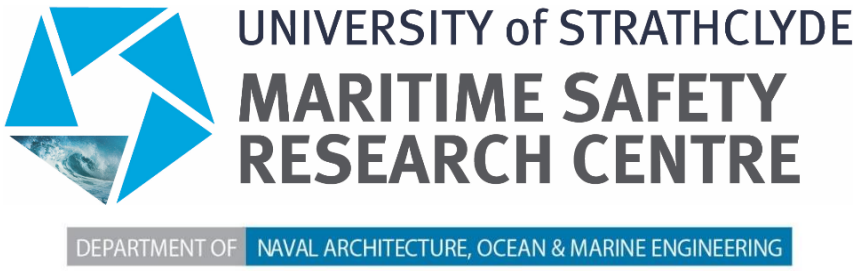

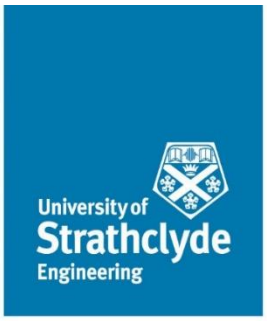

System Approach to Operational Ship Safety

By

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A thesis submitted to the University of Strathclyde
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of the degree of Doctor of Philosophy

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Abstract

In the late 1980s and early 1990s the International Maritime Organization (IMO) responded to the sinking of the Herald of Free Enterprise and the Scandinavian Star by requiring that ship operators implement safety management systems (SMSs). The requirement for using SMSs became mandatory in 2002 with the adoption of the International Safety Management (ISM) Code by the International Maritime Organization (IMO). While groundbreaking at the time, the regulation has not been significantly updated. The literature review showed that air and rail transportation SMS implementations have been significantly improved to assess hazards more comprehensively and to require safety indicators to measure the performance of the SMS. The aim of this research is to fill the gap in the use of safety indicators in the maritime domain by providing a set of safety indicators to provide ship operator with better feedback on the state of their safety management approaches. This dissertation develops a new extension of the System-Theoretic Process Analysis (STPA) to model the safety management systems at two ship operators to assess and track the hazards within each company's SMS. The STPA is extended to create safety system indicators following a revised SMS template that contains four foundational pillars: safety policy and objectives, safety risk management, safety assurance and safety promotion. Prioritization of the indicators generated in each area yields a set of key safety indicators. New indicators for repeat audit findings, quality of hazard analysis and additional indicators to track risk management performance are recommended for ship operators. Combining common results from the modelling at both companies an initial set of generic key safety indicators applicable to any ship management company was created.

Keywords: Key safety indicators (KSI), Systems-Theoretic Process Analysis (STPA), Safety Management System (SMS), generic safety indicators

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Declarations

I, Stuart Williams, hereby declare that the contents included in this PhD thesis are entirely my own work, have been developed specifically for this research, and have not been previously submitted for any other qualification. This research was self-funded, with no outside grants or other sources of funding.

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1, Introduction

"Risk is like fire: If controlled it will help you;
if uncontrolled it will rise up and destroy you."
Theodore Roosevelt

1.1. Problem definition, innovation, and impact

1.1.1 Problem definition

Ships operators still experience very serious accidents with loss of life and property. The problem addressed by this research is to create a better set of safety indicators to guide ship operators towards improved safety. The current indicators are primarily lagging indicators and do not provide the insight that ship operators need to maintain their approach to safe operations. The leading indicators produced by this research will help monitor the performance of the safety management system for ship operators. Previous research has not used a systematic analysis of the hazards contained in the required Safety Management Systems (SMSs).

1.1.2 Innovation

The objective of this research is to develop an improved set of safety performance indicators from the modelling of the SMS to provide ship operators early warning of a drift towards unsafe actions. The methodology is to model the entire existing safety control structure that a ship operator has created with an appropriate tool. Two case studies, one cruise and one ferry operator were conducted. The SMS of each was analyzed by using the Systems-Theoretical Process Analysis (STPA) technique, which is a novel hazard analysis method based on systems theory.

1.1.3 Impact

Developing a set of safety performance indicators will provide an enhanced tool for ship operators to track the performance of their safety management system. By proactively tracking changes to these indicators over time, the operators will gain insight into which elements of their safety process need improvement. The revised SMS template highlights four fundamental pillars of safety:

- better safety policy and objectives
- improved safety assurance
- better risk management
- better safety promotion

By using indicators to track performance in each of these areas, safety management will be improved.

1.2. Evolution of Safety Management

Safety management has its roots in the processes developed for quality management. As Rae pointed out (Rae, 2018):

> Central to the regulations at the European level and the national regulations in the United Kingdom and Norway is that safety shall be managed systematically following the principles of the international ISO 9000 series of quality management standards or similar national standards. Typically, such systems consist of several elements based on the PDCA[1] cycle (Deming, 1993).

The goal of implementing safety management at a ship operator is to help create a safety culture that will reduce the risk of accidents and serious incidents from occurring. This process creates a closed-loop control environment within each ship operator that clarifies the linkage between shore management and their fleet.

[1] Plan, Do, Check, Act

In the 1980s a serious of very high-profile accidents occurred in many industries. From the Bhopal chemical plant explosion (1984) to the Harold of Free Enterprise sinking in 1987, and finally the Piper Alpha oil and gas rig explosion (1988), industries suffered tremendous loss of life with huge public concerns. There was a realization that not just electromechanical failures give rise to these kinds of catastrophes, but also that the increasing complexity of the socio-technical systems being operated in a software-intensive control environment was to blame. To provide a structured safety-focused process for the management of these complex, sociotechnical systems, after the Harold of Free Enterprise sank, the IMO led the way to require ship operators develop and implement the concept of a Safety Management System (SMS).

As Maurino points out, "The object of SMS is the control of hazards and their potential consequences during delivery of services to satisfy safety management expectations" (Maurino, 2017). In the maritime world, the IMO's International Safety Management Code (IMO, 2018), as amended, sets the cornerstone for safety and risk management processes for companies that operate ships. For risk, the following guidance is contained in the Objective section of the Code*:*

> *Paragraph 1.2.2 states:*
> *Safety management objectives of the company should, inter alia.*
> *(1) Provide for safe practices in ship operations and a safe working environment.*
> *(2) Assess all identified risks to its ship, personnel, and the environment, and establish appropriate safeguards; and*
> *(3) Continuously improve safety management skills of personnel ashore and aboard ships.*

Part (2) underlined above is the only specific mention of risk management in the regulation, which therefore gives an overly broad avenue for interpretation by each ship operator.

1.3. Background

The author's original hypothesis was that if a ship operating company's risk management was robust and well-integrated into their safety management approach, then their safety record should be better than other

operators with more immature risk approaches. The author set out to determine how safety and risk management is performed and identify methods for improving its implementation and use in the ship operating community. Early in the research, the author approached four companies to see if his hypothesis was reasonable and provable. What the author discovered in this initial feasibility effort was risk management varied widely from this sample of cruise and ferry operators. During this initial fieldwork, a set of questionnaires was developed, and interviews were held with personnel responsible for administering the safety and risk management approaches at each company.

The results of this process showed the companies safety management approaches were really focused on implementing and achieving compliant Safety Management Systems (SMSs). The maturity of their risk management approaches ranged from extremely low with no formal risk approach to moderate with a few simple risk registers. Other companies had siloed risk efforts being done on new construction, repair projects and some of the departments within the operational side of the businesses. There was no evidence of any company implementing integrated or holistic enterprise risk assessments and sharing that information uniformly across their organisations. The original hypothesis could not be proven as risk management was very immature.

This redirected the author's efforts towards understanding how safety management was done throughout each company and determining how to improve their processes to yield improved safety at the ship level. The safety management system is the set of management processes and procedures put in place at each company to implement their safety programs at all levels of the company. The SMS is instrumental in creating a safety culture at each company. Knowing now that the risk management at these ship operators was underdeveloped, the author's research shifted towards applying a systematic approach to model their safety management system (SMS). The model could then be used to determine where gaps and weaknesses were and provide a tool to improve their SMS effectiveness through the creation of a set of safety indicators. By creating leading indicators, safety management could be tracked to show if the SMSs were starting to drift towards unsafe operations.

Even with requirements for implementing a SMS approach to safety being enforced by the International Maritime Organization (IMO) for over twenty years, serious accidents with significant loss of personnel and financial losses still occur at a high rate (Batalden, 2013). When the Costa Concordia sank, thirty-two lives were lost, and the total cost of the accident exceeded $2 billion (Independent, 2013). Figure 1 shows the overall trend for Very Serious Accidents based on the (IMO's) Global Integrated Ship Information System (GISIS) since the requirement for ISM Code came into effect in 1998. The total number of large ships sunk each year has remained above one hundred (Luo & Shin, 2016). To improve this trend additional changes and updates are needed to try and improve maritime safety management. Further evidence of the limited effect implementing the SMS had on the serious accident rate is indicated by data from the HIS Sea-web database for the period 2000 to 2012 (Eliopoulou, et al., 2015).

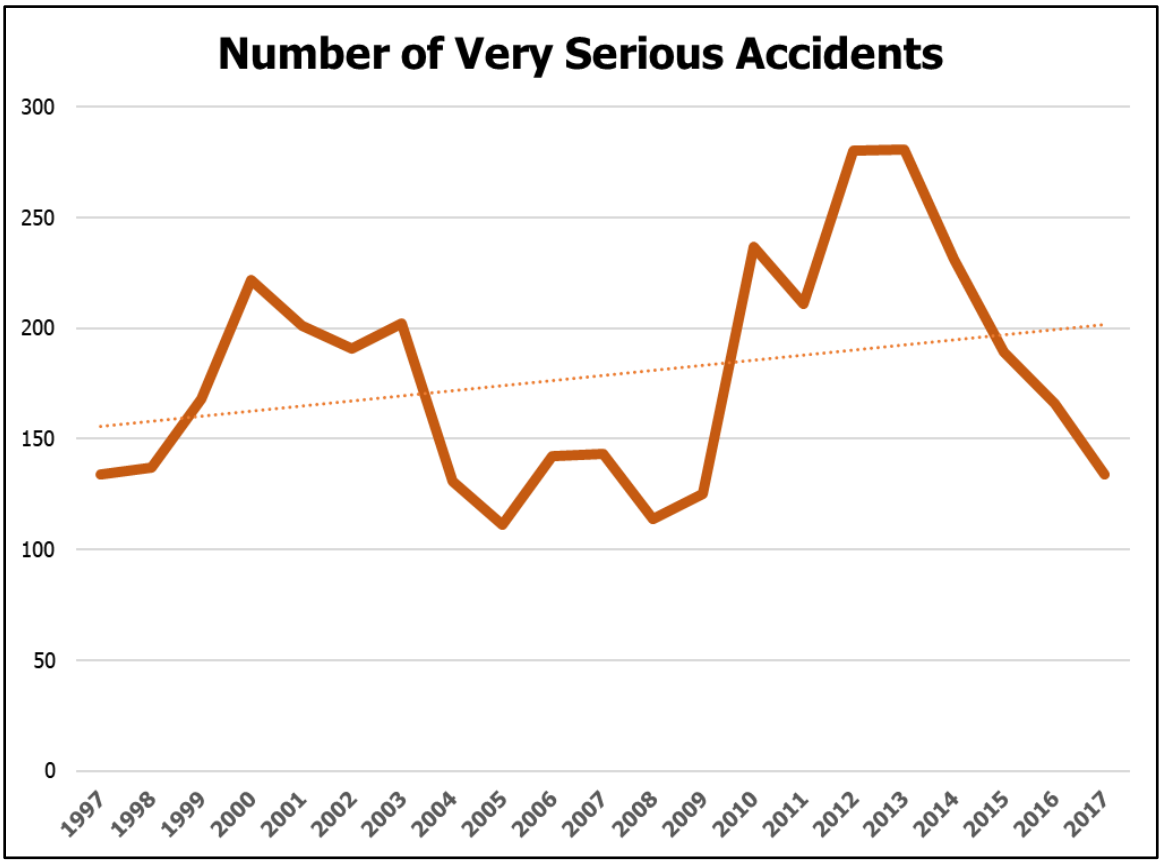

Figure 1: Very Serious Accident

During this period, the total number of lives lost was 4,302 implying an average number of lives lost per year of 384. In their conclusions, the author's noted that:

> Frequencies related to the occurrence of serious accidents show, in general, increased values in the last ten years (post-2000) of the studied period (compared to DNV, 2006), of about 30%, depending on ship type, except LPG ships, where exhibited values considerably decreased.

The systematic problem uncovered in the initial investigations of the four cruise and ferry operators is that the risk management in use currently is very immature, with no evidence of holistic or Enterprise Risk Management (ERM) displayed by any of these companies. The requirement for ship operators to do risk assessments is in the Objective section of the ISM Code. However, the problem for ship operators today is that this provides only minimal guidance to the ship operating community, leaving the implementation to their discretion.

In the intervening years since the ISM Code was created, the complexity of ships and ship systems has increased dramatically, as addressed by Pomeroy (Pomeroy, 2014). Add to that the explosion of computer-controlled equipment and the cognitive demands on the human operators have also grown. Prototypes of fully automated ships are in use now, which add another set of operational concerns for ship operators. In the past, the failure of a component could trigger a sequence of events leading to an accident, but now as Leveson points out many accidents and incidents can happen with no equipment failures (Leveson, 2011). An example of this occurred recently when the cruise ship Viking Sky suffered a total blackout and loss of propulsion. The main diesels stopped operating due to the rolling of the ship causing them to cut out due to low lube oil. The underlying issue was with the design assumptions for the lube oil system, although built to specifications and operating properly, the engines still cut out (Norway, 2019). The current safety and risk management systems in use by shipowners to ensure safe ship operations need to be strengthened to compensate for these trends. The overall risk management systems track financial, environmental and safety risks. The safety management system focuses on integrating the ISM Code's set of requirements, like

training and preventative maintenance into an auditable process. The focus of this research evolved to improve performance indicators to strengthen the safety and risk management systems at ship operators.

1.4. Way forward

The ISM Code establishes a template for an on-going safety management processes that require each ship operator to establish several verifiable actions, including training, testing, and auditing procedures. It is through these on-going actions that safety is created and enhanced. The Code establishes a series of control agents (controllers) layered within each organization ensuring that the SMS is followed and executed in a timely manner. Each layer in the organization establishes certain control actions, like requiring an audit, that must be responded to by the next layer down in the management structure. It is through the feedback of information from these various control processes that the current state of safety is judged. As Leveson points out, safety is an emergent property of the SMS (Leveson, 2004). Rassmussen's work shows that incidents can be caused by a lack of vertical integration, from the sharp end to the blunt end, across all organisation levels, thus not just hazards (deficiencies and vulnerabilities) at any one level. A lack of feedback across levels means controllers cannot see how their decisions interact with those made at other levels which can yield threats to safety (Rassmussen, 1997). The quality of this feedback has not been actively measured. One of the weaknesses identified by the IMO itself was that the ISM Code needed to be strengthened by "having an ISM Code performance measurement scheme (Maritime Safety Committee (MSC), 2005)".

Work practices like maintenance planning or operational checklists are not static, they systematically migrate over time under the influence of cost and effort gradients. The workforce responds to the managerial and business pressures to follow the path of least resistance (Goode, 2016). This migration of work practices is hard to detect because it is inconspicuous and can occur at multiple organisational levels. This creates a gradual degradation and erosion of safety defences (Woods, 2000). A key method to measure feedback on the performance of the SMS is to establish a set of performance indicators. By tracking these indicators feedback on the state of safety can be ascertained.

1.5. Structure of Thesis

After the introductory sections set the stage by explaining the evolution in the focus of this research, the literature review shows the current state of the art in implementing safety management at ship operators and tracking performance with indicators. The development and use of SMSs in ship operations are tracked and compared with other safety-critical transportation industries. The current state of the art in assessing the performance of SMSs using monitoring by implementing performance indicators is developed. By understanding the strengths and weaknesses captured in recent research, the potential gaps that the research improves can be captured.

The thesis is structured as follows:

- Chapter 1 introduction and research evolution
- Chapter 2 discusses the aims and objectives of the research.
- Chapter 3 literature review traces the development of formal safety management systems and their specific implementation for use in improving the safety of ship operations. The development of leading indicators is traced and leading and lagging performance indicators for maritime use are summarized. Gaps in the literature are captured. The current use of corporate risk management culminating in Enterprise Risk Management (ERM) is explained, including assessing risk maturity.
- Chapters 4 explains the methodology the research follows, the initial analysis and the casework conducted.
- Chapter 5 explains the results
- Chapter 6 contains a discussion of the innovation, potential changes to regulations, strengths and limitation of the findings and highlights possible future directions to be pursued.
- Chapter 7 summaries the conclusions

2 Aim and Objective

The overall aim of this research is to develop a set of key indicators of safety for use by ship operators to improve safety. The research methodology uses systems theory to model the SMS as a control process. The indicators are created by analysing the hazards within the Safety Management System (SMS) which could cause unsafe actions to occur. This approach links the indicators to the hazards that reside within the specific safety management processes implemented at each company. By analysing the common indicators shared across multiple companies, a generic set of safety indicators can be developed.

The high-level objective of this research is to improve the feedback process on the performance of safety management being executed by cruise and ferry operators. This is accomplished by creating a set of leading safety indicators. Currently leading safety indicators are developed in an ad hoc manner, usually by panels of experts basing their recommendations on past ship operating experience. Better feedback will be achieved by implementing an improved set of leading safety indicators developed through a modelling process based upon a systematic hazard analysis of the safety management implemented at ship operators.

The lower-level objective of this research is to develop a repeatable method that can be used by any ship operator to analyze its approach to safety management. The individual objectives are:

- Outline the methodology for achieving the overall objective (Section 4 Methodology)
- In cooperation with the companies, develop safety control diagrams, a model of the SMS and capture management safety and risk strategies (Section 4.3.2 and 4.3.3 Case Studies)
- Perform systematic hazard analysis of the entire safety control structure (Section 5.1.1 and 5.2.1, Hazards within Company A and Company B's SMS)
- Develop, classify, and rank leading safety indicators
- Analyze and validate the results and rankings (Section 5.4 Validation)
- Evaluate the impact on individual companies and industry (Section 5.1 Case 1 – Company A and Section 5.2 Case 2- Company B, and Section 5.3 Generic Results)

- Address limitations and directions of future research (Section 7.3 Research Strengths and Limitations and Section 7.4 Recommendations for future Research)

The final objective will be to work together with the risk management teams in the ship operating companies to implement the tracking of these indicators to monitor the performance of the SMS. Adoption of these new indicators will drive improvements in safety for ship operations. When these indicators point towards a negative trend, the operator can change processes and procedures to help prevent problems from arising, thereby improving the safe operation of their fleet.

3 Literature Review

This chapter reviews the current approach to safety management systems (SMSs) in marine and other safety-critical transportation industries. It evaluates how effective the current monitoring approaches using indicators are in delivering safe operations. A review of safety and risk models is followed by a discussion of the development and use of performance indicators to track safety. This is followed by a brief discussion of the need for improving the SMS process.

3.1 Safety Management

The ’80s saw many serious accidents across a range of industries. From Three Mile Island in the nuclear industry to Bhopal in chemical and Piper Alpha in oil and gas, major accidents created the demand to improve safety management. In the maritime area, the sinking of the Herald of Free Enterprise was the impetuous driving the IMO into action. At that point in time (the late 1980s) the literature shows that the thinking about how to improve safety management in safety-critical industries was not mature. As the complexity of company operations increased in the 1980s the need for a more systematic approach to safety became apparent. As Grote points out “Management systems are only useful when they help continuous monitoring and improvement” (Grote, 2018). For safety management then, the key is to develop a safety management approach that uses some form of metrics to track the performance of the safety approach so that the effectiveness of the management processes can be judged.

There is no consensus as to the correct set of parameters to monitor. Akyuz presented a methodology that created a set of nine Key Performance Indicators (KPIs) to track the performance of the SMS (Akyuz, 2014). Ship operations experts were polled to create an initial set of nine KPIs. Then an assessment process was done to prioritize the top three KPIs. Another paper on ship operations area by Yang (Yang, 2013) reviewed the current approaches to safety analysis for ship operations and concluded that quantification of risks using advanced modelling techniques still suffers from the lack of accident and incident data. Shortcomings like this point to the need for additional research in this area. The literature shows no clear

consensus as to the preferred set of indicators to be used to judge how well the SMS at any ship operator is performing.

3.2 Accident Models

The last thirty years have seen significant development in accident models reflecting the increasing complexity of operations in complex social-technical organizations. Qureshi summarized the history and progression of models from the traditional approaches developed in the 1970's to the present day (Qureshi, 2007). In the 1970s the Domino model was representative of the class of models based on a single chain of events, capturing what item failed to cause an accident. An example would be the Domino theory proposed by Heinrich (Heinrich, 1980). Popular risk analysis methods such as Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA) are based upon event chains (Leveson, 1995). In the 1980s the epidemiological accident models, like the Swiss cheese (Reason, 1990) model viewed accident causation more like the interactions of the spread of disease. This was followed in the 1990s by modelling based on complex socio-technical systems. Charles Perrow's seminal work on normal accident theory provided an approach for dealing with complex organizations dealing with hazardous processes like nuclear power, airline operations or ship operations. The next generation of models applied a systems theoretic approach for accident modelling, which viewed the performance of the system as a whole. In the late 1990s, Rasmussen documented an approach to modelling risk and safety in his paper entitled *Risk management in a dynamic society: A modelling problem* (Rassmussen, 1997). This work was based on several decades of research on industrial risk management. Figure 2 shows what the appropriate risk management strategy is for each type of safety-critical industry. For ship and ferry accidents the domain characteristics for the Evolutionary strategy are:

1) Well defined hazards

2) Loosely coupled system

3) Controlled by removing causes

4) Defined by analysis of past accidents

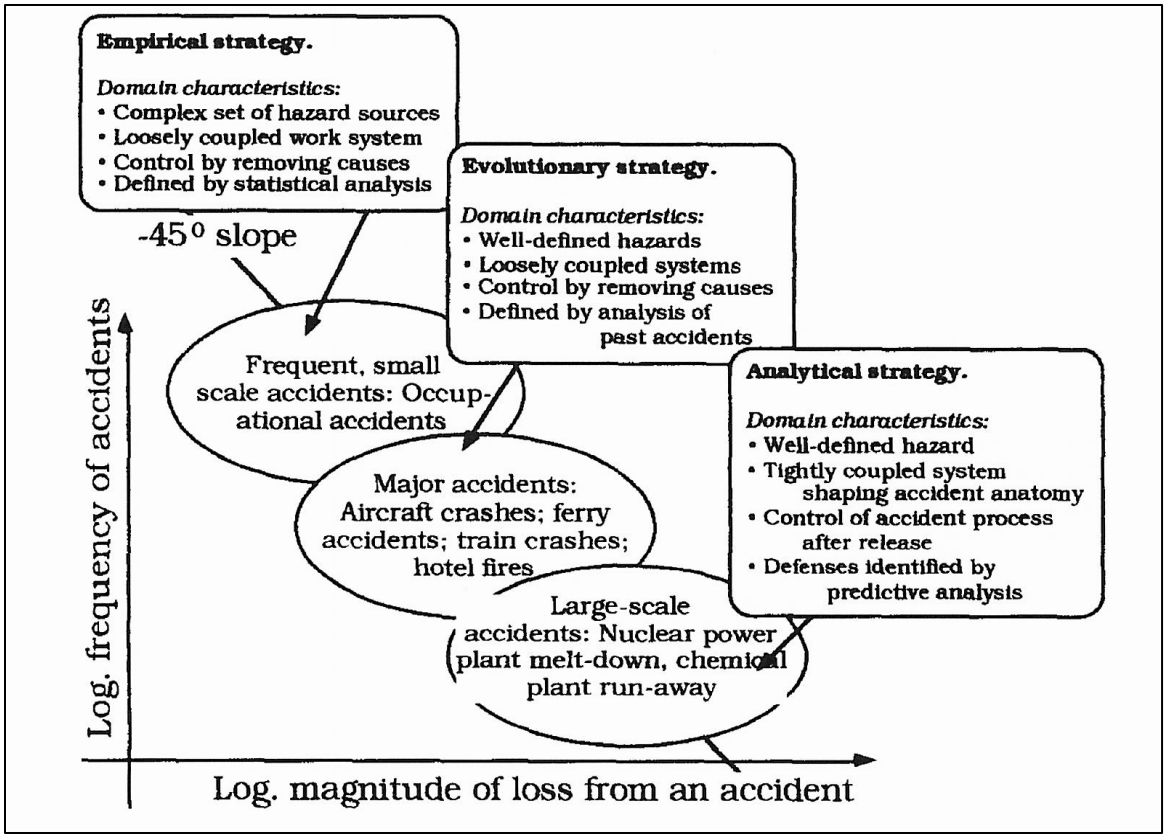

Figure 2: Risk strategy by accident types

With this understanding, Rasmussen determined that the way to improve risk and safety management was to explicitly identify the boundaries of safe operation, together with efforts to make these boundaries visible to the actors and *"to give them an opportunity to learn to cope with the boundaries."* With this understanding, Figure 3 shows that the counter gradient that keeps a company operating in a safe zone is derived from the campaigns for 'safety culture'.

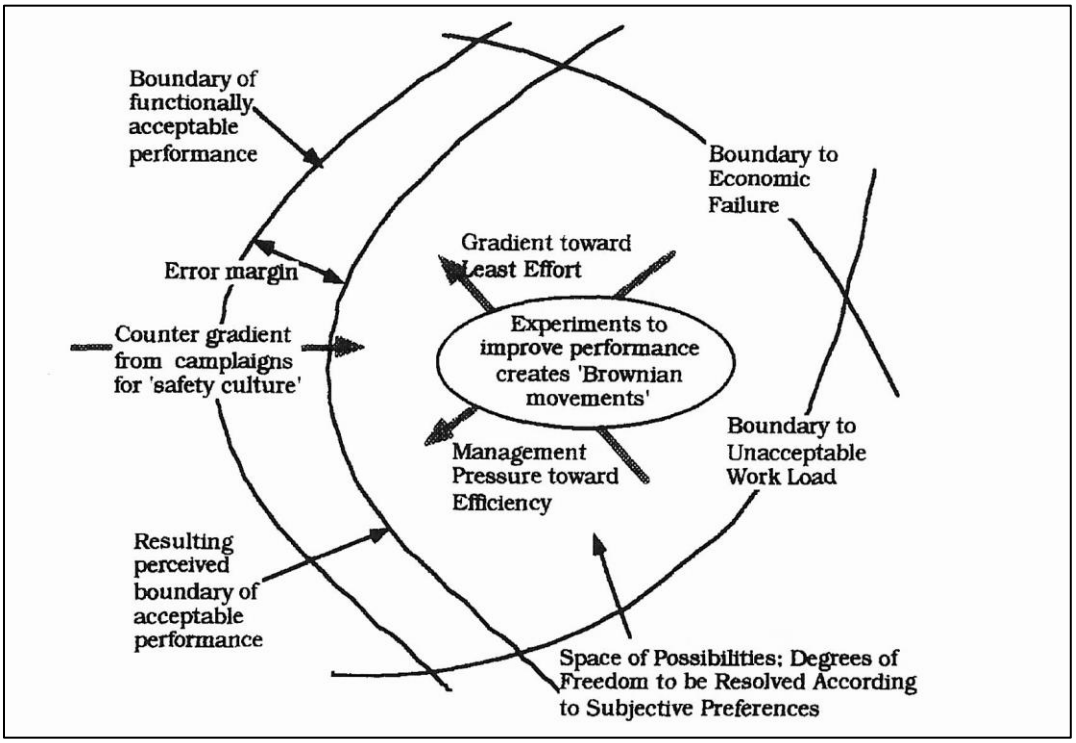

Figure 3: Boundaries of safe operations

He then states:

> It follows from this discussion, that risk management is to be considered a control function focused on maintaining a particular hazard, productive process within the boundaries of safe operations and that a systems approach based on control theoretic concepts should be applied to describe the overall system functions.

