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WORLD MARITIME UNIVERSITY

Malmö, Sweden

**Exploratory study on applying systems thinking to
examine safety in Navy / Coast Guard /
Commercial Shipping operations**

By

SETH ANTHONY DZAKPASU

GHANA

A dissertation submitted to the World Maritime University in partial
fulfilment of the requirement for the award of the degree of

MASTER OF SCIENCE

In

MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL ADMINISTRATION)

2019

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views and are not necessarily endorsed by the University.

(Signature): 

(Date): 23 SEPTEMBER 2019

Supervised by: 

Supervisor's affiliation.....



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May God bless you all.

Abstract

Title of Dissertation: Exploratory study on applying system thinking to examine safety in Navy/ Coast Guard / Commercial Shipping operations.

Degree: Master of Science

The recent succession of warship collisions questioned the Navy capacity to ensure safe navigation. This situation inspired this exploratory study of warship, coast guard and commercial ship safety in operations. In this study, Systems thinking is applied in the context of maritime safety. This novel research emphasizes behaviour and purpose (finality). As the finality of a system is deduced from its behaviour, the research differentiates allocated finality and achieved finality. Indeed, safety first motto may in some cases be purely rhetorical. To discuss this view, focus groups were organised and to benchmark the findings, an interview with an Irradiated Nuclear Fuel ship expert was conducted. The first findings show that warship, coast guard ship and commercial ship operations cannot be strictly compared. Really, ownership and mission allocation are major determinants in ship design and operation, and therefore, pre-determine safety. The institutional framework and culture of navy, coast guard and commercial shipping also affect ship safety practices. Due to the uniqueness of each system of maritime operation, ready-made safety solutions could be counter-productive if not properly adapted to the specificities and constraints of each system. Any systemic alteration has to embrace the inherent limits and resistance of any system to change.

KEYWORDS: Maritime, Systems thinking, Finality, Behaviour, Safety, Accidents, Operations.

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List of Abbreviations

AIBN	Accident Investigation Board Norway
AIS	Automatic Identification System
ARA	Armada Republica Argentina
ARPA	Automatic Radar Plotting Aid
CG	Coast Guard
CGHQ	Coast Guard Headquarters
CO	Commanding Officer
CSL	Cyprus Shipping Lines
CNC	Civil Nuclear Constabulary
ECDIS	Electronic Chart Display and Information System
FEPC	Federation of Electric Power Companies
FOF	Flag Officer Fleet
GPS	Global Positioning System
GST	General System Theory
HQ	Headquarters
IAEA	International Atomic Energy Agency
ICAO	International Civil Aviation Organisation
IHS	Information Handling Services
ILO	International Labour Organization
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organisation
INF	International Nuclear Fuel Code
INS	International Nuclear Services
IRPCS	International Regulation for Preventing Collisions at Sea, 1972
ISM	International Safety Management Code
JTSB	Japan Transport Safety Board
KNM	Kongelige Norske Marine

LNG	Liquefied Natural Gas
MAB	Marine Accident Brief
MAIB	Marine Accident Investigation Branch
MAREX	The Maritime Executive
IRPCS	International Convention for the Prevention of Pollution from Ships (1973/78)
MCA	Maritime and Coastguard Agency
MET	Maritime Education and Training
MEM	Maritime Energy Management
MLC	Maritime Labour Convention 2006
MoD	Ministry of Defence
MSA	Merchant Shipping Act 1894
MSc	Master of Science
MSEA	Maritime Safety and Environmental Administration
MT	Motor Tanker
MV	Motor Vessel
NHQ	Navy Headquarters
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation and Safety Board
OOW	Officer of the Watch
OPV	Offshore Patrol Vessel
PH.D.	Doctor of Philosophy
PLAN	People's Liberation Army Navy
PNTL	Pacific Nuclear Transport Limited
RADAR	Radio Detection and Ranging
RMS	Royal Mail Steamer
ROPAX	Roll-on/roll-off Passenger
RO-RO	Roll-on/Roll-off
SAR	Search and Rescue

SOLAS	International Convention for the Safety of Life at Sea 1974, as amended
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
US	United States
USS	United States Ship
USCG	United States Coast Guard
USCGC	United States Coast Guard Cutter
USNS	United States Navy Ship
VLCC	Very Large Crude Carrier
WMU	World Maritime University
WNA	World Nuclear Association
WNTI	World Nuclear Transport Institute

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.0 Background of the Study

Maritime operations¹ have always borne inherent risk of accidents. From the ancient era of wooden ships to steel ships of the present, preventing accidents has been a challenge in the operation of ships of all types and classification. Generically, safety is the characteristic or attribute of a system, necessary and sufficient to reduce the number of harmful events to crew, ships, organisations or environment to an acceptably low level (Hollnagel, 2014). Therefore, to effectively address safety, thinking should be organised in systems² approach. Systems thinking “is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects” (Arnol & Wade, 2015). The ability to think in systems is itself a system which creates a behaviour pattern. The above definition and explanation of systems in glossary, show that to understand and improve a system to achieve its purpose, it is important to study its behaviour. Behaviour and purpose as key concepts are applied to understand safety of systems in this research.

¹ Maritime Operations are activities and actions conducted with the aim of achieving the purposes of warships, CG ships and commercial ships. See Glossary for further description.

² See Glossary for explanations of systems.

The systems discussed in this research are Navy, Coast Guard (CG) and commercial shipping organisations. Particularly, the respective subsystems³ of these systems, which are warships, CG ships and commercial ships, will be analysed due to the apparent rise in accidents involving these ships.

Since 2017, a worrying trend of warship accidents have occurred involving Argentina, Chile, China, Germany, Italy, Taiwan, Norway and United States (US) Navies (MAREX, 2017; Schkvarkin, 2018 Septemebr 26; Larter and Sprenger, 2018; Strong, 2019; Voytenko, 2018; Voytenko, 2019a; Stickings, 2019; Voytenko, 2019b). Similarly, accidents have been recorded in CG ship operations (NTSB/MAB-17/22, 2016; NTSB/MAB-17/37, 2017). These accidents have raised concerns about warships, which are fitted with high-tech navigation equipment and are supposed to be constantly alert (Bakhsh, 2018). To understand this trend, there is a need for a closer look at maritime operations.

Five warships of the United States Navy 7th Fleet based in the Pacific, United States Ship (USS) Antietam, USS Lake Chaplain, USS Fitzgerald, USS John McCain and USS Benfold were involved in accidents between 2017 and 2018 (Navy Office of Information, 2017a; Navy Office of Information, 2017b, Bateman, 2018). On 15 November, 2017 Argentinean Navy lost the submarine San Juan, after its batteries caught fire (Rey, 2019). A German Navy Corvette, Erfurt rammed a jetty “Tirpitz mole” at Kiel on 21 September 2018, with the warship sustaining bow damages (Voytenko, 2018). On 8 November 2018, the Norwegian Navy Frigate Kongelige Norske Marine (KNM) Helge Ingstad collided with the Motor Tanker (MT) Sola TS and subsequently sank (AIBN, 2018). USS Leyte Gulf and United States Navy Ship (USNS) Robert E. Peary collided on 5 February 2019 while conducting underway replenishment (LaGrone & Eckstein, 2019). A Saudi Arabian tanker Sama on 8 March, 2019 ran into a Taiwanese Frigate Ning Yang berthed in harbour, causing damage to the warship

³ See Glossary for description of subsystems.

(Strong, 2019). On 8 May 2019, the Italian Frigate Federico Martinengo collided with the Italian fishing vessel Sofia Fabio with both ships sustaining minor damages (Voytenko, 2019a). On 1 August 2019, a Chinese warship suspected to be the Lufang collided with a Taiwanese bulk carrier Youtai No. 1 (Stickings, 2019). Recently on 29 August 2019, an explosion on Chilean warship Sargento Aldea during maintenance works led to crew injuries (Voytenko, 2019b). This alarming trend highlights the need to review warship operations in order to mitigate accidents.

CG ships show a similar accident trend. Recent collisions between United States Coast Guard Cutter⁴ (USCGC) Thetis and towing vessel Matachin, and USCGC Tampa and Tugboat Cerro Santiago also raised concerns, since CG ships are to ensure safety of navigation (NTSB/MAB-17/22, 2016; NTSB/MAB-17/37, 2017). Though safety measures were taken by the USCGC the accidents still occurred due to fatigue and improper lookout.

There have been many commercial ship accidents resulting in the loss of property and damage to the environment (Butt, Johnson, Pike, Pryce-Roberts & Vigar, 2012). Commercial ship accidents still occur such as the collision between the MV Ulysse and a ferry MV Virginia on 7 October 2018. On 12 March 2019, a fire broke out on MV Grande America which later sank. The Viking Sky was in distress when its engines failed while underway in bad weather on 23 March 2019 (MAREX, 2019; Jeffery, 2019). These instances show that accidents prevail in commercial shipping and indicate the need for an in-depth study.

Several individual, governmental and international efforts in addressing shipping accidents resulted from investigations of earlier accidents (Butt et al., 2012; JTSB, 2018). Investigations into the sinking of the Royal Mail Steamer (RMS) Titanic

⁴ See Glossary for definition of Cutter.

and the consequent development of the International Convention for the Safety of Life at Sea (SOLAS) by the International Maritime Organisation (IMO) led to changes in maritime operations, making them safer (IMO, 1974; Cathey, 2017). SOLAS and other regulations such as International Regulation for Preventing Collisions at Sea (IRPCS) 1972, recommend measures for preventing collisions and accidents (IMO, 1972). However, there is a need to approach safety differently since shipping accidents are still prevalent.

A systemic approach is a potent one. The casualty investigation into the 2011 Deepwater Horizon disaster highlighted systemic failures in management of risk as underlying causes (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling [U.S.], 2011). Additionally, Leveson (2011) states that “Safety is clearly an emergent property of systems and safety can only be determined in the context of the whole”. The purpose of this work is to understand the links and reciprocal influences between systems (i.e. Navy, CG and Shipping Industry) and their dependent sub-system ships⁵.

1.1 Problem Statement

The annual increase in seaborne trade of about 4%, with a growing world commercial ship fleet of over 93,161 ships, continues to constrict the maritime space (UNCTAD, 2017). According to the Pennant List of IHS Jane’s Fighting ships 2015/2016 yearbook, there were about 7369 warships and patrol crafts across the world (Saunders, 2016). A similar list in the 2017/2018 edition of the same publication indicated 7513 warships and patrol crafts (Saunders, 2017). The number of warships and patrol crafts in the world has increased, which may be due to increases in fleet sizes of emerging naval powers (e.g. China) (Mizokami, 2018a; Woody, 2018a; Military Factory, 2019). The occupancy of the maritime domain by increasing numbers of ships and the multiplication of offshore

⁵ See Glossary for Definition of Sub-system ship.

activities (e.g. wind-farms, oil and gas) has constricted the maritime space and raised the probability of accidents.

Efforts to improve safety have focused on ship safety but have been oblivious to the larger context of maritime operations, despite some attempts such as that of the IMO in Shipping⁶ (ISM Code) (IMO, 2000). Warships, CG and Commercial ships operate within such operational and administrative systems. These ships could be seen as tools used to achieve the objectives (finality) of the systems. High level control of subsystem-warship relies on policies, instructions and crew performance to ensure goals are achieved. Crew performance is however influenced by the training of seafarers as stipulated by Standards of Training Certification and Watchkeeping (STCW, 1978 as amended) (IMO, 1978). In contrast, Navy and CG watchkeepers are largely trained and certified based on standards set by the specific Navy or CG authority. Non-maritime focused training such as staff officer qualification draws away from watchkeeping training (US Navy, 2017a). This may limit the experience of watchkeepers.

Indeed, how warships or CG ships with relatively larger crew using high-tech navigation equipment and commercial ships operating under strict safety standards regulated by IMO can collide in open waters is difficult to comprehend. Therefore, the research problem is to assess the influence of systems on the safe operation of their respective subsystem-ships (warships, CG ships and commercial ships) using system thinking. Due to the highlighted trend in warship accidents, this exploratory research is inclined towards discussions on warship safety.

⁶ See Glossary for definition of Shipping.

1.2 Dynamics of a Typical Maritime Operations Systems

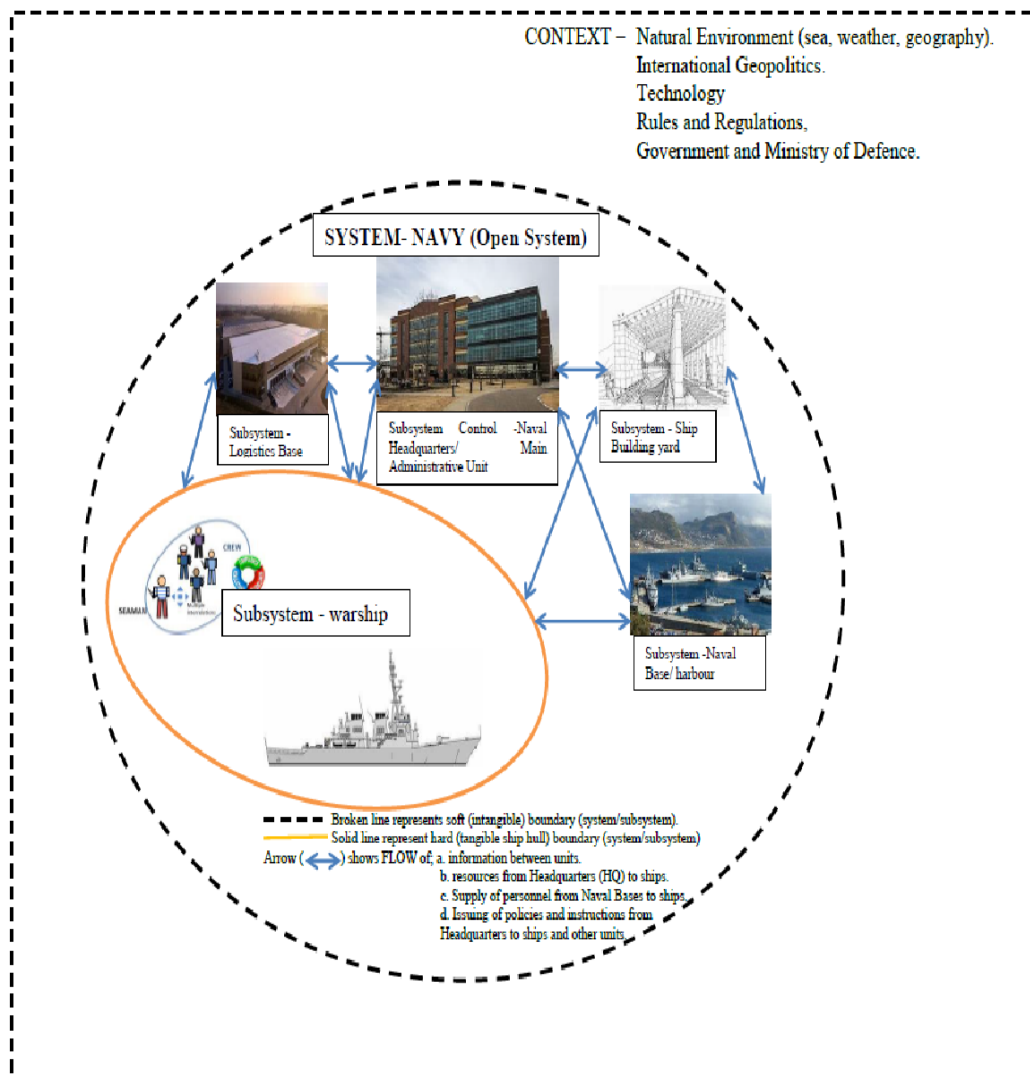


Figure 1: Modified diagram of system by Baumler (2019) to represent the dynamics of a Navy system. Source; Researcher.

Navy as a system is a collection of parts/elements/subsystems (warships, naval bases, harbours, logistics bases, ship building yards) which are interrelated/interconnected. A warship is an important subsystem (subsystem- warship⁷) of system-Navy⁸. Both are viewed as open-systems/subsystems. The interconnected

⁷ See Glossary for definition of subsystem-warship.

⁸ See Glossary for definition of System-Navy.

parts/elements in a subsystem-warship (engines and machinery, navigational equipment, weapons and weapon systems, rudders and propellers, crew, command structure) interact with each other. These interactions create a coherent whole producing a characteristic set of behaviour (war characteristics) to achieve an objective/finality (Meadows, 2008).

Elements with similar interactions (crew members of the same ship) fall into a subsystem while elements with dissimilar interactions (crew of a ship and an HQ administrative staff) fall in different subsystems (Pomeroy & Sherwood, 2006; Baumler, 2019). Subsystem-warships have a hard boundary since their boundaries are the hull of a ship. Subsystem-warships are highly influenced by HQ (systems control) inputs/decisions (policies, resources, instructions). They are also influenced by the wider environment (economic challenges, political system, and security situation) in which they are situated. These inputs and influences enable warships to achieve objectives (finality) and also build a stock⁹. Ineffective subsystem-warship administration or operation could lead to accidents. Further subsystem-warship discussions are in Chapter Four.

1.3 Aims and Objectives

The aim of this research is to explore Navy, CG and Commercial shipping operations with systems thinking to find trends and suggest ways to improve ship safety, particularly in relation to warship operations. This research seeks to attain the following objectives:

- To analyse the conduct of maritime operations in sub-systems (warship, CG and commercial ship) using the concepts of behaviour and finality.
- To analyse recommendations in recent warship, CG and shipping accident investigation reports to draw lessons which can be implemented in the 3 categories of maritime operations.

⁹ See Glossary for definition of stock.

- To examine systems- (Navy, CG and Shipping) and identify the effect of their respective context (economic, political, technical and ideological) on safety of ship.
- To suggests ways to improve the safety of warship, CG and commercial ship operations.

1.4 Research Questions

The research mainly seeks to investigate how system thinking could unveil the phenomenon of emergence and dynamics of safety in warship, CG and commercial ship operations. The work seeks to confirm whether the current conduct of maritime operations leads to the attainment of the allocated purpose (finality) of subsystems-ship. The following sub-questions serve as guide in answering the main research question:

- How the finality of warship, CG and commercial ships influences ship design and operation?
- Which institutional framework/culture predisposes ships to accidents?
- What are the strengths and weaknesses in warships, CG and commercial ships operations when considered as sub-systems?

1.5 Research Methods

To answer these questions, suitable research methods were selected. The research adopted qualitative methods of phenomenology, since it provides a means of in-depth exploration into the experiences and views of individuals (experts) (Yuksel & Yildirim, 2015). The individuals were selected based on their experience and according to purposive sampling (Cresswell & Clark, 2011). Such in-depth study of warship, CG and commercial ship safety in operations could reveal causes of recent trend of accidents and enhance its avoidance. Qualitative methods which seek to analyse phenomena and reveal details were preferentially selected instead of quantitative methods that mainly involve gathering data to generalise a phenomenon.

1.5.1 Data Collection

Data was collected from primary and secondary sources. Phenomenological data collections methods of focus groups and interviews were selected based on effectiveness in answering the research question (Palmer, Larkin, Visser & Faden, 2010). As stated by O'Dwyer & Bernauer (2013), validity, reliability and meaning were achieved through in-depth data collection, interpretation and thorough data analysis.

