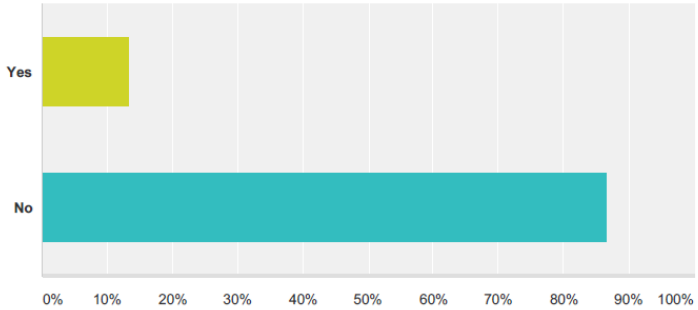
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	**100.00%**	15
No	**0.00%**	0
Total		**15**

Q39 Does your organisation have a policy on the number of nationalities onboard?

Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	**13.33%**	2
No	**86.67%**	13
Total		**15**

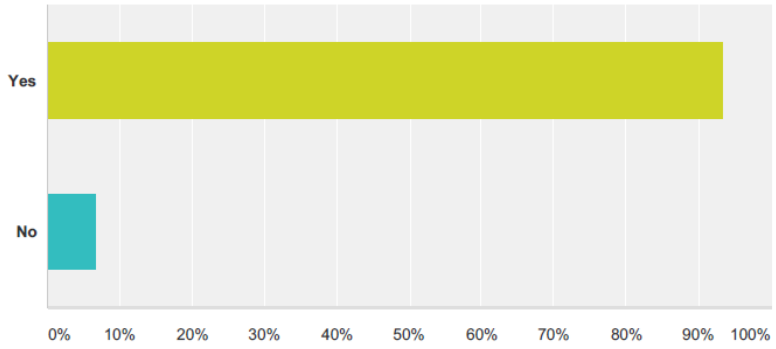
Q40 Please detail your organisation's policy regarding the number of nationalities onboard:

Answered: 2 Skipped: 14

#	Responses	Date
1	3	7/26/2016 7:06 PM
2	Mainly project specific	7/24/2016 6:30 PM

Q41 Does your organisation conduct resource management training (Bridge (BRM) or Engine Room (ERM))?

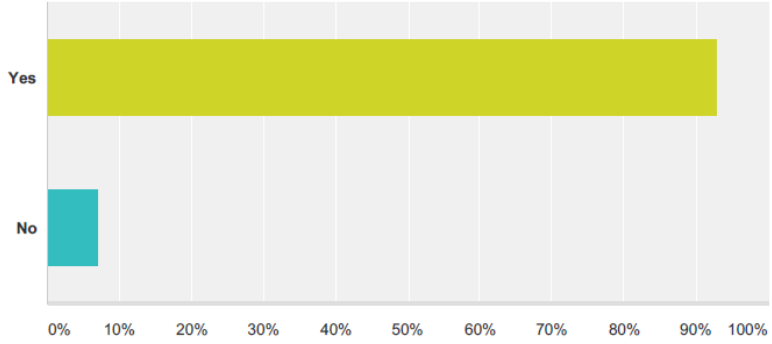
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	93.33%	14
No	6.67%	1
Total		15

Q42 Do navigating officers attend resource management training in your organisation?

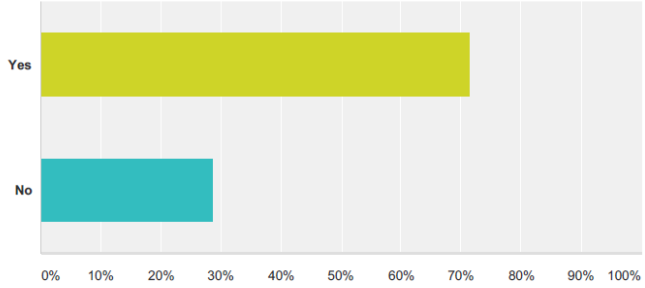
Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	92.86%	13
No	7.14%	1
Total		14

Q43 Do engineering officers attend resource management training in your organisation?

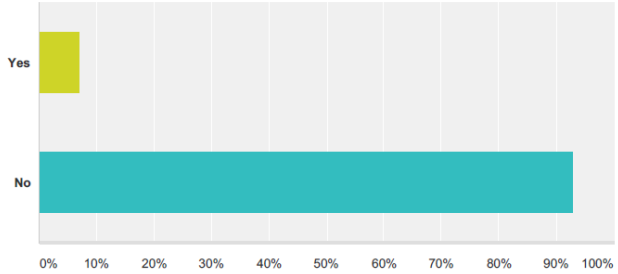
Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	71.43%	10
No	28.57%	4
Total		14

Q44 Do ratings attend resource management training in your organisation?

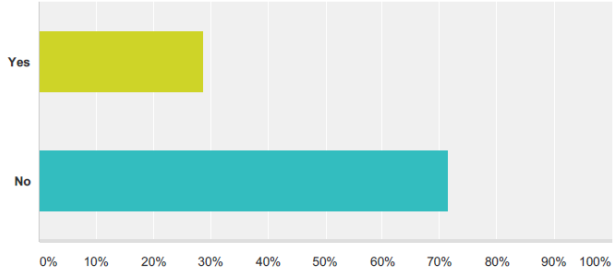
Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	7.14%	1
No	92.86%	13
Total		14

Q45 Do shore staff attend resource management training in your organisation?