Over a long period, ship accidents and incidents have been analysed and safer systems have evolved due to design improvements in response to these major accidents. Regulatory changes are then implemented to force an agreed to safety standard on the ship operating community. In this area then, safety risk management is a measure of how well the safety management system operates and protects against accidents.

Based on Rasmussen's work, Prof Leveson at MIT created the Systems Theoretic Accident Modelling and Process (STAMP) technique (Leveson, 2004). Although initially derived to perform large scale accident

investigations, the concept is based on systems theory and therefore has multiple uses, including modelling of risk and safety management within complex corporation settings. Figure 4 shows that the operating environment of a notional company resides in a multi-layer control process, where each layer influences the next when it comes to safety.

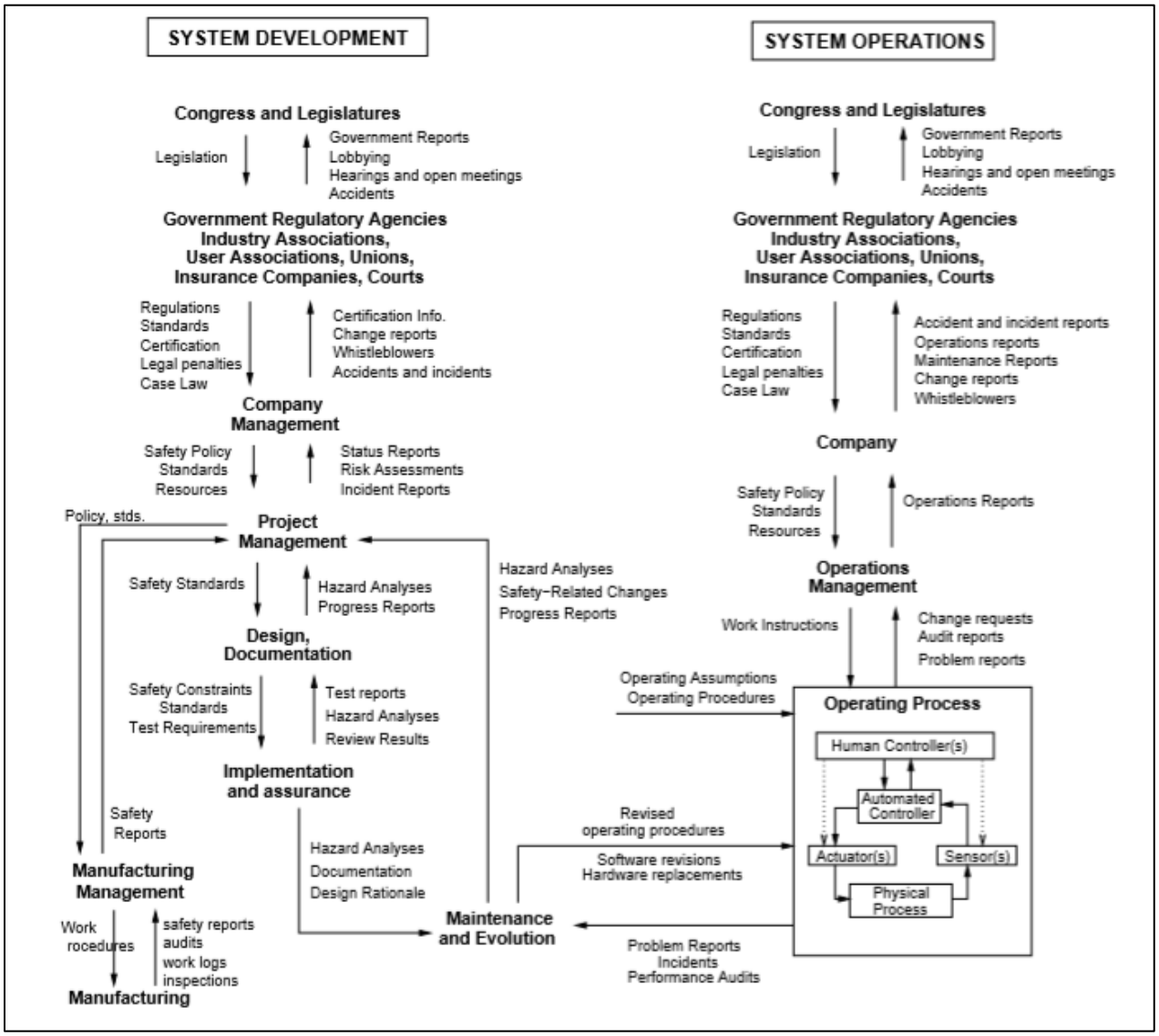

Figure 4: Operating environment for a notional corporation

Leveson explains the development of STAMP and the application of STPA in the following way (Leveson & Thomas, 2018):

> STAMP is not an analysis method. Instead it is a model or set of assumptions about how accidents occur. STAMP is an alternative to the chain-of-failure-events (or dominos or Swiss cheese slices, all of which are essentially equivalent) that underlies the traditional safety analysis techniques (such as Fault Tree Analysis, Event Tree Analysis, HAZOP, FMECA, and HFACS). Just as the traditional analysis methods are constructed on the assumptions about why accidents occur in a chain-of-failure-events model, new analysis methods can be constructed using STAMP as a basis. Note that because the chain-of-failure events model is a subset of STAMP, tools built on STAMP can include as a subset all the results derived using the older safety analysis techniques.
> The two most widely used STAMP-based tools today are STPA (System Theoretic Process Analysis) and CAST (Causal Analysis based on Systems Theory). STPA is a proactive analysis method that analyzes the potential cause of accidents during development so that hazards can be eliminated or controlled. CAST is a retroactive analysis method that examines an accident/incident that has occurred and identifies the causal factors that were involved.

STPA can thus be used to analyse the hazards within a company's SMS that may trigger an unsafe event from occurring. Current cruise and ferry operating companies operate in a complex and highly regulated industry. It is incumbent on the Flag States, regulatory bodies, and the IMO to ensure a comprehensive assessment of risk drives the safety management process at each ship operating company. The STPA process systemically guides the analysis throughout the entire socio-technical system involved in safety control, analysing individual interactions and their role in safety. Specifically, dysfunctional interactions at the system level (between the company, shipyard, regulators, and operators) can potentially represent insidious systemic factors that can give rise to a deficient Safety Management System (SMS).

Recent work (Turan, 2016) provides insight into the use of resilience engineering to improve safe operations of systems. Resilience engineering was developed over the past fifteen years. From its beginning in 2006, Resilience Engineering has expanded its focus on how to make high-risk, socio-technical systems more adaptive to internal and external threats and disruptions to system functioning through the quality of resilience (Hollnagel, 2006). As Figure 3 shows the counter gradient to the drift towards unsafe operations is the presence of a safety culture. Most accidents can be traced to human factors, which means that the safety culture created at each ship operator is important to understand. The concept of resilience engineering

can be applied to identify key human and organizational factors (Lofquist, 2017). As Lofquist explains, by building resiliency into the safety culture unanticipated events can be avoided, or their effects mitigated. The goal is to move from the concept of a Safety I approach that looks backwards to determine faults to a Safety II approach that looks forward to determine what is going right. By identifying the "soft" metrics, like assessing the safety culture qualitatively, the resilience of the organisation can be improved.

3.3 Maritime Safety and Risk definitions

One of the perennial problems in the maritime world is the lack of a consistent set of definitions for use in risk and safety. The following background in the development of risk and safety definitions guides the definitions used in this dissertation. For risk management in the maritime domain, risk has a specific definition from maritime law.

Mandaraka-Sheppard states:

> Risk is understood as the possibility of harm or loss associated with an activity or the likelihood of an incident happening that may result in danger to life, property or the environment, or may lead to commercial disputes and litigation. (Mandaraka-Sheppard, 2013)

From the IMO, the Maritime Safety Committee (MSC) adopted the following definition of risk as part of the Formal Safety Assessment (FSA) process (IMO, 2018):

> "Risk: The combination of the frequency and the severity of the consequence."

More broadly the International Standards Organization (ISO) defines risk in the following way (ISO, 2018):

> risk: effect of uncertainty on objectives
>
> > Note 1 to entry: An effect is a deviation from the expected. It can be positive, negative or both, and can address, create, or result in opportunities and threats.
> >
> > Note 2 to entry: Objectives can have different aspects and categories. And can be applied at different levels.
> >
> > Note 3 to entry: Risk is usually expressed in terms of risk sources, potential events, their consequences and their likelihood."

The ISO also defines risk management as (ISO,2018):

> risk management: coordinated activities to direct and control an organization concerning risk.

The Committee of Sponsoring Organizations of the Treadway Commission (COSO) created the Enterprise Risk Management (ERM) Integrated Framework (COSO, 2004). Over time it has become an accepted definition of ERM:

> Enterprise Risk Management is a process, effected by an entity's board of directors, management, and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity and manage risks to be within its risk appetite to provide reasonable assurance regarding the achievement of entity objectives.

In their STPA Handbook, Leveson and Thomas offer another definition of risk associated with safety management (Leveson & Thomas, 2018) :

> STAMP implies a broader or at least different definition of risk. Risk has traditionally been defined as the severity and likelihood of hazards or accidents occurring. In contrast, in STAMP:
>
> "Risk is defined in terms of the effectiveness of the controls used to enforce the safe system, i.e., the design and operation of the safety control structure. Note that this definition does not require the determination of the likelihood of the events occurring, but rather an evaluation of the effectiveness of the controls being used to prevent them.

For my thesis, the use of Dr Leveson's definition of risk in the context of the IMO's guidance that ship operators should identify all risks to its ships, personnel and the environment appears appropriate. Since the IMO wants ship operators to identify and mitigate "all identified risks", then the adoption and use of holistic or Enterprise Risk Management makes sense to look across the entire company. The ISM Code requires that this be accomplished through the implementation of a Safety Management System (IMO, 2018). Leveson's definition focuses on the effectiveness of the implementation of the control structure to

mitigate risk, thereby delivering safe operations. Every layer of the SMS control structure is important. For example, the CEO and Board of Directors should be establishing a Risk Appetite for the company to guide each management layer in the organisation as to what the key areas of focus for the next year. Without this guidance, lower levels of the organisation will not collectively address the changing safety and risk environment that needs to be addressed. Safety deficiencies can be caused by any layer, thus a model that addresses safety-related control actions at all levels of the organisation, like models based on systems theory, are needed.

3.3.1 SMS Definition

Safety-critical organizations are defined as ones that must deal with or control such hazards that can cause significant harm to the environment, public or personnel. (Reiman, 2009). According to Reiman these organizations try and control their risks and manage safety. Within the transportation sector, aviation, maritime, rail and road are considered safety-critical industries (Lappalainen, 2017).

For safety, the definition of a SMS developed by Li and Guldenmund is summarized by the following: (Li, 2018)

> Depending on the perspective taken, there are multiple definitions of a safety management system, but its definition is always concerned with three core issues: ‘safety’, ‘management’ and ‘system’. Safety refers to its opposite: accidents, losses, or risks. Management connects accident causes to organisational control and actions. The system refers to a systematic framework or models that provide the logic of safety management. To sum up, an SMS means a system containing management principles and activities for controlling risks and preventing accidents.

This broad explanation lacks detail. Fox indicates that a safety management system is generally understood to be a “formalized framework for integrating safety into the daily operations of an organization including the necessary organizational structures, accountabilities, policies and procedures” (Fox, 2009). Maurino explored the development of safety management systems across several transportation industries. His definition of a SMS focuses on the functionality of the process: (Maurino, 2017)

SMS is a decision support system for a transportation organisation senior management regarding data-based priorities in the allocation of resources towards the implementation of safety programs to address safety concerns.

The path forward is when the safety management system becomes "the" integrated management approach for a safety-critical transportation company, combining safety, risk and quality in one holistic process.

3.3.2 ISM Code

The ISM Code provides an outline of what ship operating company's Safety Management System (SMS) must address. Figure 5 contains an outline of the information required. It can be noticed that the maritime implementation of the requirements for a SMS is not organized by functional areas, and certain key elements like hazard analysis and risk management are not directly addressed.

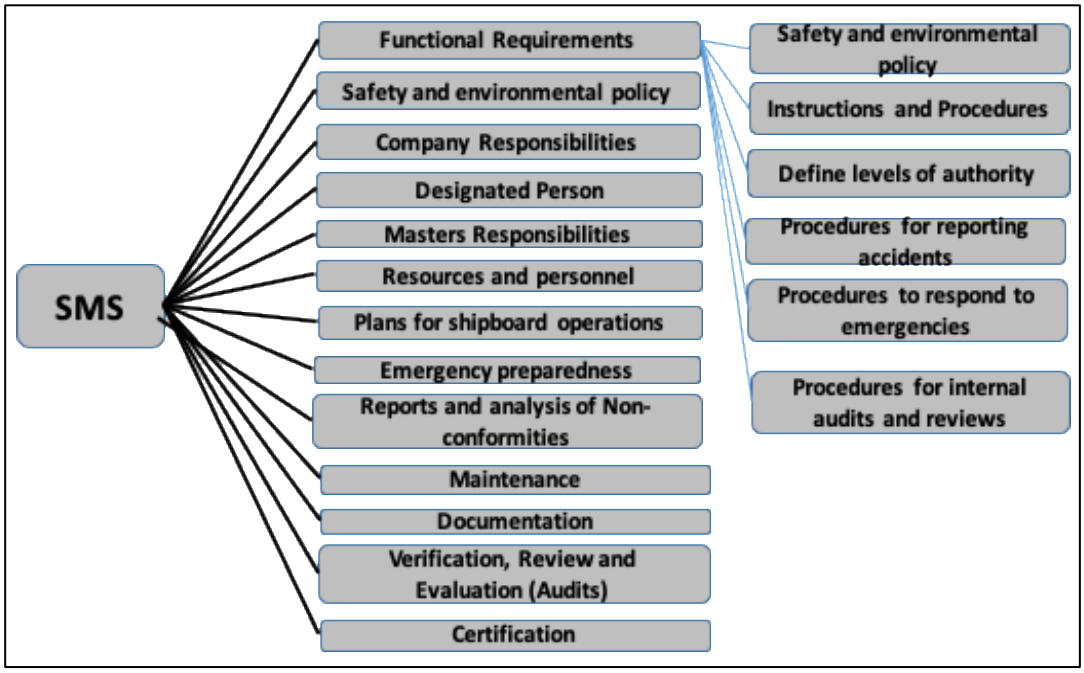

Figure 5: Template of functions required by the ISM Code

3.3.3 SMS in Rail and Air

In the fall of 2017, the author attended a two-day safety culture program sponsored by the United Kingdom's Chamber of Shipping. Speakers from the rail and airline industries gave presentations on how safety management is implemented in their fields. This precipitated a close look at the evolution of the rail and airlines requirements for Safety Management Systems. Figure 6 has the European Union guidance for implementing safety on rail systems. (Parliament, 2004) To understand how one country implemented this guidance, the United Kingdom's Network Rail system's approach to creating its SMS was reviewed. Figure 7 was developed from the Rail System Safety Board (RSSB) guidance (Office of Rail and Road (ORR), 2018). Clearly, the UK used EU guidance, creating an almost identical framework for its SMS.

Figure 6: European Union railroad safety guidance

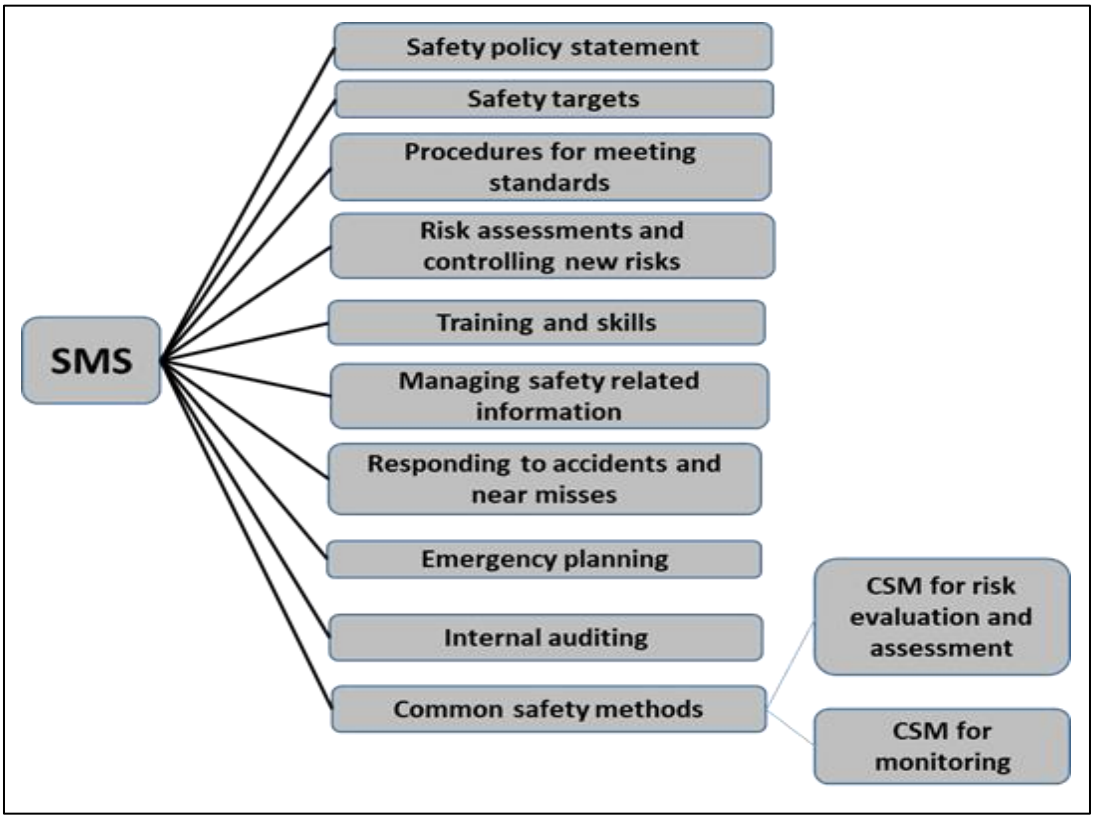

Figure 7: United Kingdom rail SMS template

The only area where the UK created a change, was to add a set of Common Safety Methods (CSMs), which provides more specific guidance on risk and monitoring. One of the required areas is risk evaluation and the implementation of risk controls. As reported by the Enterprise Risk Manager (ERM) at Network Rail (Hunter-Jones, 2016), Network Rail has a very mature ERM approach and is seeking to achieve the highest level (5) maturity over the next few years. Lappalainen also indicates that improvements and changes to the requirements for rail SMSs have evolved significantly since the initial implementation in 2004, with a major update in 2016. The standard was revised to reflect current ISO standards in 2016. (Lappalainen, 2017). By comparing the EU Directive for rail SMS implementation with the UK requirements for its SMS, it is clear the UK follows very closely the EU standard.

Similarly, airline SMS guidance was reviewed. The International Civil Aviation Organization (ICAO) created the first requirement for airline use of a SMS in 2006, eight years later than the initial maritime implementation of requiring the use of a SMS. ICAO's initial implementation benefited from the maritime

work but was much more comprehensive in its guidance. The Safety Management Manual provided general guidance in each area with a recommended 10 Steps to follow to implement a SMS (ICAO, 2006). It was not until the 2nd edition in 2009 that the characteristic outline shown in Figure 8 emerged, with the four functional building blocks for creating a SMS was implemented (ICAO, 2009). The second edition was a major re-write, focusing on how to implement and track the usage of airline SMSs.

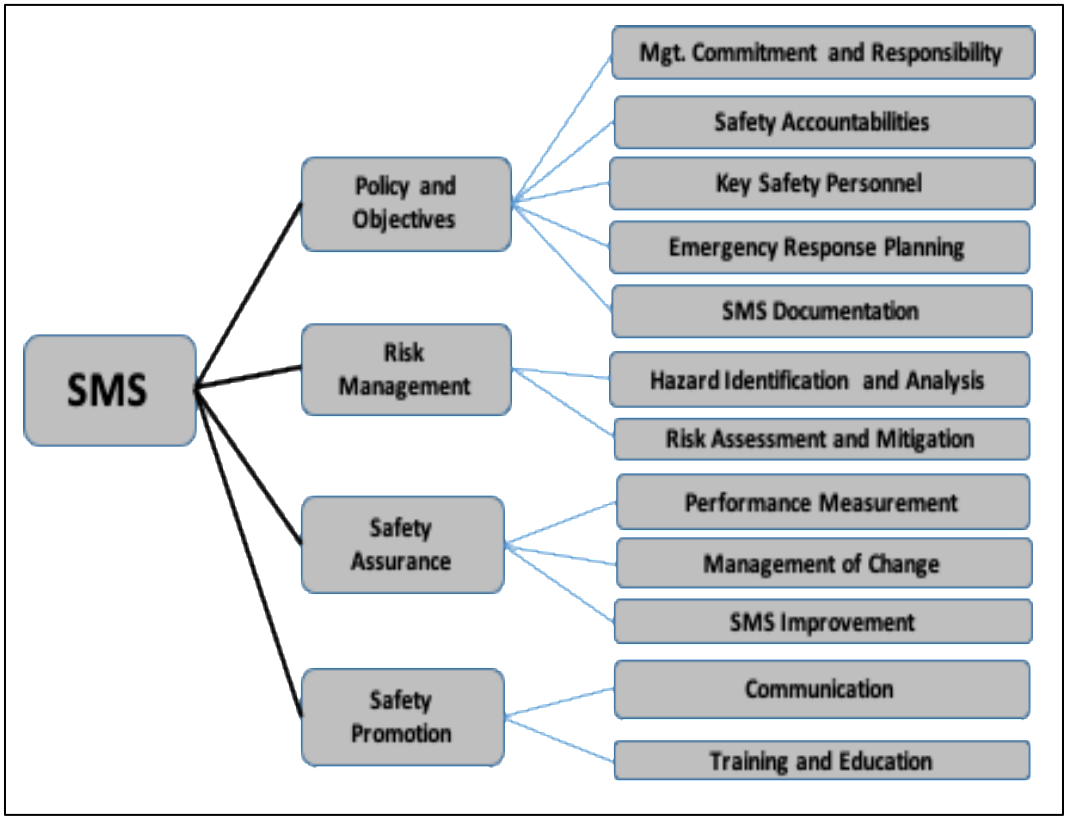

Figure 8: International Civil Aviation Organization (ICAO) SMS Template

In the airline area, the strength of the guidance in Figure 8 is that it organizes the various functions required for a strong safety management system. Each airline must establish clear safety policies, establish a visible integrated safety risk approach, measure how well the safety system is working via an assurance process and then promote the SMS by training and communicating safety and risk information throughout the company. These high-level functional categories or pillars provide a critical and firm foundation to guide

the long-term implementation of airline SMSs. When the ICAO SMS regulations in the airline industry came into force in 2006, eight years after the initial ISM Code for ships was placed in force, the airline regulations were a shopping list of items that the SMS must contain. The first update in 2009 added in the functional categories and was a major re-write of the standard. Subsequently, the ICAO did significant additional updates in 2013 and 2018. These update cycles averaged a change approximately every three years. This has pushed better integration of key elements like hazard analysis and risk management and included the active measuring of the performance of the SMS.

The ICAO standard for SMS implementation requires airlines to interweave risk and safety in their airline's SMS implementation., The standard includes a separate area focused on safety Risk Management which creates an environment where hazards and risks are integral drivers in identifying where potential unsafe operations may occur. The recent paper of Karanikas et al. (2018) uses STAMP to analyse the maturity of SMS for airline companies. The paper addresses a process for individual companies to self-assess the maturity of the SMS of their organization by measuring the institutionalization, capability, and effectiveness of their SMS implementation. This work provides a tool for the airline industry to help understand the maturity of the operation of their SMS.

3.3.4 SMS Approaches

In the transportation sector, the maritime area created the first requirement for using a SMS to improve safety. A little over thirty years ago the Herald of Free Enterprise sank shortly after leaving port. This tragedy drove the IMO into action, ultimately leading to the first requirement for ship operators to implement a Safety Management System (SMS) and address risks. That process took eleven years and was spurred on by the sinking of Estonia. The use of a SMS became mandatory for tankers, bulk carriers and passenger ships in 1998 and all ships in 2002 (IMO, 2018).

Reviewing the research progress on the science of SMS shows that during this same period (1990's) Hale, as part of the Safety Science Group in Delft, wrote a foundational assessment of what constitutes a generic

SMS (Hale, et al., 1997). In this work, he points out that "An explicit model of the SMS, which can present the dynamic nature of the management processes, would provide a good starting point to assess the completeness of audits. He noted that to that point in time the literature showed that attempts at establishing a SMS framework were fragmented and contradictory. His team at the University of Delft followed up in 2005 with the basic framework for a SMS, Figure 9.