- **Primary Data.** The focus group used semi-structured questions. This gave the participants (mostly maritime professionals) the leverage to contribute and discuss the details of each subject to reveal insights. It also allowed discussions to lead to emergent topics. Focus Groups enabled in-depth exploratory study of the dynamics of safety in Navy, CG and Commercial shipping industry. A semi-structured interview was conducted with an expert in a mode of shipping with high safety standards (zero-accident record). This served as a reference point for analysis and comparison of safety of warship, CG and commercial ship operations.
- **Secondary Data.** Literature on application of systems theory; behaviour and purpose were reviewed. Finality and purposeful behaviour are highlighted in the literature review. These concepts are considered in Gestalt States, which means concepts in their whole functioning states (Koffka, 1935). Gestalts are used in classifying the properties of systems. Therefore, Gestalts of counterfinality and purposeful behaviour are subtly used to classify qualities of systems (Navy, CG and shipping) (Florio, 2015; Sevaldson, 2017). The research investigates whether the conduct of maritime operations (behaviour) seeks to attain the purpose (finality) of the subsystem-ship. This was achieved through an analysis of the organization and structure of subsystem-ship. The International Labour Organisation (ILO) and IMO regulations were also reviewed to find useful concepts on ship and crew safety standards. Some regulations reviewed

were SOLAS, STCW and Maritime Labour Convention (MLC) 2006 (ILO, 2006).

1.5.2 Data Analysis

Participants were carefully selected to ensure useful contributions of ideas to this research. The model of a high safety mode of shipping revealed the interconnections and interactions of components in a comprehensive view. Data was analysed to see if the goal of ships were achieved by their operation. This was in line with Meadows' (2008) view that "purposes are deduced from behaviour, not from rhetoric or stated goals." Additionally, Leveson's (2011) matrix of four control conditions was used in analysing ownership and mission of subsystem-ships.

1.5.3 Systemic Solutions

Systemic suggestions on ways of influencing change in safety, particularly for warships, followed a 12 Factor approach proposed by Meadows (2008). The 12-factors are leverage points in systems where a small influence could yield a large change in behaviour.

1.6 Organisation of Research

The research is structured in five Chapters with five Appendices.

- Chapter One gives an introduction to the whole topic highlighting the problem statement, research aim and objectives and proposed research methods.
- Chapter Two gives a literature review and sets the theoretical basis for the work. Systems concepts of finality and behaviour are critically analysed to extract key concepts. Allocated and Achieved finality are also explored. A visualization of the discussion and application of finality and behaviour in this work is shown in Appendix 3.

- Chapter Three explains the methodology used in the research. It justifies the choice of the qualitative method of phenomenology. It also explains why data collections methods of focus group and interview were selected as suitable methods for achieving the research aims and objectives. It describes how the research work was planned, organised and executed. Limitations of the research effort are stated.
- Chapter Four analyses data collected, describes demographics of participants, highlights presentation and coding of data. Data analysis looks at the subsystem- ships according to ownership, mission, design and construction, crewing and operations at sea. Emergent issues are discussed in the context of safety.
- Chapter Five concludes the research showing how the pre-defined aims and objectives had been achieved. The Chapter gives suggestions for improving in system safety, contribution of the research to knowledge is stated and recommendation future research is made.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction to Safety Concepts

The concept of safety has shifted from one with mystic and religious origins to one reliant on statistics, human decision making, and technology (Berstein, 1998; Manuel, 2011). Safety is generically defined as a condition with no accidents, incidents, near misses, or where the likelihood of these occurring is low (Hollnagel, Wears & Braithwaite, 2015). The development of safety has been reliant on technology and conceptual modelling. Heinrich (1931) proposed the Domino model (earliest model) depicting accidents as caused by a unique initiating event leading to the fall of other dominos (failures). This is a sequential model of accident causation focusing on root causes of accidents as depicted in Figure 2 (Hollnagel et al., 2015). To satisfy the need for more complex linear systems (comprising latent and active failures), Reasons (1990) developed the Swiss Cheese model, an epidemiological model shown in Figure 3 (Hollnagel et al., 2015; Li, Guldenmund & Aneziris, 2017).

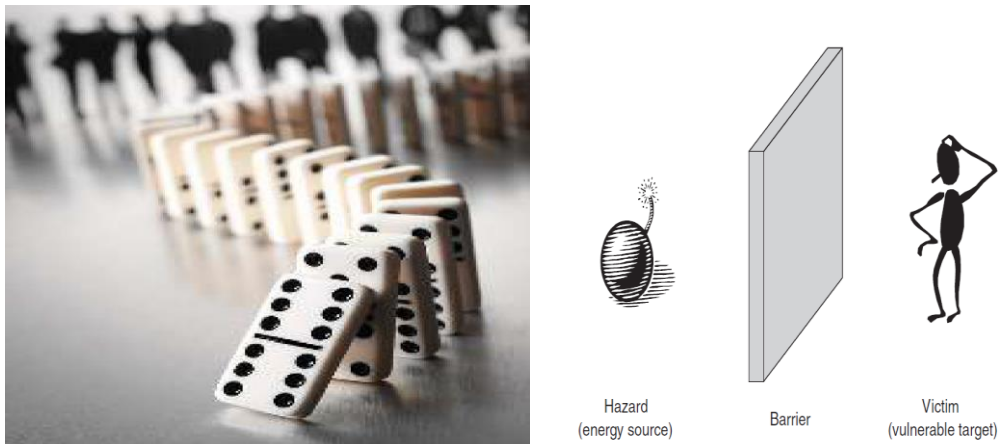


Figure 2: Linear/ Sequential models; Dominos in a series of failures and the Energy model by Haddon, (1980).

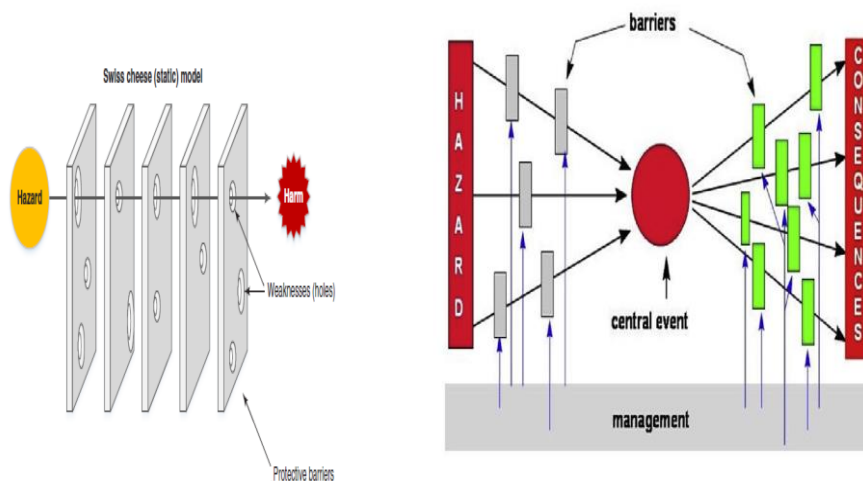


Figure 3: Epidemiological models (Swiss cheese and Bow-tie models). Source: Hollnagel, (2008) and Khan & Hashemi, (2018).

A shift in thinking from models with resultant outcomes to that of emergent outcomes triggered systemic models. Accordingly, the definition of safety changed from focusing on reducing negative events to one promoting positive events (Safety I – Safety II) (Hollnagel, 2014; Schröder-Hinrichs, Praetorius, Graziano, Kataria & Baldauf, 2015). Systemic models, such as Control theoretic and Confidence models, view the function of organisation, technology, human, and other elements as a whole (Hollnagel et al., 1999, 2015). Systems are therefore

defined as collections of elements or parts of a whole coherently organized with patterns of interconnection or structure that produce a characteristic set of behaviour to achieve a purpose or finality (Meadows, 2008).

2.1 Review of Systems Theory

Classic scientific approaches generally followed the reductionist or divide and conquer philosophy (Leveson, 2011). The reductionist approach to science and problem solving involves breaking a whole entity into parts and addressing the problem of each part in isolation from the whole. This approach assumes that parts interact to produce a linear sum or predictable product. However, interaction between parts may produce emergent properties which may not be a direct sum of the parts (Meadows, 2008). As stated in Sufi teaching story “You think that because you understand ‘one’ therefore you must understand ‘two’ because one and one make two. But you forget that you must also understand ‘and’. Therefore, a holistic (systems) approach would provide better understanding and control of systems (Meadows 2008; Leveson, 2011; Caws, 2015). Furthermore, by considering the context of the system a thorough understanding of its dynamics is achieved.

Ludwig von Bertalanffy (1968) applied systems thinking in his pioneering work in embryology and later mooted the concept of General Systems Theory (GST). GST seeks a unification of science and its approaches in all fields (von Bertalanffy, 1968). Systems theory has been applied by many scholars (Einstein, 1934; Koffka, 1935; Boulding, 1956; Katz and Kahn, 1978; Checkland, 1981; Winter et al., 1995; Rapoport, 1997; Meadows, 2008; Levson, 2009; Kruglanski, Köpetz, Bélanger, Chun, Orehek & Fishbach 2013; Sevaldson, 2017; Dauchot, 2018) in various fields (ecology, engineering, economics, anthropology, sociology, psychology, geography and the natural sciences) (Currie & Galliers, 1999). Furthermore, Pomeroy and Jones (2006), applied systems approach in re-

analysing 100 maritime accidents at sea to glean information on accident causal factors and latent failures that may have been missed in earlier investigations.

Despite many applications, systems theory is yet to be applied in a study of warship, CG and commercial ship accidents. This work fills that knowledge gap. The seminal work by Rosenblueth, Wiener & Bigelow (1943) on behaviour is the point of departure of this research. A detailed discussion on behaviour follows in the review of finality.

2.2 Review of Finality in Systems Thinking

Finality generally implies the purpose or goal(s) the system tends to achieve through behaviour (Castelle, Baugh & Bradley, 2015). In the literature there are variations of finality discussed as follows:

- **Equifinality:** is the phenomenon of having multiple strategies leading to the achievement of a specific purpose (Katz & Kahn, 1978; Skyttner, 2005; Castelle, Baugh and Bradley, 2015). In embryology, the development of a normal organism from a whole ovum or fused ova is a classic example. Different initial sizes and courses of growth in organisms could result in the same ultimate size organism (Waddington, 1957; von Bertalanffy, 1968; Zelazo, 2013).
- **Multifinality:** is the phenomenon of one particular strategy or action yielding different purposes (Castelle, Baugh & Bradley, 2015). Kruglanski et al., (2013), describe multifinality as one behaviour achieving multiple goals. The singular act of writing this review may seek to present an objective argument, impress the reader and defend an opinion (Kruglanski et al., 2013).
- **Counterfinality:** is a phenomenon or event that negates/invalidates another event from achieving its end state (Turner, 2014). This concept has vast potential in understanding socio-technical systems such as shipping, which while stating “Safety First” has relatively poor safety standards. Radar was

introduced on ships to assist navigators in avoiding collisions. However, over-reliance on Radar without applying time-tested navigational skills resulted in collisions leading to the coining of the term Radar-assisted collisions (Lee & Park, 2009; Schröder-Hinrichs, Hollnagel & Baldauf, 2012; Halpern, 2015).

It is necessary to investigate the reciprocal link between behaviour and purpose (finality), highlighting behaviour as a determinant of finality.

2.2.1 Behaviour of Systems

Behaviour means any change of an entity with respect to its surroundings (Rosenblueth, Wiener & Bigelow, 1943). Aptly, behaviour is defined in four cardinal views:

- Firstly, as the occurrence of an organism's action, inaction or reaction.
- Secondly, as a class of pattern of actions.
- Thirdly, as group behavior.
- Finally, as a change or movement of an object (Lazzeri, 2014).

Moreover, behaviour is an emergent property of systems that includes adaptiveness, goal-seeking, resilience, self-organisation or evolutionary behaviour. Therefore, behaviour can be considered as a result of system functions and objectives (purpose, finality, teleology¹⁰, goals). Behaviour can, therefore, be based on system inter-relations and interactions.

2.2.2 Classification of Behaviour

Rosenblueth, Wiener & Bigelow (1943), in their further works on behaviour, make distinctions in behaviour of systems focusing on attributes such as active, purposeful, feedback controlled and predictive behaviour. This is shown in Figure 4.

¹⁰ Fundamentally, Teleology is different from Finality. Teleology refers to a feedback driven purpose which leads to Finality as the ultimate end-state.

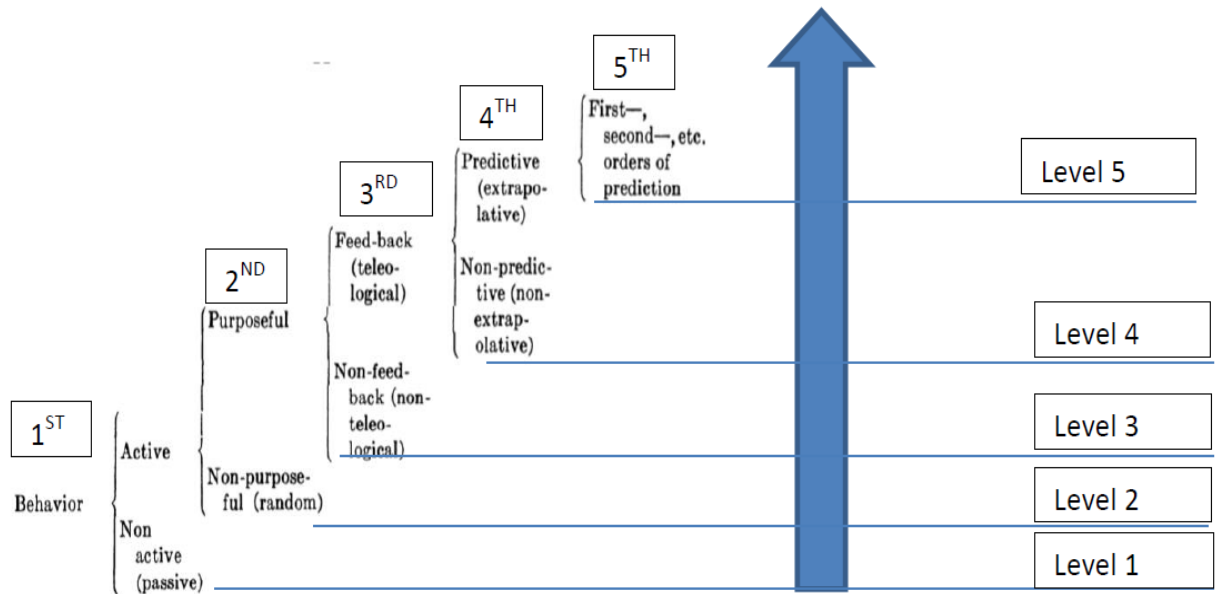


Figure 4: Adapted from Bias Pathway in Behaviour Description (Source: Rosenblueth, Wiener & Bigelow, 1943).

At **lowest/first level**, behaviour can be active or passive. Active behaviour means the object drives behaviour based on its energy, while in passive behaviour the object does not drive behaviour.

At the **second level**, Active behaviour can be divided into purposeless and purposeful active behaviour. Purposeful behaviour is the action of behaviour directed towards achievement of a goal (Mandl, 2019), while purposeless behaviour is not directed toward a goal. The concept of purposeful behaviour is supported by Castelle, Baugh & Bradley (2015) in their work on system axioms. They described purposeful behaviour as the tendency exhibited by systems in seeking goals. A more recent study of purposeful behaviour by Axelsson (2019) viewed it in the context of ecological validity. The study considered the environment to be as important as the organism under study. Therefore, both have to be studied concurrently in order to understand the behaviour of the organism. This joins Brunswick's (1952, 1955) claim that behaviours are probabilistic because the environment is non-deterministic.

At the **third level**, it is suggested that Purposeful behaviour may be feed-back driven (teleological) and non-feedback driven (non-teleological) (Rosenblueth, Wiener & Bigelow, 1943):

- Non-Feedback behaviour means no signal is captured to adjust behaviour.
- Feedback behaviour means that the studied system collects information on its behaviour to adjust it accordingly. For example, the continuous monitoring of ship's position is a feedback loop because it leads the Officer of the Watch (OOW) to adjust the ship's heading according to deviation from the expected route. Figure 5 shows a simple feedback system.

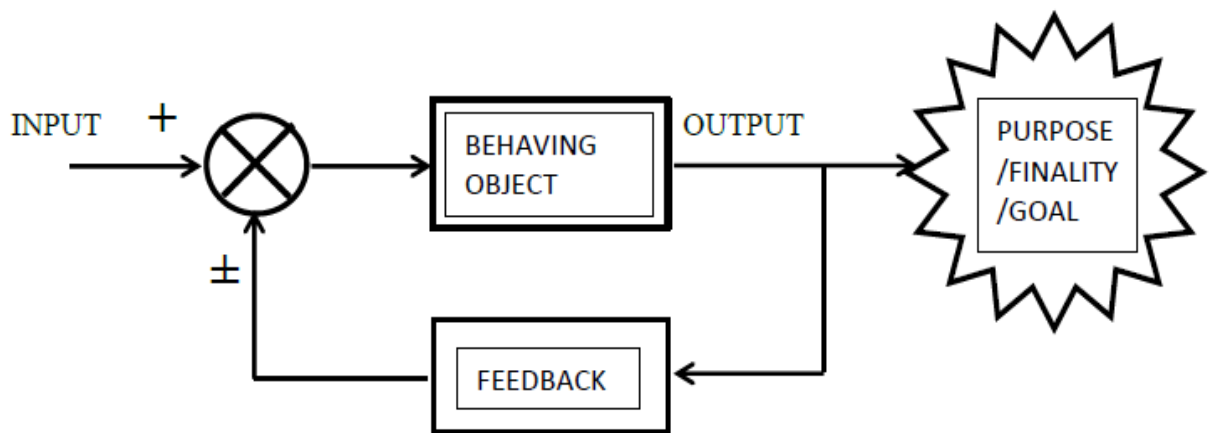


Figure 5: Model of an open system with a feedback loop.

At the **fourth level**, behaviour is Purposeful, Feedback driven and predictive. It means such behaviour exhibits predictive tendencies which could be divided into orders depending on the ability of the system to predict events.

At **fifth level**, Predictive behaviour requires the manipulation of a minimum of two coordinates; one being temporal with the other spatial. This capability of systems is dependent on their sensory receptors (Observability capacity).

De Florio (2014) reviewed two milestone works on systems behaviour by Rosenblueth, Wiener & Bigelow (1943), and Kenneth Boulding (1956) on

Systems in a social setting. De Florio identified five classes Random, Purposeful, Reactive and Social Behaviour.

Castelle, Baugh & Bradley (2015) posit that system improvement could be achieved by studying the goals, goal-oriented behaviour functions and purpose of systems.

Therefore, studying the goal oriented behaviour and purpose of different subsystem-ships will support an analysis of safety because behaviour is determined by systems structures and components as well as being goal-directed by its finality/teleology¹¹.

2.3 Safety Regulatory Approach

Historically, maritime safety regulations were adopted after devastating accidents (Juda, 1977; Psaraftis, 2002; Schröder-Hinrichs, Hollnagel, & Baldauf, Hofmann & Kataria, 2013; Karahalios, 2017). Pomeroy, & Earthy (2017), state that though these regulations have improved the safety of ships, ship accident records have not improved recently. Others such as Bhattacharya (2009) opine that safety regulations have yet to achieve their full potential. Notwithstanding, there is the need to further improve their effectiveness. The Goal-Based Approach (Proactive Approach) is a laudable safety and risk approach (Ministral Rosa, 2018). Similarly, thorough safety investigation as mandated by the Casualty Investigation Code (2010), Regulation XI-1/6 of SOLAS, is one crucial way of improving the effectiveness of regulations (IMO, 2010). Additionally, it is useful to learn from other industries, but this approach is often dismissed because the maritime sector has unique conditions (Pomeroy, & Earthy, 2017). The concept of resilience¹² in safety as proposed by scholars (Manuel, 2011; Praetorius and Lundh, 2013;

¹¹ According to De Florio (2014), purposeful behaviour is considered as finality while predictive behaviour is considered teleology. However, as this work relates to purposeful behaviour including predictive and reactive, finality and teleology will be used synonymously.