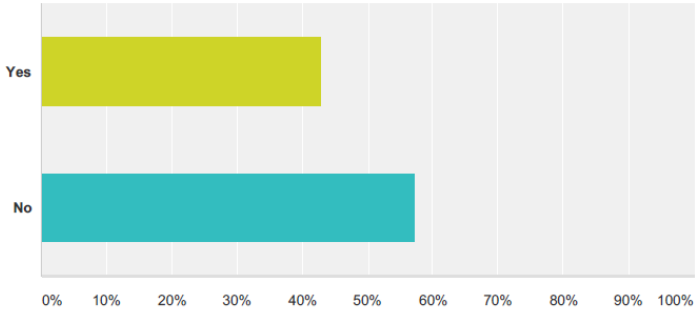
Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	28.57%	4
No	71.43%	10
Total		14

Q46 Do you assess the effectiveness of resource management training in your organisation?

Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	42.86%	6
No	57.14%	8
Total		14

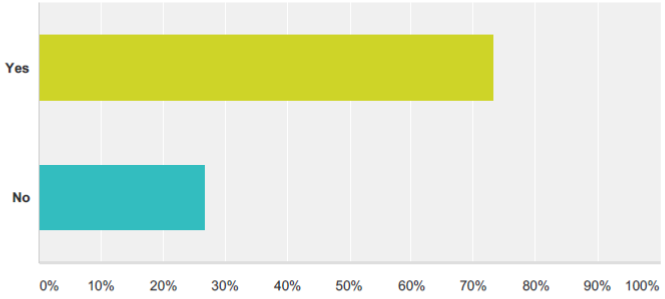
Q47 Please detail how you assess the effectiveness of resource management training in your organisation:

Answered: 5 Skipped: 11

#	Responses	Date
1	Debriefing of the observations with the participants	8/2/2016 6:09 PM
2	Superintendent assessment of performance. Weekly assessment of hours of rest.	7/25/2016 7:24 PM
3	FEEDBACK FORMS	7/22/2016 7:10 PM
4	Analysis of trends with different nationalities time on board going the extra mile to have personnel complete contract on time measurment of crew retention	7/14/2016 12:08 AM
5	Feedback from vessel and performance analysis	7/13/2016 11:12 AM

Q48 Does the Safety Management System in your organisation include, or refer to, IMO Standard Marine Communication Phrases?

Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	73.33%	11
No	26.67%	4
Total		15

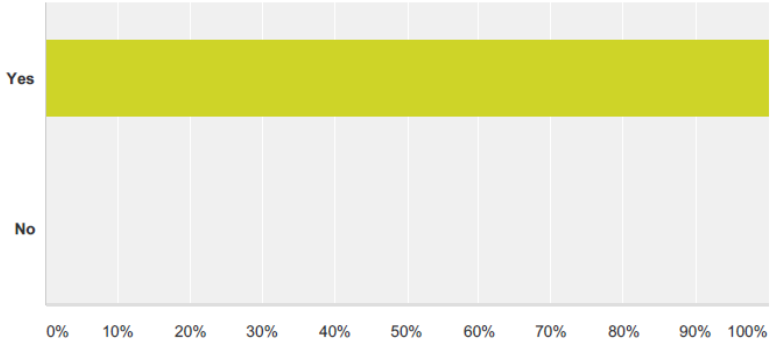
Q49 What is your company's required language for shipboard communications?

Answered: 15 Skipped: 1

#	Responses	Date
1	english	8/2/2016 6:09 PM
2	english	7/26/2016 7:07 PM
3	English	7/26/2016 3:13 PM
4	English	7/26/2016 10:43 AM
5	English	7/25/2016 7:24 PM
6	English	7/25/2016 12:48 PM
7	English	7/24/2016 6:32 PM
8	ENGLISH	7/22/2016 7:11 PM
9	English	7/15/2016 5:20 AM
10	English	7/14/2016 11:42 AM
11	Spoken English	7/14/2016 12:09 AM
12	English	7/13/2016 2:02 PM
13	English	7/13/2016 1:38 PM
14	English predominantly, Spanish on some vessels (JV owned).	7/13/2016 1:38 PM
15	English	7/13/2016 11:12 AM

Q50 Does your organisation have aformalappraisal system for seafarers in place?

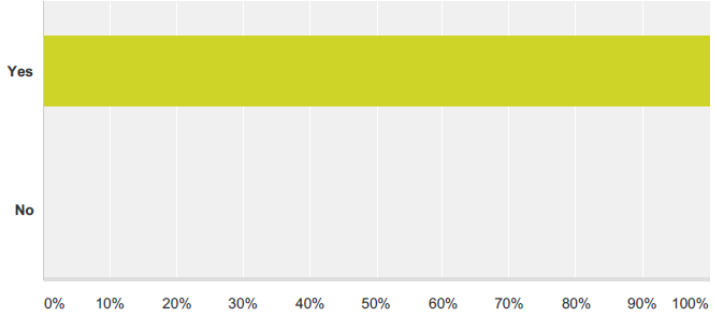
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	100.00%	15
No	0.00%	0
Total		15

Q51 Are officers appraised in your organisation?