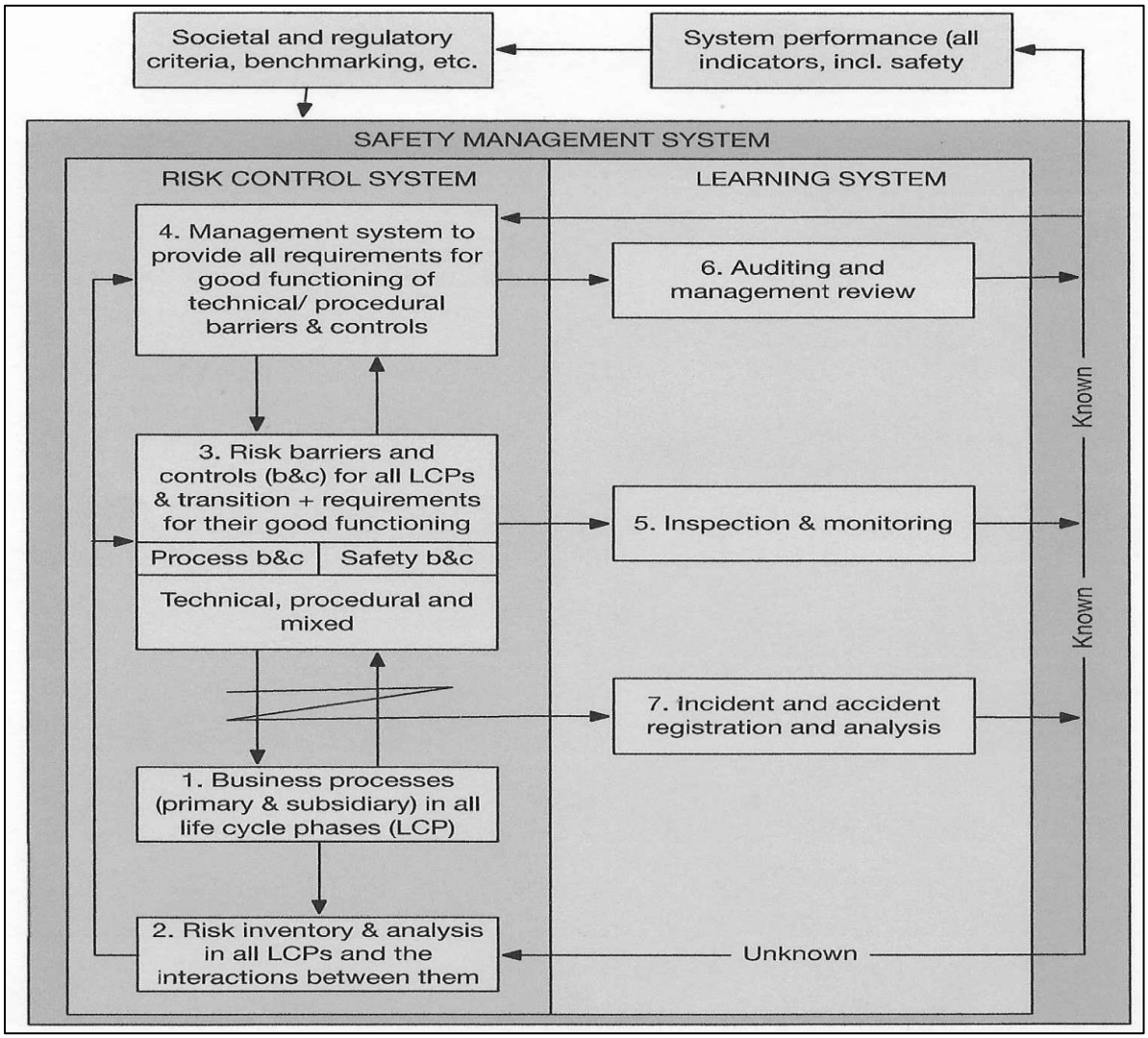

Figure 9: Hale's Model for SMS

The IMO developed its framework before the science of what constitutes a SMS being clearly established. Li published a comprehensive review of SMS literature, in 2018, that shows the building blocks of the current SMS framework in the **P**lan, **D**o, **C**heck and **A**ct (PDCA) cycle shown in Figure 10 (Li, 2018) which segments and functions are needed for complete SMS implementation. This Plan Do Check and Act cycle was championed by Deming's work (Crotty, 2008).

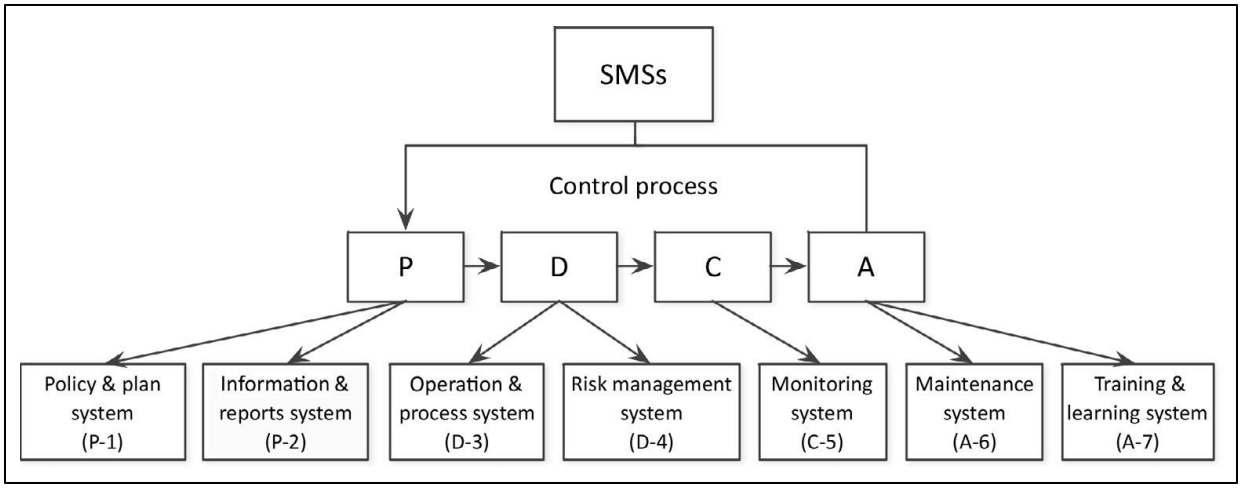

Figure 10: Plan Do Check Act [PDCA] for SMS

European rail regulations incorporated SMS next in 2004 (Parliament, 2004) followed by aviation in 2006 (ICAO, 2006). Rail and aviation benefited from the pioneering work done in the maritime area, but unlike maritime, both rail and aviation regulations have matured significantly since their initial SMS implementations (Ulfvengren & Corrigan, 2015). A careful review of the changes in the rail and airline areas shows their SMS guidance has become more prescriptive, including specific guidance on approaches to hazard analysis, better integration of risk management and ensuring that periodic assessments are done on how well the SMS is performing (Lappalainen, 2017). The author's view of why the aviation and rail regulations for SMS have matured faster over the past fifteen years relates to the size and governance of these transportation industries. For aviation, the number of airlines worldwide is relatively small compared to the number of shipping businesses. This allows the ICAO to have more focused feedback on the regulations, allowing faster turnaround of ideas and changes to the regulations. For the rail sector in Europe, the consolidation of national regulations under European Union governance meant that a unified approach

has been enabled. The rail and aviation also benefited from establishing and improving their regulations for SMS as the science of what constitutes a good SMS developed by academia matured. The fundamental components of a SMS, as shown in Figure 9, were available to guide SMS development in each of these sectors.

3.4 Issues with ISM Code

The IMO forced the adoption of SMSs for use by ship operators. Since it became mandatory, only relatively small changes to the regulation have been approved. Progress by the rail and aviation sectors has resulted in the creation of more robust and complete SMSs in those transportation industries. These other industries guide areas for improvement in the maritime SMS approach.

3.4.1 Issues of implementing the ISM Code in Ship Operating Companies

Lappalainen addressed the obstacles to successfully implementing SMS across several different safety-critical transportation industries, including rail, air, ship, and surface transportation. For the marine area he states the following:

> The ISM Code was established in the early 1990s. Since then, the Code has not been developed much further, which has also raised some criticism (Schröeder-Hinrich et al., 2013). The Code has been amended several times, most recently in June 2013, but the amendments have been very moderate (Schröeder-Hinrich et al., 2013; Lappalainen, 2016; Interview AU 18.10.2016). According to Schröeder-Hinrich et al. (2013), the Code reflects the state of the art of the early 1990s. Any new safety theories have not been taken into account. Another criticism has focused on the content of the Code (Jense, 2009; Salokorpi and Rytkönen, 2010). The ISM Code is based on very loosely written general principles and objectives. The rationale for that approach was that the Code could easily be applied in different shipping companies and ships that sail in highly varying conditions (IMO, 1993). However, the Code has been criticised to be fuzzy and a compromise between efficiency and accuracy (Jense, 2009). The Code does not give satisfactory information on how to implement a proper safety management system in a company (Jense, 2009; Lappalainen, 2016). Further, Jense criticizes that the Code does not define the requirements for a safety organisation in a company. (Lappalainen, 2017)

Since implementation, only minor changes have been made to this regulation (Schroder-Hinrichs, 2013). Shortly after the implementation of the ISM Code, Thai analyzed the reaction of the shipping community to its impact (Thai, 2006). A key finding was that the ISM Code failed to incorporate guidance for the port and shoreside operations, where many accidents happen. This is another area for improvement in the Code. Other areas of the ISM Code may need strengthening. Further evidence of the current shortcomings of the ISM Code is seen in work by Celik where the suggestion is made to incorporate the ISO standard for quality (ISO 9001:2000) into the ISM Code. The argument being that ship operational safety would be improved by integrating safety and quality into an integrated management process.

Knudsen, O and Hassler, B (2011) identified another gap. They argue that the structural weakness of the IMO member state link is the core implementation problem that urgently needs to be dealt with if Marine safety is to be improved. They argue that the high-level requirements can be fine but implementing them through the Flag States varies widely and the audits/inspections done vary significantly between countries. One suggestion is to levy fines for deficiencies uncovered during audits. Another is to bring all Flag state inspectors under the control of IMO – thus "buying" uniformity in conducting audits.

The author reviewed the series of changes to the ISM Code (2002, 2006, 2009, 2010, 2015) and found that only small refinement of the wording has occurred (IMO, 2018). The core of the Code is still eight pages. The maritime implementation of the requirements for a SMS is not organized by functional areas and when compared to Hale's template it lacks explicit areas dedicated to the monitoring of the SMS, a safety information system and clarity on the requirements for the safety risk management system.

3.4.2 SMS development

There is a wide range of reasons why safety management systems for ship operations have been slow to adapt to changes and improvements. At a high level, the IMO's process for releasing new regulations or significant update takes approximately a decade from acknowledgement of an issue to a regulation in force (IMO, 2018). Adding to this is that the accident data that forms the foundation to drive change is

underreported (Psarros, et al., 2010). In a recent article, the Secretary-General of the IMO stated that the Flag States have failed to provide the accident reports for a large number of incidents and that there is significant underreporting (Bakhsh, 2019). Without a clear understanding of what caused each of these Very Serious Accidents, it is difficult to formulate needed changes to operations, SMSs and regulations (Lappalainen, 2017). Lappalainen lists several factors that impede the improvement of safety management systems, including cultural features of an organisation and the impact of Flag State national cultures and multi-cultural crews on board ship. At the company level, these cultural impacts are exacerbated by companies having to manage a worldwide fleet from a distance. Safety management is accomplished within an environment of a high level of regulation and a competitive worldwide marketplace that puts pressure on keeping costs of operations to a minimum. With all these challenges, companies tend to establish their safety management system to meet the minimum requirements of the IMO and the Flag State where their ships are registered, so that they can successfully pass required audits and keep their fleets certified to operate.

To address some of these issues, the author developed a modified SMS template for use in this research (Williams, 2019). Figure 11 captures the initial proposed evolution of the SMS. A fundamental refinement is to add the four "pillars" from the ICAO guidance on the implementation of aviation SMSs. These focal points are Policy and Objectives, Risk Management, Safety Assurance and Safety Promotion. The individual components of the current ISM Code were placed in each of these foundational areas, then missing elements were added. What this new template highlights is that safety risk management, including hazard analysis, has a central role to play in the SMS. Also, the revision calls for safety targets to be created and the performance of the SMS to be tracked. An enhance safety information system should be created to ensure that the safety-related knowledge gained from hazard and risk assessments and the analysis of accident and near-miss data is shared more consistently throughout each ship operator. Figure 27 in Section 6.3.1 has a further refinement of this template.

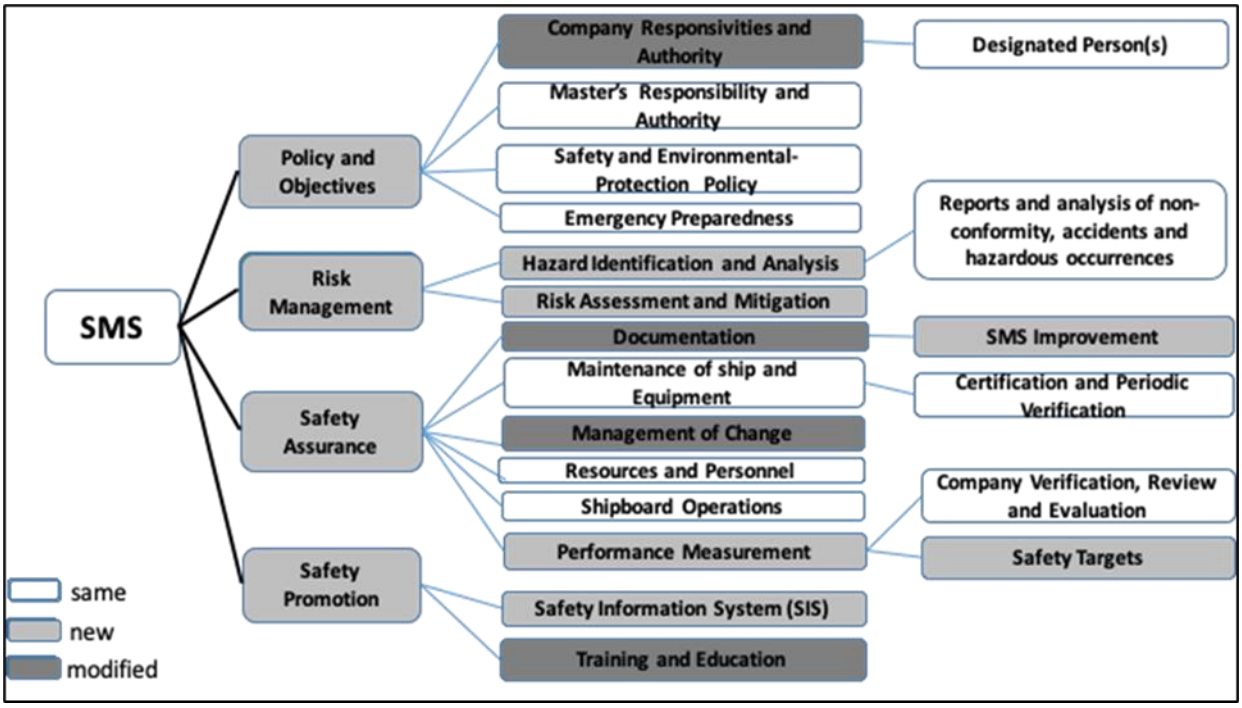

Figure 11: Proposed generic SMS for ship operations

3.5 Use of Performance Indicators

The research on developing performance indicators to help track the safe operation of each ship owners' fleet of ships covers a broad number of approaches. Several commercially available software tools provide methods to track ship operational performance via easily quantifiable indicators. A summary of the types of performance indicators recommended in the literature is developed. Examples of how indicators are used in practice are shown and various validation approaches are highlighted. Recent work on using systems theory to model organizational risk and safety management provides insight on how to create leading indicators linked to unsafe control actions to improve the safety of ship operations.

3.5.1 Leading and lagging indicator definitions

Ljungqvist points out that leading indicators are proactive metrics which can be used to discover safety weaknesses in advance of a negative event (Ljungqvist, 2013). Lagging indicators are reactive metrics

giving indications of past performance (American Bureau of Shipping (ABS), 2012). ABS notes that lagging indicators have a long history of use and have become an accepted standard approach for assessing safety.

3.5.2 Leading and Lagging indicators for ship safety operations

The literature on safety KPIs for shipping since 2000 shows that there is a weakness in the selection and use of indicators for trying to improve the safe operation of ships. As Banda points out the use of safety KPIs have been poorly followed, which has led to the need for more effective approaches to identifying, understanding and employing KPIs (Banda, 2016). Jalonen conducted a literature review of safety performance indicators in use in the maritime area (Jalonen, 2009). This research concluded that the indicators used were insufficient and that the marine domain needed a set of indicators that could measure actual and future levels of safety. The limited set of indicators identified were predominately lagging indicators.

Recent work by Arslan et al created a process for the development of KPIs to improve passenger shipping operations (Arslan, 2016). A set of forty KPIs were generated by reviewing other safety-critical industries. These were reviewed by the shore management team with internal and external safety experts. An additional forty-six key safety indicators were also created, for a total of eighty-six indicators. The next steps in the process were to see if there was a correlation between improved safety and the various KPIs. An initial analysis of the correlation between the number of safety meetings held on each ship in an eighteen-ship fleet showed no linkage between the number of non-conformities and the number of safety meeting held. A search of the literature identified the following providers of systems based on developing indicators to track ship performance:

- Baltic and International Maritime Council (BIMCO, 2018)
- Tanker Management Self-Assessment (TMSA, 2019)

- American Bureau of Shipping (ABS), as well as other commercial vendors, have products that provide a set of KPIs for ship operators to implement (ABS, 2016)

Each of these commercial tools is based on collecting a large amount of mainly empirical data on operations and then using some process to filter that data to create meaningful information to manage ship operations. As an example of one of these products, the BIMCO process creates eight Shipping Performance Indicators (SPIs) based on thirty-three KPIs. The KPIs are based on tracking sixty-four Performance Indicators (PIs). The eight SPIs cover the following areas:

- Environmental
- Health and safety
- Management
- Navigation
- Operational
- Security
- Technical
- Port State Control

The PIs are combined in a hierarchical process to create a normalized value from 0 to 100. The sixty-four PIs are combined in various summations to create the thirty-three KPIs, then these are further aggregated to form the eight SPIs (Grabowski, 2007). By aggregating many PIs into just eight system-level indicators, the impact of changes in individual indicators is shielded from view. This loss of understanding of what changes in indicators is happening means there is a dilution of the impact of individual indicators.

In 2012 ABS published guidance (American Bureau of Shipping (ABS), 2012) on safety culture and leading safety indicators focused developed for cargo ship owners. The process is based on conducting surveys of shore and ship-based staff to determine the maturity of safety management. Table 1 summarizes a general set of safety indicators recommended.

Table 1: American Bureau of Shipping (ABS) recommended safety indicators

Category	Factor	Units
Safety	Employee perception about management support of safety improvement efforts	Numeric Scale 1-5
Safety	Employee empowerment to fulfil safety responsibilities	Numeric Scale 1-5
Safety	Management response to safety issues and concerns	Numeric Scale 1-5
Safety	Number of near-miss reports submitted	Number
Safety	Number of near-miss reports closed out	%
Safety	Time to implement corrective actions	Days
Safety	Size of safety budgets	GBP
Safety	Number of safety meetings involving management	Number
Performance	Number of incidents/near misses followed by incident investigations	Number

Leveson argues that the correct approach for developing leading safety indicators is to model the safety management approach implemented by the organisation (Leveson, 2015). She uses STPA on the existing safety management structure to identify unsafe control actions and their causes. In her analysis of the safety management changes implemented after the Columbia accident at NASA, her STPA resulted in approximately 250 indicators, all linked to hazards. Before her analysis, NASA had been tracking over 600 parameters trying to ensure safe operations of the shuttle fleet.

The Italian economist Vilfredo Pareto in 1897 hypothesized that there is an 80/20 rule that roughly 80% of an effect comes from 20% of the causes. In his case, he was looking at the fact that 80% of the land in Italy was owned by 20% of the people. Richard Koch extended this approach to the broader concept that worthwhile results come from a small minority of the effort (Koch, 1998). Using this thought, David Parmenter postulated that a set of 100 performance indicators was all that was needed for companies larger than approximately 500 people. Of these, roughly 80 performance and result indicators should be tracked

and reported lower in the organization, while another 20 are key and should be reported to senior management and the board of directors (Parmenter, 2015). For a traditional corporation (non-safety critical) he recommended reporting 10 Key Results Indicators (KRIs) and 10 for Key Performance Indicators (KPIs), therefore his 10-80-10 rule.

David Parmenter (2015) provided the following guidance, Figure 12, on leading and lagging indicators.

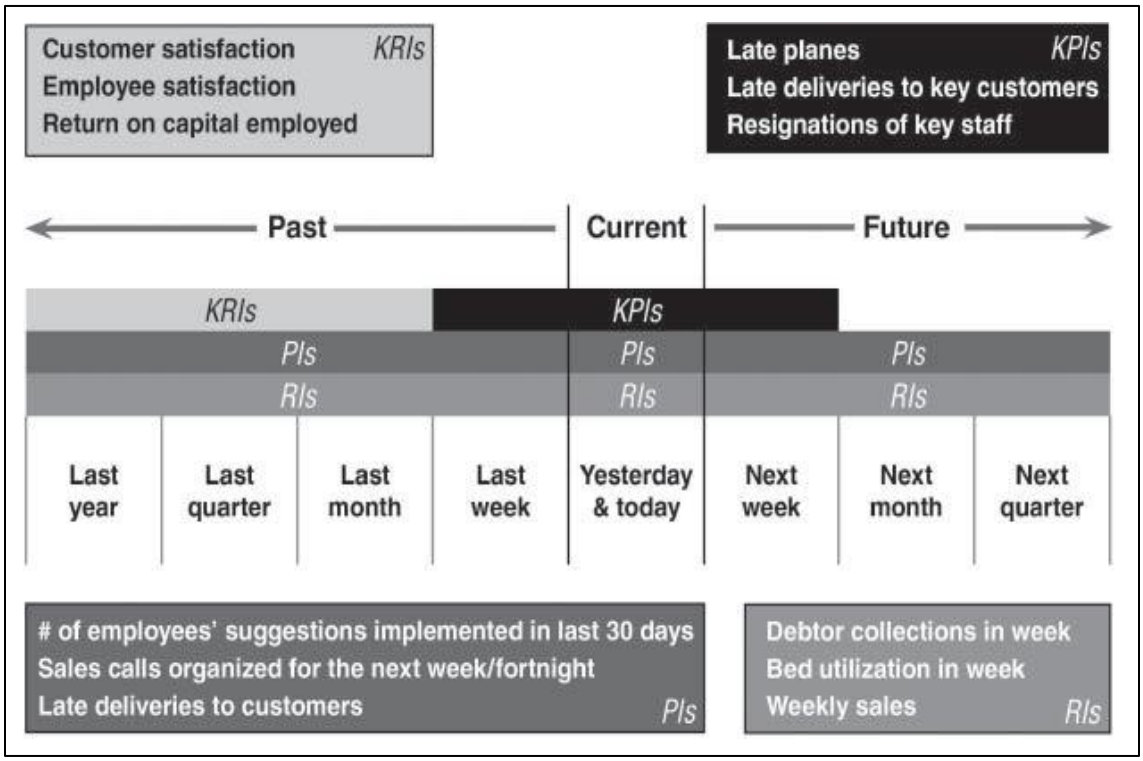

Figure 12: Leading and lagging KPIs and KRIs

Tjandra explains that both lagging and leading indicators are required to improve safety (Tjandra, 2016). The lagging indicators keep an accurate assessment of how the safety programs are operating, while the leading indicators guide the changes being implemented in indicators used to try and improve safety.

3.5.3 Evaluation of leading and lagging indicators

The underlying issue that each of these commercial systems for creating and tracking performance indicators must grapple with is that each of these processes generates large numbers of KPIs. The term "Key" becomes diminished when hundreds of "key performance indicators" are created and tracked. The BITCO example process provides an indication of the performance of the various ships in a fleet, but the effect of aggregating multiple PIs into eight SPIs means that a significant change in an individual PI value tends to be lost due to the use of multiple factors (PIs) in each SPI. This averaging together of so many variables means the impact of a change in one individual performance indicator is diluted and its change can be shielded for several review cycles. Trying to link one of these indicators to a resulting change in a lagging indicator is not possible.

David Parmenter's work focused on a range of businesses that were not in the safety-critical domain. His idea of tracking both lagging and leading indicators makes sense and his approach to limiting the reporting to the higher levels of the organization to key parameters appears to have merit. For his idealized 10/80/10 Rule if a company tracked 100 indicators just 10 would be Key Result Indicators and 10 would be Key Performance Indicators. Figure 12 shows the timeline scale for lagging and leading indicators for Key Results and Key Performance.

From the Handbook of Safety Principles: In discussing the use of safety and risk indicators, Rae makes the following assessment (Rae, 2018):

> "The end result is information which can be fed back to the system or operation for which safety is a concern. The difference between "safety management" and a "safety management system" is this feedback. Risk and safety indicators provide information on the effectiveness of management activities. This feedback allows control and optimization of safety processes, as well as targeting and evaluation of safety improvement initiatives." This is consistent with his later conclusion that:
>
> "Most applications of metrics are for the purpose of creating feedback loops. Each application involves collecting indicators, analyzing the indicators, and then applying some form of control action."

The literature on the use of indicators in ship operations provides general guidance on formulating key indicators, but there is a wide divergence of actual indicators recommended. Clearly, some gaps need to be filled to determine what the best set of maritime safety indicators are for ship operating companies to adopt.

3.5.4 How indicators are used in practice

Considering the breadth and depth of the worldwide fleet it is not surprising that a wide range of indicator programs are seen in the literature. Perhaps the most structured is seen in operators of oil tankers. Commercial software tools for tanker fleets track a myriad of indicators, but primarily focused on easily measurable ones that come from instruments or data collection devices. The data is aggregated into performance indicators to track general areas of performance like environmental compliance, efficiency, and safety. Grabowski assessed the safety culture at three tanker operators by creating a set of forty-three indicators at the company level (Grabowski, 2007). Then at the ship level, another twenty-one indicators were created and seventeen at the individual crew level. She avoids overly complex indicators to reduce the chance of errors and miscommunications. Ljungqvist created a set of 40 leading indicators but showed poor correlation to lagging indicators and felt additional research was needed to select the correct set of indicators (Ljungqvist, 2013).

For other types of fleets, there is less uniformity in the tools and processes employed for tracking performance indicators. In the initial phase of the research, the author approached six cruise and ferry operators. Each company had developed its own set of indicators that were used to brief upper management periodically (monthly or quarterly) on the performance of their fleet. Most indicators being employed were lagging indicators that provide limited insight into key drivers of safety. This highlights the need for improvements in this area so that a better cause and effect understanding can be achieved. The literature shows this gap by the lack of consensus in which indicators are critical to track to try and improve the safe operation of each ship owner’s fleet of ships.

3.5.5 Validation of indicators

The creation of a set of objective indicators involves a long-term process where an initial set of indicators is created, then the impact of safety-related metrics on safety performance is determined. Tomlinson presented an approach where once a company had established a safety management system and began collecting metrics, a set of correlations between, for example, the total number of safety metrics being utilized versus total recordable accident frequency could be checked (Tomlinson, 2011). The method used was to conduct a Spearman's rho test to determine if the organization's safety metrices correlated with its safety performance. The recommended timeline was to establish and track these factors over five years. In a similar fashion, Tomlinson also tracked the efficacy of subjective indicators created to track the safety culture of ship operators using a set of questionnaires which were administered periodically to track changes. Banda took a different approach by analyzing both the ISM Code and the TMSA process to develop a set of indicators (Banda, 2016). Banda's approach created a process whose first step was using the realist evaluation application to analyze the requirements derived from the ISM Code. This generated 183 potential KPIs for the functional requirements of the ISM Code and 322 KPI candidates for the elements of the TMSA process. The realist process then assessed each of these KPIs to select the final 53 KPIs. This process involved the use of a panel of ship operations safety experts to filter the total set of 505 KPIs down to the recommended 53.