¹² See Glossary for definition of resilience.

Praetorius and Hollnagel, 2014; Schröder-Hinrichs et al., 2015; Jain, Reese, Chaudhari, Mentzer & Mannan, 2017) could improve safety of shipping.

However, a practical case of shipping with very high safety standards would be a crucial model for improving safety. This review identified Pacific Nuclear Transport Limited (PNTL) ships to have a very high safety record (PNTL, 2019) and worthy of in-depth study.

2.4 Summary

Contemporary safety issues are viewed in a systemic approach. This study fills the knowledge gap by applying systems thinking to an analysis of warship, CG and commercial ship safety. Safety in systems is better understood through analysis of behaviour and finality. Counterfinality may be the reason why high safety is elusive in ship operations. Ship operations may exhibit purposeful feedback-driven or reactive behaviour. They may also be predictive or proactive in behaviour. Ships as socio-technical entities may exhibit social behaviour through their hierarchy, communication links and organisation. Safety regulation has evolved from reactive to proactive (GBS) in approach. Higher safety standards may be attained from studying a shipping system operating with risk level at as low as reasonably possible and zero-accident record.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Research Methodology

Research could adopt various strategies or methods (Verschuren & Doorewaard, 2010). The choice of a suitable method depends on the ability of the method to achieve the research aim and objectives (Gray, 2013). Qualitative methods were selected due to the quest of this research to investigate safety in shipping. Qualitative methods have desirable attributes in the ability to fit a context and reveal insights on a topic. They are easily applicable in a real world context and have the ability to address complex issues. Though qualitative research investigates a small number of cases, it examines those few cases in great detail and draws deep meanings (Mahoney & Goerts, 2006; Creswell 2014; Lune & Berg, 2017).

Specifically, phenomenology approach was used in the research. Phenomenology enables the exploration of experiences of individuals to reveal the true form of phenomenon or attributes such as safety (Kafle, 2011). This enhances understanding and the possibility of developing credible solutions. However, there may be a gap between solutions from the research and what can actually work in real life. Manuel (2011) suggested that the insulated settings of theoretical research requires solutions or recommendations to be adjusted to fit the practicality of the real life shipping industry. The shipping industry is a socio-technical system that requires practical measures to resolve its complicated

challenges. Solutions to such challenges should be descriptive and practicable. Qualitative approach, which enable in-depth study to give insights into novel topics or unexplored phenomena, is therefore used in this work (Panke, 2018). The most widely applied data collection methods of interviews and focus groups (Gill & Baillie, 2018) were used to gather sufficient perspectives on warship, CG and commercial ship safety.

3.1 Focus Group

A focus group is a well-planned series of discussions structured to gain perceptions on a particular subject of interest in a permissive, nonthreatening environment (Morgan, 2018; Young, 2019). Krueger & Casey (2015) assert that focus groups are successful because they produce useful results at a reasonable cost. A total of 6 focus group sessions were conducted in this study. Three sessions served as preliminary sessions and another three as main research sessions. The three preliminary sessions served as a "climate survey" and aided in planning and selecting the research theme and questions.

The main research sessions formed the core of the work. Krueger & Casey (2015) opine that the purpose of focus groups should be clear and encourage discussions on ideas. They should also clarify opinions, and make recommendations on a course of action. The main research sessions had a clear purpose of collecting data to answer the research question. Discussions clarified biased opinions and ended with suggestions on ways to improve safety in systems.

The sessions were founded on a three-stage strategy aimed at identifying trends and perceptions for effective comparison and contrast of data. The first focus group of the main research session provided an understanding of the topic; the second served as a pilot test and the third focus group (purpose-made) enabled evaluation of data as shown in Figure 6. Therefore, the findings in this research are from the three focus groups of the main session only.

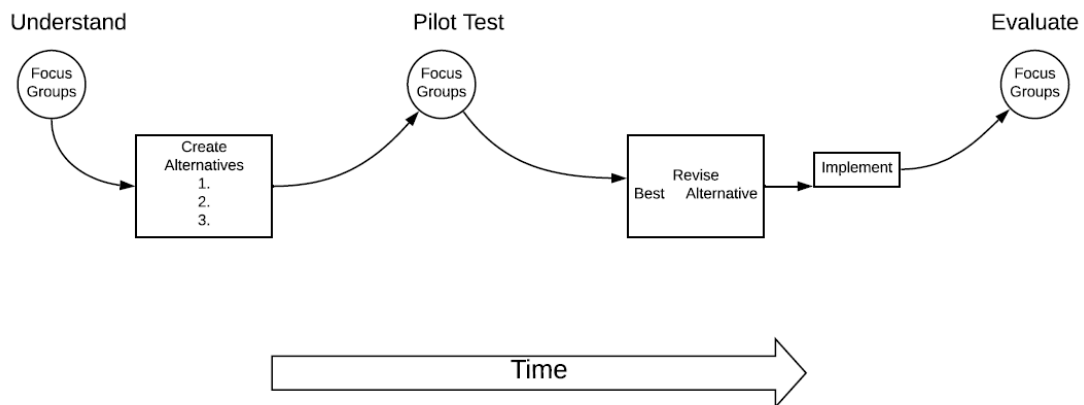


Figure 6: Three-stage strategy for research focus groups (Kruegar & Casey, 2015).

3.2 Interview

In such an exploratory study, the need for a benchmark for discussions was essential. PNTL, a member of the World Nuclear Transport Institute (WNTI), has incredible safety standards with a zero record of accidents (Chaplin, 2019), making it an excellent benchmark of “Safety First” for the whole maritime industry. This model of “Safety First” was developed from a one-on-one interview with a seasoned Master Mariner, with 26 years sailing experience (6 years as Master) on PNTL ships. To build a watertight model, the primary data gathered from the interview (primary source) were supplemented by data from internet sources (secondary source).

This study followed a semi-structured interview approach using open-ended questions. This approach allowed the interviewee to respond without providing clues or setting boundaries on anticipated answers (Krueger & Casey, 2015). The non-directive approach enabled the development of a rich model. Deductively, practices, standards and measures which make PNTL ships operate at high safety standards could also make warships, CG and commercial ships safer.

On completion of the interview, extensive time was dedicated to manual transcription. Auto-transcription was not used since there are higher chances of error necessitating a re-transcription and equating the work effort to a manual transcription. Submitting the whole raw data from an interview to an online transcription service may not be ethical. Regardless, manual transcription provides the opportunity to review answers and glean subtle meanings, which may not be possible with auto-transcription. Additionally, manual transcription enables re-organization and effective structuring of answers to enhance meaning. Lecture notes from a series of four lectures presented on PNTL to the Maritime Safety and Environmental Administration 2019 class in World Maritime University were used to supplement the interview.

3.3 Participants

Focus group participants were selected based on professional experience, unique qualities and the ability to contribute rich information to the research purpose (Etikan, Musa & Alkassim, 2016). All participants in this research had maritime or maritime affiliated backgrounds.

Moreover, the setting of all focus groups made participants feel comfortable; respected, willing and free to give opinions without judgement. There was spontaneous self-disclosure among participants, revealing what they really thought and felt. This was due to participants sharing similar backgrounds. Therefore, many opinions were offered towards the achievement of the research aim.

Participants were introduced to the research topic and the respective methods (focus group and interview). Forms explaining research ethical and confidentiality standards were administered. Participants signed the forms, giving full participatory consent.

3.4 Data Collection

During focus groups, data was collected on whiteboards and organised in tables. Data collected was compared and contrasted without necessarily coming to a decision or consensus. All focus groups were supplemented with audio recordings and photographs. Photographs have a history of being effective tools in research; particularly in anthropology and ethnography (Flick 2006; Gray, 2009). Photographs capture details and are quicker than the human eye in recording facts.

Data was collected with open-ended questions during both focus group and interview. The questions were sequenced from general to specific.

Audio recordings, supplemented by notes, were the main tool for collecting data during the interview. Questions were carefully selected, sequenced and organised in the following thematic areas:

- The owners of ships and maritime operations systems.
- The main mission of each maritime operation system.
- The critical safety design factors of the various ships.
- The recruiting, organization and training of crew as individuals and a whole.
- Certain critical operations conducted at sea.
- The management of fatigue.
- Factors considered in promotion of crew.
- Sea time and its effect on crew fatigue and capability.

3.5 Theoretical Orientation

The theoretical orientation of the research is based on application of the highlighted concepts of systems theory in Chapters 1 and 2. As earlier stated, finality is derived from behaviour and not rhetoric or stated goals. Finality and behaviour are the main theoretical themes in this research. Equifinality, counter finality and purposeful behaviour are important facets of the two main themes

which guided this work. Additionally, allocated finality¹³ or “espoused theory” may differ from achieved (real-life) finality¹⁴ (Argyris & Schon 1996; McLaren 2015). Therefore “safety first” can be the allocated finality of a ship, but not its achieved finality.

3.6 Reliability, Credibility and Transferability

Reliability and validity of such a research relies on its conformity with ethics, framing of data collection, analysis and the way findings are presented (Meriam & Tsidell, 2016). The researcher used thorough approaches in collecting data and applied systems thinking tools and matrices to analyse data and present findings in a sequential manner.

To ensure credibility, participants were given transcribed copies of focus group sessions and interview to peruse for accuracy and correct if necessary.

Transferability is proving that research findings could apply to different context, times and populations (Lincoln & Guba 1985; Statistics Solutions, 2019). Generalizability and transferability is deemed to be low in phenomenological studies (Johnson, Onwuegbuzie & Turner, 1997). The researcher enhanced transferability by giving “thick description”¹⁵ (Ponterotto, 2006) of the research settings and data collection methods.

3.7 Research Ethics

This research complied with WMU’s Research and Ethics Committee and generally accepted research ethics standards. Consent of participants was obtained and documented on a form prior to interview and focus group sessions. A sample of this form is in Appendix 5. To ensure transparency and gain confidence of the

¹³ See Glossary for definition of allocated finality.

¹⁴ See Glossary for definition of achieved finality.

¹⁵ See Glossary for explanation of thick description.

interviewee, the purpose, essence, sequence, and future use of interview and focus group answers were explained.

All research participants completed the consent forms after agreeing, without reservation, to partake in the discussions. Interestingly, participants were eager to offer answers and even provided unsolicited answers which enriched the research. Both the interview and focus groups exceeded their allocated time period and had to be stopped by the researcher.

3.8 Limitations of the Study

It would be shallow and hypocritical not to indicate that a novel study as this would be without limitations. The limitations influenced the definition of the research topic, data assessment, test for reliability and validity of data and choice of research methods. The researchers' rationality of limitations was bounded and became relatively comprehensive upon completion of the study.

3.8.1 Limitations of Qualitative Study

Qualitative research is known to be limited by biases and subjectivity in opinions of respondents. Largely, perceptions may not be true and this is a limitation in obtaining objective results and fair analysis. Additionally, the results of a qualitative study may be limited to the context of the study and may not be applicable in other contexts which may even have similar characteristics. However, to gain insight into subjects it may be necessary to sacrifice generalization for precise investigation.

3.8.2 Participant Perception and Rhetoric

Perceptions of safety practices and standards in their system of operation may be higher than what really pertains. This may be due to the need to create a good perception or perpetuate rhetoric. These differences between reality and perception could have affected the study and were addressed by cross-examining

responses. Similarly, some participants intellectualized answers to make them seem thoughtful and reflective. However, real-life decision making is unconscious (Zaltman, 2003) and different from focus group answers.

3.8.3 Experience of the Researcher

The researcher, as a serving naval officer with some training in commercial shipping operations, tends to view answers with a bias based on experience. The particular tendency for the researcher to be prejudiced in assessing the safety standards of warships is high. Flick (2006), asserts that qualitative research data could be misinterpreted due to the influence of the researcher's own opinion. However, this was addressed by having a moderator (supervisor) for the focus group who was a commercial ship Master with some naval experience and by reducing the researcher's interview both in the focus group and interviews.

3.8.4 Data limitations

Though the researcher cited many cases of recent warship accidents, data from investigative reports was limited. Except for the US and Norway Navies, which show transparency, most navies have no open publications of accident reports or even official publication of accidents. More often, the work cites US and Norwegian accident cases because of the availability of information.

3.8.5 Time Limitation of a Master's Programme

Data collection through interviews and detailed engagement with navy, CG and commercial shipping companies was limited by time since the research had to be completed within the space of 14-months for an MSC in WMU.

3.9 Summary of Chapter

The research used qualitative methods of focus groups and interviews to effectively investigate and collect data on the dynamics of safety on ships. These produced findings that fit the socio-technical industry of maritime operations. Six

focus groups, divided into two parts of three, were held. The first three set the tone for the research and the second three gathered data to answer the research question. An interview to build a model of “Safety First” on PNTL ships was conducted to serve as benchmark for analysis.

All participants in the research had maritime or affiliated backgrounds. Data was collected using semi-structured questions in order to allow emergent opinions. Notably, allocated finality may not be achieved. Limitations were considered through all stages of the research and measures were taken to mitigate their effects on outcomes.

CHAPTER FOUR

DATA ANALYSIS

4.0 Introduction

This chapter presents and discusses the data, demographics of participants and data coding. The chapter focuses on data analysis and concludes with a summary of the analysis.

4.1 Data Presentation and Participant Demographics

To enhance clarity of presentation, data from the focus groups and interview are presented in tables as shown in appendices 2 and 4, respectively. Data are grouped under similar headings to enable easy correlation and analysis.

4.1.1 Interview (PNTL Model)

Data from the interview were sectioned into 5 themes: owners, mission, design of ship, crew, operations of ship at sea as well as emergent discussions. Emergent discussions centred on involvement of management and role of regulators in ship safety. The PNTL Model served as a benchmark of an organisation with safety as achieved finality. The organisation and operations of PNTL ships were used in the analysis.

4.1.2 Main Focus Groups

Tables in Appendix 4 are organised into 5 thematic parts: ownership and mission, crew, design of ship, operations at sea and emergent discussions. Each part

contains consolidated data from the focus groups (main research session). Participants of the focus groups had relevant seafaring expertise and experience in warship, CG and commercial ship operations. However, in some working groups, persons without seafaring experience also participated in discussions. Discussions were conducted on the following dates with persons grouped as indicated subsequently:

- Focus Group 1 was held on 16 January 2019 with 8 students of Maritime Energy Management Class. Professionally, the 8 students represented a Captain of an oil rig, Chief Engineer, warship Captain, Second Engineer, Economist, Computer Engineer and two classification society Surveyors. These participants were from 8 different countries in Africa, Europe and Asia.
- Focus Group 2 was held on 22 January 2019 with 22 students of Maritime Safety and Environmental Administration Class. The 22 students comprised 8 Maritime administrators, 7 Merchant mariners, 5 CG officers, 2 Naval officers and 2 classification society Surveyors. Participants were from 20 countries in Asia, Africa, Middle East, the Caribbean, Pacific Islands and South America.
- Focus Group 3 (Purpose-made focus group) was held on 4 June 2019 with 9 persons selected based on their unique experience in warship, CG and commercial ship operation. The 9 persons included 3 persons each with experience in Navy, CG and Commercial ship operations. The group comprised a balanced spread of participants from 9 different countries across Middle East, Africa, Asia and South America.

Participants from each category of maritime operations were interested in highlighting the negatives of the other categories while defending and boosting the positives of theirs. This shows the inertia of systems to learn from others. Therefore, participants had poor perspective of other modes of maritime operations. The moderator (research supervisor) and assistant moderator (researcher) had cross knowledge in the various areas discussed having undergone

training and served time on ships of different systems. This served to correct these misconceptions, which could have negatively impacted the research. The participants were actively encouraged to contribute opinions during the discussion and measures were taken to prevent the dominance of few individuals. Again, the discussions confirmed the theoretical background of the research given in the earlier three chapters indicating that behaviour is an indication of purpose and not rhetoric.

4.2 Data Coding

To enable clarity, colour codes were used to represent data found in multiple and individual focus groups. **Green** for multiple (2 or 3) focus groups, **blue** for focus group 1, **red** for focus group 2 and **purple** for focus group 3, in that order. The colour coding used in this research is based on Grounded theory (Burnard, Gill, Stewart, Treasure & Chadwick, 2008; Skjott Linneberg & Korsgaard 2019). Coding was used for focus group data only.

4.3 Data Analysis

The research used qualitative content analysis in studying data from documents, audio, video, and photographs (Hseih & Shannon, 2005; Verschuren & Doorewaard, 2010; Boréus & Bergström, 2017; Lune & Berg, 2017). Prior to the commencement of the purpose-made focus group, participants were required to indicate which category of ship was the safest. Most respondents indicated that they considered the ship environment or category they work in as safest, which shows that subjectivity influenced perception of safety. Additionally, individuals judged safety with a parochial view of their institution, without the ability to compare and project themselves in other sectors with different safety practices and constraints.

4.3.1 Analysis of Ownership and Mission as High Level Control and Finality

Subsystem-Ships form important parts of maritime systems. Each system works to achieve finality and each subsystem participates in achieving the overarching finality.

The owner can be assimilated as the control element because they have the ultimate power. They impose constraints in order to drive behaviour of ships towards achievement of the overarching company/organisational finality. Social systems such as private or public companies have mechanisms of control. Owners in social systems use various control mechanisms which could be formal (specific laws and processes) or informal (culture and traditions). Communication or flows (physical, monetary, etc.) are necessary to bind systems together and to ensure the effectiveness of the control. In our studied systems, control relies heavily on information distribution, written documents, verbal orders, resource allocation and supply systems.

Notably, ownership of a system gives the legitimate power to determine the type of control mechanism to influence behaviour and to achieve **allocated finality** (Leveson, 2011). Effective control ensures coherence and stability (through resilience) of the system. Control mechanisms in the Navy and CG are typically constructed as vertical hierarchies of command. In shipping companies, the top management, appointed by owners or shareholders, exercises control over the system and its subsystems.

In order to assess the overall performance of a system (including its safety aspects), Leveson (2011) proposes a matrix of analysis highlighting the importance of feedback loops and controls. Therefore, the researcher considers that efficient control processes have to fulfil these four conditions:

- **Goal Condition.** The controller must have a goal or goals. FINALITY could be actually achieved or just rhetoric. Finality is the final state of the

goal. It is synonymous with Aristotle's idea of "Final Cause" as stated in Pérez-Álvarez (2017). Though a specific finality could be stated (rhetoric), behaviour could lead to a different achieved finality. The achieved finality could counter the allocated finality.

- **Action Condition.** The controller must be able to affect the state of the system, and have POWER over the system and its parts (Leveson, 2011). It is the ability to affect or influence the functioning of the system.
- **Model Condition.** The controller must be (or contain) a model of the system (Leveson, 2011). It is ability to UNDERSTAND the system itself, its part and its functioning. Since this work is viewed in an open social-technical system there is the need for participants (people) in the systems to contribute to the modeling of the system. The model so obtained would be a best-fit for the specific environment and not just a best model.
- **Observability Condition.** The controller must be able to ascertain the state of the system (Leveson, 2011). This entails the ability to COLLECT DATA and INFORMATION from parts of the system and subsystems. It shows the importance of feedback loops in systems.

Additionally, effective systems control requires effective communication flows. Moreover, communication in the system does not only enable transmission of information but also binds the systems as a coherent unit. This binding ensures interaction between parts in order to form a complete whole having emergent properties. As per Leveson (2011), safety is an "emergent property of systems". In this work, the ship being a subsystem, we can deduce that the safety of the overall system depends on the safety of each subsystem. The accidents involving KNM Helge Ingstad, USS McCain and USS Fitzgerald affected the overall Navy system (US Navy, 2017a; AIBN, 2018). This is identical in the context of shipping where a single casualty can damage the entire system. In the case of Herald of Free Enterprise or Exxon Valdez accidents, the entire network of related shipping companies (system) folded or changed ownership (MSA1894, 1987; NOAA,

2014). Safety is, therefore, important for survival of shipping institutions and navies.