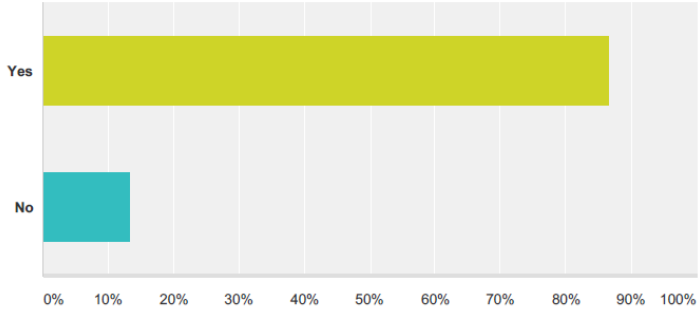
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	100.00%	15
No	0.00%	0
Total		15

Q52 Are ratings appraised in your organisation?

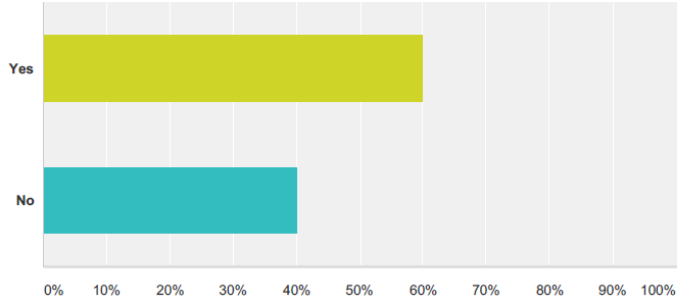
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	86.67%	13
No	13.33%	2
Total		15

Q53 Does your organisation have a Competence Management System (CMS) in place?

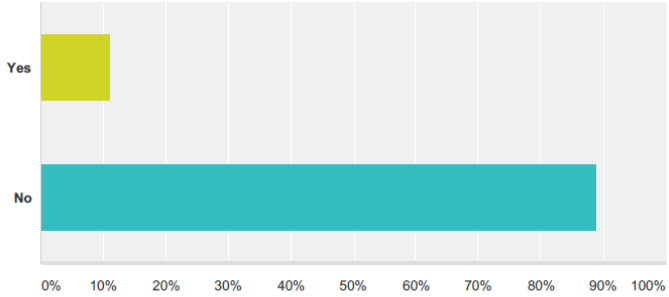
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	60.00%	9
No	40.00%	6
Total		15

Q54 Is the CMS in your organisation a third party system?

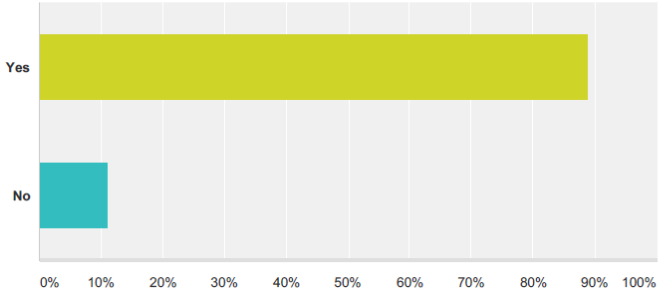
Answered: 9 Skipped: 7



Answer Choices	Responses	
Yes	11.11%	1
No	88.89%	8
Total		9

Q55 Does the CMS in your organisation include learning tools?

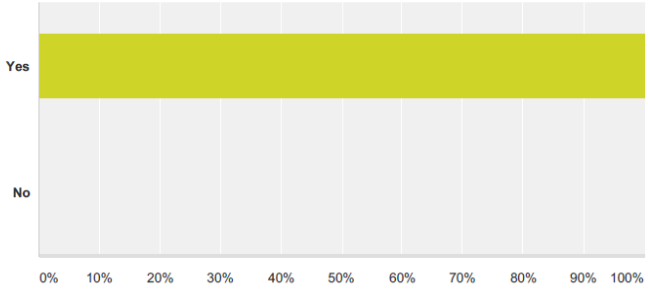
Answered: 9 Skipped: 7



Answer Choices	Responses	
Yes	88.89%	8
No	11.11%	1
Total		9

Q56 Does the CMS in your organisation include assessments?

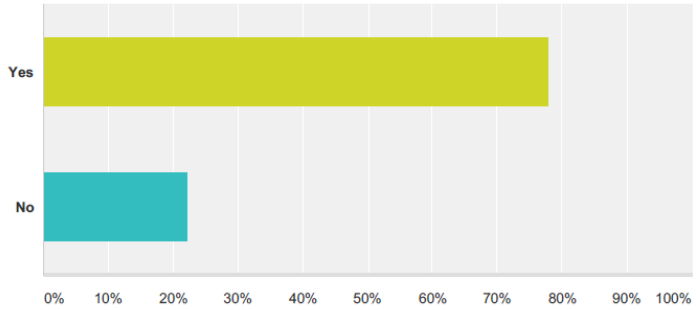
Answered: 9 Skipped: 7



Answer Choices	Responses	
Yes	100.00%	9
No	0.00%	0
Total		9

Q57 Does the CMS in your organisation include a skill gap analysis?