3.6 Risk Maturity

Safety management systems are used to manage the safety risks facing each ship operator. To better understand the risk management process employed by each company, a method of assessing the risk management maturity was needed. Once the maturity is determined, then an indicator can be created to track how the maturity varies over time.

The objective section of the ISM Code requires all ship operators to "assess all identified risk to its ships, personnel and the environment and establish appropriate safeguards" (IMO, 2018). Risk maturity level can be determined by using the process from the Risk and Insurance Management Society (RIMS) (Minsky, 2008). Their five-level method to assess corporate enterprise risk management maturity is presented in Table 2. Each ship operator's maturity was assessed by reviewing the artefacts related to each level in this table, through a serious of interviews at each company. The documents to be reviewed include internal risk management plans, risk policy, risk registers and tracking of the flow of risk assessments throughout the organization.

Table 2: Enterprise Risk Management (ERM) maturity levels

Level 1: Ad Hoc	No coordinated focus on risk management
Level 2: Initial	Some risks identified, silo focused, audit focused
Level 3: Repeatable	Risks are tracked, enterprise risks identified, risk management plan
Level 4: Managed	Business planning and investments are linked to risk, the board of directors briefed periodically
Level 5: Leadership	The corporation understands its risk tolerance/appetite, risk is part of the day to day management of the organization with a strategic focus

3.7 Chapter Summary/Conclusions

Summary

Driven by the serious accidents that occurred in the '80s, industries were forced to improve safety management. In the maritime area, the IMO led the way by invoking the requirement for each ship operator to modify their management approach by creating a safety management system at each company. The IMO guidance is quite general, it is contained in just eight pages, and allows each company to implement its own

approach. To understand the process being used, a model of the safety and risk approach is needed. Early accident models were based on a single chain of events focused on equipment failures. Rassmussen created a systems model that views safety as a control problem (Rassmussen, 1997). Leveson at MIT built on this work to create the Systems Theoretic Accident Model and Process (STAMP) (Leveson, 2004). This model views safety as an emergent property of the safety control methodology. Leveson broadened Rassmussen's groundbreaking work to better define the entire social-technical control structure. The Systems Theoretic Process Analysis (STPA) is a hazard analysis method that can assess a wide range of sociotechnical and social systems and corresponding management processes. By modelling each layer and the flow of control actions by each controller and analysing the hazards that can cause the system to create unsafe control actions, an assessment of a current SMS can be made. STPA can be used to create a set of performance indicators so that the health of the SMS can be determined and tracked. While the IMO's ISM Code ploughed new ground and created a requirement for every ship operator to implement a Safety Management System, the rail and airlines quickly followed suit and developed their own versions of SMSs. By reviewing the literature on air and rail safety management, it is clear that although each of these safety-critical transportation industries started their implementation of SMSs after the maritime lead, they have matured and advanced their approaches to SMSs with better integration of hazard and risk analysis, and additional functionality. They added requirements for their industries to track the performance of the SMS and provide a safety information system to share the knowledge throughout the organisations gained as the systems are used. There are very few papers in the maritime area about tracking the performance of SMSs, another area where my research should help improve the operator's processes. Numerous papers address the shortfalls and problems with the ISM Code. There is room for improvement and by using STAMP to model the process and identify unsafe control actions companies are provided insight into weaknesses in their SMSs. My research provides a clear path for creating a set of performance indicators from the model of the company's SMSs, that should allow ship operators to reduce accidents and near misses. Enterprise Risk Management (ERM) is being used in both the rail and airline sectors to further improve safety, which provides insight into the path forward for the maritime community to enhance its use of risk management.

Recent research in key performance indicators for safety-critical industries does not show a consensus on what parameters should be tracked. Konsta points to a focus on Lost Time Injury Frequency as a KPI for tracking work time lost to injuries. She also points out that the development of KPIs needs more research (Konsta & Plomaritou, 2012). ABS has created a set of performance indicators focused on cargo ship operations. They use a series of questionnaires to assess the safety culture and create a set of indicators that ship operators can track. Over five years, they check whether the indicators adopted show a linkage to improved safety. Indicators are assessed and changed if no strong linkage is observed.

Conclusions:

The conclusions from the literature review are summarized:

- The ISM Code was transformational for ship operators as they became responsible for ship safety. They were required to establish a SMS. The process of measuring the performance of a ship operator's SMS by implementing leading indicators has not matured to a point where a standard set of metrics is evident in the literature.
- Traditional accident models were based upon event chains (domino, swiss cheese) where the failure of a component could precipitate an incident. This type of modelling worked well for an electro-mechanical system but fails to account for the many new modes of failure possible in today's highly complex social-technical systems. Models progressed by viewing safety as an emergent property of the control structure created by organisations to manage the operations of their companies and in this case their fleets.
- The Systems-Theoretic Process Analysis (STPA) method is a hazard analysis technique based on systems and control theories that can be adapted to model the safety management process. STPA views the SMS as a control structure where the various control actions, with their corresponding unsafe control actions, can be analyzed to determine a set of performance indicators to measure the drift of operations towards an accident.

- The ISM Code has issues due to the slow pace of change. It lacks a requirement for performance assessments of the efficacy of the Code.
- The literature shows that no standard or generic set of performance indicators exists to help ship operators improve the safe operation of their ships. There is a wide range of indicators listed in different references usually developed by a process of establishing panels of subject matter experts that base their selection on knowledge of SMS operations.
- The risk maturity of a ship operating company can be established by applying the five-level model developed by the Risk and Insurance Management Society (RIMS). A leading safety indicator tracking the change in risk maturity of a ship operator can be created to guide improvements in ship operators.
- There are three gaps identified that this research fills:
    - By creating a STPA model of the SMS at ship operators the hazards within the SMS can be identified and a set of key safety performance indicators developed. Active monitoring of these indicators allows the health of the SMS to be determined and tracked.
    - There are very few papers in the maritime area about tracking the performance of SMSs, another area where my research should help improve the operator's processes.
    - My research provides a clear path for creating a set of generic indicators from the results of modelling of the company's SMSs, that should allow other ship operators to reduce accidents and near misses

4 Methodology

A structured process was created to generate a set of performance indicators that ship operators can implement to continuously monitor the performance of their safety management approach. The first step was to determine an appropriate modelling technique that could be adapted to generate safety indicators. The literature review explored accident, hazard and risk models looking for an approach that could analyse complex management systems reflected in today's ship operations. The Systems-Theoretic Process Analysis (STPA), developed by Professor Leveson at MIT, emerged as an appropriate candidate to model and analyze the SMS implemented by ship operators, and produce a set of performance indicators. Leveson used this approach to analyze the organization of safety management within NASA's shuttle program (Leveson, et al., 2005). Leveson states that "STPA can be used to identify safety-critical assumptions that can then form the basis for a leading indicator program" (Leveson, 2015).

For each shipping company, the STPA-SMS assessment approach models the SMS as a hierarchical control structure with feedback loops. With this model, a STPA-SMS assessment was undertaken to generate scenarios of inadequate control within the control structure. When identified, these served as a basis for generating a set of SMS performance indicators. The final step was to combine the analysis results from both companies assessed to generate a generic set of SMS indicators.

The scope of the work is to create a revised set of performance indicators that ship operators can implement to improve the safe operations of their fleets of ships. This will be accomplished by modelling the SMS of a sample of cruise and ferry operators so that the flow of control actions designed to keep operations safe is understood using the following steps:

- create a STPA model of the safety management systems currently being used
- use the model to identify hazards and gaps in the management structure and processes
- develop requirements for preventing hazards from occurring
- create a corresponding set of company-specific safety system indicators

- develop a set of generic safety system indicators

The following section provides further arguments to justify the selection of the STPA-SMS assessment process and a detailed description of the approach.

4.1 Method selection

The path to selecting an appropriate model to create safety indicators started by reviewing traditional event chain techniques. From Section 3.2 of the literature review, it is clear that hazard analysis techniques like Hazard and Operability Study (HAZOP) and Hazard Identification (HAZID) were based on linear models of accidents as linear chains of events (Yousefi, 2019). Yousefi explains that hazard analyses were done on physical component diagrams and did not embrace the complex sociotechnical environment. These models would not be acceptable to use for the complex organisational safety processes implemented by current ship operators. Risk models, like the Risk Contribution Tree, combined fault tree models to analyze the process leading to an accident with event tree models to analyse the consequences (Jalonen, 2009). Jalonen states: “Risks can be modelled using accident models as a basis, but a sufficient risk model is usually much more comprehensive than a pure accident model.” The Risk Contribution Tree combines risk models and requires a significant amount of quantitative input data to produce a numerical assessment of risk. This level of data is not collected or readily available from the ship operators reviewed for this dissertation, making it unrealistic to use these types of models. Epidemiological accident models are also based on a linear chain of events. These models regard events leading to an accident as like the spread of disease (Yousefi, 2019). The earlier sequential and epidemiological accident models do not capture the reality of modern complex operations represented by today’s cruise and ferry operators as well as models based on system theory. Leveson points out that these earlier models relied on several simplifying assumptions (Leveson & Thomas, 2018):

- Each component or subsystem operates independently if events are modelled, then they are independent except for the immediately preceding and following events.
- Components act the same when examined separately (singly) as when they are playing their part in the whole

- Components and events are not subject to feedback loops and other indirect interactions
- The interactions among the components or events can be examined pairwise and combined into a composite value.

These assumptions are important because earlier (traditional) hazard analysis is based on decomposition and therefore all these assumptions hold. Accidents are assumed to be caused by the failure of a component, which is reasonable for electro-mechanical systems. Today's complex multi-level management systems execute safety by layers of management control based upon receiving feedback. Examples for ship operations include safety reports, audit and accident findings which are fed back through the management control structure. Systems Theory views the amalgamation of all the components to be greater than the sum of the parts (see Figure 4 in Section 3.2, p.15).

The next step in the evolution of accident models was to look at the process as a control problem. As explained in Section 3.2, this led to the development of systemic accident models based on systems theory. Rassmussen's work in the 1990s laid the foundation for this evolution. (Rassmussen, 1997). Leveson then created the Systems-Theoretic Accident Model and Process (STAMP) that views safety as an emergent property of a complex socio-technical control system, which ship operations represent (Williams, 2019). Leveson notes that "the identification of system safety constraints does provide the possibility of identifying leading indicators applicable to a specific system" (Leveson, 2011). Leveson used her organizational analysis to determine a set of leading safety indicators for NASA (Leveson, et al., 2005). By using the approach of tracking safety indicators, the management of a company was able to improve the safety record of the company (Leveson, 2015). Since the STPA-SMS assessment is based on systems theory and can be used to analyze the hazards within a complex socio-technical environment like ship operations and generate safety performance indicators, it was selected to model the safety management approach at each ship operator.

4.2 Method Description

The STAMP/STPA technique can be adapted for analyzing planned or existing organizational management structures. Figure 13 provides the overarching framework for applying the STAMP/STPA

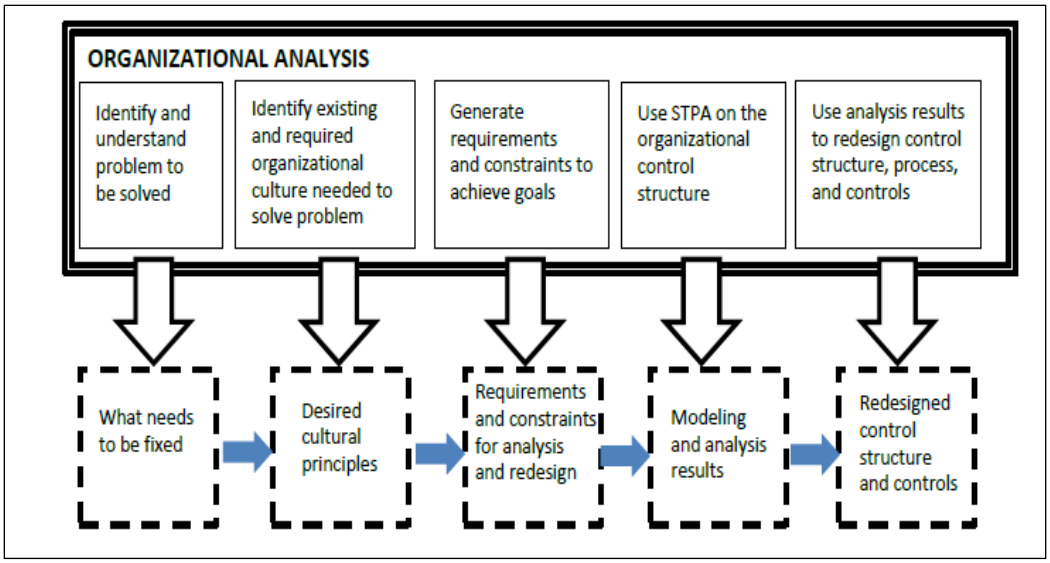

Figure 13: Approach to organizational STPA (Leveson & Thomas, 2018)

process to an organization. This approach applies systems engineering or reengineering to the organisation itself. An output of the STAMP/STPA analysis is to show how to improve the organisation structure, identify leading indicators and design (or re-design) the management process.

The problem to be solved for this research is to improve the feedback on the operation of the SMS. Each company being assessed has an existing compliant SMS. The assumption is that although the current system provides a level of safety, the incorporation of a proactive set of safety indicators developed through this process will ensure progressively better safety over time. Interviews with the Designated Person Ashore (DPA) at each company helped focus this research on monitoring the SMS as an important problem to be addressed. The next step in the analysis was to review the existing organizational culture in use for implementing safety. Leveson uses Edgar Shein's definition of organizational culture, which is: Organizational Culture is the shared values and deep cultural assumptions of a group or organization that provides the basis for decision making (Leveson & Thomas, 2018). To change the organization the culture

needs to be modified to promote a new direction. The information gained from interviews with the safety and risk managers at each company showed there was less focus on the development of safety culture and more on just meeting the minimum regulatory requirements. The adoption of new leading safety indicators, driven by the risk and safety managers will help alter the safety culture at these companies. The third step in the process was clearly captured in the online documentation of the SMS. Each company has developed all the components of their SMS to meet the minimum requirements contained in the ISM Code. These components formed the foundation for tracking the implementation of the SMS through the various layers of the organization by using the STPA-SMS assessment process in step four. The STPA-SMS assessment process, extended for this research, is captured in Figure 14. When using STPA to model the SMS and create system indicators, several additional steps are necessary past the identification of loss scenarios. For each loss scenario, a corresponding constraint or requirement needs to be generated. This requirement establishes what process should be accomplished to prevent each unsafe control action from occurring. With this knowledge, a system indicator can be created to track changes in this unsafe condition. If a change in the indicators shows a negative trend, then the operations staff can modify their procedures to prevent the change from generating an accident or incident.

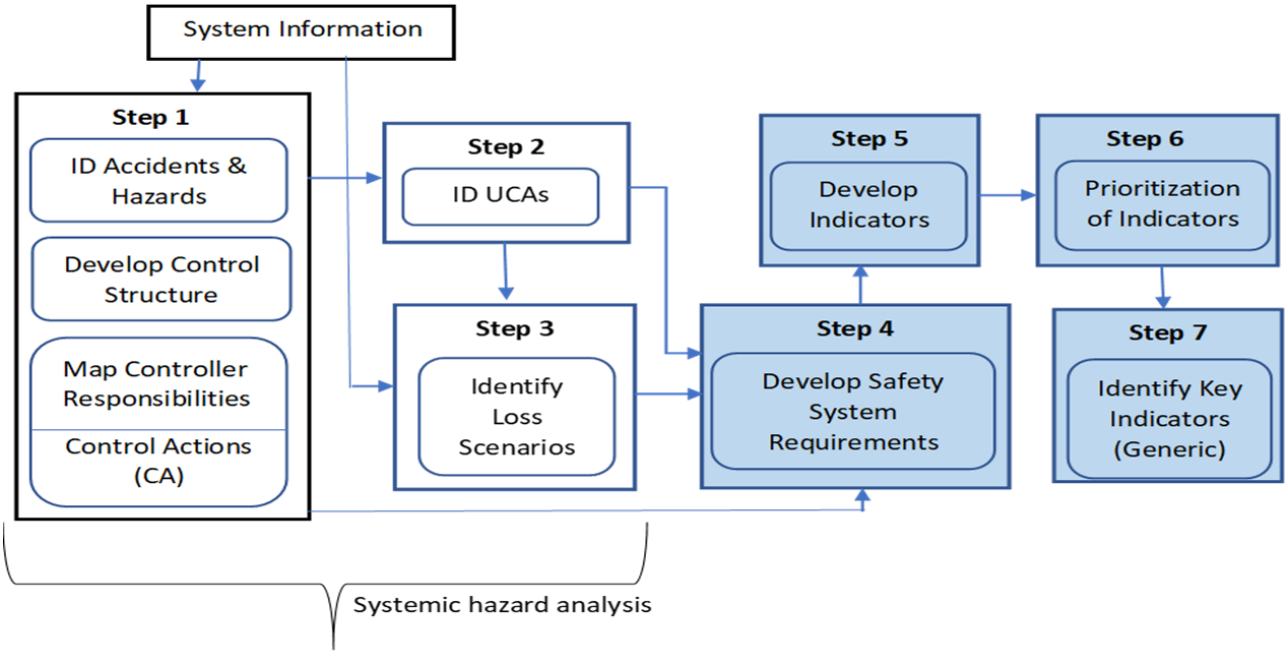

Figure 14: Extension of STPA process to create indicators

The first three steps are the core STPA process from Leveson, the remaining four steps (highlighted in blue) are the author's extension to the STPA process to create indicators of each company's SMS, and generic indicators.

Step 1) Identification of Accidents and Hazards

- Identify possible SMS accidents (losses) that may occur in the system
- Identify SMS hazards
- Develop the SMS control structure
- Map controller responsibilities
- Identify control actions for each Controller

Step 2) Identify Unsafe Control Actions (UCAs)

- Based on the control actions, identify the UCAs
- Create the process model by identifying the control actions between layers
- For each unsafe control action

  - Postulate control action behaviours that could generate unsafe control actions:

    - the control action is provided
    - the control action is not provided

    - the control action is provided too early or too late
    - the control action is stopped too soon or too late
- Determine if control action behaviours create an unsafe condition for each scenario

Step 3) Identify loss scenarios

- Identify possible causes of unsafe control actions or improper execution of control actions causing loss scenarios

Steps four thru seven extend the STPA approach to create and prioritize the set of safety system indicators:

Step 4) Create a requirement

- For each loss scenario, create a requirement that needs to be met to prevent the loss scenario from occurring

Step 5) Create a system indicator

- For each requirement, where feasible, create an indicator that can be monitored to determine if the SMS is drifting towards less safe operations
- Determine whether the indicator is leading or lagging

Step 6) Indicator prioritization

- Work with each controller within the company's control structure to rank the system's indicators in importance. Priority 1's that are judged the most hazardous to the performance of the SMS, Priority 2's that track potentially troublesome areas of safety management and Priority 3's that track regular performance aspects of the SMS.
- Create the key indicators (Priority 1) and regular indicators, then have each company implement and start to monitor.

The last step in the process, Step 7, is to use the results of this analysis to generate a set of generic indicators based on results from both companies:

- Create a set of generic indicators from safety system indicators that are common between Case 1 and Case 2 findings.

With the above-established process for the approach to create the indicators, the companies were approached to start the process of collecting the data to develop the STPA-SMS assessment.

Table 3: Data provided by each ship operator

Item	Source	Use in STPA-SMS assessment
Organisation chart	Internal company document	This provides the core of the relationships in the control diagram
Safety Management System	Online document – access provided	Defines the responsibilities of each controller and identifies the control actions and feedback from each controller.
Safety Alerts	Recent samples provided	Provides details on possible hazards
Audits (internal, flag and port state)	Past five years' worth of audit data	Identifies the procedures for identification and closeout of findings
Near miss data	Past five years' worth of data	Provides an understanding of the type of data being collected and allows the establishment of a lagging indicator.
Accident and incident data	Past four to five years' worth of data	Establishes baseline performance of the SMS and data to create a lagging safety indicator
Minutes of safety meetings	Samples from several ships	Highlights timing of closeout of safety issues
Risk registers	Samples from recent assessments	Provides data to create a lagging indicator of high, moderate, and low risks
Quarterly reports (KPIs, safety assessments)	Sample of recent assessments	Captures the current set of safety indicators for comparison

Each case study began with several visits to the shore staff responsible for fleet operations. Each company designated a single individual to act as the point of contact for coordinating the visits and responding to requests for information. The point of contact was a risk or safety manager within the shore side ship health, safety, and environment area. After several meetings and the signing of a non-disclosure agreement, the information listed in Table 3 was provided

Based upon the organization chart and the flag state of the fleet of ships, a very large-scale governance control structure diagram was created, identifying all the control layers that could affect the safe operation of the fleet. Once this diagram was available, the individual controllers were identified and the set of control

documents flowing down to the next layer in the organization was identified. The corresponding feedback information (audit findings, safety meeting minutes, etc.) was identified for each controller. Audit findings and accident data were reviewed to provide insight into what hazards were being addressed. This provides a context for the indicators currently being employed and the potential impact of new indicators recommended from this research. This information provided the framework for populating the STPA-SMS assessment model.

A framework, Table 4, for the STPA-SMS assessment was created based on the proposed generic ISM Code template shown in Figure 11 (Section 3.4.2, p. 29) This template has the four functional areas forming the pillars of the SMS.

Table 4: Listing of SMS categories for STPA-SMS assessment

Functional Area	Category	Description
Safety Policy and Objectives	A1	Company responsibility and authority
	A2	Master's responsivity and Safety Accountability
	A3	Safety and Environmental protection policy
	A4	Emergency preparedness
Safety Risk Management	B1	Hazard identification and analysis
	B2	Risk assessment and mitigation
Safety Assurance	C1	Documentation
	C2	Maintenance of ship and equipment
	C3	Management of Change
	C4	Resources and Personnel
	C5	Shipboard Operations
	C6	Performance Measures
Safety Promotion	D1	Safety Information System
	D2	Training and Education

The following definitions of terms unique to this dissertation are provided:

Control Action: direction provided by one controller to another to safely manage a system.

Control structure: Hierarchical relationship diagram of the functions of a sociotechnical organization.

Controller: Provides control actions on the system and gets feedback to determine the impact of the control actions. The controller enforces constraints on the behaviour of the system (Leveson & Thomas, 2018).

Hazard: Issues or conditions that can lead to loss of human life or injury (traditional safety) or more broadly to include other losses like a mission loss, loss of performance, environmental losses, etc. (Leveson & Thomas, 2018)

Risk appetite: ISO 31000 states the "Risk appetite is the amount and type of risk that an organization is prepared to pursue, retain or take." This annual guidance, usually set by the Board of Directors and the CEO, helps guide an organization's approach to risk and risk management.

Safety Management system (SMS): a structured and documented system enabling company personnel to implement effectively the company safety and environmental protection policy (IMO, 2018).

Systems-Theoretic Process Analysis (STPA): a hazard analysis technique based on an extended model of accident causation (Leveson & Thomas, 2018)

Systems-Theoretic Accident Model Process (STAMP): an accident model based on systems theory.

Unsafe Control Action (UCA): is a Control Action that, in a particular context and worst-case environment, will lead to a hazard (Leveson & Thomas, 2018).

4.3 Case Studies

Four of the original six companies approached agreed to provide the information needed to allow the modelling of their SMS and supply supporting data on accident, near miss and audit information for an assessment to be made. During the research one company eventually withdrew their support. Data was provided by two cruise and one ferry operator. The complete STPA-SMS assessment process was performed on one cruise company and one ferry operator; therefore two complete case studies were developed. Each of the companies used in this research has ongoing reporting of a set of performance indicators. Each company selected its current set of indicators based on experience and continue to add and modify their indicators over time.

4.3.1 Case studies

The selected companies represent a typical mid-sized ferry operator (Company A) and a large cruise ship company (Company B). Similar processes were conducted to generate all the data needed to model the SMS and create indicators for each operator. For Company B, the decision was made to focus on one brand that would be representative of the company's other brands and allow for a reasonably sized fleet to be

assessed. Based on the company's recommendation, the selected brand had a total of 10 ships in operation. Company A had a total of 32 ships in operation.

For each case study, the current set of performance indicators was captured. Table 5 contains the indicators from the monthly Company A status reports and Table 6 contains the indicators from Company B's Quarterly reports.

Table 5: Company A's current performance indicators

Category	Factor	Units	Type
Training	Number of training days taken place	% crew	Lagging
Training	Number of people attending training events	Number	Lagging
Performance	The average speed of answer at the Contact Centre	Seconds	Lagging
Performance	Vehicle deck utilization	Percentage	Lagging
Performance	Carrying trends (passengers, cars, coaches and commercial vehicles	Percentage change	Lagging
Performance	% of vehicle deck available	Percentage	Lagging
Performance	% Port services offered	Percentage	Lagging
Safety	Number of MAIB investigations	Number	Lagging
Health	Reporting of Injuries, Diseases and Dangerous Occurrences Regulation (RIDDOR),	Number of incidences	Lagging
Safety	Near miss to accident ratio	Ratio	Leading
Audit	Formal internal investigations fleet/shore	Number	Lagging
Audit	Vessel food safety & compliance audits	Number	Lagging
Audit	Port safety compliance audits	Number	Lagging
Audit	Port safety compliance inspections	Number	Leading
Audit	Internal ISM audits	Number	Leading
Security	Internal security audits	Number	Lagging
Audit	External ISM audits	Number	Lagging
Security	External security audits	Number	Lagging
Performance	Reliability	Percentage	Lagging
Performance	Punctuality	Percentage	Lagging
Performance	Total number of sailings	Number	Lagging
Performance	Number of customer complaints	Number	Lagging
Performance	Number of customer appreciations	Number	Leading

The current method of reporting using performance indicators was captured from one of the quarterly reviews. Table 6 has the listing of the indicators used with a determination of whether the indicators are leading or lagging.