In open systems such as Navy, environmental factors need to be considered. A system environment is the immediate surroundings that interact with the system and can influence the functioning of the system. In this respect, the economic crisis in Argentina affected the allocation of resources to the Navy which ultimately impacted its vessels leading to a major disaster for a submarine (Woody, 2017; Archus, 2019). Indeed, a system component (e.g. a ship- subsystem) may function safely in an environment but could malfunction and cause accidents in another environment (natural, social, economic, political, and cultural).

4.3.1.1 Warships in Navy-system

Warships, as subsystems, have individual finality which forms part of the overall finality of the System-Navy. The Navy has other subsystems and components like network of buildings and people constituting administration, logistic support, medical care, repair yards, personnel accommodation, financial and training institution. Each subsystem has its own finality, which leads to the achievement of the overall finality of the System-Navy. At the centre of these subsystems is the control element (ownership) which is the Government or Ministry of Defence (MoD). MoD decides and exercises its control via strict hierarchy of command, which circulates information flows between all parts of the system in order to guide each part's behaviour.

Hierarchical mechanisms imply that there are at least two levels in the system. Navy systems and even subsystems have several levels of command, structured to facilitate task execution and relay of orders. A typical warship-subsystem hierarchy is shown in Figure 7, with highest authority being the Flag Officer Fleet (FOF).

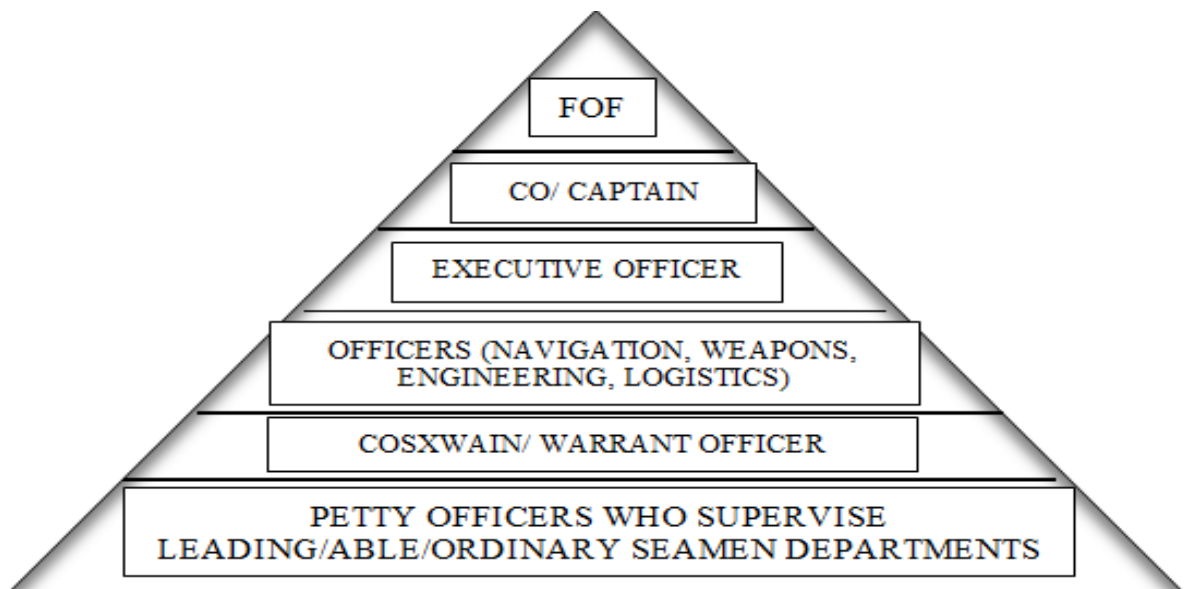


Figure 7: Typical subsystem-warship Hierarchy or Command Structure. Based on British Navy and Commonwealth Navy structure. Source: Researcher

Communication of policies, instructions, feedback and resources is attained through hierarchical structure. It is a two-way communication mechanism from higher command to lowest rank individuals and vice versa.

Under government control, MoD acquires legitimate power over the System-Navy and set the necessary constraints to guide behaviour as determined or allocated. In rare cases, accidents occur which are largely out of the control of MoD or even warships. The earlier stated case of MT Sama running into a Taiwanese Frigate Ning Yang berthed in harbour shows an accident that MoD or the frigate could have done little to prevent (Strong, 2019). The four conditions in the warship context are as follows:

- **Goal Condition.** The goal of the System-Navy is to protect State interests using the maritime domain (e.g. defence of national territory and the projection of national power abroad). This requires subsystem-warships to conduct combat operations against external aggression or other military (or non-military) vessels. Safety is not an allocated finality of subsystem-warship but an essential condition for success in military operations. For

example, the US Navy in the Pacific maintains a combat force ready to be deployed for protection of US interests (Sputnik, 2015; US Pacific Fleet, 2016). Therefore, it may be “mission first” in navies. However, such overseas deployment has cost implications and can lead to a drain on resources. The result would be a decision to make cutbacks which have possible negative effects on safety.

- **Action Condition.** Action condition entails MoD’s ability to command and direct operations, administer personnel, manage and allocate resources, and promote, reward and punish undesirable acts. Generally, action condition is having power over the system to attain allocated goals. For example; the decision by the US Navy to train sailors according to standards in STCW could greatly improve training and performance of sailors (US Navy, 2017a). However, re-occurring accidents may be evidence of an insufficient action condition. On 22 April 2017, a fire incident occurred on Chilean warship Sargento Aldea during maintenance works on oxygen bottles for the ship’s infirmary. A similar explosion and fire incident re-occurred on 29 August 2019 on the same ship during similar maintenance but this time led to crew injuries (Sabado, 2017; Voytenko, 2019b). Some actions or influences may also lead to negative unintended effects.
- **Model Condition.** A good model condition is the capacity of MoD or Navy Headquarters (NHQ) to understand the subtleties of subsystem-ship functioning. In socio-technical systems, model condition should be fitted to the environment or paradigm in order to be effective. Wrong understanding/construction of the model, the environment or the paradigm of operation may challenge the subsystem efficiency, performance or safety. To ensure models are as accurate as possible, participants in the operations of the model (Captain, watchkeepers and sailors) must partake in the refinement of the modeling.

A good warship Model condition can be achieved through enhanced communication flows between MoD or NHQ decision-makers and operators through trust and established feedback loops. For example, the decision of the Argentinian Navy to cut budgetary allocations to ships should have considered the specificities of submarines. Submarines have special propulsion systems and operate in an enclosed environment without escape. The investigation suggested that budgetary cutbacks and insufficient maintenance resulted in deterioration in the operational status of the submarine. The sinking of San Juan (S-42) has been attributed directly to a fire in batteries though budgetary cuts and wider organizational failure seems to be the main causes (Cropsey, 2017; Archus, 2019). Indubitably, Navy authorities knew the specificities of submarines but seemed unable to model the impacts of cutbacks on maintenance of such vessels.

However, the Russian Navy changed its approach to integrate environmental changes. Contrary to the US Navy, the Russian Navy is not pursuing an interventionist strategy but rather intends to maintain a regional presence of small ships (Axe, 2019). Consequently, the Russian Navy has adapted its subsystems-warships accordingly. It is building smaller ships with a full load of armaments instead of large ships (Axe, 2019). Following the sinking of the PD-50, a floating drydock which was used to maintain the aircraft carrier Admiral Kuznetsov, Russian Navy HQ has planned to decommission the aircraft carrier (Kut, 2018). This shows flexibility in modelling warship operations but its impact on safety is yet to be observed.

- **Observability Condition.** Observability in the Navy system is the ability of MoD or NHQ to accurately assess the status and confirm the proper functioning of any part of the system at any period. The formal feedback mechanism in Navies follows hierarchical communication and its multiple levels. This feedback structure could lead to distortion/disruption of

information, particularly in can-do cultures such as the US Navy (US Navy, 2017a). Can-do culture leads ship Commanding Officers (COs) to attempt challenging tasks with continually decreasing resources without questioning or complaining about related-risks. COs with Can-do culture are usually glorified as resourceful. This could gradually degrade the safety standards across the fleet, leading to series of accidents (possibly the case in the US Navy). US Navy High Command seemed not to properly understand the operational condition of ships deployed in the Pacific fleet as demonstrated by the casualty investigation concerning USS McCain and USS Fitzgerald (US Navy, 2017b). It shows a limited observability condition, missing feedback to top management on the true state of ships (US Navy, 2017a). Poor observability condition has been highlighted by an investigative report to the Argentine parliament as the cause of the loss of San Juan (Rey, 2019). Navies should consider multiple ways of gathering accurate feedback in order to ensure an appropriate level of operational demand on each part (subsystem) of the entire system.

4.3.1.2 Coast Guard Ships in Coast Guard Institution-System

Control in CG is often similar to that in Navy because some CG institutions are structured as military organizations under the MoD. The four control conditions analysed in the CG system are as follows:

- **Goal Condition.** This condition involves policing and emergency response. These goals require specialized training, relevant equipment and sufficient resources. Notably, CGs goals are easily observable when achieved. CG and Naval goals could conflict, particularly in coastal maritime security (Bansal, 2008; Blickstein, Conley, Tannehill, Schendt & Etchegaray 2018). However, they share the same overall objective which is to protect State interests.
- **Action Condition.** Similar to Navy, the controller of the system is CG Headquarters (CGHQ) which depends on government/Ministry (Defence

or Interior) decisions. The strict military hierarchy makes the control system mechanical, i.e., top-down and authoritative structure. During the 2019 US federal breakdown, the USCG was affected by the lack of budgetary in-flows (Woody, 2019). This lack could have affected missions and general order in the organisation since salaries were also affected. In this respect, the Commandant of the USCG Admiral Schultz declared the commitment of USCG to fulfil its missions (relying on budgetary stock) while awaiting budgetary inflows (Woody, 2019). This example shows that the control structure of any system is heavily dependent on in-flows and stocks. A prolonged disruption of in-flow and empty stock would affect the overall command structure and the survival of the system. The decision to initiate actions also depends on in-flows of information as shown by the following example. The recent encounters and collisions between Chinese and Taiwanese ships have caused the Taiwanese CGHQ to decide to install anti-collision systems on 17 of its new ships (Martina, 2019). This shows a good action condition which could improve safety of ships and crew as well as ensure effective patrols.

- **Model Condition.** Model condition depends on the ability of CGHQ to model subsystem-ship function of saving lives, protecting the environment or enforcing regulations. Following the 2016 USCGC Thetis versus towing vessel Matachin accidents in Panama the model of operation of USCGC in the complex environment of the canal may not have been appropriate. The 2017 collision between USCGC Tampa versus tug boat Cerro Santiago (NTSB/MAB-17/22, 2016; NTSB/MAB-17/37, 2017) in similar conditions at night supports this position.
- **Observability Condition.** Observability is also influenced by a vertical hierarchical structure. This may cause authority gradient which cripples the ability to gather accurate feedback. The collision between USCGC Cuyahoga and MV Santa Cruz II is a classic case of authority gradient where the Commanding Officer (CO) of the ship made an incorrect

assessment of the navigational situation (USCG, 1979). Due to the strict command structure on the ship, no crew member could give the CO feedback on the looming danger.

4.3.1.3 Commercial Ships in Shipping-System

Ship-owners or company¹⁶ are defined in international regulations as the control system of ships because they assume the “responsibility for the operation of the ship” either directly as owners or through subcontractors (reference to MLC, 2006 and ISM Code). Here-after, shipowner/company represents all forms of private control over commercial ships. In this context, ships are subordinate to the power of company management.

- **Goal Condition.** The specific goal of ships (subsystem) is to carry-out maritime activities in order to generate profits for shareholders. Shareholders have legitimate power and define management structures to remotely control and command ship operations. Shipping companies claim “Safety First” because it is a mandatory requirement allocated under the ISM Code (IMO, 2000). Despite the “Safety First” rhetoric, the behaviour of some ships may be in contradiction. It indicates that “Profit First” may be the real goal to attain. For example, Exxon shipping had “Safety First” as an allocated finality. However, the reduced manning levels and increased work load on crew generated the condition of unsafe practices (counterfinality) leading to the Exxon Valdez disaster (NTSB/MAR-

¹⁶ As The ISM Code (#1.1.2) defines company as: the owner of the ship or any other organization or person such as the manager, or the bareboat charterer, who has assumed the responsibility for operation of the ship from the ship-owner and who, on assuming such responsibility, has agreed to take over all duties and responsibility imposed by the Code."

The MLC 2006 defines shipowner as: the owner of the ship or another organisation or person, such as the manager, agent or bareboat charterer, who has assumed the responsibility for the operation of the ship from the owner and who, on assuming such responsibility, has agreed to take over the duties and responsibilities imposed on shipowners in accordance with this Convention, regardless of whether any other organization or persons fulfil certain of the duties or responsibilities on behalf of the shipowner.

90/04, 1990). Therefore, the goal of “Safety First” should be deduced from behaviour (conduct of the ship in ship operations) but not rhetoric.

- **Action Condition.** This condition infers the ability of shipowners to influence the activities in the system. In commercial shipping, the capacity to influence is derived from owners’ rights. A shipowner decides on ship design and construction, type and areas of ship operation and activities. Shipowners also utilize hierarchical mechanisms. Though this hierarchy is usually bureaucratic and has limited number of layers, it does not often affect organisational effectiveness. In 1988, the Scandinavian Star under its owners had a fire incident resulting in chaotic firefighting due to inability of crew to communicate among themselves (Ulfsson, 2018). The ship was transferred to a new owner in 1990. The new shipowner decided to operate the ship on a new route, soon after acquiring it, without properly training its multi-national crew (Norwegian Official Report 1E, 1991). A fire incident on the ship’s first day of operation resulted in a similar chaotic situation due to the inability of crew to communicate amongst themselves and passengers, leading to the loss of 159 lives (Palmberg & Georgsson, 2009; Ulfsson, 2018). This shows an inability of the shipowner to take necessary action to positively influence the safety of the ship. Furthermore, the trend of fire on Ro-ro passenger/ passenger/cruise ships (Norman Atlantic, Carnival Triumph, Cruise Ship Caribbean Fantasy, Grande America, Viking Sky and Santika Nusantara fire) has continued over the years (Mileski, Wang and Beacham 2014; Shipdetective.com, 2019; Voytenko, 2019c; SFGATE, 2019; Savvides, 2019). There seems to be a lack of ability of shipowners to take necessary action to stop these fire incidents. The inability of action may be due to lack of commitment to safety.
- **Model Condition.** This is the capacity to understand the system functioning in its particular environment. Basically the design and construction of the subsystem-commercial ship is based on the

understanding of shipowners. Since models are simplifications of the real world they are wrong (or have limited validity). Models of dynamics in systems explore what would happen if certain driving factors changed in certain ways. Such models ask “what if?” (Meadows, 2008). There was an ineffective model condition during the Torrey Canyon disaster. As the “what if?” of a passage through a short cut would have revealed the high possibility of the ship hitting an underwater rock. Conversely, PNTL ships have been optimally modelled to ensure “Safety first”. The “What if?” of an accident is reputation damage to the whole Nuclear industry. As such, safety is considered more important than the mission (transport of cargo). Additionally, former ship Masters are appointed into top management positions and have a major role in the safety management of ships. In a case where the security of the cargo is threatened, two ships sail in tandem to serve as distractions to would-be attackers.

- **Observability Condition** in commercial shipping is necessary to allow shipowners to know exactly the state of the system at all times. This informs decisions on actions and redefinition of the model of operation. A classic case of observability in commercial shipping is the reporting of accident near misses. It is widely known that there is underreporting of near misses in shipping (Bhattacharya, 2011; Lappalainen, Kuronen & Tapaninen, 2012; VanderHoon & Knapp, 2015; Xue, Tang & Walters, 2019). Near misses could inform taking of adequate corrective measures to prevent accidents. Additionally, feedback on safety hazards is limited by authority gradient leading to accidents as in the case of Bow Mariner (Bureau Enquetes –Accident/Mer [BEAmer], 2003). PNTL ships have an effective safety culture where the Master and crew are not blamed for near misses but rather given sufficient resources to correct those potential accident conditions. A good safety culture which encourages crew members to report possible safety hazards creates good observability condition.

4.3.1.4 Common trends in control mechanism

- The Goal of warship, CG ship and commercial is “Mission first” and not “Safety First” as claimed or allocated. The design, crewing and operations of ships are highly dependent on owners who decide based on the purpose of the ship.
- The action of owners to manage fatigue on ships is ineffective since it is still prevalent. Fatigue is a common cause of accidents.
- Safety of ships is determined by the amount of resources committed by the owners. Reducing resource in-flow (ie, cutting budget, smaller crew, less time at sea) reduces safety level of ships. To maintain high safety levels ship operations, need to be re-modeled to suit their context. Participation of crew in modeling ship operations makes it more accurate which enhances safety. Ship operation should be modeled to fit the environment.
- Institutional cultures such as authority gradient and strict hierarchies, as in Helge Ingstad, Cuyagoha and Bow Mariner, contribute to accident. Good observability conditions could be enhanced through crew feedback, encouraging crew to speak up when safety hazards are noticed.

4.3.2 Analysis of Crewing of Ships

The discussions in this session apply to warships, CG ship and commercial ships.

- **Group Think.** Some scholars opine that Group think¹⁷ contributed to the events that unfolded in the Titanic disaster (Bureau Enquêtes-Accidents/Mer 2003; Manuel, 2011; Schröder-Hinrichs et al., 2012). Similarly, the collision of Helge Ingstad could have been averted if any watchkeeper had reassessed the situation. That will enable taking action to avoid collision instead of assuming the ship was passing a stationary floating object to starboard.

¹⁷ See Glossary for definition of Group think.

- **Magnitude of Recent Warship Accidents.** Recent warship accidents were devastating. In the Helge Ingstad collision, Norway with 5 state-of-the-art Frigates lost 20% of its naval combat capability (Larter & Sprenger, 2018). The Argentine Navy with 3 submarine (Saunders, 2016), lost 30% of its fleet with the sinking of San Juan. Similarly the US Navy strategically maintains an average of 52¹⁸ operational ships and suffered loss/damage to 4 ships in 2017-2018 representing nearly 8% of its active fleet through accidents. A commercial shipping company with such losses or casualty could lose its competitive edge or even collapse. The high profile Navy accidents and investigation reports has raised concerns about training and experience, bridge operation, ship construction standards, maintenance, effects of budget adjustments, hierarchical structure and top level management, etc.
- **Human Element.** It is claimed that between 70% - 90% of accidents are caused by human elements (i.e. operators) (Osés & Ventikos, n.d.; Mundin, 2015; Barnett & Pekcan, 2017). A critical examination of this statement may lead to certain fundamental questions (Soares & Teixeira, 2001; Haraati-Mokhtari, 2007; Graziano, Teixeira & Soares, 2016). Indeed, every aspect of the shipping industry is constructed by humans, meaning all causes of accidents are due to the human element (IMO, 2003; Barnett & Pekcan, 2017). The ramming of a jetty by USCGC Cypress following a propulsion control computer failure could also be attributed to the human element (NTSB, 2017; Safety at Sea, 2019) – software designers. The implication of the human element (from operators to designers and decision-makers) in accident requires a holistic approach which could be facilitated by system thinking.
- **Systems Approach.** System approach offers an effective way of viewing safety as an emergent property of systems. Recent accidents involving

¹⁸ https://www.navy.mil/navydata/nav_legacy.asp?id=146

Argentinean, Norwegian and US warships reveal systemic problems such as cutbacks on maintenance resources, poor leadership and safety culture caused by unsafe practices and insufficient training and experience. The development of Safety II culture (Hollnagel et al., 1999, 2015) requires top management, leadership and the active participation of all crew members. Safety II¹⁹ focuses on successful or good safety practices and seeks to enhance those desirable practices. The application of Safety II concepts to warships, CG and commercial ships reveals organisational (systemic) influences on safety culture on ships (subsystems). Therefore, Safety II is a useful concept in system thinking.