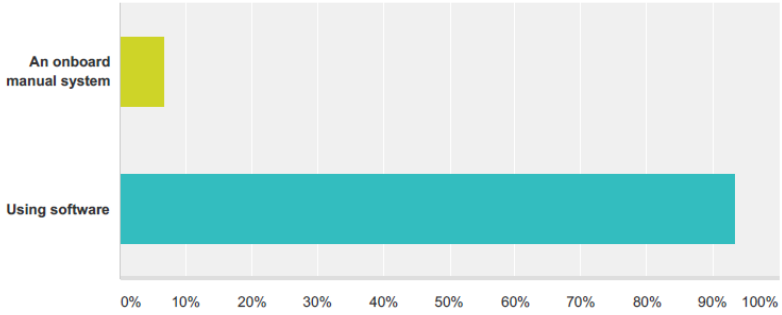
Answered: 9 Skipped: 7



Answer Choices	Responses	
Yes	77.78%	7
No	22.22%	2
Total		9

Q58 How does your organisation monitor hours of work/rest onboard?

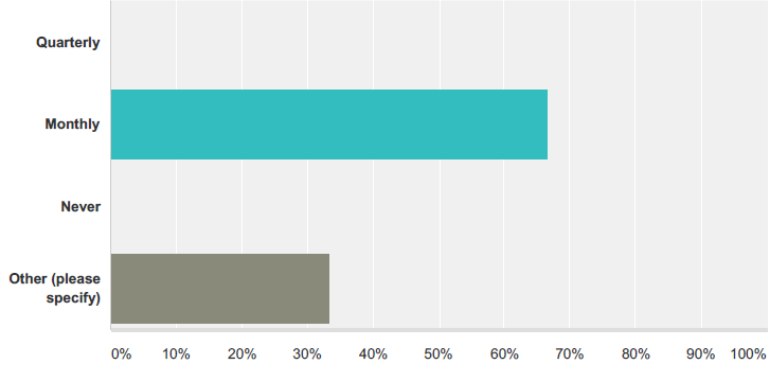
Answered: 15 Skipped: 1



Answer Choices	Responses	
An onboard manual system	6.67%	1
Using software	93.33%	14
Total		15

Q59 Are records of hours of work/rest sent into your organisation?

Answered: 15 Skipped: 1

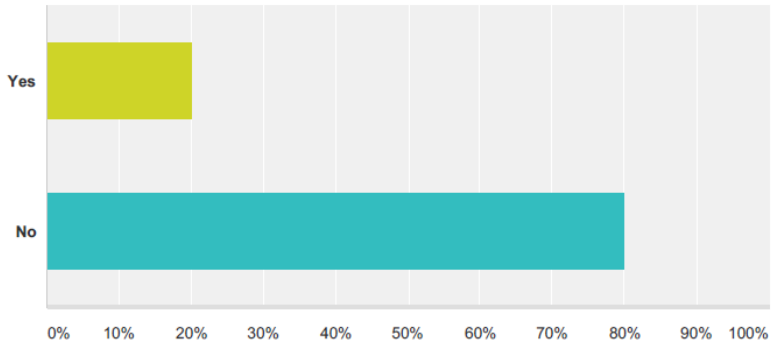


Answer Choices	Responses	
Quarterly	**0.00%**	0
Monthly	**66.67%**	10
Never	**0.00%**	0
Other (please specify)	**33.33%**	5
Total		**15**

#	Other (please specify)	Date
1	online	8/2/2016 6:10 PM
2	instantly by software	7/26/2016 3:14 PM
3	It is live system where office can monitor record of rest hours	7/26/2016 10:45 AM
4	Weekly NC report	7/25/2016 7:29 PM
5	Monitored via ship shore electronic system	7/25/2016 12:49 PM

Q60 Does your organisation have a Fatigue Risk Management Plan?

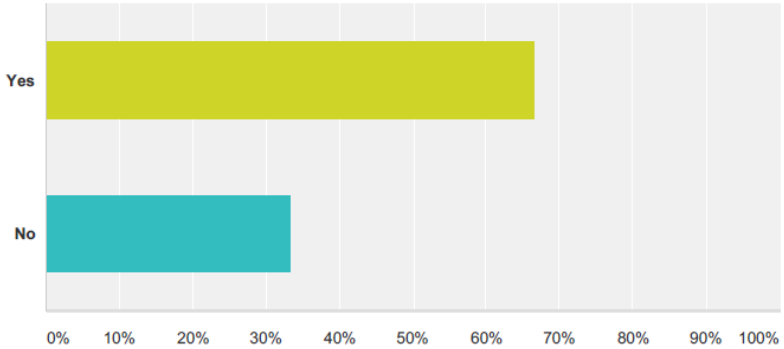
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	**20.00%**	3
No	**80.00%**	12
Total		**15**

Q61 Does your organisation conduct a health medical above statutory requirements for seafarers?