Table 6: Company B's current performance indicators

Category	Factor	Measurement	Type
Health	Fatalities: crew and passengers	Deaths per 200,000 exposure hours	Lagging
Health	Injuries: crew and passengers	Injuries per 200,000 exposure hours	Lagging
Health	Gastrointestinal Illness	% crew, % passengers	Lagging
Health	Gastrointestinal Illness trend	Number of Reported incidents of increased GI per ship	Lagging
Health	Public health inspection results (per ship)	Score (100 is highest)	Lagging
Environmental	Discharge incidents by type and root cause	Number	Lagging
Environmental	Pollution prevention equipment issues by system and cause	Number	Leading
Environmental	Environmental incident rate trend	Number	Leading
Environmental	Environmental officer gaps	Number	Leading
Performance	Number of collisions, allisions, and grounding by type	Number	Lagging
Performance	Number of complete power loss incidents	Number	Lagging
Performance	Significant fires	Number	Lagging
Performance	Incinerator fires	Number	Lagging
Performance	Fire system failures	Number	Lagging
Performance	Number of fuel/lube oil leaks	Number	Leading
Safety	LSA failures	Number	Lagging
Safety	Shoreside emergency response organisation exercises	Number	Leading
Performance	Number of drug and alcohol test failures (Watchkeeping Officers)	Number	Leading
Security	Sexual Incidents per 100,000 passengers	Number	Lagging
Security	Serious physical assaults per 100,000 passengers	Number	Lagging
Security	Prohibited items reported	Number	Lagging
Security	Missing persons per 100,000 passengers	Number	Lagging
Security	Attempted security breaches	Number	Lagging

Category	Factor	Measurement	Type
Security	Suspicious activities and security threats	Number	Lagging
Financial	Net operating profit	Percentage	Lagging
Financial	Advanced bookings	Number and $	Leading

Most of the indicators being employed are lagging indicators (19 of 25). The six leading indicators include one financial, two safety and three environmental indicators.

4.3.2 Case Study #1: Safety Management at Company A

This case study is based on an analysis of a mid-sized ferry operator providing services in the United Kingdom. The Company operates a fleet with a mix of passenger and passenger/vehicle carrying ships ranging in size from 11.6 meters to 117.9 meters. This company operates 365 days a year with over 150,000 sailings annually. Ships are UK flagged and use Lloyds for their inspections and surveys.

The STPA-SMS assessment was implemented for analyzing the ship operator's safety and risk management approach by following the steps outlined in Figure 14 (Section 4.2, p.46). Requirements and constraints of the company's safety control structure and risk management processes were developed from fundamental safety-related documents, operation manuals, management policies and interviews with company staff. The STPA-SMS assessment captures the entire social-technical structure that Company A's ship managers must respond to for successful fleet operations. Every layer can potentially cause an issue that can directly affect the safe operation of each ship.

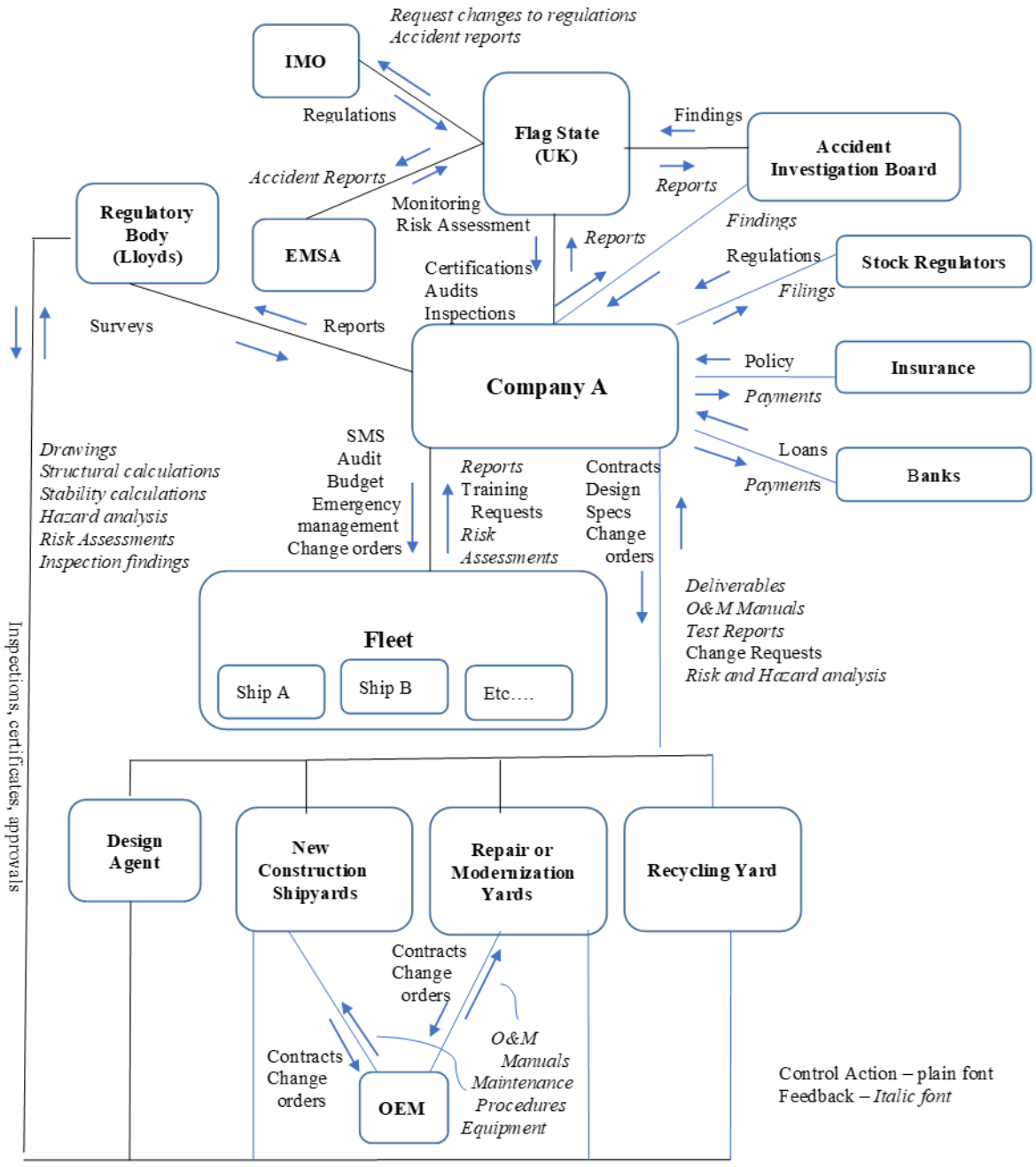

Figure 15: Overarching control structure for Company A

Figure 15 is the control structure for Company A. This is the basic overarching structure for Company A. This diagram shows the key control actions flowing between layers in the organization and the corresponding feedback of reports and information in response. The STPA-SMS assessment process starts

by identifying the accidents and hazards that the SMS is designed to prevent. The accident and hazard categories were created by reviewing past accident and audit findings. Several years' worth of accident, near miss and incident data were analyzed along with internal and external audit results of the SMS process for a similar period. Section 5.1.4 contains Company A's findings.

Accidents:

System Accidents (SAs):

SA-1 Ship is lost or sustains major damage.
SA-2 Loss of life on a ship, at a port facility, or on a shore excursion.
SA-3 Ship release of hazardous materials causes damage to the environment

Safety Management System Accidents (SMSAs):

SMSA-1 SMS fails an audit, implying a weak safety process (i.e. a type of finding that indicate poor SMS)
SMSA-2 SMS fails to identify risks.

Hazards:

System Hazards (SHs):

SH-1 Ship is involved in a collision (SA-1,2,3)

SH-2 Ship operation results in a grounding event (SA-1,2,3)

SH-3 Ship suffers from fire (SA-1,2,3)

SH-4 Ship operations pose health and safety risks to crew and passengers (SA-2)

SH-5 Hazardous materials on board are not contained/managed (SA-1,2,3)

SMS Hazards (SMSHs):

SMSH-1 SMS is not designed according to standards (SMSA-1)

SMSH-2 SMS is not implemented in accordance with company policy (SMSA-2)

SMSH-3 SMS and risk management are not well integrated (SMSA-1, SMSA-2)

SMSH-4 SMS and risk management are not suitable for the organization (SMSA-1, SMSA-2)

SMSH-5 SMS and risk management are not effective (fail to mitigate hazards and risks) (SMSA-1, SMSA-2)

Requirements:

System Requirements (SRs):

SR-1 Ship shall maintain a safe distance from other moving or stationary objects.

SR-2 Ship shall not be operated in areas that could lead to grounding.

SR-3 Ship design and operation shall prevent fires.

SR-4 Ship design and operation shall prevent crew and passenger injuries at sea, in port or shore.

SR-5 Ship design and operation shall prevent toxins being released to the environment at sea and in port.

SMS Requirements (SMSRs):

SMSR-1 SMS shall be designed according to standards

SMSR-2 SMS shall be implemented in accordance with company policy and risk plan

SMSR-3 SMS and risk management shall be well integrated

SMSR-4 SMS and risk management shall be suitable for the organization

SMSR-5 SMS and risk management shall be effective.

Using this listing of hazards and requirements the STPA-SMS assessment process was initiated. The control actions contained in the SMS represented by the management artefacts (audits, safety alerts, etc.) for each controller were traced to the SMS hazards. For each control action, the unsafe control actions (UCAs) were determined. The STPA-SMS assessment process was executed on each artefact by assessing what happens when each control action is executed, not executed, executed late, or done too early. This process generates a large volume of data. To efficiently handle this set of information an Access database was developed. This database is a tool that each company can use to review, modify, and track progress over time. For each UCA, a set of loss scenarios, safety system requirements and indicators were documented in the database. For each of these loss scenarios, the related safety system requirement (SSR) was generated and in most cases, a safety system indicator (SSI) was created. These component-level indicators form the foundation for a set of performance indicators to track the status of each of these hazards so that preemptive action can be taken by the ship operators. By tracking these SSIs a continual assessment of the state of the SMS can be made and any negative changes can be tracked. Tracking these indicators should allow adequate time to adjust procedures so that accidents and incidents can be avoided. This approach does a good job of capturing the formal guidance flowing between controllers, such as requirements for conducting audits, but does not capture less formal reporting and guidance that occurs between organizational elements. The formal system

created by each company to handle both internal and external audits provides important insight into the functioning of the SMS. Regulations require annual audits of the SMS and resolution of the findings.

The STPA-SMS assessment created several system indicators to judge how well the audit process is functioning. Since the regulations do not prescribe how to conduct audits, each company developed its own implementation process. The STPA-SMS assessment captures the functioning of the audit process and creates a set of indicators tuned to the specific operator.

For Case Study #1 the STPA-SMS assessment provides a structured framework to ensure all elements of a robust SMS are in place for safe ship operations. Using the STPA-SMS assessment on Company A's safety management process revealed several weaknesses in the current approach and generated a detailed set of requirements and indicators for each controller.

4.3.3 Case Study #2: Safety Management at Company B

This case study is based on an analysis of one brand of a large cruise ship operator that provides worldwide cruise experiences. The parent company uses flags of convenience and is incorporated in Panama. The brand operates a fleet with a range of passenger ships varying in capacity from 1,875 to 3,650 passengers. The brand operates ten passenger ships ranging in size from 76,000 gross tonnage displacement to 149,000 gross tons. This company operates 365 days a year. Ships are Bermuda flagged and use Lloyds for their inspections and surveys.

Like the approach for Case Study #1, a STPA-SMS assessment was applied to model the company's safety management system. The process identifies hazards and loss scenarios within the SMS that might cause accidents. This analysis generates a set of requirements for safe operations and ultimately a corresponding set of safety performance indicators. Requirements and constraints of the company's safety control structure and risk management processes were developed from fundamental safety-related documents, operation manuals, management policies and interviews with company staff.

The STPA-SMS assessment captures the entire social-technical structure that Company B's ship managers must respond to for successful fleet operations. Every layer can potentially cause an issue that can directly affect the safe operation of each ship. Figure 16 is the control structure for Company B. This is the basic overarching structure for Company B.

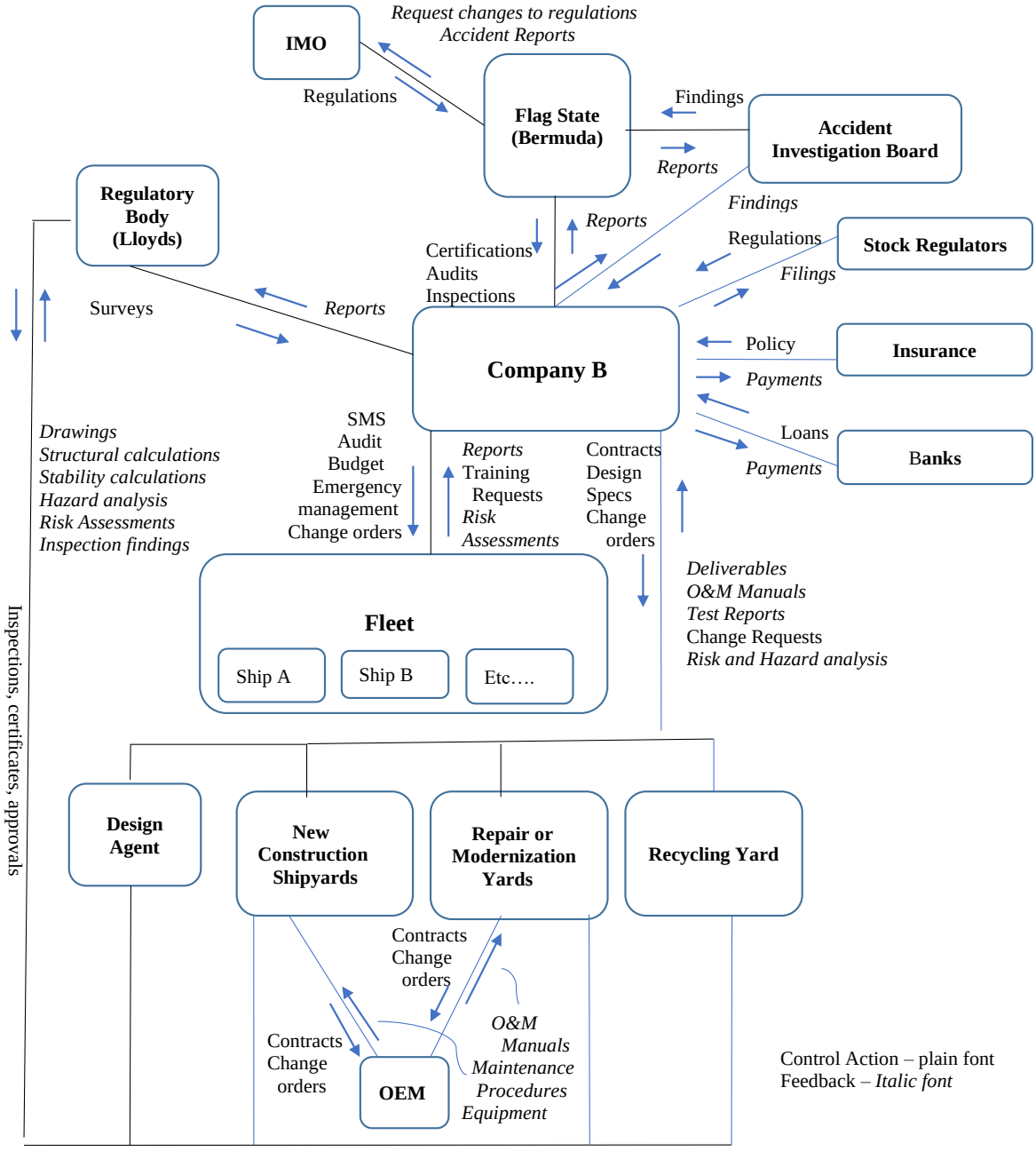

Figure 16: Overarching organizational control structure Company B

The STPA-SMS assessment process starts by identifying the accidents and hazards that the SMS is designed to prevent. The accident and hazard categories were created by reviewing past accident and audit findings. Several years' worth of accident, near miss and incident data were analyzed along with internal and external audit results of the SMS process for a similar period. Appendix B-1 contains a summary of Company B's

findings. The STPA-SMS assessment process assesses each control action undertaken by the various controllers and determines what unsafe control actions (UCAs) are created by each control action. Each UCA is linked to a Safety Management System Hazard (SMSH). Through this detailed analysis, the various weaknesses in the control structure and the SMS are delineated. A set of indicators can be derived that help point to where the ship operators should focus their mitigation efforts to reduce hazards. By tracking these indicators the influence of the UCA's can be monitored and their impact actively mitigated.

Accidents:

System Accidents (SAs):

SA-1 Ship is lost or sustains major damage.

SA-2 Loss of life on a ship, at a port facility, or on a shore excursion.

SA-3 Ship release of hazardous materials causes damage to the environment

Safety Management System Accidents (SMSAs):

SMSA-1 SMS fails an audit, implying a weak safety process (i.e. a type of finding that indicates a poor SMS)

SMSA-2 SMS fails to identify risks.

Hazards:

System Hazards (SHs):

SH-1 Ship is involved in a collision (SA-1,2,3)

SH-2 Ship operation results in a grounding event (SA-1,2,3)

SH-3 Ship suffers from fire (SA-1,2,3)

SH-4 Ship operations pose health and safety risks to crew and passengers (SA-2)

SH-5 Hazardous material on board are not contained/managed (SA-1,2,3)

SMS Hazards (SMSHs):

SMSH-1 SMS is not designed according to standards (SMSA-1)

SMSH-2 SMS is not implemented in accordance with company policy (SMSA-2)

SMSH-3 SMS and risk management are not well integrated (SMSA-1, SMSA-2)

SMSH-4 SMS and risk management are not suitable for the organization (SMSA-1, SMSA-2)

SMSH-5 SMS and risk management are not effective (fail to mitigate hazards and risks) (SMSA-1, SMSA-2)

Requirements:

System Requirements (SRs):

SR-1 Ship shall maintain a safe distance from other moving or stationary objects.

SR-2 Ship shall not be operated in areas that could lead to grounding.

SR-3 Ship design and operation shall prevent fires.

SR-4 Ship design and operation shall prevent crew and passenger injuries at sea, in port or shore.

SR-5 Ship design and operation shall prevent toxins being released to the environment at sea and in port.

SMS Requirements (SMSRs):

SMSR-1 SMS shall be designed according to standards

SMSR-2 SMS shall be implemented in accordance with company policy and risk management plan

SMSR-3 SMS and risk management shall be well integrated

SMSR-4 SMS and risk management shall be suitable for the organization

SMSR-5 SMS and risk management shall be effective.

Using this listing of hazards and requirements the STPA-SMS assessment process was initiated. The control actions contained in the SMS represented by the management artefacts for each controller were traced to the SMS hazards. For each control action, the unsafe control actions (UCAs) were determined. The STPA-SMS assessment process was executed on each artefact by assessing what happens when each control action is executed, not executed, executed late, or done too early. This process generates a large volume of data. To efficiently handle this set of information an Access database was developed. For each UCA, a set of loss scenarios, safety system requirements and indicators were created. For each of these loss scenarios, the related safety system requirement (SSR) was generated and in most cases, a safety system indicator (SSI) was created. These safety system indicators form the foundation for a set of performance indicators to track the status of each of these hazards so that preemptive action can be taken by the ship operators. By tracking these SSIs a continual assessment of the state of the SMS can be made and any negative changes can be tracked. Tracking these indicators should allow adequate time to adjust procedures so that accidents and incidents can be avoided. One limitation in this approach is that it does a good job of capturing the formal

guidance flowing between controllers, such as requirements for conducting audits but does not capture less formal reporting and guidance that occurs between organizational elements. The formal system created by each company to handle both internal and external audits provides important insight into the functioning of the SMS. Regulations require annual audits of the SMS and resolution of the findings. The STPA-SMS assessment creates several system indicators to judge how well the audit process is functioning. Since the regulations do not prescribe how to conduct audits, each company develops its own implementation process. The STPA-SMS assessment captures the functioning of the audit process and creates a set of indicators tuned to the specific operator.

Indicators for each controller were developed and presented for their review. Each controller was asked to prioritize each system indicator. As subject matter experts in their specific areas, they assessed the effectiveness of each indicator for eliminating the hazards linked to the indicator. They validated the importance of an indicator by applying a factor, with the Priority 1 indicators judged as critical, Priority 2 as being important, and Priority 3 as less important.

For Case Study #2 the STPA-SMS assessment provides a structured framework to ensure all elements of a robust SMS are in place for safe ship operations. Using the STPA-SMS assessment on Company B's safety and risk management process revealed several weaknesses in the current approach and generated a detailed set of requirements and indicators for each controller.

4.4 Results analysis

4.4.1 Ranking and assessing indicators

Initial results of the STPA-SMS assessment analysis indicated that the process yields a very comprehensive and thorough analysis of the SMS implementation at each company. The STPA-SMS assessment generated close to 300 indicators to track the performance of each company's SMS. The goal is to make useful information for each company from this large dataset by selecting a subset of more important indicators.

The literature review highlighted work by David Parmenter and others on creating a smaller subset of indicators that are reported up through each company's management hierarchy. Most of the literature attempts to reduce the set of indicators down to a few key ones that are a small per cent of the total identified. Many references use Pareto's 80-20 rule to identify the most important 20% of the indicators. This is a representative number for a reduction in the total number of performance indicators. David Parmenter takes this one step further in arguing that companies should have at most 100 indicators, of which 10 would be lagging (results) indicators and 10 would be leading (performance) indicators. This creates his 10-80-10 Rule (Parmenter, 2007). He postulated that a company (in a non-safety critical industry) should track 80 indicators lower in the organization, while another 20 are key and should be reported to senior management and the board of directors. The important concept to apply to this research is reducing the number of indicators to the critical ones that judge the performance of the SMS.

Extending this approach to safety-critical industries like ship operations, the author suggests that the correct mix of indicators for these industries should focus on four key areas: Key Performance, Key Risk, Key Safety and Key Financial Indicators (Williams, 2019). These would be the indicators provided to the executive and board level of a ship operator to understand the overall performance of their company.

For the Key Safety Indicator area, the author proposes applying the concept of Stu's (4x5) x80 Rule to the SMS indicators created by the STPA-SMS assessment process. This method more narrowly focuses the set of key safety indicators into the following areas that are based on the revised SMS template:

- 5% for Key Safety Policy & Objectives Indicator (KSPOI),
- 5% for Key Safety Assurance Indicator (KSAI),
- 5% for Key Safety Risk Indicator (KSRI) and
- 5% for Key Safety Promotion Indicator (KSPI),

with the remaining 80% reserved for lower priority indicators divided equally into the four functional areas. This initial concept needs ultimately to be validated by conducting STPA-SMS assessments at many ship

operators. Equally splitting the key indicators (5% in each functional area) is an initial concept that needs confirmation by determining what the actual STPA-SMS assessment determines for each company.

One other aspect of the analysis process was to determine whether an indicator was leading or lagging. As Reiman indicates, “Safety management needs a continuous focus on lagging indicators of past outcomes, including deficiencies and incidents, and ‘‘leading’’ indicators of technical, organizational and human functions that drive safety forward.” (Reiman, 2012). Companies should ideally mix the key lagging indicators with the key leading indicators. Examples of key lagging indicators would include accident data and number of training days taken. Key leading indicators include the number of repeat audit findings, the number of unfilled crew positions and the quality of the risk assessments for example.

4.4.2 Results validation

Two qualitative methods were used to validate the resulting sets of indicators produced by this research and one longer-term quantitative method is proposed. The first validation qualitative method results from the systematic application of the STPA-SMS assessment process to the actual company’s implementation of their SMS. This structured process categorizes the indicators by systematically examining the types of hazards that each management process is designed to overcome. This process serves as a detailed review of the entire SMS developed by each company. The indicators are linked to the hazards identified by the STPA-SMS assessment providing guidance to each company on weaknesses in their SMSs. Each company can then compare the set of indicators they are tracking and determine qualitatively the strength or weakness of their current set of indicators. The assessments also highlight gaps where there are no current indicators.

The second step in validation was accomplished by enlisting company experts in reviewing the STPA-SMS assessment results. The set of indicators for each control action was reviewed by the responsible controller. Each controller prioritized the indicators by how critical they were for assessing the hazards being managed. The prioritization methodology developed required each controller to rank the indicators according to their perception of the severity of the hazards being controlled. They ranked the importance of an indicator by

assigning a rating to each indicator. The Priority 1 indicators were judged as critical, Priority 2 as being important, and Priority 3 as less important. This prioritization process served to validate the selected indicators. This prioritization process can be affected by the bias of the individual subject matter experts. Research by psychologists shows that humans exhibit biases in making these determinations (Tversky, 1982). In this research, the creation of generic indicators was accomplished by identifying common indicators identified by experts at the two companies. This tends to compensate or reduce the individual biases and would improve the recommended generic indicators over time as more company's assessments were added.

Long term quantitative validation of the SMS indicators, as explained in Section 3.5, relies on collecting safety data over multiple years. The performance of the leading indicators recommended from this research would be tracked with corresponding lagging indicators of safety performance. When the correlation of an indicator is established then that set of indicators is reviewed over time. The indicators that show good linkage are kept, while the ones showing poor correlation are replaced. Future work would include a determination of the causal relationship. The indicators created by this research will ultimately be part of each company's long-term verification process.

4.4.3 Generic results

To expand the utility of the results from this work at two ship operators, a set of generic indicators was developed. These indicators were created to provide other ship operators with a base set of safety indicators to review for use in their fleet operations. By adopting this initial set of generic indicators any ship operator can check the robustness of their current set of indicators against this initial set of indicators.

The STPA-SMS assessment of Companies A and B provided an initial set of safety system indicators based on each company's approach to implementing safety management. By looking for common indicators between these assessments, an initial set of generic performance indicators, Figure 17, can be created. A set of normal (Priority 2 and 3) and key (Priority 1) indicators can be identified. The generic indicators of

safety span four areas: safety Policy and Objectives, Safety Risk, Safety Assurance and Safety Promotion. By providing indicators in each of these areas, companies will elevate safety reporting within their business environment. Over time additional company's data will be added to the limited data set of two companies, expanding the generic set of performance indicators. This augmentation is identified in the future work section.

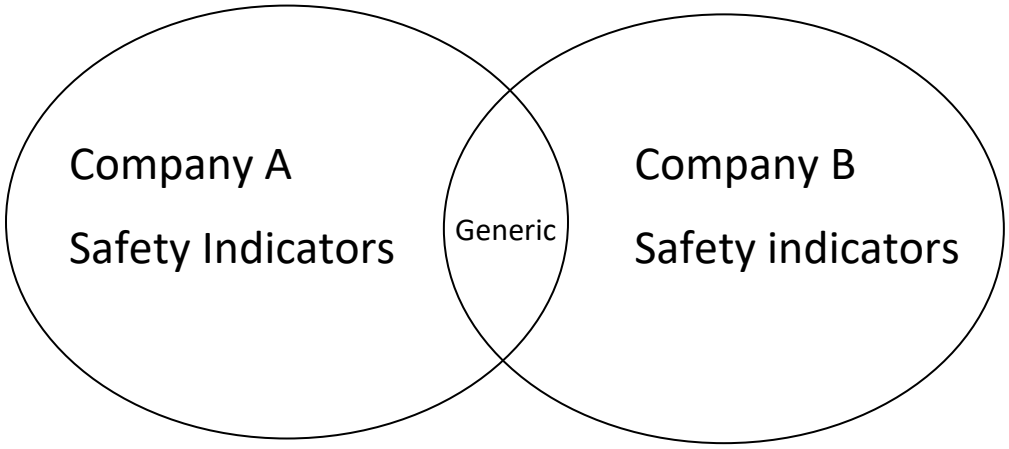

Figure 17: Common generic indicators

4.5 Chapter Summary/Conclusions

The development of a structured process to develop safety performance indicators started with an assessment of modelling techniques that could generate a set of indicators to monitor the performance of the SMS. Modelling techniques based upon a chain of events were reviewed but did not capture the complexities of current ship operations. The accident model STAMP, which is based on systems and control theories, was determined to be appropriate, consequently, the STAMP-based hazard analysis method, STPA, was adopted for the analysis of Company A and Company B. The method was extended to include analysis steps to created safety indicators for the SMS. This modified method is referred to as the STPA-SMS assessment.