- **Liability.** The practice of apportioning full blame to individual crew members may lead to counter-finality because it cuts the link between the individual and the system inside which his/her actions were pre-determined. Therefore, no systemic investigation is conducted.

4.3.3 Analysis of Ship Design and Construction (Trade-offs)

Generally, ship design and construction are determined by the intended purpose of the ship. The design and construction of warships, CG and commercial ships may, therefore, be similar or significantly different. Below are presented some key characteristics discussed by the participants of the focus groups.

4.3.3.1 Warships

- **Subdivision and Aesthetic.** Warships are designed with high subdivisions to enable isolation of compartments to withstand combat damage. It causes a reduction in aesthetic appeal of these compartments. Therefore, sailors on such warships have to squeeze through tight spaces and move through several compartments, possibly increasing crew fatigue. Better fatigue management would be facilitated with an optimal balance between decent

¹⁹ See Glossary definition of Safety I and Safety II.

accommodation and adequate compartmentalization. Further, better crew rotation could limit fatigue.

- **Structural Strength and Hydrodynamic hull.** Warships are built to be slender with a relatively smaller width to enhance manoeuvrability and hydrodynamic capabilities. In such design trade-offs, structural strength and damage survivability may be affected. The sinking of Helge Ingstad raised concerns (Larter & Pine, 2018) because it was expected that a warship should have sufficient damage stability.

4.3.3.2 Coast Guard Ships

- **Specialised and Multi-purpose.** CG ships are usually small or medium size vessels but fully equipped with the tools and systems needed to perform specialized missions. Considerations in the design of these ships may involve a trade-off between spare room for rescue and equipping the ship for specialized missions.

4.3.3.3 Commercial Ships

- **Tonnage and Compliance with Regulation.** The Tonnage Management Convention (1969) incentivizes ship owners and designers to shrink enclosed spaces which may be detrimental to safety, comfort and equipment/machinery spaces. This trade-off between tonnage and safety raises safety concerns and affects the occupational health and safety of crew (increases chances of fatigue).
- **Subdivisions, Redundancy and Cargo Carrying Capacity.** SOLAS, as a constraint, requires ships to have a certain number of subdivisions based on their length. Naturally, shipowners want ships with larger holds that can carry cargo efficiently in bulk. It may even be required to construct bigger ships, taking advantage of economies of scale, without thoroughly analysing the structural stresses on such large ship. The fracturing into two and sinking of the MOL Comfort on 11 July 2013, is an example of trading

off between structural strength for cargo carrying capacity (Bahamas Maritime Authority, 2015; Jiang, 2015). A trade-off between objectives or constraints, therefore, leads to an optimal design (Olcer, 2019). The final design may lean more towards one objective, which may be based on the decision of a moderator considering owner preferences, marketable design, route to be used or availability of cargo handling equipment in ports to be visited. High number of subdivisions balanced with decent crew accommodation is a feature of PNTL ship design, making them safe. Additionally, PNTL ships have redundancy in systems (alternative means of propulsion, steering, navigation and emergency response). However, redundancy²⁰ takes away cargo carrying capacity from a commercial ship.

- **Equipment and technology.** Accidents caused by over-reliance on technology have been termed Computer-assisted. These include Radio Detection and Ranging/ Global Positioning System/ Automatic Identification System/ Electronic Chart Display Information System (RADAR/GPS/AIS/ECDIS) collisions or accidents. The 1956 collision between Andrea Doria and Stockholm, where both ships navigating in dense fog collided after Andrea Doria misinterpreted the actions of Stockholm is an excellent case of Radar-assisted collision (Mattsson, 2003). Similar misinterpretation of GPS and AIS data or false AIS data could lead to GPS or AIS- assisted collision (NTSB, 1997; Spaans, 2003; Cockcroft, 2003). An ECDIS-assisted grounding occurred on 14 July 2014 when the ro-ro passenger ferry (ROPAX) Commodore Clipper ran aground because the crew over-relied on ECDIS (MAIB, 2015; Nielsen, 2016). These show poor application of technology in shipping.

The ergonomics of bridge systems on US warships has been considered as a contributor to serious collisions because it was challenging to operate and interpret them (US Navy, 2017a; US Navy, 2017b; Eckstein, 2019; Villalovos, 2019). Specifically, the collision between the USS McCain and

²⁰ See Glossary for definition of redundancy.

Alnic was due to the inability of a sailor to properly operate the helm and throttle controls (US Navy, 2017b) leading to a “Touch-screen assisted collision”. The need to ensure simplicity in human-technology interface (Leveson, 2011) should not be traded-off when designing and installing ship sensors and equipment.

In short, design and construction are determined by the system control power often without or with limited input of the operator (crew). Therefore, the frontline operators are trapped to function in a setting and with equipment which may not be well-suited for the operation of ships.

4.3.4 Analysis of Ship Operation

Ship operations which are considered as the behaviour of ships are analysed subsequently.

4.3.4.1 Warship Operations

- **Combat Operations.** Warships are primarily designed and operated for combat. Security may be the essential element in warship operations though safety is an important factor for successful completion of missions. It is worrying that warships are regularly colliding or grounding during exercises in peacetime. Effective consideration for immediate operational environment and traffic (ie, situational awareness) could improve warship safety.
- **Training Exercise.** Most Navies and Military organizations conduct training in line with doctrine (Hebbar, 2019). The common concept is to train as you would fight. Training is designed to reflect as much of reality as possible, including the simulation of risks and hazards. This doctrinal foundation makes warship operations inherently risky and, consequently, prone to accidents. Inadequately supervised training exercises/ simulations in the real world environment could lead to costly accidents. Helge Ingstad had taken unacceptable risk, transiting at 17 knots in a narrow fjord during

navigational training (Mizokami, 2018b; Wijnen, 2018). Even more troubling was the absence of the Captain or very experienced navigators from the bridge during a risky navigational manoeuvre (Newsbreezer, 2018). Additionally, the Italian Frigate Federico Martinengo collided during training on a night mission (Voytenko, 2019a). These are few examples of major casualties during training at sea. Strict monitoring of the environment could have mitigated the risk involved in this training.

4.3.4.2 Commercial Ships Operations.

Commercial ships readily justify their existence by generating revenue when at sea. The need to deliver cargo at a quicker rate and the desire for higher profit margins may result in disregard for safety in operation. As such, the need for an optimal trade-off between maximising efficiency of cargo transport and safety of ship operations in line with Efficiency Thoroughness Trade Off (ETTO) principle by Hollnagel (2009).

In short, operational environments and their risks may become secondary because the control structures expect the fulfilment of its agenda (military training or commercial pressure) and imposes it on ships' commanders/masters who usually do not resist. Such situation may increase risk level of the entire maritime operation system within a specific environment.

4.4 Emergent Discussions

Though not initially considered as themes in the research, sea time, promotion in rank and fatigue emerged through discussions and are included herewith.

4.4.1 Analysis of Fatigue

Issues pertaining to fatigue are present in all categories of shipping but have different dynamics.

4.4.1.1 Warships and Coast Guard Ships

- **Manning levels and Rest Hours.** Comparatively, warships and CG ships have large crew sizes. Helge Ingstad had a crew of 137 compared to the 23 of MT Sola TS, though the warship was about 5130 tons and the Tanker was about 62,000 tons (Mizokami, 2018c; AIBN, 2018). It is interesting that a tanker more than 10 times the tonnage of a warship had just about one-sixth its crew. This is understandable because their missions differ: warships need to continue their operations even when casualties occur during combat while cargo shipowners tend to minimize operating expenditures concerning crew.

Despite large crew, fatigue has been known as a contributory factor in warship accidents. The Captain of Helge Ingstad had his sleep interrupted four times during the night of the collision (Newsbreezer, 2018) affecting quality of sleep. Unadjusted watchbill²¹ scheme also contributed to crew fatigue in the Fitzgerald, Antietam and McCain accidents (US Navy, 2017a). The US Navy has therefore adopted a circadian rhythm watchbill scheme (shift system) which considers the routine of the specific ship involved.

4.4.1.2 Commercial Ships

- **Manning Levels.** The logic behind manning choices is to reduce crew related expenses. Unsurprisingly, fatigue is considered as a major contributor to marine casualties (UK MCA, 2016). Though fatigue in the maritime sector is regulated internationally by IMO (STCW) and ILO (MLC), the incidence of fatigue among seafarers is currently unabated. As stated by Bhattacharya (2009) ineffective management by shipping companies, particularly of the ISM code, may be the cause. Therefore, more effective management should consider the socio-economic and

²¹ See Glossary for Watch bill definition.

organisational factors as well as encourage the participation of seafarers in safety management.

- **Underreporting of Rest and Work Hours.** Several researchers (Smith, 2007; Lützhöft, Thorslund, Kircher & Gillberg, 2007; Allen, Wadsworth & Smith, 2008; Grech 2015; Anund A et. al., 2015; Chembukkavu, 2017; NEPIA, 2017) have suggested that seafarers and shipping companies underreport rest hours, rendering regulations on rest and fatigue ineffective. Basically, larger crews on ships would be an effective way to improve safety.

In short, fatigue both in Navy and Commercial shipping must be properly recognized and addressed by the authorities having the power to select appropriate crew quantity and quality as well as to adjust work organization to avoid cognitive impairment.

4.4.2 Analysis of Promotion

Promotion serves as motivation for various actions which could support the attainment of an assigned finality or even counterfinality.

4.4.2.1 Warships and Coast Guard Ships

Officers and Sailors on warships are promoted as in most military organizations. Promotion to senior ranks requires individuals to engage in some level of interaction with top ranking officials. Promotion of senior officers to top positions (Commodore and Captain of Capital Warships) in the Navy and CG is authorized by political authorities. Consideration for promotion includes time served ashore as well as time served aboard ships.

Watchkeepers are usually required to pass an examination (theory and practical) before they are promoted to sensitive ship borne appointments. Though a watchkeeper may pass an examination for a position, they might not have gathered

the necessary experience. To correct this, the US Navy has abolished the deployment of Surface Warfare Officers (seafarers) on staff appointments (LaGrone, 2018). Improperly considered promotion, may lead to appointment of low-experienced officers as Captain of ships.

4.4.2.2 Commercial Ships

Seafarers on Commercial ships are promoted based on similar criteria. They are required to obtain Certificates of Competencies which legally require minimum training and experience. Mostly, seafarers would have gathered the needed experience since most parts of their career would have been spent onboard the ship. To comply with shipowners demands or supposed expectations, some seafarers and captains may engage in unsafe practices such as underreporting rest hours and disregarding safety management practices.

In short, though promotion of seafarers serves to encourage efficiency, it could lead to unsafe practices and accidents if wrongly done.

4.4.3 Analysis of Sea Time

Sea time provides all seafarers to build experience and proficiency.

4.4.3.1 Warship and Coast Guard Ships

The lack of adequate experience in operating ship systems and proficient decision making capability could be the result of lack of adequate sea time. The US and Norway Navy accidents showed that watchkeepers lacked the capability to take decisions during critical periods. Mainly these warship versus commercial ship collisions seemed to be caused by the meeting of inadequately experienced warship watchkeepers and very fatigued commercial ship watchkeepers. It is critical to note that lack of experience and fatigue are organizational failures. Solutions to this problem need to be taken from a system perspective.

The structure and organisation of Navy or CG institutions make it challenging for personnel to accrue sufficient time at sea. Comparatively, as at 24 July 2019 Maersk owned 316 ships and operated 730 ships with about 89,000 employees (Statista, 2019; MoverDB.com, 2019). The US Navy also had 43 ships deployed on missions and a total of 290 ships with 336,978 personnel (Navy.mil, 2019). Therefore, warships have high crew-to-ship ratio affecting rotation of personnel on ships and in watchkeeping functions.

Warship and CG ships supplement inadequate sea time with extensive use of simulators. However, over-reliance on simulators may erode certain time-tested practices (looking out of bridge windows or conning from bridge wings) limiting the ability of seafarers to appreciate real-life scenarios (situational awareness). Over reliance on simulators or the use of unrealistic simulators may produce “simulated seafarers”, seafarers who lack the rudiments of navigation.

As pertains to PNTL ships, Navy and CG authorities should consider attaching seafarers to commercial ships for specific periods of time to build experience in real operational context.

4.4.3.2 Commercial Ships

Commercial ships spend almost all their time at sea. The longer time at sea increases exposure to accidents. Due to intensity of commercial activities, ship maintenance or/and familiarization of newcomers may not be conducted as expected. Additionally, simulators used for training in Maritime Education and Training (MET) institutions (RADAR/ARPA/ECDIS/Engine Control Unit simulator training) are often different from the equipment on board ships. The seafarer could then be on ships with very different navigational equipment without prior familiarization.

Therefore, while exposure to real situations at sea may be complicated for military staff, the incapacity to train prior to joining a ship often affects ability of seafarers

to properly use shipborne equipment. In both cases, the solution requires the system and its control structure (management) to determine adequate solutions.

4.5 Recap of Research Questions

To enhance clarity of the findings of the research, a recap of the research questions is as follows. The key findings and summary of the chapter are structured as the answers to the research.

- How the finality of warship, CG and commercial ships influences ship design and operation?
- Which institutional framework/culture predisposes ships to accidents?
- What are the strengths and weaknesses in warships, CG and commercial ship operations when considered as sub-systems?

4.6 Overview of Key Findings

The key findings of this research are highlighted as follows:

4.6.1 Paramount ownership and mission

Governments/shipowners have been identified as the owners of their respective systems. They hold power and allocate the main missions. For example: shareholders hold the legitimate power in companies and organize it according to their needs and believe. In Navy and CG, the power originates from the Ministry through a military or police structure.

Control mechanisms are developed to ensure that the goals determined by the owners of the systems are achieved. In each system, the control mechanisms are organised and distributed differently but their aims remain to control subsystems and to alter them when deemed necessary.

In maritime domain, the control mechanisms are top-down and hierarchical in nature (e.g. from ministry of defence to officers then to sailors). Higher hierarchical levels have ultimate power to modify the missions of each ship through the allocation of (or not) resources. This therefore enhances or degrades

safety at any stage of a ships life cycle, from design/construction to operation of ships.

In short, the finality (missions) of warship, CG and commercial ship are allocated by owners (Government or shipowners). Owners seem to consider “Mission First” (Combat, Protection or Profit) above other consideration. This motivates owners to build and operate ships to mainly achieve allocated missions. Safety may only be a condition to achieve “Mission First”. Missions, as allocated finality, determine the design and operation of ships. Ship design and operations are more inclined to “Mission First” than “Safety First”.

PNTL ships are particularly interesting because “Safety First” is the main objective. The transportation of cargo (mission) is subordinate to achievement of safety. This is evidenced by the special design of each ship and the higher amount of resources allocated to their operation in comparison to any other cargo ships.

- The trade-off decisions during the design stage (between competing domains such as regulation, safety, comfort, etc.) are determined as usual by the owner. In the case of PNTL, the owners always favor safety. For example, flooding of each compartment does not affect the floatability of the vessel (contrary to Titanic or Costa Concordia).
- The hull and cargo holds of PNTL ships are reinforced against collision damages. All essential ship systems are designed with high redundancy (two separate engines, propellers and rudders). This ensures the ship functions safely even with damage or failure of primary systems.
- In operations, owners focus on safeguarding ships and cargo even to the point of using two ships to transport one cargo.

This safety first behaviour demonstrates that the finality of PNTL is safety before any other consideration. This is understandable because any failure or accident could affect the reputation of the overall Nuclear industry. Owned by three nuclear countries via specific agencies, PNTL ownerships is not located inside shipping but inside the Nuclear industry which has different practices related to safety.

4.6.2 Institutional framework/culture predisposes ships to accidents

Each of the 3 systems of maritime operations has unique frameworks and cultures. These frameworks and cultures have been historically and socially determined by the respective missions of each system.

4.6.2.1 System-Navy

System-Navy has a strict hierarchy to enable effective command and control in (life-threatening) combat operations. This hierarchy has consequences such as in training operations:

- Military doctrine requires training to be conducted as real-time combat operations. Such training at sea could lead to taking unacceptable risks. However, not taking adequate risk mitigation measures, related to the maritime environment, may create conditions for accidents.
- A Can-do culture could generate risk acceptance. Limited government funds may affect ship maintenance despite requiring ships to operate at optimal levels. A case in point is the loss of the Argentinean submarine. Cutbacks can also affect capacity to effectively train crew at sea.

4.6.2.2 System- Coast Guard

System-Coast Guard has similarities with Navy. However, CG crew are usually more exposed to the sea environment because their missions (police, SAR and pollution response) occur more frequently (and more often than war). So, CG crew are regularly mobilized in to conduct real operations causing them to acquire adaptive and reactive skills which are needed in operation at sea. The attainment of CG goals, through operations, is readily seen by the public and concerned authorities. Consequently, budgetary cuts immediately affecting the capacity of the CG units to perform their missions may trigger public outcry.

4.6.2.3 Systems-Shipping

System-shipping is internationally regulated. These regulations provide a network of measures to mitigate uncontrolled race toward profit-making. However, the regulations are not exempt from loopholes. For instance, reduced manning levels for cost efficiency causes crew to over work, creates fatigue and possible accidents. Ineffective safety management, blame culture and job insecurity may limit feedback and lead to unsafe practices and accidents.

Owners of PNTL ships are under three frameworks; IMO, ILO and International Atomic Energy Agency (IAEA). Therefore, the safety requirements of the regulatory bodies are higher and the enforcement regime is augmented by them working together. Moreover, safety and security standards in nuclear industry are different and more stringent than shipping.

For example:

- Before departure, the crew confirms the safety of the voyage and the ship. In cases safety concerns (including fatigue) are raised, the departure is delayed to remedy the issue.
- Near miss reporting is actively encouraged by top-management and necessary steps are taken to correct hazards conditions without blaming crew. This is contrary to reported practice in shipping (Bhattacharya, 2011).
- Promotion and appointment of crew are not just based on experience and certification for that rank but crew must have that for the next higher rank. Therefore, to be promoted from second officer to chief mate an officer must possess the certificate and qualification of a Captain.
- Due to the relatively low sailing time on PNTL ships, crew are attached to other commercial ships to enable them accrue relevant time at sea and experience.
- To ensure ship and cargo security, the ship embarks a specialised security team, with its weaponry, that operate as an integral part of the crew.

4.6.3 Strengths and weaknesses of warships, CG and commercial ships operations

Though the research commenced with this idea, it was soon realised that it is shallow to attempt a comparison. Each ship relates to a specific system and operates within a unique context. It signifies that different networks of interactions exist and affect each ship differently. Additionally, each vessel is subject to different orders (levels as shown in Figure 4) of finality (purpose).

Therefore, the research cannot compare the sectors but rather gives insight into understanding these categories of maritime operations and their safety limitations which are inherent to the system they are in.

However, it is good to study the best safety practices used in the three categories of shipping to cross-fertilise ideas. This should be done by adapting the practices to best-fit the particular context and environment of maritime operations.