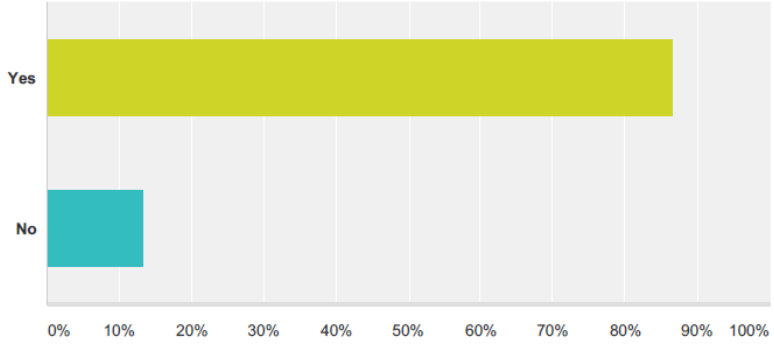
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	66.67%	10
No	33.33%	5
Total		15

Q62 Does your organisation supply and maintain gym equipment onboard?

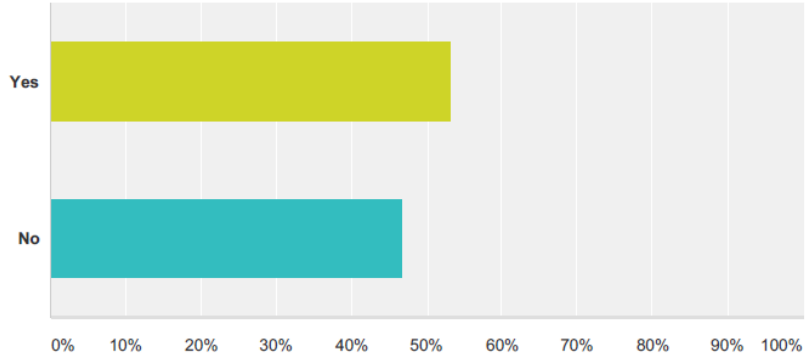
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	86.67%	13
No	13.33%	2
Total		15

Q63 Does your organisation use a food professional to review the onboard daily menus to ensure a healthy diet?

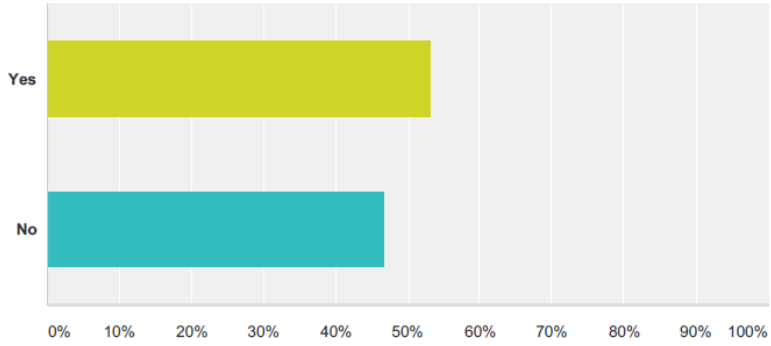
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	53.33%	8
No	46.67%	7
Total		15

Q64 Does your organisation allow the consumption of alcohol by seafarers whilst onboard?

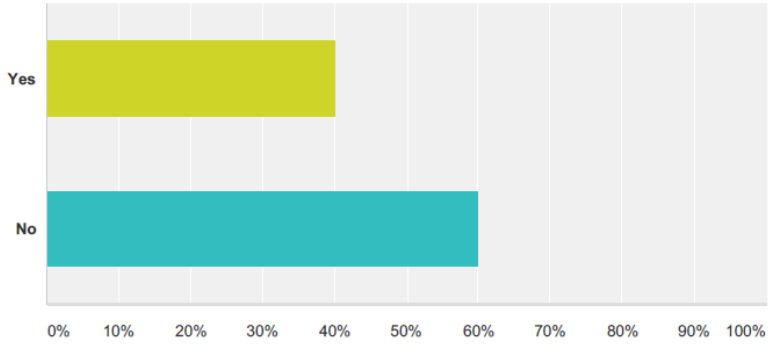
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	53.33%	8
No	46.67%	7
Total		15

Q65 Does your organisation have a smoking cessation programme in place for seafarers?

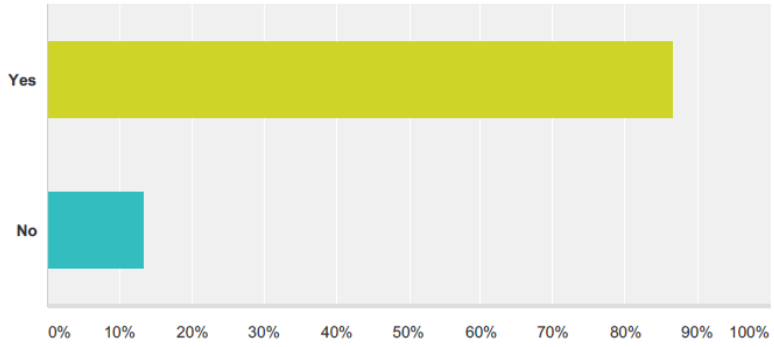
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	40.00%	6
No	60.00%	9
Total		15

Q66 Does your organisation use a standard method for accident investigation?

Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	86.67%	13
No	13.33%	2
Total		15

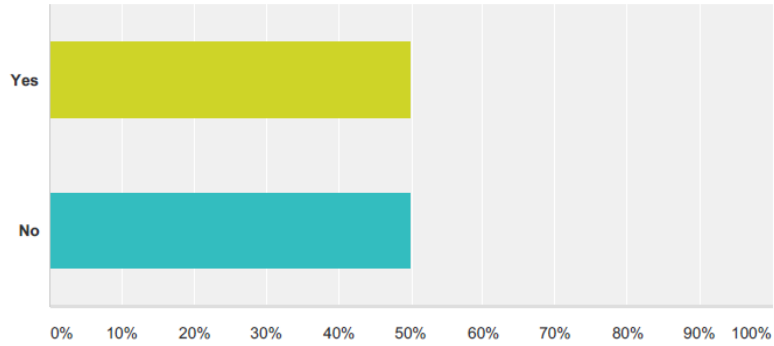
Q67 Please briefly describe the methodology your organisation uses for accident investigation (format & description):

Answered: 1 Skipped: 15

#	Responses	Date
1	PROFESSIONAL COMMITTEE	7/22/2016 7:14 PM

Q68 Is the standard method used for accident investigation in your organisation supplied by a third party?

Answered: 14 Skipped: 2



Answer Choices	Responses	
Yes	50.00%	7
No	50.00%	7
Total		14

Q69 Please detail the standard method used for accident investigation in your organisation:

Answered: 6 Skipped: 10

#	Responses	Date
1	Tripod and Causal learning	8/2/2016 6:11 PM
2	collecting evidence - identifying direct causes - identifying root causes - identifying lessons learnt, correctice and preventice measures	7/26/2016 3:17 PM
3	In house accident investigation procedure is followed in accordance with our SMS	7/24/2016 6:35 PM
4	Developed in-house using the Loss causation model	7/15/2016 5:22 AM
5	In house ICAM reporting.	7/13/2016 1:39 PM
6	A dedicated team of marine professionals form part of the investigation team	7/13/2016 11:14 AM

Q70 Which company supplies the third party accident investigation method used in your organisation?

Answered: 8 Skipped: 8

#	Responses	Date
1	Case by case basis	7/26/2016 7:09 PM
2	GL	7/26/2016 3:15 PM
3	Shell	7/26/2016 11:02 AM
4	Taproot	7/25/2016 7:33 PM
5	Kelvin TopSet	7/14/2016 11:43 AM
6	TapRoot	7/14/2016 12:11 AM
7	DNV-GL	7/13/2016 2:05 PM
8	DNV GL	7/13/2016 1:40 PM

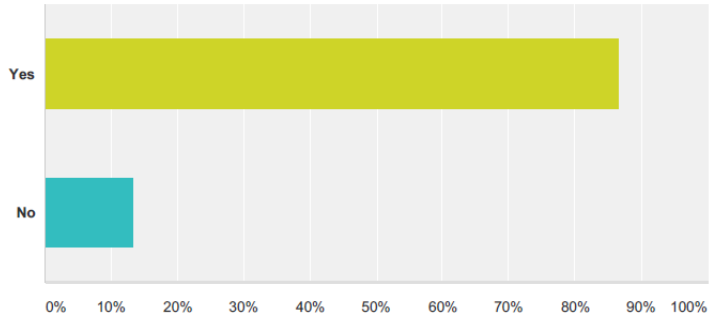
Q71 Please provide details of the third party accident investigation method used in your organisation:

Answered: 5 Skipped: 11

#	Responses	Date
1	Case by case basis	7/26/2016 7:09 PM
2	TRIPOD	7/26/2016 11:02 AM
3	7 step process- plan investigation, determine sequence, define CF, analyse each CF's RC, generic root cause, develop CA, implement CA	7/25/2016 7:41 PM
4	Kelvin TOPSET system	7/14/2016 11:44 AM
5	TapRoot	7/14/2016 12:11 AM

Q72 Are the staff in your organisation specifically trained in accident investigation?

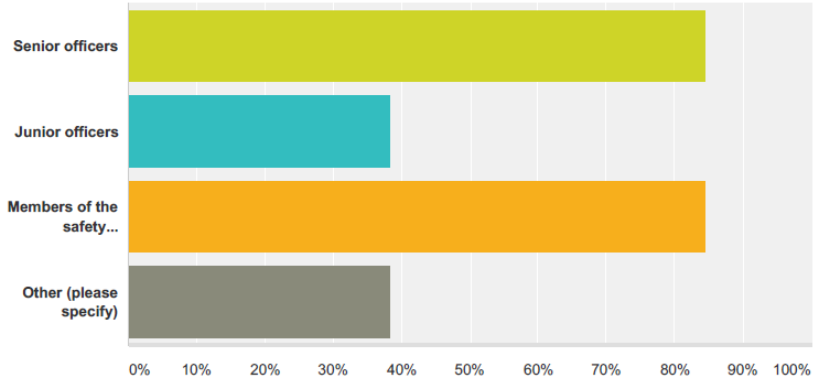
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	86.67%	13
No	13.33%	2
Total		15

Q73 Which staff are trained in accident investigation in your organisation? Please selectall that apply.