To elicit the required input for the analysis, the author arranged multiple visits to each company, accumulating information about the controls put in place by operating procedures, reporting methods, and safety and risk assessments were identified. The feedback reports and information flows were determined and incorporated into the model. By assessing the hazards and loss scenarios that the safety management system can encounter, a set of requirements was developed with a corresponding set of indicators. For each Case Study, the governance structure within which each company operates was created. The identified controllers and their control actions were captured.

Safety system indicators in the following categories were created:

- Safety Policy & Objective Indicators (SPOIs)
- Safety Assurance Indicators (SAIs)
- Safety Risk Indicators (SRIs)
- Safety Promotion Indicators (SPIs)

Each of these categories is based on the functional areas identified in the revised SMS Template developed by the author (Figure 11, Section 3.4.2, p.31). A subset of these indicators was selected as key indicators and was captured in Stu's (4x5) x80 Rule. The final step in the process was to develop a set of key generic indicators by combining the results from both companies.

A methodology based upon the STAMP/STPA accident and hazard analysis approach has been developed to model the safety management process for ship operations and create a set of safety indicators. The STPA-SMS assessment systematically analyzes the hazards within a ship operator's SMS. The methodology developed was applied for two Case studies for a cruise and a ferry operator. A prioritization process was created to generate key safety indicators. The common findings from both case studies will be combined to form an initial set of generic safety system indicators.

5 Results

Individual results for Companies A and B are presented. Hazards, unsafe control actions and loss scenarios within each company's SMS are summarized and impacts explained. Sets of prioritized indicators from the STPA assessment for each company are developed. The distribution of the proposed sets of indicators is shown within the control structure. Generic results are presented based on combining the common results from both companies. Initial feedback from the review of the results at each company was positive. Both companies validated the indicators through the prioritization process. The indicators highlighted certain weaknesses in safety management processes at each company. In response, Company A modified its audit processes and Company B revamped its safety risk management approach.

For each of the companies studied, approximately ten to fifteen visits were carried out over a twenty-four-month period to various headquarters, training, and operational facilities. Initial visits focused on understanding the organizational structure and meeting with the safety and risk managers to understand the procedures in place for implementing the SMS and delivering safe fleet operations. The safety-related control actions were identified, for example, the risk registers, audit procedures, accident and near-miss data tracking and use, etc. Later visits provided time to meet with the various controllers and better understand the mechanisms in place to manage safety. Ultimately when results were available from the STPA process, each controller had the opportunity to review and discuss the findings. Controllers were instrumental in helping prioritize the system indicators generated from the STPA process.

5.1 Case 1 - Company A

The STPA-SMS assessment created a set of system indicators for each controller within the safety control structure. Table 7 shows that the STPA-SMS assessment generated 105 control actions performed by 26 controllers, with a corresponding 364 Unsafe Control Actions (UCAs). These UCAs generated 364 loss

Table 7: STPA-SMS assessment results for Company A

Function	# Company A
Controllers	**26**
Control Actions (CAs)	**105**
Unsafe Control Actions (UCAs)	**364**
Loss scenarios (LSs)	**364**
Safety System Requirements (SSRs)	**364**
Safety System Indicators (SSIs)	**278**

scenarios with 364 corresponding system requirements created to try and prevent the loss from occurring. The STPA-SMS assessment created 278 safety system indicators. There were several situations where the set of loss scenarios and corresponding requirements did not generate the need for an indicator. An example would be in tracking deliverables from shipyards or repair yards for hazard and risk analysis. If the yard did not produce the deliverable they would be in violation of their contract. Having an indicator for failure to produce a deliverable was deemed not as important as creating an indicator to track whether the deliverables were late. This explains the fact that there are slightly fewer system indicators than UCAs. A total of 53 Priority 1 indicators, 149 Priority 2 and Priority 3 indicators were created. The 53 Priority 1 system indicators form the pool of key safety Indicators to be tracked by the company.

5.1.1 Hazards within Company A's SMS

During the STPA assessment, each UCA was linked to a hazard within the SMS. Figure 18 shows the distribution and type of hazards by categories for Company A. The five categories of SMS hazards are:

- SMSH-1 SMS is not designed according to standards
- SMSH-2 SMS is not implemented in accordance with company policy
- SMSH-3 SMS and risk management are not well integrated
- SMSH-4 SMS and risk management are not suitable for the organization
- SMSH-5 SMS and risk management are not effective (fail to locate hazards and mitigate risks)

The predominate hazards within the SMS are when control actions are not executed in accordance with company policies. An example would be that an audit report is supposed to be issued within so many days of completing an audit, but that deadline is not met.

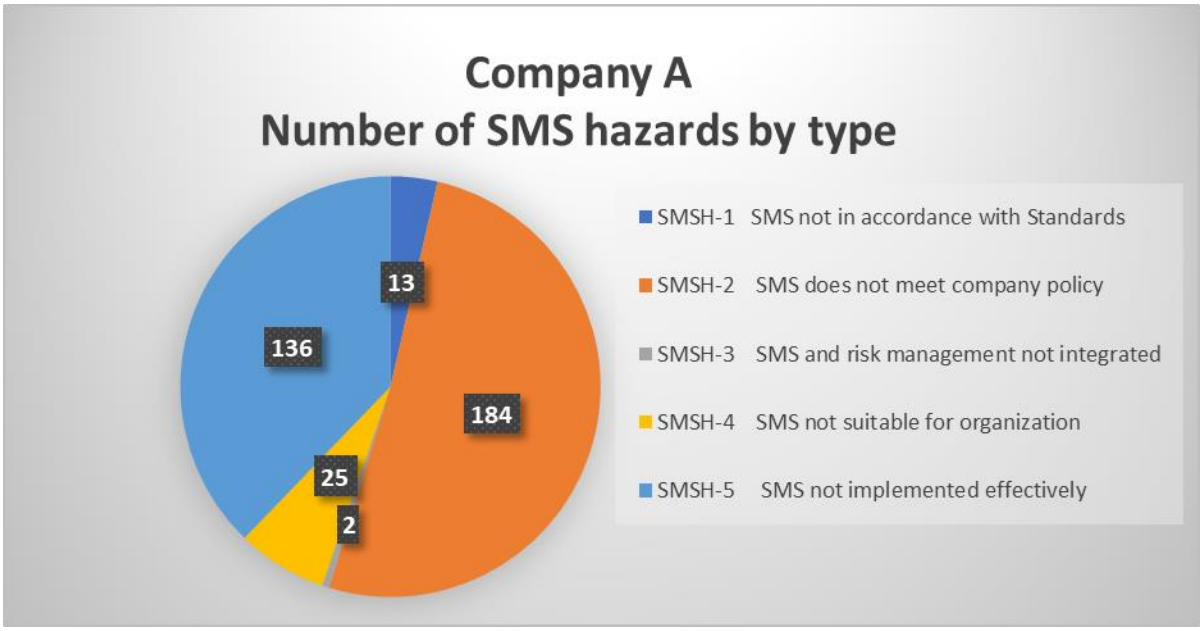

Figure 18: Company A - Number of SMS hazards by type

The second highest set of hazards is created when a control action is taken within the SMS and it is not effective. An example of that would be when a safety assessment is conducted, but the results are superficial and fail to uncover a safety issue.

These results provide guidance to the companies to create indicators to better track safety policies and to measure the effectiveness of their safety management control actions. Company A is exposed to the hazard of SMS procedures and processes being misaligned with company policies. This result means that Company A needs to review each control action periodically and determine its effectiveness in meeting the required company policies established by the control actions. By establishing this set of safety indicators better adherence to company policies will be reached.

The second main area to use indicators is to gain an understanding of how well the SMS is functioning. This is accomplished by focusing on ones dealing with the effectiveness of the control actions. These safety indicators will point to areas of the SMS that need to be strengthened.

Indicators for each controller were developed and presented for their review. Each controller was asked to prioritize each system indicator. As subject matter experts in their specific areas, they assessed the effectiveness of each indicator for eliminating the hazards linked to the indicator.

5.1.2 STPA-SMS assessment steps: Control Actions, Unsafe Control Actions (UCAs), Loss Scenarios, Safety System Requirements and Safety System Indicators

The development of safety system indicators follows the methodology explained in Section 4.2. For Company A, a sample of the types of control actions emanating from the Director of Marine Operations is elaborated in Table 8. This table shows details of a sample of one individual controller's control actions.

Table 8: Sample Control Actions (CAs) for a controller

Control Action Category	Recipient	Description
Resources	Master (each ship)	Provide adequate resources for good safety and risk management
Audits	Heath, Safety, Quality and Environment Committee	Request for audit support
Safety Alert	Ship's Safety Committee	Receive and respond to safety alerts

Table 9 shows the corresponding unsafe control actions that were generated. This traces the control actions from the Director of Marine Operations (Fleet) to the various other controllers in Company A that are on the front line of managing each ship in the fleet. Focusing on just one UCA, (Audits Performed), the STPA analysis generates a requirement that the Audit be of high quality and the corresponding indicator is that the quality of the audits should be assessed annually. This process creates a set of systems indicators based on the underlying implementation of the SMS.

Table 9: Corresponding UCAs

Control Action Name	UCA Name	Recipient
Resources	Safety and risk management Resources Provided	Master (each ship)
Resources	Safety and risk management Resources not Provided	Master (each ship)
Resources	Safety and risk management Resources Provided Late	Master (each ship)
Audits	Audits performed	HSQE Committee
Audits	Audits not performed	HSQE Committee
Audits	Audits performed late	HSQE Committee
Safety Alert	Safety Alert issued	Ship's Safety Committee
Safety Alert	Safety Alert not issued	Ship's Safety Committee
Safety Alert	Safety Alert issued late	Ship's Safety Committee

Drilling down into the information generated by the STPA process for one of the Control Actions is shown in Table 10. This excerpt from the STPA-SMS assessment Access database demonstrates the shore-based Director of Marine Operations executing the issuance of a safety alert to the fleet. The first Unsafe Control Action happens when the safety alert is accomplished but still creates an Unsafe Control Action because the alert is not specific. The second case creates a UCA when the Alert is not issued. The final case creates a UCA by issuing the alert late.

Table 10: UCA descriptions

Control Action Title	UCA Description
Safety alert	Safety Alerts lack specificity to work on every ship, thereby creating an unplanned hazard
Safety alert	By not issuing a Safety Alert, a known hazard is not mitigated
Safety alert	By issuing a Safety Alert late, a known safety hazard is not mitigated, causing an accident/incident/near miss

In this case, the issuance of a Safety Alert by the Director is not checked to determine whether it applies to every ship in the fleet. Without checking this applicability, executing the action may cause an accident. The other two safety alert cases are more direct, by not issuing a safety alert or issuing it late the information does not get to the fleet and therefore an accident can happen.

The next step in the STPA-SMS assessment is to create the corresponding loss scenarios for each UCA. Table 11 shows the loss scenarios for these UCAs.

Table 11: Loss Scenario Description

UCA Title	Loss Scenario Description
Safety alert issued	Broad or general Safety Alert does not “fit” every ship, allowing a potential accident, incident or near miss to occur.
Safety alert not issued	Failure to issue a Safety Alert triggers lower company performance or allows an accident/incident/near miss to occur.
Safety alert issued late	Late delivery of the Safety Alert allows an accident/incident or near miss to occur.

The STPA process then creates a set of safety system requirements that the SMS must be designed to satisfy. For this same case, Table 12 shows the corresponding set of requirements to ensure that the UCA’s

Table 12: Safety system requirements descriptions

UCA Title	Safety System Requirement Description
Safety alert issued	The Safety alerts should be focused and specific for each ship so they can be effective
Safety alert not issued	The Safety Alert shall be issued.
Safety alert issued late	The Safety Alert shall be issued on schedule.

caused by the Safety Alert process are handled by the SMS. The power of the STPA process is that the current SMS can be assessed by looking at the hazards and the weaknesses identified allowing for improvements to be made. The requirements generated can be used to check that the right barriers are in place for safe operations and to generate a set of system indicators to be used to monitor the state of the SMS. Table 13 shows the safety system indicators created to track each of these UCAs. Appendix A.8 contains the details of the requirements of the assessed Control Actions and Appendix A.5 thru A.7 contain all the safety system indicators created.

Table 13: Safety System Indicator Description

UCA Title	Safety System indicator Description
Safety alert issued	Quality of Safety Alerts shall be assessed annually.
Safety alert not issued	An average number of Safety Alerts issued per month shall be tracked and reported quarterly.
Safety alert issued late	The number of days late for Safety Alert issuance is tracked on an annual basis.

Appendix C lists the periodicity for reporting the various types of indicators. The rate of reporting varies from daily to annually depending on the criticality of the system indicator.

5.1.3 Company A indicators and prioritization

The analysis generated 278 system indicators to monitor the functioning of the SMS. Considering the sheer number of UCAs, the STPA Access database was created to track the interactions between the controllers. The creation of this database is another result of this research that provides each company with a tool to track future changes in the actions they employ to monitor their SMS. The Asset tool was developed to guide the steps in the STPA process by providing automatic linkage of each control action with the related unsafe control actions. The corresponding loss scenarios, system requirements and system indicators are all linked and tracked. Analysis and reporting modules allow the user to parc the data by the priority of the indicators and types of hazards. This enabled the generation of the information in this results section and the tool will simplify *the* use of the process for future use by Company A.

A total of 53 Priority 1 indicators, 163 Priority 2 indicators and 62 Priority 3 indicators were created. The 53 Priority 1 system indicators form the basis for the key safety Indicators to be tracked by the company. These would be reported at a higher frequency (daily, weekly, monthly) to higher levels of management. The operating group would track the lower level indicators to develop a longer-term understanding of the functioning of the SMS. These indicators would be checked less frequently. Figure 19 shows the number of indicators created by each controller to track the performance of the SMS. Appendix A.6, A.7 and A.8 were created from an assessment of the set of indicators generated from the STPA model of Company A's SMS.

Figure 19 shows that the indicators are concentrated in the Company's executive level, the shore side operations department and onboard each ship. As an example, Table 14 contains a sample of the Priority 1 Key Safety Assurance Indicators (KSAIs). (Appendix A.6 has the complete set). Of these ten indicators, all are leading indicators.

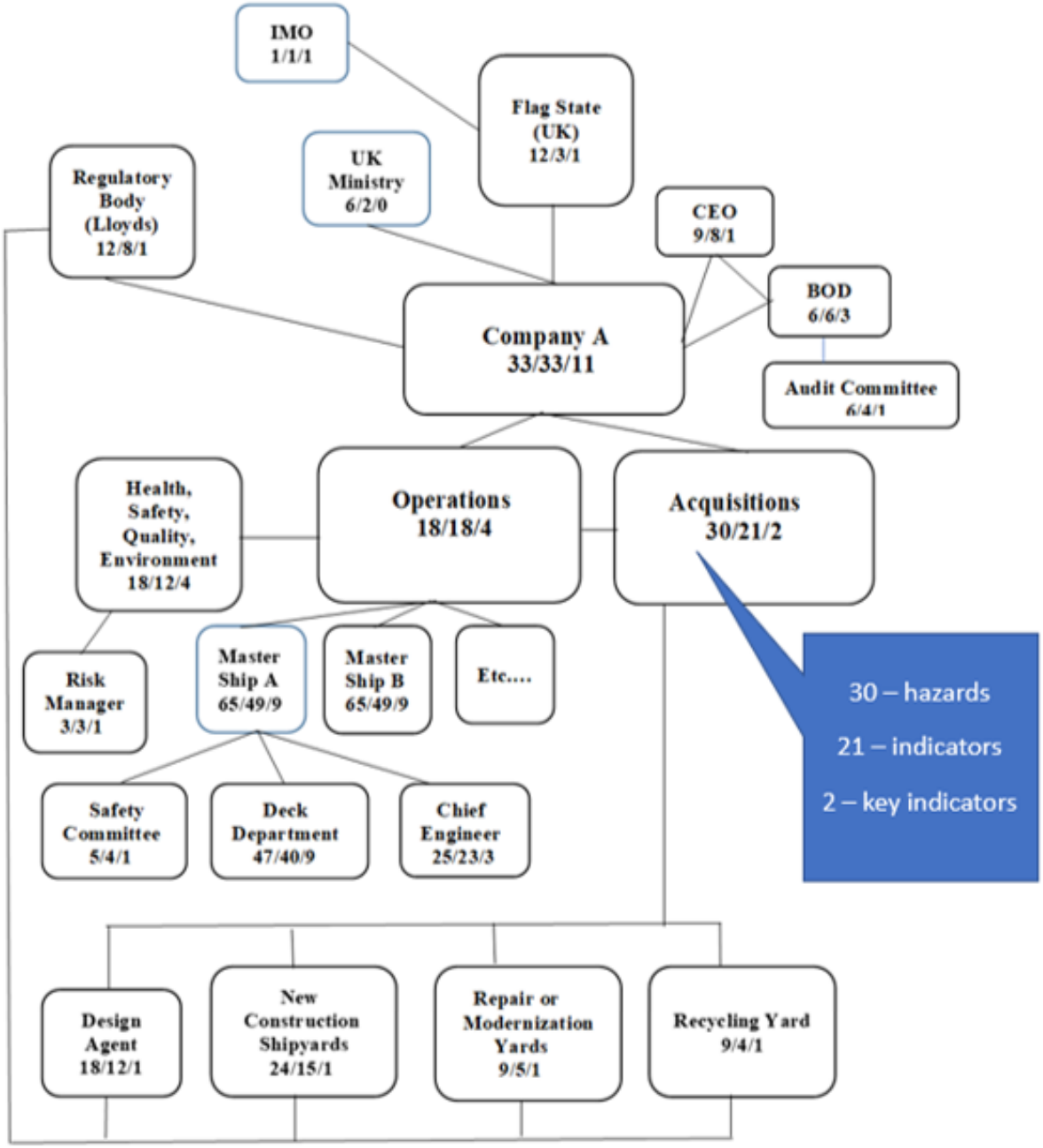

Figure 19: Distribution of hazards and indicators by Controllers

Table 14: Sample of Company A's Key Safety Assurance Indicators (KSAIs)

Indicator	Type	Controller	Measure
Safety meeting minutes	Lead	Master	Master reports monthly/annually on the total number of safety deficiencies and the number not being dealt with.
SMS Update	Lead	Director HSQE	The number of changes to the SMS should be tracked and reported on annually.
Planned maintenance	Lead	Master	The number of incidents caused by planned maintenance should be tracked yearly.
Planned maintenance	Lead	Master	The number of planned maintenance activities scheduled, but not completed, reported monthly.
Change requests	Lead	Design agent	Number of change requests, waivers and deviations that are not acted upon by Company A Acquisitions in thirty days, reported monthly
Resources	Lead	Director of operations	Level of funding for risk and safety mitigation efforts tracked monthly.
Resources	Lead	Director of operations	Crew manning levels shall be tracked weekly.
Safety assessment	Lead	Deck Department	Track number of safety assessments conducted monthly, including the number of hazards found
Safety meeting	Lead	Safety Committee	The number of times ship fails to hold the Monthly safety reviews, reported monthly.
Audit	Lead	Director HSQE	The number of repeat findings each review cycle shall be tracked and reviewed annually.

By separating these high priority safety indicators into their functional areas, the following observations of these factors emerge from the hazards highlighted by the STPA process. In the Safety Assurance area the following results are highlighted:

- One of the Key Safety Assurance Indicators (KSAIs) highlighted by the STPA analysis provided guidance to the Company to assess the crew manning levels on a more frequent basis with a new indicator.
- The area of planned maintenance performance needs to be tracked by an indicator and reported, which was not being done at Company A.
- Several of the indicators focus on the change process, which is especially critical after an availability, repair period or modernization. This is critical as Leveson points out “Most accidents

occur after some type of change" (Leveson, 1995). The horizontal link back to changes in operational procedures is weak at Company A and is reflected in several accidents and near misses after repairs and modernizations took place. STPA addresses this with several proposed indicators.

- A final KSAI metric that is critical to track is repeat audit findings. If the number of these start to grow it is a clear indication that the whole audit process is drifting towards unsafe operations as the same nonconformities continue to exist year after. If the normal process fails to close out audit findings within a year, allowing a repeat finding, then the whole audit process is weak. Company A does not track repeat findings.

In the Safety Promotion area:

- A Key Safety Promotion Indicator (KSPI) relates to training completion rates and the amount of funding available for training needs to be tracked monthly. Reduction in safety training or cuts to funding for training are leading indicators highlighting future issues.
- The quality of the Safety Alerts being issued should be tracked; something not being accomplished currently.

For the Key Safety Risk Indicator (KSRI) area, the following observations result from analysing the STPA findings:

- Company A has a risk register, but it does not drive the collection of risk items down to the ship level. This is an area that can allow early insight into conditions on each ship so that mitigations can be developed. This would pay additional dividends as several ships in this fleet are identical, thus a risk uncovered on one would be beneficial to multiple vessels. An additional indicator that tracks the quality of the risk register needs to be created and tracked annually.
- The Board of Directors (BODs) and the Managing Director have not developed a Risk Appetite document for Company A. This shortcoming should be addressed as it means the various Controllers are not being guided as to what the priority is in the company regarding risk reduction.

- The quality and use of accident and incident information are crucial to understanding how to prevent recurrence of similar events in the future. A review of the process at Company A showed a weakness in determining the root causes of accidents and incidents. An indicator is needed to track this area.

Finally, the Key Safety Policy and Objectives Indicators (KSPOI) show that:

- Upper management at Company A needs to track the periodic issuance of the Safety Policy. This annual report guides the organization as to where they should concentrate their safety efforts for each year.

Appendix A contains a complete list of all Control Actions (A.2), UCAs by Controller (A.3), Unsafe Control Actions (A.4), and System Safety Indicators, Safety System Requirements (A.8) and Key Safety Assurance Indicators (A.9) for Company A, Priority 1 Safety System Indicators (SSI) (A.5), Priority 2 Safety System Indicators (SSI) (A.6), Priority 3 Safety System Indicators (SSI) (A.7).

5.1.4 Company A's audit and accident investigation processes

Each company's handling of the conduct of audits and accidents investigations provides insight into the functioning of the SMS. Reviewing the results of the STPA-SMS assessment allows an understanding of the audit and accident procedures in place and produced a set of indicators to track the performance of these critical functions.

The STPA-SMS assessment process shows several Unsafe Control Actions (UCAs) that are related to the audit process at Company A. The first system indicator produced tracks the growth of Repeat audit findings, Table 15 lists other important indicators. The second is an indicator that assesses the quality of the audit process. Company A does not track repeat findings nor periodically assess the quality of its audit process.

Table 15: Audit safety system indicators

Unsafe Control Action Name	Priority	System Indicator Name	Description
Growth of repeat audit findings	1	Number of repeat findings	The number of repeat findings each review cycle shall be tracked and reviewed annually.
Deterioration of audit quality	1	Audit quality [assessed on a scale of 1 (poor) to 5 (excellent)]	The quality of the audit process should be assessed annually and reported.
Growth of new audit findings	1	Number of new findings	The number of new findings for each review cycle shall be tracked and reviewed annually.
Growth of audits not conducted	2	Audits not conducted	The number of audits not conducted shall be tracked and reported quarterly.

Company A currently assesses each audit non-compliant finding as having a low, moderate, or high rating. The company's goal is to close out the Low findings within 60 days, the Moderates within 30 days and the Highs within 7 days. In the data provided, the Lows (370 findings) were closed in an average of 70.3 days, the Moderates (10 findings) in an average of 81.5 days and the Highs (2 findings) were closed in an average of 28 days. Currently, Company A does not have an indicator tracking the days late for each category of indicator (high, moderate, and low). Adding this indicator would provide insight into how well the audit process is operating. When presented with these findings Company A decided to incorporate this indicator into their monthly reporting. From these results, it is clear the company's process for using audit findings could be strengthened. Further, there are certain of the findings that should trigger a closer review and timelier closeout.

Accident, incidents and near misses are routinely reviewed by the ship operator. The STPA process models the approach taken by tracing the control actions established for reviewing the post-accident procedures required by regulations as part of the SMS. The effectiveness of the internal processes set up by the company to learn from the accidents, incidents and near-miss data is a key area for building better safety. The use of this information can be tracked by systems indicators created through the STPA process.

Currently, the review process at Company A is not well structured. The STPA analysis addressed this by creating indicators to track the timeliness, trends and quality of the accident, incident, and near-miss data.

The company's accident, incident and near-miss data were reviewed based on the records for 2014 to 2018. Almost 3000 entries were reviewed. Table 16 shows the past four complete years' worth of data, plus 2018 through June. This data establishes a baseline so that the company can judge the effectiveness of the use of the recommended performance indicators developed by this research as they track safety performance going forward, and serves to highlight the operational areas that cause the largest number of problems.

Table 16: Company A's accident/incident data 2014-2018

Accident/Incident	2014	2015	2016	2017	2018*
Vehicle Mishaps	82	80	112	94	82
Fires	3	2	2	1	2
Slips, trips, falls, minor injuries	130	171	174	167	112
Docking mishaps	27	10	13	9	11
Bike. Motorcycle incidents	16	8	10	6	9
Ramp Mishaps	36	28	21	21	10
Maintenance incidents	6	3	1	2	0
Hull damage	12	11	8	9	12
Miscellaneous	6	5	0	4	2
Machinery Failures	1	4	5	10	4
Fuel Incidents	1	0	1	0	0
Boat incidents	1	1	4	10	2
Steering system issues	2	1	0	0	0
Groundings	0	1	0	0	0
Totals	**323**	**325**	**351**	**333**	**246**

Figure 20 shows one year's worth of the data to indicate the major categories that have most of the accidents and near misses. By reviewing the indicators the ferry company can see that a majority of accidents onboard are related to slips, trips and falls from both passengers and crew. The next highest problem areas are related to vehicle movement on the vehicle decks and the ramps to shore. The STPA indicators created to track the

quality of the accident reports, their timeliness and an assessment of whether the root cause of the accident was determined. Company A does not track this information. The only current indicator in this area is one used to track the number of events that trigger a Marine Accident Inspection Branch (MAIB) formal review.