4.7 Summary of Chapter Four

Each subsystem-ship interacts with the entire system and its parts. Ship operations are related to the system structure and functioning because the system and its control mechanisms determine how the ships are designed, built and operated. Therefore, numerous reciprocal interactions exist between ships and systems. Each ship category exists in its own system and cannot be studied in isolation or compared one by the other.

The interaction between ships and their respective system has to be understood particularly in relation to safety. As safety is an emergent property of a system (Leveson, 2011), enhancing safety requires studying the system as a whole within its environment and contexts.

Due to the uniqueness of each system, importing ready-made solutions could be counter-productive if not preliminary absorbed and adapted to the system's specificities and constraints.

Notably, none of the three subsystems under consideration can be considered as a reference for the others but each of them can inspire better practices.

The control mechanism of PNTL ships has been designed to ensure maximum safety of ships. The overall PNTL system is committed to safeguard ships in operation. Resources are mobilized to achieve this finality and it is achieved by enhanced ship design and optimized crewing and operation. This satisfies the unstated mission to preserve by all means the reputation of the nuclear industry while ensuring that no ships are involved in accidents.

CHAPTER FIVE

CONCLUSIONS AND SYSTEMIC SUGGESTIONS

5.0 Introduction

This final Chapter concludes the work and provide some systemic suggestions.

5.1 Conclusion of Research Work

Finality, behaviour and control mechanisms were the main systems thinking principles used in the analysis. The analyses were structured according to a matrix of goal, action, model and Observability conditions. Emergent discussions were also analysed and deductions made leading to key findings.

In a simplified analysis, the trend of warships versus commercial ships accidents seems related to insufficient experience of warship watchkeepers and fatigued commercial ship watchkeepers.

As pertains in PNTL ships, which have allocated and achieved finality of “Safety First”, inexperienced or fatigued watchkeepers do not exist because the system behaves to avoid such risky situations.

The application of systems thinking in this research revealed that accidents were caused by interactions between elements in the system and subsystems. It also showed that the safety of a system is influenced by its context and environment. The importance of a comprehensive and properly organised higher institutional framework should not be ruled out. These validate systems thinking as a potent tool to investigate operations of Navy, CG and Commercial shipping in order to

improve their safety. Further research in this topic is necessary to enhance the validity of systems thinking in safety improvement.

The following suggestions complement the conclusion by providing directions of analysis and further research.

5.2 Suggestions on Changing System Behaviour to Enhance Safety

This novel research has uncovered some practicable ideas capable of addressing some challenges in maritime operations, which are deeply embedded in system functioning.

Regardless, the studied systems of maritime operations have built stock over time which has created system inertia. Therefore, major system modifications may not be easy. However, some minor changes in a system, in appropriately chosen areas, may generate major modifications.

Forester, as cited in Meadows (2008), asserts that to enable system changes, leverage points need to be identified and used. Leverage points are places in systems where a relatively small change can cause large alterations.

Improving safety will require adjusting elements of the system. In this respect, Meadows (2008) proposed 12 factors to be considered in order to alter system behaviour. Each factor requires different levels of commitment. The factors are on a scale which increases from 12 to 1:

- In factor 12, the changes are easy to accept (so easy to implement) but have marginal impacts.
- In factor 1, modifications require structural adjustments which are challenging to initiate but may trigger major effects on system behaviour.

These recommendations are considered in System-Navy as it is the main concern in this exploratory work. For each factor, numerous adjustments may exist but selected examples are given due to research limitations. Extensive analysis to

adjust each factor would require intense work and the contribution of Navy stakeholders to identify and select the best options. However, that is beyond the scope of this research.

Factor 12

Numbers – Constants and parameters.	Meaning in Context of Navy
Change the numbers of elements in the system.	<p>Increasing redundancy to overcome deficient elements (technical, procedural, human, etc.).</p> <p>Increasing time at sea for watchkeepers.</p> <p>Increasing navy budget to ensure optimal maintenance, training and sufficient periods at sea for each ship and crewmember.</p> <p>Modify procedures for appointing watchkeepers (e.g. to favour longer sea time).</p>

Factor 11

Buffers – The sizes of stabilizing stocks relative to their flow.	Meaning in Context of Navy
Stocks stabilize system but increase their inertia.	<p>Too big a buffer, such as isolated Navy culture, makes a system rather inflexible and liable to fail.</p> <p>There is the need to manage stocks and flows of new ideas and cultures.</p> <p>Integrating STCW requirements in naval training could influence safety culture.</p>

Factor 10

Stock-and-Flow Structures – Physical systems and their nodes of intersection.	Meaning in Context of Navy
Optimal construction and efficient management of resource flow increases safety of the system	Create mutual flow of safety ideas (best practices) between Navy and other military forces as well as with Navy and Commercial shipping. Consider ergonomics of navigation equipment. Enhance comfort on warship to reduce fatigue. Though stock and flow changes can improve warship safety, systems take time to change.

Factor 9

Delay – the lengths of time related to the rate of system changes	Meaning in Context of Navy
Delay suggests time required to absorb changes at appropriate moment without destabilizing the system.	Estimate time to train watchkeepers according to STCW if considered in novel training scheme in Navy. Manage crew fatigue by adjusting watchbills. Installation of new equipment should require time to train people.

Factor 8

Balancing Feedback Loops	Meaning in Context of Navy
Feedback required for system equilibrium or ensuring goal-seeking objective. Feedback loop to verify the system is in appropriate track.	Reporting of incident and accidents should be effective to indicate areas for improvement. Crew fatigue, health, recreation and socialization should be constantly monitored to ensure crew efficiency. Feedback to achieve the system goal is good but feedback to rapidly improve it is better.

Factor 7

Reinforcing Feedback Loops	Meaning in Context of Navy
Self-improving feedback.	Near miss reporting should be incentivized to reinforce feedback from onboard safety. Safety performance and experience at sea should prevail in promotion to ship officer appointment. Ships with good safety records should be given recognition. Strengthening safety-related feedback should be promoted. High safety performance should be appreciated. Both would demonstrate the focus of the institution on safety.

Factor 6

Information Flows	Meaning in Context of Navy
Where information goes and who gets the right information.	<p>Facilitates communication beyond traditional hierarchy gap.</p> <p>Promote unusual reporting systems such as anonymous feedback with whistleblowers protections.</p> <p>Enhance transparency such as information flow, decisions, budgets, etc.</p>

Factor 5

Rules – Incentives, punishments, constraints.	Meaning in Context of Navy
“The rules of the system define its scope, its boundaries and its degrees of freedom.”	<p>Develop rules considering “Safety First” during peacetime training and non-combat missions even when against the doctrine. Avoid Can-do culture in peace time.</p> <p>Establish an independent safety department.</p> <p>Consider new rules and transparent mechanisms for promotion of staff throughout their carrier.</p> <p>Create rules on accident investigation (e.g. open investigation to non-navy staff) and transparent distribution of reports.</p> <p>Consider rules to eliminate blame-culture.</p> <p>Provide complain procedures and ensure confidentiality of reporting.</p>

Factor 4

Self-Organisation	Meaning in Context of Navy
Adaptation and restructuring for resilience.	Empower all crewmembers in ship safety. Allow crew and stakeholders to construct safety (e.g. decisions related to ship design, appointment of staff and operation) Allow ship command and crew to take autonomous safety decision.

Factor 3

Goals – the purpose or function of the system.	Meaning in Context of Navy
	Identify the achieved finality and not allocated finality by assessing behavior of the overall system. Assess the importance of experience at sea in promotion to ship command positions. Review privileges in resource allocations. Question the meaning of Navy in peace time and its goals in such context.

Factor 2

<p>Paradigms – the mind-set in which the system arises</p>	<p>Meaning in Context of Navy</p>
<p>Fundamental mind-set or deep understanding of a system. Unstated assumptions of a systems’ foundation.</p>	<p>Question if Navy should participate in income generation by multiplying its commercial activities</p> <p>Consider the stability of employment in Navy and outsource functions such as navigation, maintenance, catering, etc. Special arrangements should be made for wartime.</p> <p>Consider novel ship design to extend operational profile: war, CG and limited commerce (feeder/breakbulk services with navy auxiliary vessels).</p> <p>Design warship with wood and sails. This reduces operational cost and allows longer time at sea.</p> <p>Enhance management and high management responsibility regime. As in the philosophy of Jonas (1984), power implies responsibility.</p> <p>Explore the possibility of reporting serious safety issues to MoD/Prime Minister’s office without passing through Navy filter.</p> <p>Modify the command system on ships to be based on competency and experience more than rank.</p> <p>Think ship operation and crew as an organic structure and not a mechanical structure.</p>

Factor 1

Transcending Paradigms	Meaning in Context of Navy
Flexibility in transcending paradigms.	<p>Question the Navy model in use (former colonies have imported models)?</p> <p>The necessity of Navy functions in the current era of weapon systems?</p> <p>The employment of Navy in meeting a nation's maritime needs?</p> <p>Consider the transformation of Navy into another type of force to enforce law, ensure security and protect national interest at sea.</p> <p>Consider the meaning of Navy as a tool for power projection in the hand of a higher system which is the State.</p> <p>Consider a system which positions safety of crew before the accomplishment of the mission, specifically in peacetime. This should be reviewed in wartime.</p>

5.3 Research Contribution to Knowledge

This research tested systems thinking in an exploratory study of warship, CG and commercial ship safety. It has highlighted the value of the approach by demonstrating the link between subsystem-ship functioning and safety with the control mechanism in shipping/CG/navy systems. It has provided some areas of investigation to enhance safety in relation to warship operations.

5.4 Recommendation from Research

Further research is required to validate the findings and examine in-depth the factors of change briefly introduced in the work.

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Appendices

Appendix 1

Glossary of Terms

Achieved Finality means the purpose or goal(s) actually attained by a system through behaviour.

Allocated (stated) Finality means the purpose or goal which a system is supposed to achieve through behaviour. A system may not achieve its allocated finality and could even achieve a counterfinality (negating purpose).

Captain is the generic name for a leader of any size of ship. In this work, Captain means the commander of a warship or CG ship who is of a senior rank in the military/CG.

Coast Guard Cutter is a Coast Guard vessel 65 feet in length or greater, having accommodation for a crew.

Commanding Officer (CO) is a military officer in command of a military vessel or shore establishment.

Commercial Shipping means the act or means of transporting goods by sea for a fee. Usually a business entity driven by profit and uses ships as its main tool.

Corvette is usually a small, manoeuvrable and lightly armed warship. It is differentiated by size or displacement; usually between 55-100 m long or 550- 2790 tons²². It is smaller than the average Frigate but bigger than coastal crafts and missile boats. However, some modern Corvettes may be similar in size to a Frigate.

Coxswain is a person or senior non-commissioned officer in-charge of a ship's boat and crew which are under the Command of an officer and particularly responsible for steering the boat or even a ship. This title is popularly used on warships.

Destroyer means a heavily armed, fast, manoeuvrable warship with long-endurance which escorts larger lesser armed warships or convoys to protect them against attack from other warships. Destroyers are the main surface combatant warships. They have multi-sensors and have anti-submarine capability. They may be about 120-160 m long or about 9000 tons.

Divisional System is the system of organising the crew or company of warships into smaller groups often based on trade or mess deck. On warships it is usually commanded by a junior officer with the aim of improving discipline, welfare and running of the ship's routine. It is also a leadership, communication and systems for command and control and for addressing personnel grievances.

²² <https://www.wrightys-warships.com/corvette.html>

Executive Officer (XO) is the Second in-Command of a warship who aids, deputises and reports directly to the Commanding Officer or Captain. He is responsible for the daily, efficient and safe running of the ship. He is usually a navigator or a deck officer.

Feedback Loop is a closed chain of causal connections from a stock, through a set of decisions or rules or physical laws or actions that are dependent on the level of the stock, and back again through a flow to change the stock.

Flag Officer Fleet is usually a senior naval officer of the rank of Commodore or Rear Admiral, who is in Command of a group of warships assigned to him. The CO/Captains of these ships report directly to him. He is responsible for the operational deployment, maintenance, safety and security of the ships as well as the discipline and welfare of the crew.

Flows are the mechanism of operation in systems, which drive interactions through interconnections. They bind systems and enable communication.

Frigate is a warship highly specialised in anti-air warfare though it may have anti-submarine capability. It is similar to but larger than a corvette and smaller than a Destroyer. Frigate design, role and size vary widely.

Group Think a way of thinking which leads to self-deception of safety, involuntary consenting to group decision and conforming to the values and ethics of a group.

Hierarchy is the arrangement of aggregation of subsystems to form systems. Subsystems also have internal hierarchies, which enables them to regulate, maintain and take care of themselves. Larger systems coordinate and enhance the functioning of the subsystems as stable, resilient and efficient structures. Meanwhile, subsystems serve the needs of the larger systems. Hierarchical systems evolve from bottom up. The purpose of the upper layers of the hierarchy is to serve the purposes of the lower layers.

Inertia is the apparent delay, buffer or shock absorbers in systems reaction to inputs, influences or changes in interactions.

Maritime Operations are activities and actions conducted with the aim of achieving the purposes of Warships, Coast Guard and Commercial ships. The term used in this work mainly covers Warship, Coast Guard and Commercial ship operations. Maritime operations include; combat operations, navigation, security operations, safety inspections and operations, transport of cargo and search and rescue.

Master is a senior ranking mariner who has overall command of ship. The ultimate responsibility for the safety, efficiency, seaworthiness, cargo operation and compliance with regulations lies with the Master.

Ministry of Defence (MoD) is the government agency responsible for maintaining an active and effective Armed Force for the Defence of a State. MoD formulates national defence and security strategies, issues policies and provides resources for the attainment of strategic goals.

Naval Headquarters (NHQ) the highest command, control and administrative establishment in a Navy. It is responsible for the modelling of naval operations, safety, maintenance, deployment and manning of ships.

Operations are acts, processes or ways of operating or group of activities conducted to achieve an aim.

Petty Officer is a naval rank for a non-commissioned officer superior to seamen (ordinary, able, leading) but junior to Chief Petty Officers. They are usually heads of Departments under the Divisional System and supervise men junior to them in rank.

Redundancy is the addition of extra components and channels of information to the critical ones in use in order to enhance the reliability and damage survivability of a system.

Resilience is the ability to bounce or spring back into shape or position after being pressed or stretched. It is measure of a system's ability to survive and persist or recover from perturbation within a variable environment.

Safety I means the ability of a system to function successfully under differing conditions, by reducing the number of harmful outcomes (accidents / incidents / near misses) to as low as possible. Safety-I is achieved by making sure that things do not go wrong, either by reducing the causes of malfunctions and hazards, or mitigating effects.

Safety II means the ability of a system to function successfully under differing conditions, by raising the number of purposed outcomes to as high as possible. Safety-II is achieved by making as many things as possible go right, rather than by preventing them from going wrong.

Self-organization is the capacity of systems to structure themselves, to create new structures, to learn, diversify, and complexify.

Shipping is used with the same meaning as commercial shipping.

Stock is the memory of the history of changing flows within the system.

System are collections of elements or parts of a whole coherently organized with patterns of interconnection or structure that produces a characteristic set of behaviour, usually classified as its function or purpose or finality. Systems behaviour could be adaptiveness, goal-seeking, resilience, self-organisation or evolutionary behaviour. Key concepts in systems are flow, stock, delay, feedback and wholeness. The Systems described in this research are System-Navy, System-CG and System-Shipping which represent Navy, CG and Shipping as systems.

Subsystems are the components of systems or the elements that make up system. The behaviour and functions of these subsystems contribute to overall systems behaviour and function. Interactions between subsystems also produce emergent properties that are different from mere summations of these subsystems. Subsystems are also made up of elements which function in a systemic view. Subsystem-ships discussed in this work are Subsystem-Warship, Subsystem- CG ship and Subsystem- commercial ship as part of their respective Navy, CG and Shipping Systems.

Submarine is a unique type of warship capable of submerging and conducting combat operations underwater for long periods (about 3 months or more). It usually attacks surface ships with torpedoes or attack other submarines. Few submarines are capable of firing missiles (Nuclear).

Thick description means describing the thinking, planning and intentionality behind the research work in its context of the maritime world. Thick description seeks to show the social relations, motivations and emotions of researchers and participants in a research but not just a mere accumulation of details of research data. A researcher employing Thick description is required to describe and interpret observed social behaviours and actions within the specific research context.

Watchbill is a table containing a list of officers and crew of a ship, their work stations and special duties.

Wholeness an entity containing all parts (without any component) and made up of interrelated parts forming a complete entity.

Appendix 2

TRANSCRIPTION OF FOCUS GROUP WITH COMMENTS

PART 1 – OWNERSHIP AND MISSION (High Level Control System and Finality)			
	WARSHIP	COAST GUARD SHIP	COMMERCIAL SHIP
OWNER	<p>State (2). Ministry of Defense (2). Government (2). Naval support by third party country (1).</p>	<p>State (2). Ministry of Interior (2). Ministry of Defense (2). Government (2). Alternative ownership to complete specific missions (SAR, oil spill, etc.) NGO/Mutualship – ownership of specific missions, ie, Swedish Sea Rescue Society in Search and Rescue services.</p>	<p>Privately owned company by an individual or shareholders (3). Difference between these types of systems occurs during decision making. State owned or supported (2). It could be privately operated and based on profit/position in the world.</p>

<p>MISSION</p> <p>NB</p> <p>Navy & Coast Guard could both be tasked to protect the State. Missions could be subcontracted.</p>	<p>MILITARY RESPONSE</p> <p>War (2).</p> <p>Projection of national power and interests abroad and international waters (2).</p> <p>Combatting and other types of military operations (1).</p> <p>Defence against military action from other states.</p> <p>Protection of national waters against external aggression even in peril.</p> <p>Offensive Operations.</p> <p>Conduct long range operations (Poise).</p> <p>Secondary missions; counter piracy, disaster relief, peace enforcement operations.</p> <p>Sea blockade</p> <p>Commercial ship Escort operations.</p>	<p>POLICE RESPONSE</p> <p>Law enforcement (3).</p> <p>Search and Rescue (could be shared among all 3 classifications) (3).</p> <p>Pollution prevention /response (2).</p> <p>Escort duties/ operations (2).</p> <p>Maritime Regulatory functions</p> <p>Emergency Response.</p> <p>Defense of Territory (National waters).</p>	<p>PROFIT</p> <p>Profit and trade (3).</p> <p>Transportation of goods (3).</p> <p>Survive as a business venture.</p> <p>Research / survey.</p> <p>Services (Hospital, etc).</p>
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Description and Comments

Ownership and control as reported by participants

Governments or states are the usual owners of Warship and Coast Guard ships. Specifically, Ministries of Defence are the main government organizations which own warships. Coast Guard ships may be under the ownership of the Ministry of Interior or Defence.

Commercial ships are mostly privately owned companies by individuals or shareholders. Commercial ships may also be state owned. A privately owned company may be owned by individuals or other entities (integrate in groups).

In some case there is a distinction between ownership and control in Navy, CG and Commercial shipping as some function may be outsourced. In this respect, state may subcontract the some functions of the Navy to another country through a Memorandum of Understanding (MoU); especially when it has no capability to own a Navy (A protectorate, colony or failed state). Equally, some Coast Guard missions may be subcontracted. This is the concept in which Search and Rescue

(SAR) functions are performed by the Swedish Sea Rescue Society and similar organizations in other countries (e.g. Germany, UK, France, etc.). Finally, cargo ships can be owned by one company (e.g. a bank) but effectively controlled and operated by a nexus of other companies (shipmanagers, operators, charterers, etc.).