Answered: 13 Skipped: 3

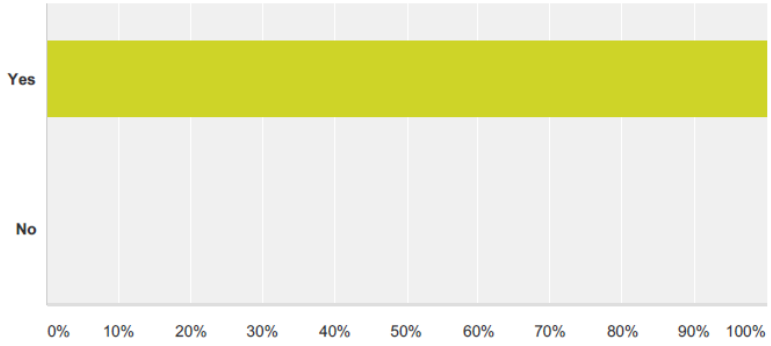


Answer Choices	Responses	
Senior officers	84.62%	11
Junior officers	38.46%	5
Members of the safety department	84.62%	11
Other (please specify)	38.46%	5
Total Respondents: 13		

#	Other (please specify)	Date
1	Vessel's Superintendent	7/26/2016 11:03 AM
2	Senior Mgt (GM)	7/25/2016 7:43 PM
3	All Fleet Managers and Superintendents	7/14/2016 12:11 AM
4	Technical and Operations Department personnel	7/13/2016 2:05 PM
5	Techincal, Marine and Risk and regulatory requirement	7/13/2016 1:42 PM

Q74 Does your organisation consider human factors as root causes in accident investigation?

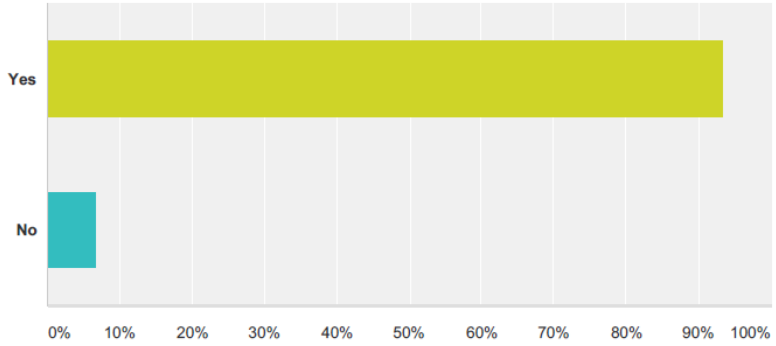
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	100.00%	15
No	0.00%	0
Total		15

Q75 Does your organisation consider organisational factors as root causes in accident investigation?

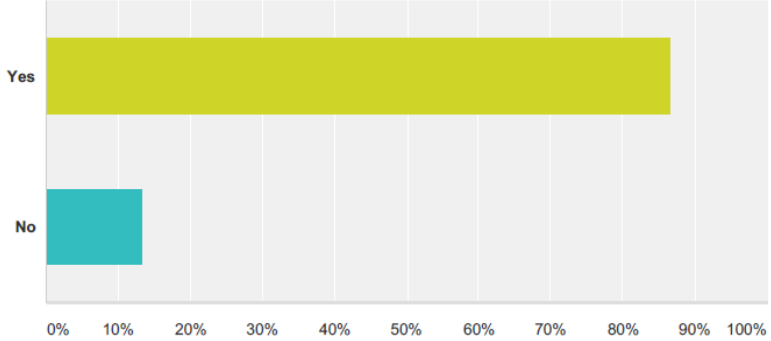
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	93.33%	14
No	6.67%	1
Total		15

Q76 Have any conclusions for operational improvement come out of accident investigations in your organisation?

Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	**86.67%**	13
No	**13.33%**	2
Total		**15**

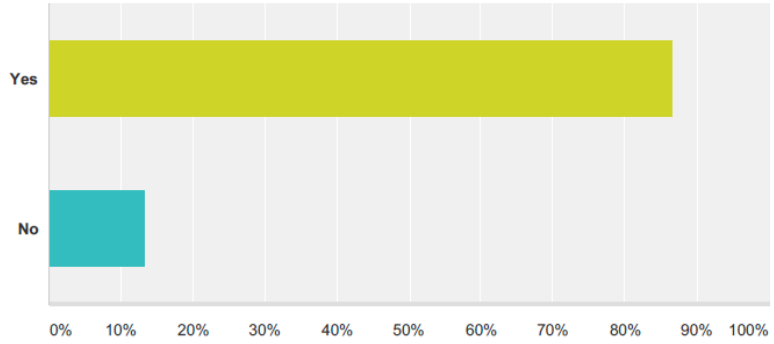
Q77 What improvements have been implemented as a result of conclusions from accident investigations in your organisation? Please detail:

Answered: 12 Skipped: 4

#	Responses	Date
1	Procedural, human elenment, communciations	7/26/2016 7:10 PM
2	improvements to the SMS (e.g. amendment of critical equipment list, amending checklists, procedures, risk assessments)	7/26/2016 3:18 PM
3	As a result of an incident investigation related to a Life boat incident, the company had to fit a cut off switch to life boat winch. This will allow to cut off power supply to winch when cranking handle is engaged thus avoiding injury to crew members.	7/26/2016 11:09 AM
4	Control of Moorings during loading vehicles	7/25/2016 7:45 PM
5	Implication of changes to checklists and addition of checklists	7/25/2016 12:53 PM
6	Procedural	7/24/2016 6:36 PM
7	CAUSAL LEARNING / ENHANCED TRAINING	7/22/2016 7:16 PM
8	procedural changes, improved training needs	7/15/2016 5:24 AM
9	Procedural changes, software development, equipment changes, change of PPE supplier, etc	7/14/2016 11:45 AM
10	Implementation of BCF	7/14/2016 12:12 AM
11	Procedural amendments	7/13/2016 1:43 PM
12	Lead to global restructuring of certain departments w.r.t reporting lines.	7/13/2016 1:40 PM

Q78 Is your organisation aware of the accident reporting requirements of IMO?