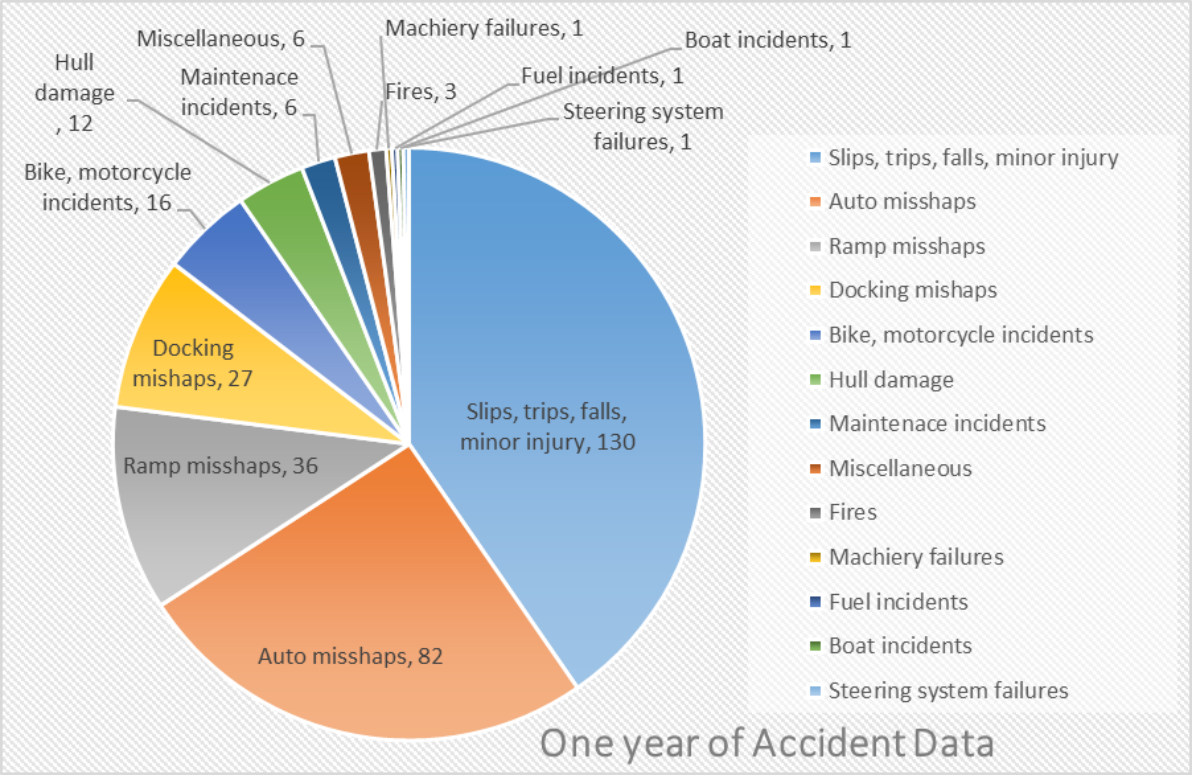

Figure 20: Company A accident data for one year

5.2 Case 2 - Company B

The STPA assessment created a set of system indicators for each controller within the control structure. Table 17 summarizes the STPA findings. Company B's 100 control actions related to the management procedures for implementing the SMS resulted in 310 Unsafe Control Actions. This resulted in a total of 270 system indicators. The large number of system indicators were prioritized using the approach described

in Section 4.2. A total of 69 Priority 1 indicators, 178 Priority 2 and 23 Priority 3 indicators were created. The 69 Priority 1 system indicators form the pool of key safety Indicators to be tracked by the company.

Table 17: Summary of STPA-SMS assessment of Company B

Function	# Company B
Controllers	**35**
Control Actions (CAs)	**100**
Unsafe Control Actions (UCAs)	**310**
Loss scenarios (LSs)	**310**
Safety System Requirements (SSRs)	**310**
Safety System Indicators (SSIs)	**270**

5.2.1 Hazards within Company B's SMS

During the STPA-SMS assessment, each UCA was linked to a hazard within the SMS. Figure 21 shows the distribution of the hazards by categories for Company B. The predominate hazard within the SMS is that UCAs occur when control actions are not executed per company policies. An example would be that an audit report is supposed to be issued within so many days of completing an audit, but that deadline is not met. The second-highest level of exposure of SMS hazards is created when an action is taken within the SMS and it is not effective. An example of that would be when a safety assessment is conducted, but the results are superficial and fail to uncover a hazard. These results guide the companies that they need

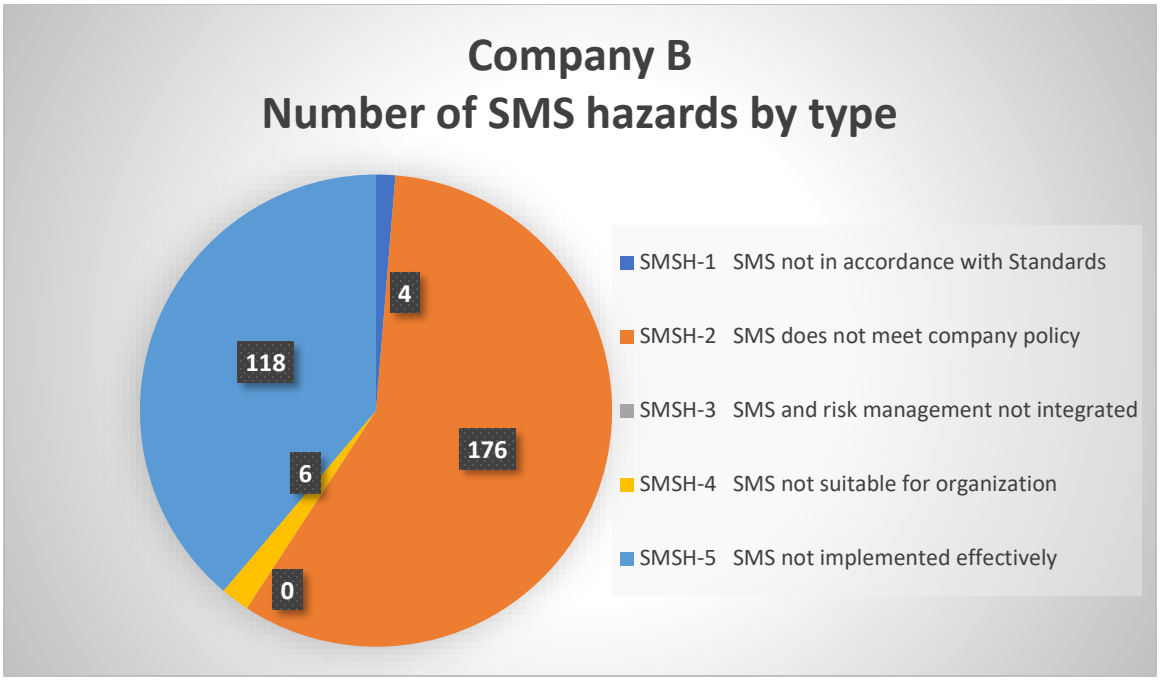

Figure 21: Company B number of hazards by type

to create indicators to better track safety policies and measures of the effectiveness of the safety management methods.

5.2.2 STPA-SMS assessment steps: Control Actions, Unsafe Control Actions (UCAs), Loss Scenarios, Safety System Requirements and Safety System Indicators

The development of safety system indicators follows the methodology explained in Section 4.2. For Company B a sample of the types of control actions emanating from the Master is further elaborated in Table 18. This table shows details of a sample of the Master's control actions and the recipients. The Master was responsible for a total of twenty-five Control Actions.

Table 18: Sample Control Actions (CAs) for a controller

Control Action Category	Recipient	Description
Planned maintenance	Chief Engineer (each ship)	Guidance on the use of planned maintenance approach provided
Environmental deficiencies	Chief Engineer (each ship)	Required reporting of environmental deficiencies
SMS assessment	Staff Captain (each ship)	Provide Deck Department inputs for annual SMS assessment

Table 19 shows the corresponding unsafe control actions (UCAs) that were generated via the STPA-SMS assessment. This Table traces the control actions from the Master to other controllers onboard that are on the front line of managing ship safety. Focusing on just one set of UCAs, (Planned maintenance), the STPA-SMS assessment generated a requirement that the planned maintenance program be followed and accomplished on time. This process creates a set of systems indicators based on analyzing the UCAs that can occur from implementing planned maintenance.

Table 19: Corresponding UCAs and recipient

Control Action Name	UCA Name	Recipient
Planned maintenance	Planned maintenance accomplished	Chief engineer (each ship)
Planned maintenance	Planned maintenance not accomplished	Chief engineer (each ship)
Planned maintenance	Planned maintenance accomplished late	Chief engineer (each ship)
Environmental deficiencies	Environmental deficiencies reported	Chief engineer (each ship)
Environmental deficiencies	Environmental deficiencies not reported	Chief engineer (each ship)
Environmental deficiencies	Environmental deficiencies reported late	Chief engineer (each ship)
SMS assessment	SMS assessment provided	Staff Captain
SMS assessment	SMS assessment not provided	Staff Captain
SMS assessment	SMS assessment provided late	Staff Captain

Another example of the information generated by the STPA process is shown in Table 20. This excerpt from the STPA Access database, demonstrates the Chief Engineer ensuring that the planned maintenance program guidance from the Master is properly implemented. Three types of Control Actions are shown. The first Control Action has the planned maintenance being accomplished, but it creates an Unsafe Control Action because the planned maintenance generates an accident. The second case creates an UCA when the planned maintenance is not accomplished. The final case creates an UCA when the planned maintenance is done late.

Table 20: UCA descriptions

Control Action Title	UCA Description
Planned maintenance	The planned maintenance is accomplished but the maintenance triggers an accident/incident/near miss.
Planned maintenance	The planned maintenance is not accomplished which allows an accident/incident/near miss.
Planned maintenance	The planned maintenance is accomplished late allowing an accident/incident/near miss.

In the first case, the planned maintenance work takes place, but that causes an accident. The other two cases are more direct, by not performing the planned maintenance or performing it late an accident can happen.

The next step in the STPA-SMS assessment is to create the corresponding loss scenarios for each UCA. Table 21 shows the loss scenarios for these UCAs.

Table 21: Loss Scenario Description

UCA Title	Loss Scenario Description
Planned maintenance accomplished	Shipboard planned maintenance is accomplished but causes an accident/incident or near miss to occur.
Planned maintenance not accomplished	Failure to perform a planned maintenance activity triggers an accident/incident or near-miss.
Planned maintenance accomplished late	Late completion of a planned maintenance activity causes an accident/incident/near miss to occur.

The STPA process then creates a set of safety system requirements that the SMS must be designed to provide. For this same case, Table 22 shows the corresponding set of requirements to ensure that the UCA's caused by the Safety Alert process are handled by the SMS. The power of the STPA process is that

Table 22: Safety system requirements descriptions

UCA Title	**Safety System Requirement Description**
Planned maintenance accomplished	Master shall track any adverse incidents caused by successfully following the planned maintenance approach.
Planned maintenance not accomplished	Planned maintenance activities shall be completed according to the schedule
Planned maintenance accomplished late	Planned maintenance shall be completed on schedule.

the current SMS can be assessed by looking at the hazards and the weaknesses identified allowing for improvements to be made. The requirements generated can be used to check that the right barriers are in place for safe operations and to generate a set of system indicators (Table 23) to be used to monitor the state of the SMS. Appendix A.8 contains the details of the requirements of the assessed Control Actions.

Table 23: Safety System Indicator Description

UCA Title	Safety System indicator Description
Planned maintenance accomplished	The number of incidents caused by planned maintenance should be tracked on a yearly basis.
Planned maintenance not accomplished	The number of planned maintenance activities scheduled, but not completed, reported monthly.
Planned maintenance accomplished late	Number of planned maintenance activities not completed each month reported monthly

Appendix C lists the periodicity for reporting the various types of indicators. The rate of reporting varies from daily to annually depending on the criticality of the system indicator.

5.2.3 Company B indicators and prioritization

Figure 22 shows the distribution of indicators at each Controller location in the overall control diagram.

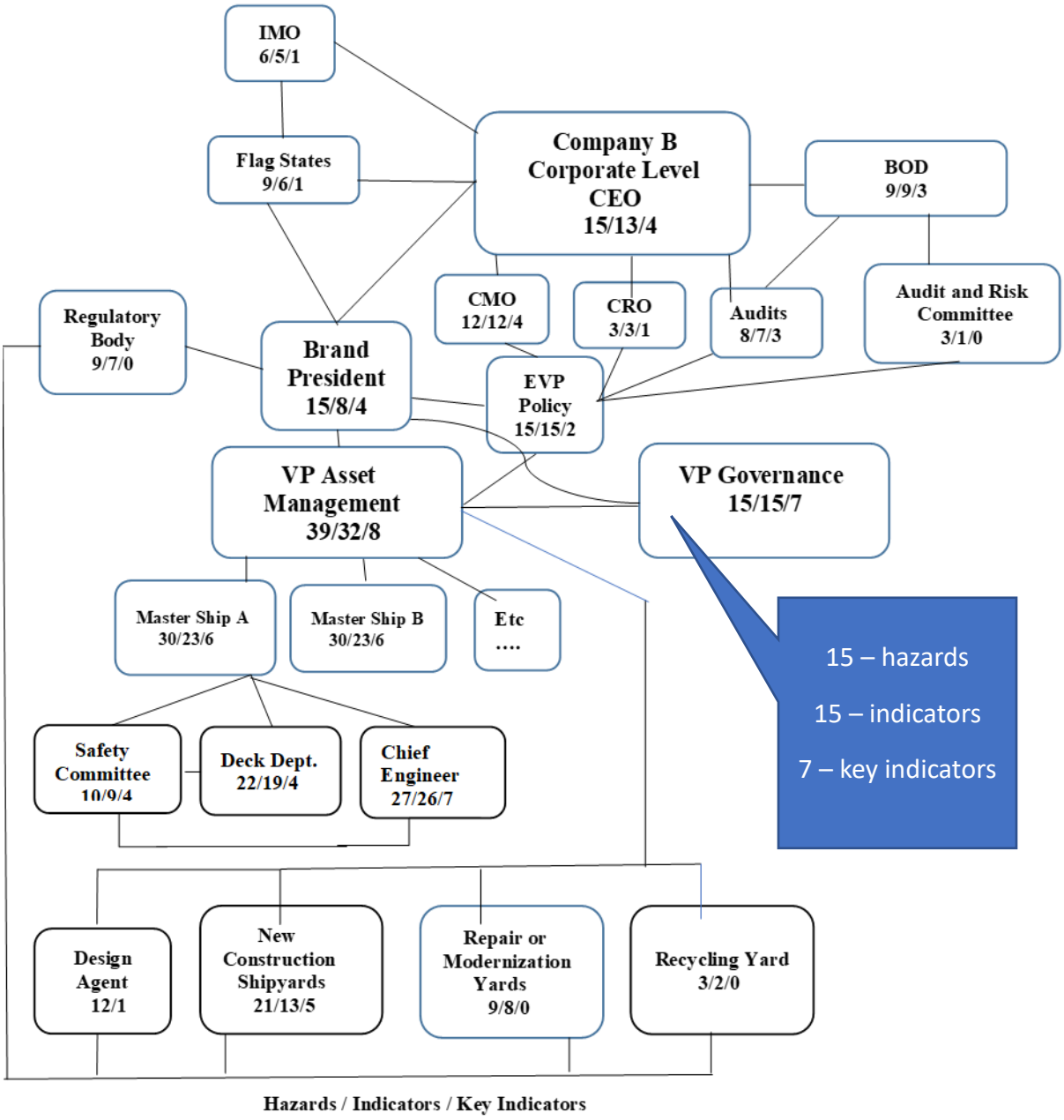

Figure 22: STPA results for hazards, indicators, and key indicators per controller

The first number is the total number of loss scenarios linked to hazards, the second number is the total

Table 24: Sample of Company B's Key Safety Risk Indicators (KSRIs)

Key Safety Risk Indicator	**Controller**	**Measure**	**Type**
Risk assessment	CE	A summary report of the total number of risk assessments and the percentage delivered late should be produced annually.	Lag
Risk assessment	Staff Captain	The number of new risks identified without mitigation plans shall be tracked and reported monthly.	Lead
Risk appetite	CEO	The number of times the CEO fails to issue the Risk Appetite shall be tracked and reported annually.	Lead
Risk assessment	Director, Risk Engineering	An assessment of the quality of the ERM report shall be made and reported annually.	Lead
Risk register	Director, Risk Engineering	Quality of the Risk register shall be assessed, and findings reported annually.	Lead
Risk register	Master	The average number of days past due for the risk register shall be reported monthly.	Lead
Risk assessments	Master	The total number of unfunded and unstaffed risk assessments should be reported monthly.	Lead
Risk assessments	Master	The total number of risk assessments should be tracked/plotted on a monthly/quarterly/annual basis.	Lag

numbers of indicators and the last number is the key indicators. As an example, Table 24 contains a partial listing of the priority one Key Safety Risk Indicators (KSRI). The complete list is in Appendix B.6

By separating these key safety indicators into their functional areas, the following observations emerge from the STPA process.

In the Key Safety Assurance Indicators (KSAIs)area the following results are highlighted:

- The Company needs to assess the crew manning levels on a more frequent basis with a new indicator. In the area of planned maintenance performance, the number of planned maintenance activities scheduled but not performed needs to be tracked by an indicator and reported, which was not being done at Company B.

- Several of the indicators focus on the safety assessment process. Company B should create an indicator to track the number of open (not completed) safety assessments monthly.
- A final KSAI metric that is critical to track is repeat audit findings. Company B records the data on this parameter but does not have an indicator that tracks the performance of this parameter.

In the Key Safety Promotion Indicators (KSPIs) area:

- A Key Safety Promotion Indicator (KSPI) relates to requests for training not approved. Lack of training tracked by this leading indicator provides an early warning of potential operational issues.
- The quality of the Safety Flashes being issued should be tracked which is something not being accomplished currently.

In the Key Safety Risk Indicators (KSRIs) area, the following observations result from analysing the STPA findings:

- Company B has a risk register, but it does not drive the collection of risk items down to the ship level. This is an area that can allow early insight into conditions on each ship so that hazards can be avoided. An additional indicator that tracks the quality of the risk register needs to be created and tracked annually.
- The Board of Directors (BODs) and the CEO have not developed a Risk Appetite document for Company B. This shortcoming should be addressed as it means the various Controllers are not being guided as to what the priority is in the company regarding risk reduction.
- The quality and use of accident and incident information are crucial to understanding how to prevent recurrence of similar events in the future. A review of the process at Company B showed a weakness in determining the root causes of accidents and incidents.

Finally, the Key Safety Policy and Objectives Indicators (KSPOIs) show that:

- Company B does not have an indicator that tracks the number of emergency system tests accomplished per year. This indicator would provide a good understanding of the preparedness level of the operations group at Company B.

Appendix B contains a complete list of all Control Actions (B.2), Priority 1 Safety System Indicators (SSI) (B.3), Priority 2 Safety System Indicators (SSI) (B.4), Priority 3 Safety System Indicators (SSI) (B.5).

5.2.4 STPA results of Company B's audit and accident investigation processes

Each company's handling of the conduct of audits and accidents investigations provides insight into the functioning of the SMS. Reviewing the results of the STPA-SMS assessment allows an understanding of the procedures in place and produced a set of indicators to track the performance of these critical functions.

The STPA process shows several Unsafe Control Actions (UCAs) that are related to the audit process at Company B. In Table 25 the repeat findings UCA is especially important. This one indicator tracks the health of the whole audit process at the company. An uptick in this indicator would show that the entire audit process is not performing the role of uncovering and removing serious safety and operations issues. The other UCAs related to the audit process are important in that they require an assessment of the quality of the audit process be made, as well as tracking the timeliness of the closeout of findings. While Company B does have the data to track repeat findings, they do not report that information or have an indicator to track it. Similarly, there is no indicator to track the quality of the audit process over time.

Table 25: Additional system indicators for tracking other Unsafe Control Actions (UCAs)

Unsafe Control Action Name	Priority	System Indicator Name	Description
Growth of repeat audit findings	1	Number of repeat findings	The number of repeat findings each review cycle shall be tracked and reviewed annually.
Deterioration of audit quality	1	Audit quality [assessed on a scale of 1 (poor) to 5 (excellent)]	The quality of the audit process should be assessed annually and reported.
Growth of new audit findings	3	Number of new findings	The number of new findings from each review cycle shall be tracked and reviewed annually.

The areas highlighted by the STPA analysis serve to focus on the operational findings that have a higher impact on safe ship operations. An example would be Company B does not track the time to close out the high medium and low audit findings. Without an indicator, there is no clear indication of how well the audit process is being executed. Some management check should be created to ensure that these operationally oriented findings receive attention and are closed out within the required number of days.

The trends indicated by the continuing high level of fuel leaks, full blackouts and loss of power events shows that more aggressive use of indicators tracking accidents and incidents needs to be established at Company B.

5.3 Generic Results

Table 26 contains a set of thirty-eight initial generic indicators developed by combining the matching STPA results from both companies. The eleven Priority 1 indicators form the Key indicators while the twenty-seven Priority 2 were used to populate the regular indicators. A blend of leading and lagging indicators, some quantifiable and some qualitative were created from the results of the STPA output done on both companies. Leading indicators are in Blue while lagging indicators are shown in Red.

Table 26: Initial generic safety performance indicators

Indicator	Measure	Responsible	Type
Key Safety Policy & Objectives Indicators (KSPOIs):			
KSPOI-1 Regulations	Length in months between updates of the SMS regulations shall be tracked and reported annually	CEO	Lagging
KSPOI-2 Safety policy updates	The quality of the Safety Policy updates shall be assessed on a scale of 1 to 5.	Health, Safety and Environment manager	Leading

Safety Policy & Objectives Indicators (SPOIs):			
SPOI-1 Safety policy	Length in months since the last update of the Safety Policy reported annually	CEO	Lagging
SPOI-2 Updated regulations	Length in months since the last update of the ISM Code reported annually	Vice President - Policy	Lagging
Indicator	**Measure**	**Responsible**	**Type**
Key Safety Risk Indicators (KSRIs):			
KSRI-1 Resources	Training, Safety and Risk Management funding tracked and reported monthly	CEO	Leading
KSRI-2 Quality of Risk Assessments and Risk Register	Quality of the risk assessments and risk registers assessed and reported on annually	Risk Manager	Leading
Safety Risk Indicators (SRIs):			
SRI-1 Accident/incident/ near-miss reports	Quality of the accident/incident/near-miss reports tracked and assessed annually	Fleet Manager	Leading
SRI-2 Accident/incident/ near-miss reports	Number of times the accident/incident/near-miss reports are note issued shall be tracked and assessed annually	Fleet Manager	Leading
SRI-3 Hazard Analysis	Number of days late for delivery of the hazard analysis assessed and reported monthly	New Construction Manager	Lagging
SRI-4 Resources	Risk mitigation funding tracked and reported monthly	Fleet Manager	Leading
SRI-5 Risk Assessments	Total number of risk assessments tracked and plotted monthly	Risk Manager	Leading
SRI-6 Risk Mitigation	Total number of risk mitigation plans produced tracked and reported quarterly	Fleet Manager	Leading

SRI-7 Risk Register	Number of times the risk register is not produced tracked and reported quarterly	Risk Manager	Lagging
SRI-8 Risk register	The time between audits of the Risk process tracked and reported annually	Risk Manager	Leading
SRI-10 Risk Register	Number of days past due for issuance of the Risk Register reported monthly	Risk Manager	Lagging
KSRI-11 Hazard analysis	Quality of the hazard analysis deliverables assessed when received and results reported annually	New construction and modernization managers	Leading
Indicator	**Measure**	**Responsible**	**Type**
Key Safety Assurance Indicators (KSAIs)			
KSAI-1 Planned Maintenance	The number of incidents caused while performing planned maintenance tracked and reported monthly	Master or Staff Captain	Leading
KSAI-2 Repeat audit findings	The number of repeat findings tracked and reported monthly	Audit Team	Leading
KSAI-3 Resources	Number of unfilled crew positions onboard tracked and reported weekly	Fleet Manager	Leading
KSAI-4 Safety assessments	The ratio of safety assessments conducted versus the number of accidents/incidents/near-misses tracked and reported monthly	Master or Staff Captain	Leading
Safety Assurance Indicators (SAIs)			
SAI-1 Audits	Number of audits not conducted tracked and reported monthly	Audit team	Lagging
SAI-2 Change requests	Average time to approve a change request tracked and reported monthly	New construction and modernization managers	Leading
SAI-3 Environmental deficiencies	The number of environmental deficiencies tracked and reported weekly	HSE Manager	Leading

SAI-4 Environmental releases	The number of environmental releases tracked and reported weekly	HSE Manager	Leading
SAI-5 Planned maintenance	The number of accidents or incidents occurring when conducting planned maintenance tracked and reported monthly	Chief engineer	Leading
SAI-6 Planned maintenance	Number of planned maintenance activities not completed each month	Fleet Manager	Leading
SAI-7 Crew retention and turnover	Track the crew manning levels and turnover monthly	Master	Leading
SAI-8 Safety assessments	The number of cancelled safety assessments tracked monthly	Fleet manager	Leading
SAI-9 Safety assessment	Track the number of safety assessments conducted monthly, including the number of hazards identified.	Risk manager	Leading
SAI-10 Safety meeting reports	Number of safety deficiencies identified monthly, including the number not being addressed	Ship safety committee	Leading
SAI-11 SMS review	Number of flaws identified in the annual review of the SMS reported annually	Master	Leading
Indicator	**Measure**	**Responsible**	**Type**
Key Safety Promotion Indicators (KSPIs)			
KSPI-1 Safety Alerts/flashes	Quality and timeliness of safety alerts/flashes are assessed annually	Fleet Manager	Leading
KSPI-2 Training requests	Number of training requests not approved reported monthly	Fleet Manager	Leading
KSPI-3 Training requests	Number of training requests approved reported monthly	Fleet Manager	Lagging
Safety Promotion Indicators (SPIs)			
SPI-1 Training	The number of times training is delayed tracked and reported monthly	Master	Leading

SPI-2 Training	Plot training expenditures versus the number of accidents/incidents/near-misses	Fleet Manager	Leading
SPI-3 Quality of accident/incident/ near-miss report	Quality of accident/incident/near-miss report, on a scale of 1 to 5, reported annually	VP Operations	Leading

To strengthen and improve safety, the focus should be on leading indicators. This set of generic key safety indicators has 9 of the 11 indicators as leading, while the remaining safety indicators show 20 of 26 as leading indicators. Figure 23 shows the percentage of leading indicators by each of the functional areas. Changes in safety policy and objects reflect the slow, long term nature of the indicators, which results in predominately lagging indicators. By actively tracking this set of indicators, safety trends will become clear. Currently, Company A reports four safety indicators in their monthly report, while company B reports only two in their quarterly report.