Mission of ships according to participants

As State owned systems, navy and CG vessels are primarily engaged in State protection missions. Navy protects State from external aggression and CG protects State from internal or coastal risks. The main mission of warships is maritime warfare operations to protect the national waters against external aggressors. It also involves offensive operations as part of projecting a nations power overseas into international and hostile territory. A full suite of military operations (military response) originate from this overarching mission such as counter piracy, counter terrorism, anti-narcotics trade, sea blockade and commercial ship escort operations. The military in peace time may perform missions requiring it to provide assistance to civil authority such as Search and Rescue, peace support operations and disaster relief missions. Missions of warships imply behind exposed eventually to two categories of risks. The first category relates to marine environment (weather, piracy, etc.) and a second category of risks relates to combat operations and their implication in conducting the vessel. Though warships are be prepared for these missions.

Coast Guard ships engage in missions in maritime domain which are typical police response operations. The main missions involve maritime law enforcement and emergency response operations. These include border control, traffic alleviation, SAR, pollution prevention and response, disaster relief and defence of national territories/waters. Coast Guard missions may also be in support of military missions.

On another hand, commercial ships exist, historically, to generate profit to their owners by transporting good by sea. Commercial ships may be involved in survey, research, hospital or medical services and migrant rescue. The case of State owned company may be different. Originally, they were created to support national trade and independence. Profit-making was essential but secondary. This mission of making profit may be the element causing shipping companies to accept high levels of risk and trade-off safety.

PART 2 – CREW (SOCIAL SYSTEM)

	WARSHIP	COAST GUARD SHIP	COMMERCIAL SHIP
<p>CREW AS A WHOLE</p> <p>CREW AS INDIVIDUALS</p>	<p>Crew as a whole:</p> <p>Large sized crew (3).</p> <p>Same nationality (3).</p> <p>Bureaucracy and hierarchy (2).</p> <p>Strict compliance with chain of command (2).</p> <p>Specialization.</p> <p>Combat constraints Special teams for specific emergency response.</p> <p>Crew as a whole has a Safety First mantra.</p>	<p>Crew as a whole:</p> <p>Medium sized crew (3).</p> <p>Same nationality (3).</p> <p>Crew is specifically trained for emergency response and highly specialized jobs. This training could be national or multinational (3).</p> <p>As a whole is organized in a vertical hierarchy.</p>	<p>Crew as a whole is multinational (2).</p> <p>Crew as a whole is rarely of only one nationality.</p> <p>General training in most areas and less specialized training.</p> <p>Small size crew.</p> <p>Flexible career patterns mainly based on voyage contracts.</p> <p>Multi-tasking of crew.</p> <p>Less division in task execution.</p>

	<p>Crew as individual:</p> <p>Loyalty (Influenced by salary, patriotism) (2).</p> <p>Specialized training (2).</p> <p>Minimum training in other fields.</p> <p>Social stability.</p> <p>Special disciplinary codes.</p> <p>May be defended by military in liability cases. Crew as individuals face high levels of fatigue; but is seen to be normal in military service.</p> <p>Regulated career pattern with minimum sea service.</p> <p>Contract with Government.</p> <p>Specialized tasks for crew.</p> <p>High divisions in task execution.</p>	<p>Crew as individuals:</p> <p>Loyalty; salary and job satisfaction (2).</p> <p>Specialized training and tasking of crew.</p> <p>Broader responsibilities in ship operations due to wider scope of operations.</p> <p>Training in multiple operations.</p> <p>Dependent on national standards.</p> <p>May be civilian or military.</p> <p>May be defended by authorities in liability cases.</p> <p>As individuals are employed in Public service.</p> <p>Regulated career pattern with minimum sea service.</p> <p>Contract with Government.</p>	<p>Crew as individuals is trained according to STCW.</p> <p>Loyalty driven by social conditions of employment.</p> <p>More likely to speak up against violations and abuses.</p> <p>Large responsibilities.</p> <p>Effective in multi-tasking.</p> <p>Legal liability.</p>
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Description and Comments on Crew/ Crewing

Shipping as a socio-technical system, currently requires people to operate it. A critical aspect of this system is the crew borne on ships. Crewing of ships is determined by the Controller/Owner who manages the crew and determines recruitment standards, training, organization, career progression, promotion and other terms of employment contract. Issues with crew could be discussed in the view of crew as individuals and crew as a whole.

Crew are usually selected and recruited as individuals, who have basic training. This training is supplemented by Shipping Company, Naval and Coast Guard training to build the level of capability required of crew of to operate the relevant ships. Distinctively, Naval and Coast Guard crew have same nationality and trained based on national or multinational standards. This is similar to the practice on PNTL ships. Commercial ships have multinational crew whose training is based

on International Maritime Organisation (IMO) standards (STCW). Onboard training is conducted for the crew after joining the ships. Warships, Coast Guard and Commercial ships train and operate at an acceptably safe level. Commercial ships use Safety Management Systems while Warship and Coast Guard ships follow Standard Operating Procedures. Though Navy and Coast Guards have policies and SOPs on individual crew training, the differences between that training and STCW training may have contributed to the trend of warship/commercial ships accidents. This ideology is supported by the US Navy's policy to train its sailors according to the STCW standards (US Navy, 2017a; LaGrone, 2018 June 29). Training of crew develops the capability of crew members but this occurs overtime. Time considerations should be factored in the training of individual crew members. Premature deployment of crew, without sufficient time to build experience, could be result in human-error caused accidents.

At the center of the discussion on safety of ships, are issues of manning levels which are key determinant of human element issues mainly fatigue. Basically, higher manning levels or larger crews creates lesser concerns with fatigue while smaller crews cause more issues of fatigue due to more work load (Rothblum, et al, 2000). Commercial ships have relatively smaller crew sizes due to the desire to cut cost involved in paying seafarer salaries and allowances causing fatigue. Fatigue is known to have caused some major ship accidents (Exxon Valdez, Royal Majesty, Star Princess, Jambo and Eagle Otome) negative unintended effect of high cases of fatigue among seafarers resulting in accidents and a greater loss of revenue for ship owners (Smith et al., 2003; Strauch, 2015). Reduction in crew size leading to increased workload and seafarer fatigue was an identified cause of the Exxon Valdez grounding (Exarchopoulos et al., 2018). Contrarily, Warships and Coast Guard ships have larger crew sizes due to the need for redundancy in operations and high specialization in crew tasks. This larger crew sizes should normally translate to lesser cases of fatigue. However, due to poor crew management practices, excesses in simulation of training scenarios and poor safety management systems, Warship and Coast Guard crew also suffer cases of fatigue and accidents. Additionally, military and police establishments maintain a culture of performing under extreme states of tiredness and fatigue which encourages causes fatigue to exist in these organizations. Optimal manning levels with effective safety management systems are ideal in ensuring ship safety as practiced by PNTL ships. PNTL ships have two crews (sailing and stand-by crew) for each ship ensuring each crew member is properly rested and ships are adequately manned.

PART 3 – DESIGN OF SHIP (TECHNICAL SYSTEM)

	WARSHIP	COAST GUARD SHIP	COMMERCIAL SHIP
DESIGN OF SHIP	<p>Strengthened hull and structures (3). Heavy weapons, sophisticated weapon systems and large ammunition storage (3). High speed maneuverability (3). Camouflage (grey) colour / stealth shaped design (flare shape of hull) (3). Highly compartmentalized/ more subdivisions (2). High redundancy. Multiple Command and Control Stations. Engine room redundancy with multiple high power engines (Diesel, gas, nuclear, which can be combined for higher speeds) (3). Water and air tight compartment. Large accommodation. Many different sizes and designs. No international regulation on design standards. Nationally designed and built. Large fuel capacity efficient for military missions. Full type + combine.</p>	<p>High speed (3). Mission purpose-built (2). Special capabilities. Heavy weather characteristics. Mostly diesel engines. Designed for medium ranged coastal operations. Ice breakers. For rescue operations. Smaller in size. Mostly of white colour. Smaller weapons. Comply with national regulations. Shallow drafted ships. Diverse size and design of ship (specialized vessels for firefighting, oil pollution response, etc). Lighter weapons. Highly hydrodynamic hull. Communication and detection systems</p>	<p>Maximized cargo space. Volume is quantified as profit so space is optimized for profit (3). Regulated tonnage (GT), light and loaded displacement (2). Designed for longer distance (intercontinental trade). Large and complex engine rooms. Cost efficient. Complies with international regulations. Optimization of profit. Classification society compliant. Regulated living and working spaces (accommodation). Constrained by international regulations (highly regulated ie, SOLAS). Ship-port interface (ie; ramps, cranes, etc). Deeper drafted/ bigger sized. Focus on energy efficient ships / low pollution ships. Regulated redundancy in ship systems. Regulated environmentally friendly design.</p>

	<p>Reliable (Performance in damaged state).</p> <p>Reduced complexity.</p> <p>Complies with national regulations.</p> <p>Highly hydrodynamic with block coefficient of about 0.6.</p> <p>Long range detection capacity (surface/subsurface).</p> <p>Supply capacity.</p> <p>Medical/ Infirmary capacity.</p> <p>Specialized firefighting system.</p> <p>Communication / detection capacity (advanced).</p> <p>Low noise / vibration design (subs).</p> <p>Diesel oil/ nuclear propelled.</p>		<p>Runs on Heavy Fuel Oil; requiring auxiliary equipment to use in propulsion.</p> <p>Specialized vessels.</p> <p>Design influenced by gigantism, making use of economies of scale.</p>
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Description and Comments on ship design

Warships Design

Warship are mostly designed with high redundancy, high survivability in damaged conditions, sustained performance in extreme conditions, heavy weapons, sophisticated weapon systems and large ammunition storage capacity. These ships are also noted for high speed manoeuvrability, high compartmentalization, hydrodynamic, camouflaged colour and stealth design, and high redundancy in systems and design. Basically, warships are designed for war; making heavy weapons and high compartmentalization critical aspects of the ship. The design of warships is constrained by regulations which are mostly national and ship specific in nature. Other constraints include available technology on the market, traditions and conventions in warship design. The decision to settle on a specific warship design is taken through a process of trade-offs amongst desirable elements. Trade-offs affecting the safety of ships are of utmost concern.

Warship are designed and built with high redundancy to enable them function in cases of combat damage to one of the systems and to enable supplemented performance during high risk operations.

Having an operations room supplementing the functions of a navigational bridge serves as support and safety check on ship operations. A warship could have a combination of diesel, electric or gas turbines which enable it to attain higher speeds during critical periods. However, redundancy in systems puts demands on resources which might be limited. Multiple engine types in one ship may result in extra cost and sacrificing of spaces which could be used for crew accommodation. Therefore, the need for safety causes a trade-off between crew accommodation and amenities and desire for redundancy.

Coast Guard Ship Design

Design and construction of coast guard ship depends highly on its use. A Coast Guard cutter resembles a commercial ship design while a fast rescue or patrol vessel may resemble a warship. Decisions on trade-off in design and construction of coast guard ships are constrained by national regulations and technology. Coast Guard ships are diverse and usually specialized in designs such as icebreakers or shallow-drafted vessels and even vessels with heavy weather characteristics.

Commercial Ship Design

Commercial ships design has been drastically affected by gigantism, economies of scale and technology with the overarching aim of making profits. Generally, commercial ships are more box-shaped, deep drafted, have cargo handling equipment, maximized cargo carrying capacity, aesthetically designed and fitted with environmentally friendly equipment. Though, commercial ship design has been focused on energy efficiency and reducing environmental pollution, these ships have long used heavy fuel oil which causes pollution. Additionally, commercial ships are known to have high block co-efficient (0.84 for a 172000 Bulk Carrier) which makes them relatively less hydrodynamic and energy efficient (Choi et al, 2010). Regardless of the design concept, commercial ship design is strictly regulated internationally. Commercial ships vary in design and operation depending on the aspect of maritime trade they are built for. Decision on what aspects of such ships to focus is affected by trade-off between most desirable qualities.

PART 4 – CONDUCT OF OPERATIONS			
	WARSHIP	COAST GUARD SHIP	COMMERCIAL SHIP
OPERATIONS AT SEA	Training, exercises and drills (2). Coastal functions/littoral operations. Supply operations. Escort mercantile ships. Preparing for war. Supports SAR, emergency response, crime interdiction operations, etc. Surveillance operations.	SAR (2). Law enforcement and crime interdiction (2). Oil spill response. Drug interdiction. Anti-piracy. Emergency response. Survey and research operations. Construction and servicing of aids to navigation.	Transport of cargo (2). Bunkering operations. Assistance to ships and persons in distress if encountered. Energy efficient operation; just-in time arrivals, slow steaming, trim optimization and weather optimized routes. Shipping operations; as link in world trade. Clinical services. Dredging operations. Salvage operations. Offshore drilling and support operations.

Description and Comment

Warships mainly conduct combat operations in defence of territorial waters or offensive action to project national interest in international waters or overseas territories. Other operations include support of commercial ships; as escorts through high threat (piracy prone) waters, keeping sea lanes of communication open and patrols to ensure the general protection of ships in national waters. Emergency response, crime interdiction operation and sea evacuation of stranded persons are also included in the array of naval operations. Though most warships conduct frequent and nearly continuous training for combat operations, real-life combat operations do not occur often. This translates to Navies spending lots of time training for combat missions rather than actually engaging in these missions.

PART 5 – EMERGENT DISCUSSIONS IN THE CONTEXT OF SHIP SAFETY			
		Coast Guard Ship	Commercial Ship
FATIGUE	<p>Not internationally regulated but managed with customary 4 hours shift system (watch system).</p> <p>HQ policy and instructions guide fatigue regulation.</p> <p>Owner regulated.</p>	<p>Not internationally regulated but managed by customary 4 hours shift work system.</p>	<p>Internationally regulated.</p>
PROMOTIONS	<p>Political (Not partisan politics but you need to be seen as hardworking and effective).</p> <p>Impressive career performance.</p> <p>Years of service not necessarily a specified sea time.</p> <p>Promotion examination. Not fully dependent on sea time.</p> <p>Based on superior's assessment.</p> <p>Trust in-confidence of President/Cabinet/Minister.</p> <p>Regardless, a more defined promotion process.</p>	<p>Political (Commission on appointment).</p> <p>Need to have a good network.</p> <p>Same as that in the Navy.</p>	<p>Time at sea.</p> <p>Need to be recognized by peers (other Captains and officers).</p> <p>STCW (certified as competent).</p> <p>Promoted based on necessity.</p> <p>Could be promoted at sea in different capacities.</p>
TIME AT SEA (Time spent underway and making way)	<p>Satisfies operational requirements or mission (training for war and patrolling).</p>	<p>Satisfies requirements (patrols and enforcement of regulations).</p>	<p>More time at sea.</p> <p>Motivated by trade/profit.</p>

	<p>Estimate for developing countries – 2 months at sea/year.</p> <p>Estimate for developing countries – 4 to 6 months.</p> <p>Sea time causes direct loss of money to state.</p> <p>Sea time constrained by resources.</p> <p>Nuclear submarines spend 4 months at sea/year.</p>	<p>Estimate for developed countries – 4 to 6 months.</p> <p>Sail on demand (SAR) and may cause direct loss of money.</p> <p>Resource constrained.</p>	<p>Nearly at sea everyday (10-11 months).</p> <p>Gains money while at sea.</p>
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Description and Comments

Though not considered as key part of the discussion, certain important topics which concerned safety emerged. The topics were spontaneously volunteered by respondents who though such topics were crucial aspects of ship safety and could unveil answers to questions posed by this research. Safety is an emergent property of shipping systems and can only be described and analysed in context of a whole (Leveson, 2011). Focusing on one property or aspect of shipping and during accident investigation or safety analysis may be ineffective if not counter-productive in improving safety. Therefore, after considering all the facets of shipping (owner, mission, design, crewing and conduct of shipping operation) as a whole in the shipping context it is necessary to discuss some emerging themes.

It should also be noted that Navy, Coast Guard and Commercial Shipping systems have their peculiarities and specificities which may make an otherwise good solution in one system ineffective in the other. The specific context should be considered when discussing and addressing emergent safety issues. The emerging discussions covered are sea time, promotions and fatigue.

A critical look at safety in systems theory reveals certain instrumental ideas which aid further understanding. In this concept, accidents are seen as the result of interactions within components/subsystems, interactions between components/subsystems and interaction between components and their environment. Additionally, an understanding of operation process and functions of feedback loops gives a full understanding of causes of accidents. Inappropriate imposition of constraints is the common cause of all these accidents. Accident events are the

symptom of inadequate constraints and control. This further supports the concept of safety being an emergent property of systems.

Fatigue

The discussion concerning fatigue was intricate with varying opinions some of which turned to be too passionate for academic purposes. Unanimously, fatigue was agreed to be a major cause of ship accidents and a result of some unscrupulous shipping companies exploiting seafarers. Some seafarers present during the discussion, indicated that their high levels of fatigue on ships drove them to stop sailing and pursue administrative jobs; a reason for pursuing MSc in WMU. Regardless, fatigue is widely known to be a cause of accidents. Fatigue is known to have been a major human factor cause of the Exxon Valdes disaster (MSC.1/Circ.1598, 2019). The Marine Accidents Investigation Branch (MAIB) in 2004 studied 66 accident investigation reports and concluded that ship Masters' inability to discharge their responsibilities, low watchkeeper manning levels and fatigue were major causes of ship grounding and collisions (Akhtar & Utne, 2015).

Promotions

Promotion is an essential tool in motivating and ensuring career progression of seafarers. It has an added advantage of enabling the organization internally develop capability of seafarers and employ them in positions with more responsibilities. Usually, seafarers have an understanding of requirements for promotion at employment (usually stated in contract). Since, employees (seafarers) are required to satisfy certain requirements (professional capability and performance of duty); they tend to increase their performance in order to earn promotion at the earliest. The desire of seafarers to increase their performance and be professional is constructive and helps the organization attain its mission. However, an uncontrolled desire to impress authorities may lead to extreme or wrong practices which may be detrimental to the sustenance of the company.

Sea time

Discussions revealed Warships and Coast Guard ships spent lesser periods at sea as compared to commercial ships. Warships are deemed to be underway from 2 to 4 months per year at the least. A seafarer serving on such a ship for 5 years would have accumulated between 10 to 20 months at sea which is inadequate to master the many navigational and safety critical scenarios that could occur.