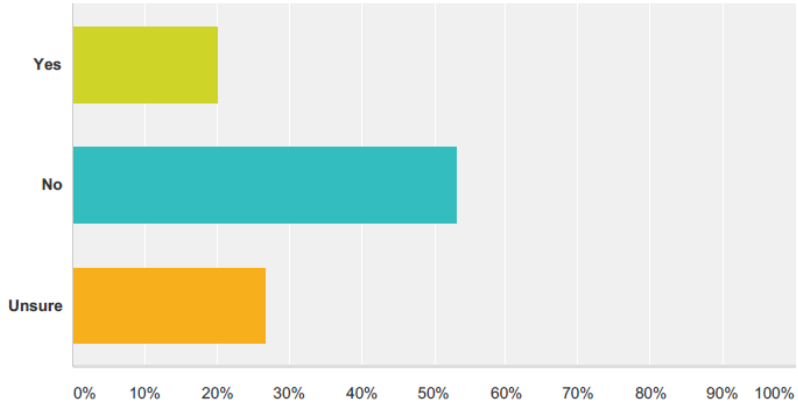
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	**86.67%**	13
No	**13.33%**	2
Total		**15**

Q79 Has your organisation submitted anything to the IMO Global Integrated Information Shipping (Marine Casualties and Incidents) database?

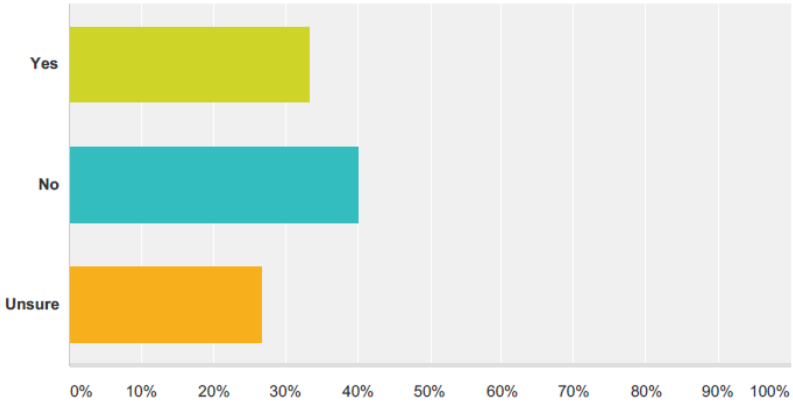
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	**20.00%**	3
No	**53.33%**	8
Unsure	**26.67%**	4
Total		**15**

Q80 Has your organisation accessed the IMO Marine Casualties and Incidents database for information purposes?

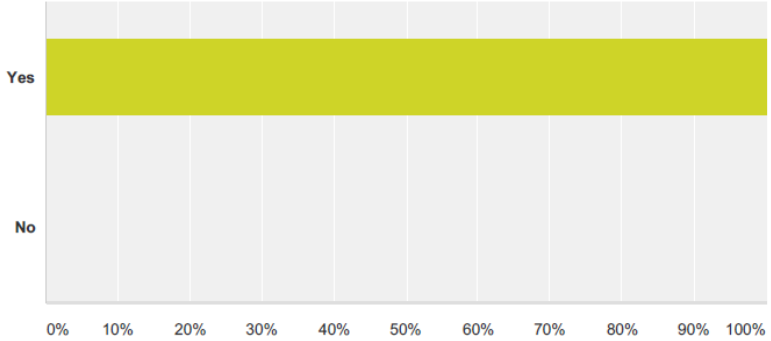
Answered: 15 Skipped: 1



Answer Choices	Responses	
Yes	33.33%	5
No	40.00%	6
Unsure	26.67%	4
Total		15

Q81 Has your organisation found the information on the IMO Marine Casualties and Incidents database useful?

Answered: 5 Skipped: 11



Answer Choices	Responses	
Yes	100.00%	5
No	0.00%	0
Total		5

Appendix 2 – Summary of Interview Participants

Respondent Number	Organisation Type	Speciality
1	Owner/Manager	Ship Operations
2	Owner/Manager	Ship Operations
3	Consultancy	Ship Operations
4	Owner/Manager	Ship Operations
5	Flag	Regulatory
6	Owner/Manager	Ship Operations
7	Marine Insurance	Loss Prevention
8	Owner/Manager	Ship Operations
9	Class	Regulatory
10	Owner/Manager	Ship Operations
11	Consultancy	Human Factors
12	Class	Human Factors
13	Flag	Human Factors
14	Class	Human Factors
15	Owner/Manager	Ship Operations
16	Marine Insurance	Loss Prevention
17	Owner/Manager	Ship Operations
18	Consultancy	Ship Operations
19	Class	Human Factors
20	Industry body	Industry Association