Appendix 3

Application of Systems Thinking in Research Work

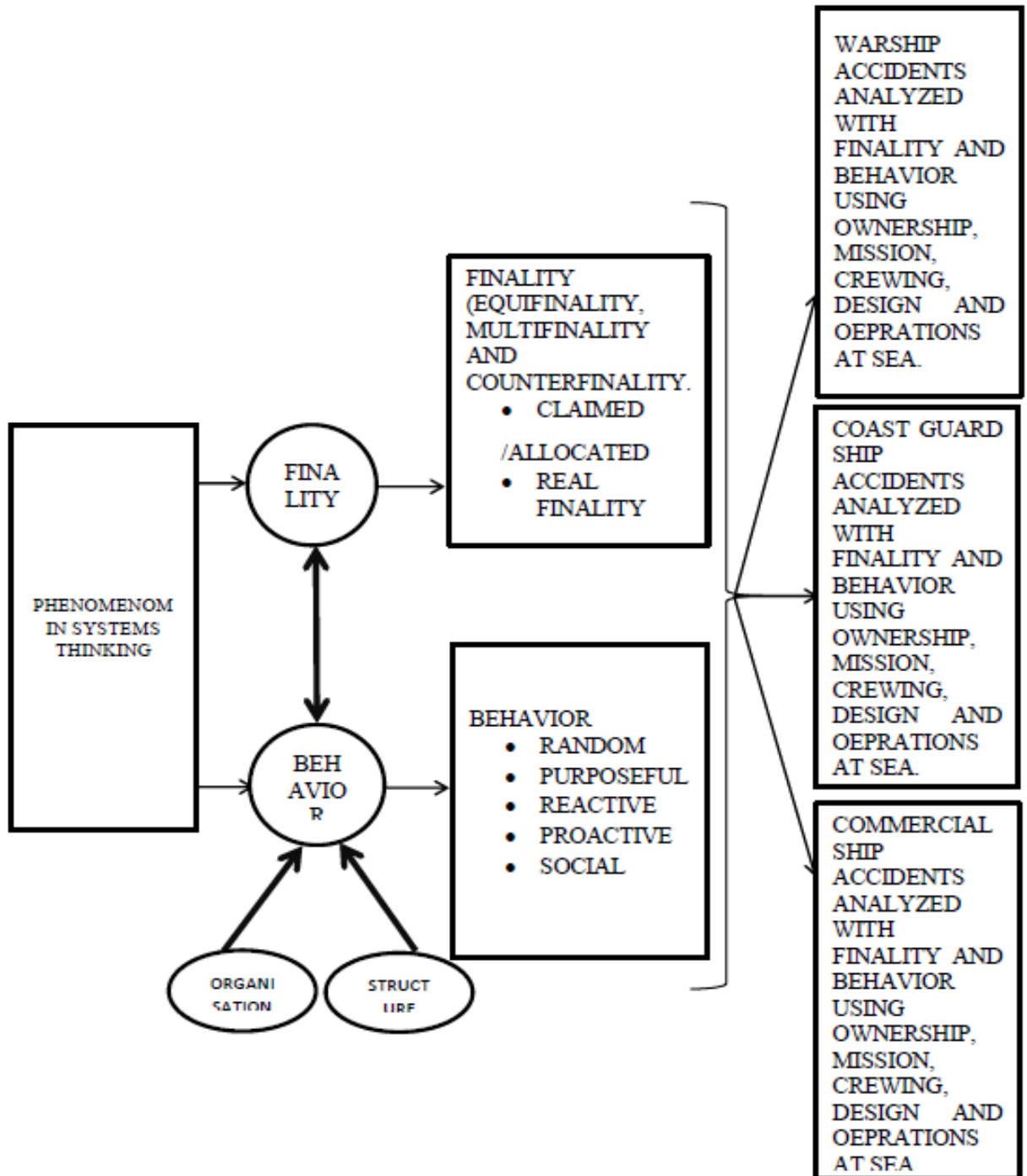


Figure 8: Diagram of application of systems thinking in research. Source: Researcher.

Appendix 4



TRANSCRIPTION OF INTERVIEW WITH CAPTAIN SIMON CHAPLIN ON 24 APRIL 2019

Pacific Nuclear Transport Limited (Model of High-Level Safety)

Serial	Question	Answer (Discussion)
1.	<p>Owners.</p> <p>Who are the owners of PNTL ships?</p> <p>Are there any other interest parties in ownership of this ship?</p>	<p>Pacific Nuclear Transport Limited (PNTL) is owned by International Nuclear Services (68.75%), ORANO (12.5%) and Federation of Electric Power Companies (FEPC); a consortium of Japanese nuclear companies (18.75%). It operates as a subsidiary company of International Nuclear Services and its fleet is managed by Serco Limited. This network of owners was due to the need to transport Nuclear fuels (nuclear fuel and used nuclear fuel) between Japan and Europe.</p> <p>PNTL is a member of the World Nuclear Transport Institute which has 47 other members, as shown in Figure 1 (WNTI, 2019a). These institutions are interested in the ownership and regulation of nuclear transport ships worldwide due to the reputation damage an accident on one nuclear transport ship could cause to other ships and the entire nuclear fuel cycle. This is the motivation for operating high safety standards in order to maintain the reputation of the nuclear clear. Sufficient resources are made available for the design and construction of the ships.</p>
2.	<p>Mission.</p> <p>What is the mission of Nuclear transport Ships (Organisation)?</p>	<p>The primary purpose of PNTL ships (Organisation) is to provide transport services and not to make money, though I am not in a position to determine if the company is making profit or loss.</p>

		<p>The ships serve as a critical link in the fuel cycle by providing transportation of back end materials in the nuclear fuel cycle. Specifically, they carry spent fuel, Mixed Oxides fuel assemblies and vitrified high level waste mainly between Japan and Europe. The International Maritime Organisation's (Code) for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High Level Wastes in Flasks On Board Ships (INF Code) regulate these back end materials (PNTL, 2019). These waste materials are removed from power stations for long term storage or recovered for re-use. About 96% of the initial energy in nuclear fuel is re-used (WNTI, 2019b). These Nuclear power stations provide 16% of the world's electricity (WNTI, 2019c). A total of 20 million consignments of radioactive materials are transported around the world yearly (WNA, 2019).</p>
3.	<p>Design of ship. What are the key elements in the design of PNTL ships?</p>	<p>Importantly, INF ships are classified into three categories: INF 1 is the lowest level and carries radioactive fuel of INF material up to 4000 terra-becquerel of activity. It could be a cross channel ferry. INF 2 is restricted to 2×10^6 terra Becquerel and has more stringent regulations on the level of radioactivity. INF 2 could be a regular commercial ship that could carry other cargoes. INF 3 has no limit on the level of radioactivity involved. INF 3 ships are ships, specifically made to carry radioactive material.</p> <p>PNTL ships are constructed and operated according to international regulations. They comply with regulations such as SOLAS, MARPOL, STCW, MLC, Nuclear regulations (Orange Book- United Nations Committee of Experts for all Dangerous goods by all modes of transport, IMDG Code (Class 7) by IMO, SSR6 by IAEA, Nuclear Security (Convention on physical protection of nuclear materials). SSR6 is, however, the reference for clarifying any doubts arising from differences in the use of terminology. The possible interference of regulations on each other (i.e., safety and security) is taken into account and a trade-off or balance is established in compliance.</p>

		<p>Though no accidents have occurred (Zero-accident record), the ship will be able to withstand collisions due to its high standard of design. The first generation of INF ships had the highest safety standards ever, though there were no regulations by then. However, these high safety standards are resource-dependent. INS sought the highest construction standard to ensure safety due to the need to gain and retain the public perception of safety of the ships and the entire Nuclear energy system. Currently, these safety standards are above and beyond regulation standards.</p> <p>In hull construction, the ships have collision bulkheads which are similar to that of average cargo ship though with some reinforcement. Extra reinforcement is placed on hatch covers to provide radiological protection. The ships have extra plating and high subdivisions with four holds and double hull construction to give collision protection.</p> <p>Notably, PNTL ships have reserve buoyancy in 4 hatches, enabling it to float in a fully flooded condition. This is an essential factor since water is the best treatment for radioactive leakage meaning holds could be flooded in case of radioactive leakage without affecting the buoyancy of the vessel. The ship has sufficient reserve buoyancy for this purpose and has been a design feature since the first-generation of vessels.</p> <p>Another design feature is high redundancy built into most systems to enable the ship to operate even after damage. These include:</p> <ul style="list-style-type: none"> Twin independent engine rooms. Independent shafting systems and twin rudders. Dual navigation and communication systems. Extensive fire detection and fighting systems. <p>The ships could operate with one engine room while the other is shut down for maintenance. These ships also run on low sulfur fuel oil.</p> <p>Design plan of ships is approved by UK MCA; who visit shipbuilding yards to confirm standards of construction of</p>
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	<p>Do PNTL ships conduct special-to-type (specialized) operations, making them different from other ship types.</p> <p>How different are these elements from that on other ships?</p> <p>Do the ships have access to repair yards during voyages.</p> <p>Does cargo inhibit the conduct of operations?</p>	<p>PNTL and other nuclear transport ship. Goal-Based Standards could be used in regulating the construction of these ships meeting INF Code standards.</p> <p>Conspicuously, the ships have no deck cranes, which limits the capability of attackers in simply assessing cargo. Ships are fitted with transponders to enable echolocation in case of a ship sinking.</p> <p>Generally, ships conduct normal operations. Ship conduct specialized operations when carrying category one cargo (MOX) requiring higher security levels. In territorial waters of other states, the security apparatus of the concerned state may require special measures; restricting any port entry until PNTL vessel enters ports. Highly dependent on security risk analysis of the territorial state.</p> <p>Mainly PNTL ships have relatively higher stability and collision protection.</p> <p>Yes, we have access to repair yards just like any other ship on a voyage. Additionally, we do carry some level of spare equipment (spare propeller blades) which enables repairs in shipyards along our voyage.</p> <p>Notwithstanding these, the aim of high redundancy (twin engines, twin rudders) is to mitigate the effects of damage to systems that could cripple the entire operation of the ship.</p> <p>The shipping line has close collaboration with a salvage company that would salvage ships or cargo should they sink.</p> <p>The cargo does not inhibit operations because the ships are designed to enable the conduct of operations without going into cargo holds. When necessary to go into a cargo hold cargo, packaging and safety procedures enable safe entry and operations in holds. Conceptually, the design of the ship enables a ship to move cargo safely from one point to the other</p>
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		while the package of the cargo is mainly to ensure the safety and integrity of the radioactive material during transport.
4.	<p>Crew as a whole. How is the crew organized as a whole?</p> <p>How is the crew trained as a whole?</p> <p>How does this organization of crew, enable the response to emergencies.</p>	<p>The Captain is in absolute command of the ship. The next senior line of appointments involves Heads of Department for Deck (Chief Officer), Engine (Chief Engineer) and Catering Departments who report to the Captain. In each department, the chain of command filters down.</p> <p>Security personnel are also integrated into crew and Chain-of-Command. They are led by Chief Inspectors/ Inspectors who report directly to the Captain. The team has sergeants who are senior to other junior ranking officers. The Captain is on top of the overall Command structure and makes final decisions based on advice by the head of security team and other departments. The Captain does not do watches but takes the ‘conn’ to conduct high-risk and relatively complicated manoeuvres and emergencies.</p> <p>Voyage specific training starts from the Safety Management System; which gives safety procedures required as minimum standards. Two vessel familiarisation sheets are given to every new crew member; one stating basic safety requirements such as the location of fire extinguishers and a second list giving detail requirement on position-specific functions. An example is deck crew knowing how to operate emergency steering. Health physics training is also carried out for all crew members when a ship is carrying cargo.</p> <p>General drills are conducted departmentally, and wholly with the Captain as the overall authority, every week with more specific drills conducted less frequently. Training for all LSA and FFA equipment is conducted on a two-month rolling schedule. SOPEP drills are also done every six months. The ship is provided with a shipboard marine emergency plan (SMEP) with flow charts that gives specific functions of the crew for initial response to various emergencies. Though not comprehensive, it contains step-wise instructions to enable clarity of action in urgent situation and prevents the risk of missing critical steps in the sequence of responding to incidents</p>

<p>6.</p>	<p>Operations of ships at sea. Which operations do PNTL ships engage in at sea?</p> <p>How do your crew maintain and accrue Sea time?</p>	<p>Ships usually conduct Coastal and Ocean navigation. Vessel security, included armed security, is determined on a voyage specific basis in line with the Transport Security Plan. The ships operate a heightened security regime whenever they transport Category 1 cargo (Mixed Oxide– pellets, plutonium). However, for passages without Category I cargo through choke points like the Panama Canal, security personnel are embarked to protect against unarmed attacks (demonstrators) and gunboat escorts are used. Security personnel are usually from the UK Civil Nuclear Constabulary (CNC) and comply with International Atomic Energy Agency and the UK’s Nuclear Industries Security Regulations 2003.</p> <p>Masters usually give security briefs before the voyage aiming to ensure adequate measures are enforced and to limit the unauthorized sharing of information.</p> <p>Moreso, Mixed Oxide transport requires two ships to sail in tandem which provides mutual protection and serves to confuse would-be attacked of which particular ship was carrying the cargo in transport.</p> <p>Sea time is challenging to accrue due to voyages being far-in between. Few sailings make it challenging for crew members to accumulate sea time to maintain their certificates and also conduct training and certification for the next level of training. Therefore the company employs certain measures designed to give all crew a fair opportunity to accumulate sufficient sea time. Crew selection for voyages considers crew with the least sea-time. Deck officers and cadets are required to keep a record of their sea time. Twice yearly, each ship sails for 10-day training (familiarisation) voyages around the UK. This gives the opportunity to test all equipment, rectify shortcomings, train crew (anchoring practice for each deck vessels acting as the Captain, SAR exercises, Manoverboard exercises), and enable staff to claim voyage sea time based on the 10-day voyage. Additionally, the crew is divided into a standby and sailing crew which usually spends up to three months at sea or off sea duties. However, this is occasionally seen as</p>
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	<p>What are the main voyage or transport routes?</p> <p>What could negatively impact the operation of the vessel?</p>	<p>insufficient, causing junior officers to leave the company despite the benefits of working on these ships.</p> <p>An alternative and more effective solution to insufficient sea time is loaning crew out to other companies with high sailing frequencies. This is specific to deck officers since engineers do not need sea time. Engineers can keep their knowledge base current while the ship is in port. Serco (who operated ferries, Royal Navy support vessels) and British Antarctic Survey vessels are places where the crew is loaned. However, this could lead to the poaching of the crew by other companies. Notwithstanding, the crew may be assigned to other jobs aside from ship duties. The crew may be assigned to INS as marine advisors or to ship the management office.</p> <p>Our main transport route runs Europe-Japan. Occasionally, we operate trans-Atlantic routes (Med to US), Japan to US, Australia to UK, UK Coastal waters, and European routes.</p> <p>Most conditions or causes which could negatively impact the operational safety of the vessels have been addressed. However, the vessels could become un-operational in the situation where the vessels are operated over long periods without adequate spare parts (possibly due to the manufacturer no longer fully supporting certain equipment). Currently, PNTL ships have an average age of 10 years and could last another 15 years before being decommissioned. Regardless of age, these vessels are managed according to top class safety standards.</p> <p>Ships are usually fully crewed, making it theoretically ready to sail at any time. However, issues with bunkering and crew falling sick and going off for other reasons make this difficult sometimes.</p>
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	<p>EMERGENT DISCUSSIONS</p> <p>7. Management involvement in safety.</p> <p>Is top management involved in ship safety standards and operations?</p> <p>What is the reaction of top management/ operators to near-miss or non-compliance reports?</p> <p>Do crew participates in the development of safety culture and issues on ships?</p>	<p>Top management is deeply involved in ship safety management and continuously reminds the ship crew of safety standards. Ships have a safety code requiring the reporting of near-misses and similar issues. Serco, as the ship Manager, monitors near-miss reports. They monitor the number and analyze the causes in order to take appropriate corrective actions. Serco expects ship Masters to lead in safety issues and keep the momentum on safety issues high. INS is also involved in ship safety in order to ascertain ships are reliable for nuclear transport without causing accidents, which may result in bad publicity for the nuclear transport system. Stakeholders have regular safety meetings, held close to the port in order to have direct inputs from ship's crew on safety matters.</p> <p>Owners/ Managers want to know near-miss reporting is done correctly and receive feedback from lessons learned in near misses. All crew are trained in near-miss reporting. The Managers Office collects information, analyses, and circulates the information and findings among the ships. Trends are generally easy to determine and discuss during safety committee meetings. Safety and near misses are thoroughly discussed during these meetings, and remedies to trends are feedback into the system to enable improvement of safety.</p> <p>Top management tries to be positive and maintain a no-blame culture. This is challenging since there is a need to highlight when an individual has erred. Therefore this is better referred to as a Just-culture and not blame-culture.</p> <p>Everyone is encouraged to participate in the development of safety culture. This is done subtly and not forced on crew to enable willing and effective participation. The Master leads by example with the hope of making crew emulate his/her lead.</p> <p>The Master is allowed a diversion from passage route for safety reasons such as bad weather or other factors. A decision by a</p>
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	<p>Are Masters given enough resources to ensure correct safety levels?</p> <p>8. Role of Regulators. What is the role of regulators in the safety culture?</p> <p>What is the implication of a ship failing an audit?</p> <p>What happens after an accident?</p>	<p>Master to divert course is usually not challenged and seen as good safety or administrative practice.</p> <p>A proposal for passage is sent to the ship. The crew analyses the proposal and plans for passage by checking the readiness of the ship.</p> <p>Yes, enough resources are given to Masters. There are regular meetings between the Masters' and Managers to agree what resources should be provided. The Managers must strike a balance between what resources are needed for safety management and what is requested.</p> <p>There is a pre-sailing safety inspection, testing, and basic training in the use of all systems onboard the ship. This involves all crew and owner representatives who come to certify all is well.</p> <p>Failure of an MCA audits may include invoking of Code 17, which will require the ship to be stopped from sailing. They could also give a deadline for repairs of corrections to be effected in order to enable ships to return to sea.</p> <p>For UK registered vessels, and accident in the UK, accident investigations would be conducted by the Marine Accident Investigation Branch (MAIB) for the UK Maritime regulator (MCA). Other States may also investigate (such as if the accident occurred in their territory). The nature of an investigation would also depend on whether the accident involved nuclear/radioactive material and if there was a release of radioactive material.</p>
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Figure 9: Forty-Eight members of the World Nuclear Transport Institute.

Appendix 5



Interview/Focus Group Consent Form

Research topic: Exploratory study on using system thinking to analyse Navy/Coast Guard /Commercial Shipping safety in ship operation

Date of interview/group work: 28 March 2019

Expected duration:

Name of participant:

Name of researcher: Seth Anthony Dzakpasu

Dear Ms/Mr.

Thank you for agreeing to participate in this **interview/focus group**, which is carried out in connection with a research project which will be conducted by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime affairs at the World Maritime University in Malmo, Sweden.

This consent form intends to ensure that you understand the purpose of your involvement and that you agree to the conditions of your participation.

- Your interview will be recorded (if you agree) and notes will be taken during the meeting.
- From the interview, there will be a transcript of main points retained by the researcher.
- The transcript will be sent to you to provide you with the opportunity to correct any factual errors.
- The transcript will be analyzed by the researcher to support the investigation.
- The access to the transcript will be limited to researchers and academics involved in the research.
- The information provided will be used for research purposes and will form part of a research reports or/and academic papers as well as eventually in presentations.
- Any extract or quotation of the interview used for publicly available publication will be anonymized.

Moreover, you have the right to stop the interview or withdraw from the research at any time, and your personal data will be immediately deleted on your request.

Anonymized research data will be archived on a secure drive linked to a World Maritime University email address. All the data will be deleted after completion of the research.

Your participation in the interview is highly appreciated.

Student's name	Seth Anthony Dzakpasu
Specialization	Maritime Safety & Environmental Administration
Email address	w1802820@wmu.se

* * *

Quotation agreement

I consent to my interview, as outlined above, being used for this study. I understand that all personal data relating to participants is held and processed in the strictest confidence. I also understand that my words may be quoted directly. With regards to being quoted, please initial next to any of the statements that you agree with:

<input type="checkbox"/>	I wish to review the notes, transcripts, or other data collected during the research pertaining to my participation.
<input type="checkbox"/>	I agree to be quoted directly.
<input type="checkbox"/>	I agree to be quoted directly if my name is not published and a made-up name (pseudonym) is used.
<input type="checkbox"/>	I agree that the researchers may publish documents that contain quotations by me.

By signing this agreement, I agree that;

1. I am voluntarily participating in this research project and I can stop the interview at any time;
2. The transcribed interview or extracts from it may be used as described above;
3. I have read the Information sheet;
4. I can request a copy of the transcript of my interview and may make edits;
5. I am free to ask any questions I wish to researchers and to contact them in the future.

Name:

Signature:

Date:

Contact Information

This research has been approved under WMU Ethics. For additional questions or concerns, please contact:

Student's name Seth Anthony Dzakpasu
Specialization Maritime Safety & Environmental Administration
Email address w1802820@wmu.se

You can also contact research supervisor

Supervisor's name Dr. Raphael Baumler
Position Associate Professor
Email address rb@wmu.se