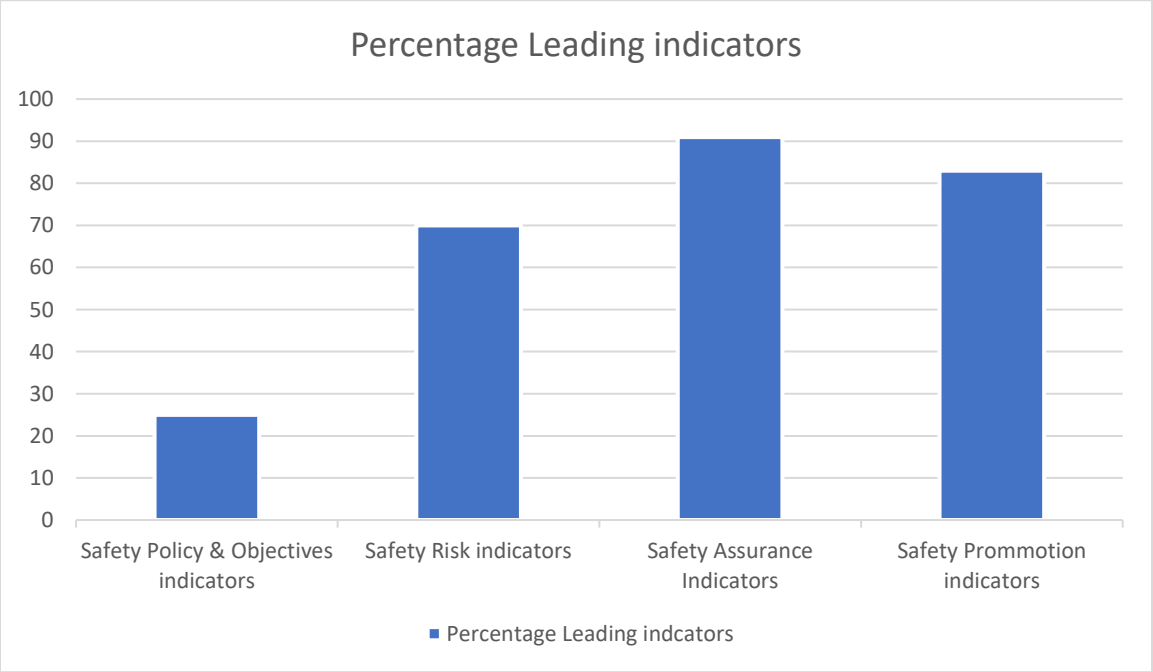

Figure 23: Percentage of leading SMS indicators by functional area

5.4 Results Validation

Sets of safety indicators were created for both companies. The validation of these indicators was accomplished in two ways. The first validation occurred during the creation of the accident model of each company's SMS. The structured process based on systems theory links each control action generated by the SMS to a hazard. For each of the loss scenarios in the STPA-SMS assessment a requirement to prevent the hazard from occurring was generated. Each indicator addresses a specific unsafe control action, which preserves the linkage to the hazards created in the model.

The second validation occurred when the companies prioritized the set of safety indicators through the process described in Section 4.4.2. The prioritization meant that each controller reviewed the criticality of each safety indicator. By placing each indicator into these levels, the company's acceptance of each type of indicator was validated. The result of the prioritization process was the identification of 53 Priority 1 indicators for Company A and 69 for Company B. This is respectfully 19% and 25.5% of the total safety indicators at each company. The average percentage of Priority 1 indicators was 22.25%, which is in line with Pareto's 80-20 Rule.

5.5 Chapter Summary/Conclusions

STPA provided a very thorough assessment of the SMS at each company. The safety indicators were validated by STPA-SMS assessment process and the controllers. Because of their expert knowledge and understanding of the processes, each company's controllers helped prioritize the indicators. This diverse set of subject matter experts at Company A reviewed all 278 system indicators. They identified only 53 as most important (Priority 1). Company B had 270 system indicators identified, with 69 selected as most important (Priority 1) by the controllers. This prioritization process served to validate the proposed set of indicators. Generic indicators, twenty-nine leading and eight lagging, were derived by combining common indicators identified at each company.

The STPA-SMS assessment results in a comprehensive set of system indicators for each company to use to monitor their SMS. For other ship operators, a generic set of system safety indicators was developed. This provides initial guidance on safety indicators to the broader ship operations community. By looking at the underpinning hazards that are linked to hazards the following conclusions are drawn:

- The category of hazards with the largest number of Unsafe Control Actions (UCAs) is where control actions do not follow company policies. Each company needs to use the system indicators developed in this area to track and strengthen the procedures and processes being executed.
- The next largest set of hazards relates to the control actions implemented that are not effective. Each company needs to expand the use of indicators that show the quality of the control actions being executed.
- The prioritization process for the indicators created a subset of the most critical indicators (the Priority 1 indicators). This subset was approximately 22% of the total number of indicators identified for the companies. These high priority indicators allow each company to actively track the most critical parts of their SMS.

6 Discussion

While there is a large body of work in the literature on performance and key performance indicators, little in the maritime domain is focused on creating leading indicators to track ship safety management. By studying and modelling the exact SMS implementation at these companies, the specific safety indicators tuned to each company were created. This research on improving the safety management of ship operations by creating a comprehensive set of performance indicators is innovative in that it uses STPA to perform a thorough, systematic hazard analysis of how the SMS works. The indicators developed linked to the hazards are predominately leading indicators, which allows ship operators to proactively make changes in their management of safety. The creation of a set of key safety indicators provides a more focused tool for ship operators. The research identified a revised template for the ISM Code that better integrates risk, hazards, and safety targets into the SMS. This revision created four functional areas of safety policy and objectives, safety risk, safety assurance, and safety promotion for each company's SMS. An innovative prioritization of the results by adapting Pareto's 80/20 rule was developed and a set of generic indicators was determined.

Potential changes to the ISM Code are developed and the strengths and limitations of the research are explained. The strengths and limitations of this research are addressed. Future work linking the proposed leading indicators with lagging indicators of safety is addressed. Other future work is proposed on strengthening risk management, including the integration of each ship's set of risks, into a more holistic approach.

6.1 Use of indicators

This research yielded a new set of safety system indicators to enhance the feedback ship operators receive on the functioning of their safety management system. The creation and use of safety indicators in the maritime and other transportation fields continues to generate extensive research. Research in key performance indicators for safety-critical industries does not show a consensus on what parameters should be tracked. Konsta points to a focus on Lost Time Injury Frequency as a KPI for tracking work time lost to

injuries. She also points out that the development of KPIs needs more research (Konsta & Plomaritou, 2012). This research fills the gaps in this area by structuring a set of indicators customized for each company looking at four functional areas of safety: Safety Policy and Objectives, Safety Risk Management, Safety Assurance and Safety Promotion.

In the maritime domain, the literature contains a wide range of recommended indicators, but no clear set of key indicators has emerged focused on improving the safe operation of ships. The current commercial products used to track ship safety performance rely on parameters that can be measured and reported easily. An example of these products was created by BIMCO, the Baltic and International Maritime Council (BIMCO, 2018). Their approach uses over 30 KPIs to present a picture of each ship's performance covering safety, environmental, navigation and other parameters. These indicators are then combined to create a set of System Performance Indicators (SPIs) that are tracked to indicate trends. While useful information is generated, the effect of any change in an individual indicator tends to be hidden from view and its impact diminished. Most of these indicators are lagging indicators, which provide limited information on what needs to be changed to mitigate any negative trends shown. The safety indicators are focused on lost time due to injuries and other health metrics. The American Bureau of Shipping (ABS) has created a set of performance indicators focused on cargo ship operations. They use a series of questionnaires to assess the safety culture and create a set of indicators that ship operators can track. Over five years, they check whether the indicators adopted show a link to improved safety performance. Indicators are assessed and changed if no strong linkage is observed. This process of linking the leading indicators to safety outcomes needs to be implemented at Company A and B so that they gain insight into safety trends created by the indicators.

Another aspect of current approaches is that the determination of what to measure is normally done by gathering a group of subject matter experts and brainstorming. The experts tend to be senior deck and engineering officers that are asked to list important parameters based on their experience. A list of these parameters is then created and implemented to be tracked. This is the approach taken at the two companies

studied. As shown in Section 5.1.3 and 5.2.3 the sets created were primarily lagging indicators with limited safety indicators.

Current research shows that the adoption of using leading indicators improves the safety management process. In the United States, the Occupational Health and Safety Administration (OSHA) has shifted its focus from the use of lagging indicators to requiring leading indicators (Sparkman, 2019). The process for implementing active use of leading indicators is shown in Figure 24, developed for implementation in manufacturing plants, but universally applicable (Hinze, 2013).

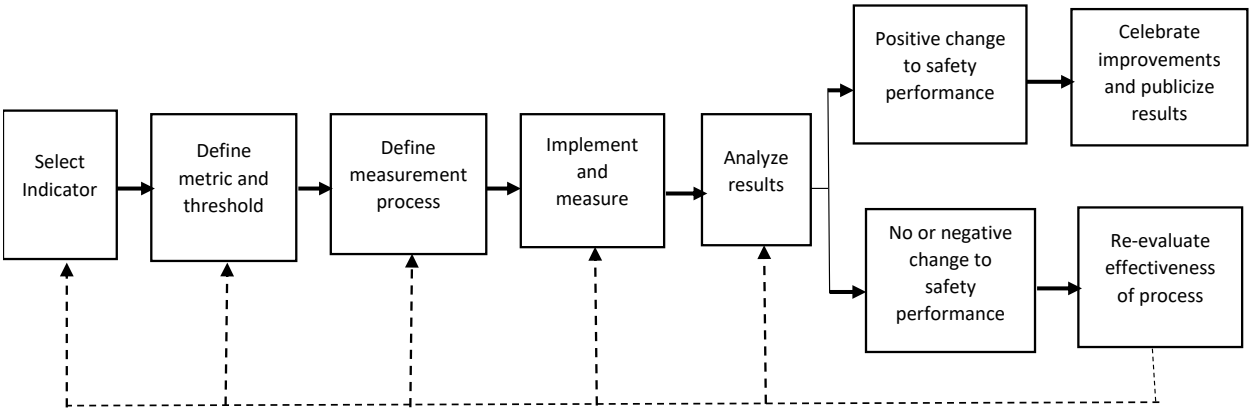

Figure 24: Implementation flowchart of active leading indicators (Hinze and Hallowell, 2013)

The steps depicted instil in the organization the long-term process of continually checking the validity of the selected set of indicators against the actual performance of the SMS.

The use of Stu's (4x5) x80 Rule is an attempt to focus each company's indicators on the important areas that drive ship safety. The literature provides many examples of companies using large numbers of KPIs, but with no clear linkage back to the safety management system or the underlying areas of risk and safety that need to be tracked by these indicators. The STPA-SMS assessment created a complete set of indicators to track the SMS's performance over time. Given the set of indicators generated by the STPA-SMS assessment, a process needs to be established at each ship operator to implement and use the information being generated. Leveson points out certain characteristics that the process should exhibit (Leveson, 2015):

- Leading indicators should be integrated into the risk management program
- They must be communicated to appropriate decision-makers
- Detailed action plans should be created for critical scenarios
- Indicators should be produced on a specific timeline
- Responsibility for monitoring the indicators and resulting mitigations should be assigned to specific individuals within the organisation
- Periodically the list of leading indicators needs to be revisited and updated if necessary
- A continuous improvement process that reviews the indicators in light of near misses and incidents needs to be established.

Company A currently is contractually bound to report a set of indicators (Table 5, Section 4.3.2, p.53) monthly. Of these current indicators, only four out of the total of twenty-three indicators are leading indicators. The Company needs to implement the fifty-three key safety indicators listed in Appendix A.6. With that implementation, the monthly review will be more focused on managing safety as forty-five of the fifty-three indicators are leading indicators. The task of creating these metrics and tracking them should be added to the role of the risk manager. This can augment the current reporting,

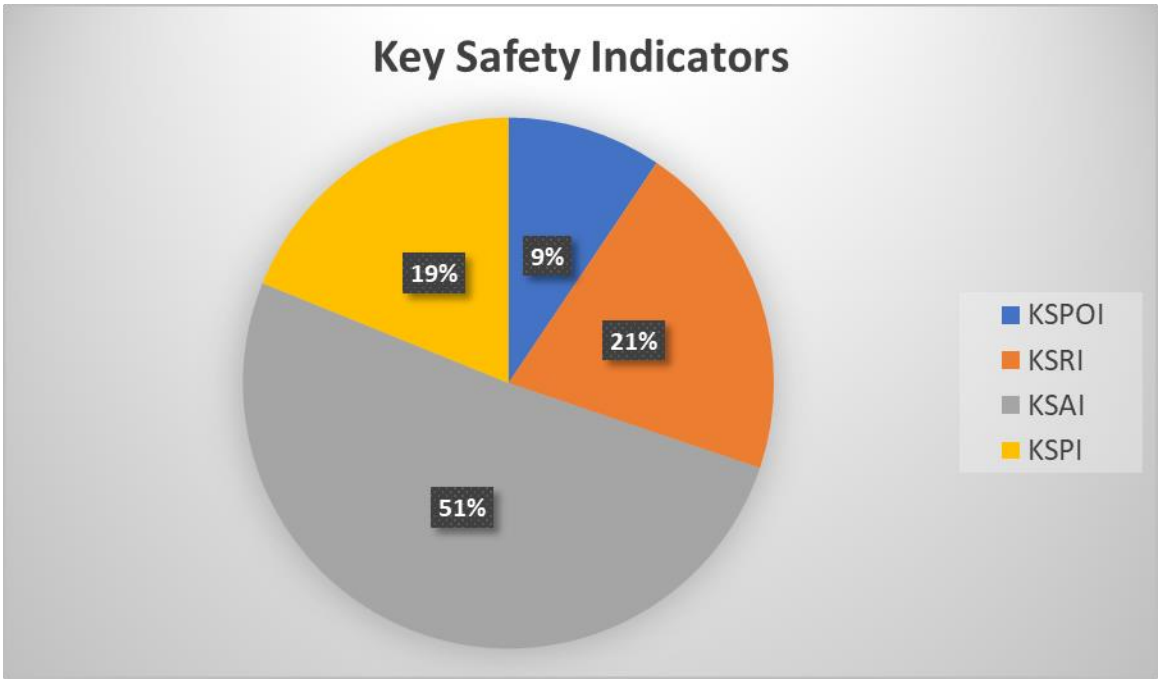

Figure 25: Key Safety indicators for Company A

which is reviewed at the appropriate level within senior management to allow mitigations to be approved. Figure 25 shows that the largest grouping of key indicators for Company A is the Key Safety Assurance Indicators (KSAI) followed by the Key Safety Risk Indicators (KSRI).

Company B's review process is done for upper management every quarter where a set of predominately lagging indicators are used. (Table 6, Section 4.3.3, p.54). To be effective, the lower management level controllers will need to track the new leading indicators more frequently. At Company B

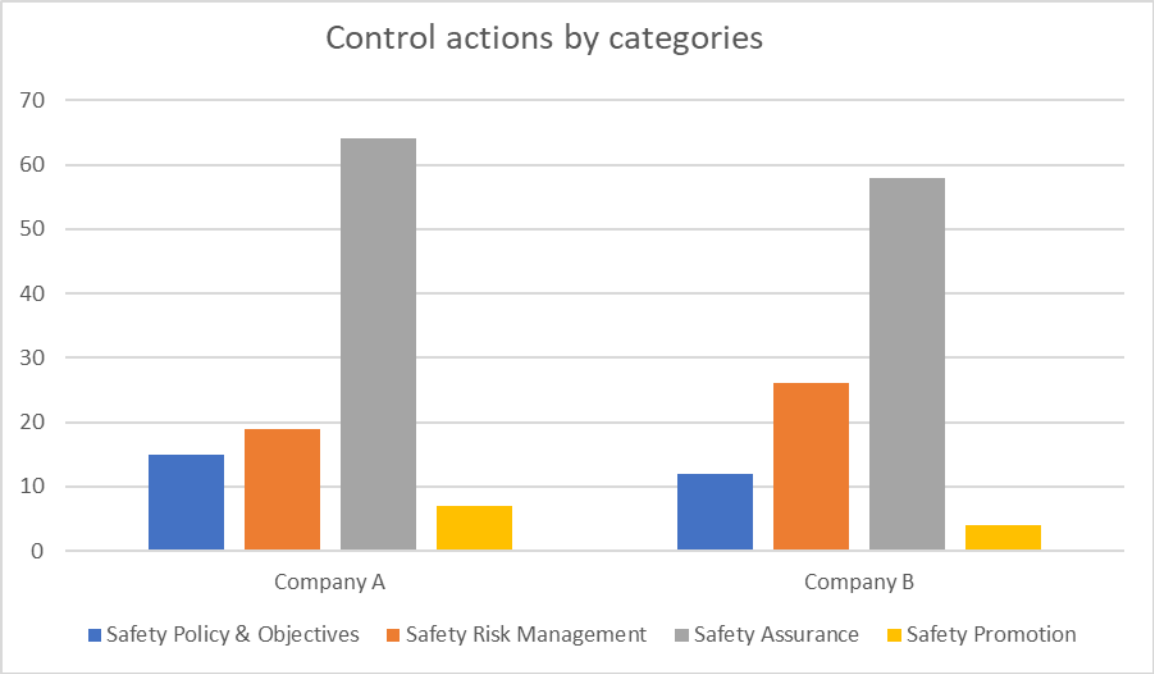

Figure 26: Company B Control Actions by categories

Figure 26 shows that the largest group of control actions is in the Safety Assurance area, while the least is in safety promotion.

David Parmenter's 10-80-10 Rule provides insight into the future path for the use of key performance indicators. His research points to limiting the maximum number of indicators for any company to one hundred (Parmenter, 2015). He recommends that ten would be Key Result Indicators (KRIs) and ten would be Key Performance Indicators (KPIs). He argues that the KRIs would be non-financial and be sent to the

Board of Directors monthly. The KPIs would be sent to the CEO much more frequently, even daily depending on what parameters are being tracked. Applying this thought process to safety-critical industries led the author to propose his Stu's (4x5) x80 Rule. The four key indicators of companywide performance are Safety, Performance, Risk and Financial, which would be reported to the executive level (Williams, 2019). Each of these areas would contain a maximum of five indicators. The five Key Safety Indicators would be derived from the set of generic indicators developed (Section 5.3). The remaining eighty indicators are comprised of 20 lower level indicators from each of the four functional safety areas. A process for reducing the total number of KSIs to a total of five indicators for reporting to the Board and senior management needs to be developed as part of future work.

6.2 Results and findings

Company A can improve its safety management approach by revising its current set of performance indicators. The current set of performance indicators used by Company A (Section 4.3.1) contain only 2 of 23 indicators with a safety focus, approximately 9 per cent of the total number of indicators. The STPA-SMS assessment created a total of 278 safety indicators to track the operation of the SMS.

By implementing the set of key indicators outlined in Section 5.1.3 the Company can start the process for improving the tracking of the performance of key parts of their SMS. Their use of these indicators will help strengthen the SMS and ultimately improve their accident record. The following summarizes the STPA recommended indicators in the four functional areas.

From the Policy and Objectives area of the STPA-SMS assessment results, the key indicator recommended for creation is to track the issuance of the risk appetite guidance. This should be generated by the executive level of the corporation and reviewed by the risk sub-committee of the Board of Directors. Indicators tracking that the policy is released and that it is timely are recommended. Company A does not currently create and issue a risk appetite policy.

In the Assurance area, the audit process has several key indicators recommended by the analysis. Although the audit process has set times for closing out high, moderate, and low rated findings, the data showed that the desired closure times were not being met. By tracking the audit closure metric and the number of repeat findings Company A can improve their audit process. New indicators for tracking the performance of the preventative (planned) maintenance system need to be established. In addition, several indicators to track the safety assessment process, safety meetings and change management processes need to be implemented.

For the Risk functional area, the performance of the process to review accidents needs to be tracked. Indicators for timeliness of closing out findings and quality of the determination of root causes of accidents need to be established. When looking at the organizational structure, there is no executive-level individual responsible for risk across the whole organization and the Board does not have either a dedicated subpanel addressing risk or clear tasking to one of the existing subpanels to also review risks. By adding this focal point, and creating new indicators, Company A's current risk process will be strengthened.

Finally, in the Promotion area, new indicators for tracking requests for training need to be created. In addition, the issuance process for safety alerts and the number of incidents caused by conducting LSA drills need to have indicators established. Currently, Company A has no indicators tracking the performance of these specific areas.

Through better use of the information they are already collecting and using the proposed indicators to track the operation of their fleet, Company A should see a long-term improvement in safety.

Company B can improve its safety management approach by revising its current set of predominately lagging performance indicators. By implementing the set of key indicators outlined in Section 5.2.3 the Company can start the process for improving the tracking of key parts of their SMS. Their use of these indicators will help track the performance of the audit process, the timeliness of preventative maintenance and the use of accident and incident data. The audit process sets times for closing out all findings, but the times are not a function of whether the non-conformity findings are rated high, moderate, or low. The data

showed that the desired closure times were set arbitrarily. By tracking the closure metric and the number of repeat findings, Company B can improve the safety of its ship operations.

When looking at the organizational structure, there is no executive-level individual responsible for risk across the whole organization and the Board does not have either a dedicated subpanel addressing risk or clear tasking to one of the existing subpanels to also review risks.

Through some organisational changes and by better use of the information they are already collecting, the safe operation of their fleet should improve. By using the proposed indicators to track the operation of their risk management approach and driving the risk process down to the ship level, better risk management will help to improve the safety process.

6.3 Potential changes to regulations

During the research for this dissertation, the author completed and an internship at the International Maritime Organization (IMO) to better understand the development of the ISM Code and the background on the Global Integrated Shipping Information System (GISIS). During the internship, the history of the development of the ISM Code from 1987 was reviewed and the author's SMS template (Figure 27) was revised. Also, when looking at rail and airline SMS implementation, it was clear that although these industries started requiring the use of SMSs later than the maritime sector, they have continuously added to the scope of what is required within their SMSs. They have strengthened the use of hazard and risk analysis and required the establishment of safety information systems and safety targets (ICAO, 2009). This led the author to create an updated SMS template for maritime use, blending insight gained from the rail and airline's continual enhancement of their approaches to SMS development. This updated template was used in the STPA-SMS assessment process. The IMO was briefed on this new template and supported a presentation of these findings to the Maritime Safety Committee (MSC) to start the process of revising the ISM Code.

6.3.1 SMS Template

Figure 27 shows the suggested changes to the ISM Code to better:

- highlight the need for company safety policies and objectives
- more overtly integrate risk management by creating a highlighted safety risk area
- strengthen the required safety assurance
- promote safety via an improved safety information system and the establishment of safety targets to measure improvements in safety.

This new template was created by fusing aspects of the airline and rail approaches to safety management with the ISM Code. Some of the categories are modified, while other areas are new additions.

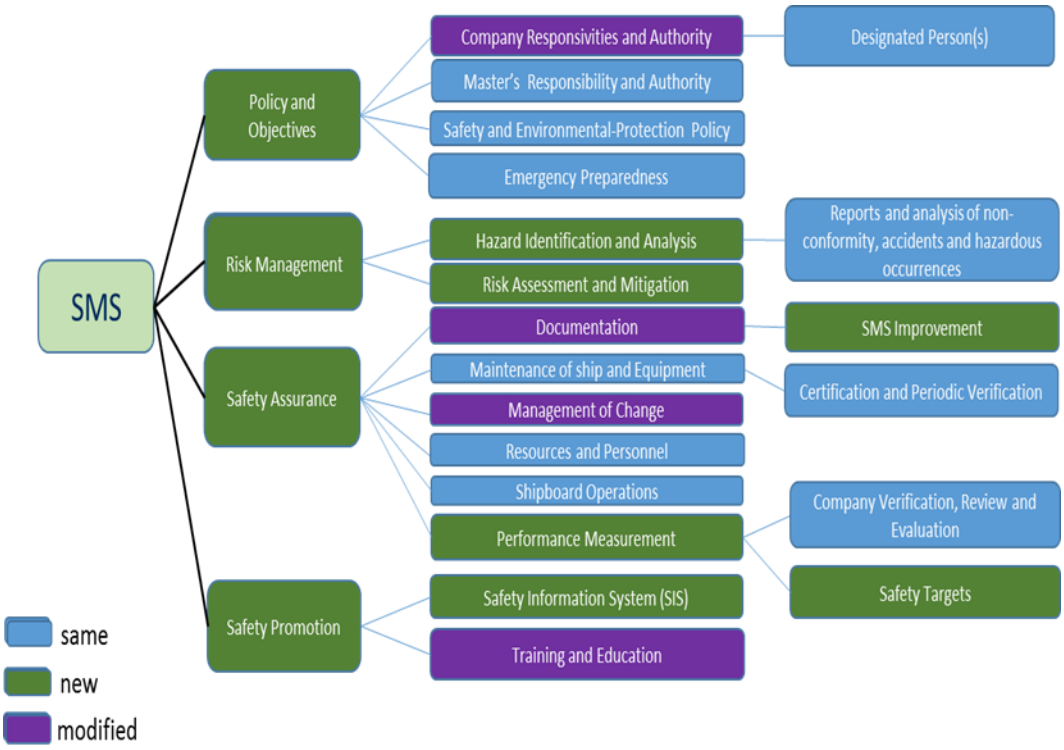

Figure 27: Proposed generic SMS template for a revised ISM Code

The literature review showed serious shortcomings with the current ISM Code. The author's proposed template improves the process by implementing four pillars of safety. These new areas create a strong focus

on hazard and risk analysis, as well as improving the continual monitoring of the whole SMS to improve its performance over time.

6.4 Chapter Summary/Conclusions

By using systems theory to model the SMS in use by cruise and ferry operators, this research provides an innovative new tool focused on developing a set of primarily leading safety indicators to track the safety of fleet operations. The author created a new paradigm for tracking and reporting key indicators, Stu's (4x5) x80 Rule that tracks key safety performance indicators in four functional areas: safety policy and objectives, safety risk, safety assurance and safety promotion. The key indicators in these areas from the case studies were used to create a generic set of indicators. As part of the process of setting up the SMS model a revised template for the ISM Code was created. This was based on SMS shortcomings identified in the literature, and a comparison to airline and rail SMS regulations. This restructured template establishes a path for future changes to the ISM Code. One strength of the STPA-SMS assessment process is that it generates a very comprehensive assessment of the factors affecting the operation of the SMS. A limitation is that the research is based on limited data from just two ship operators. Additional ship operators need to be modelled to increase the validity of the generic results. Also, additional research in improving risk management at ship operators will help to continue the improvements in safety gained to date.

7 Conclusions

The research objective of improving feedback on the performance of the ship operator's SMSs was achieved by developing STPA models of the overall control structure at each company. The STPA methodology was adapted and extended to generate safety indicators for each company's SMS approach. From the common findings at both companies, a set of generic indicators was created. The strengths and limitations of the research are explained and recommendations for further research are provided.

7.1 Research objectives revisited

The initial concept for this research started with the hypothesis that if ship operators had very robust enterprise risk management then their safety level would be better than other operators with less mature risk management approaches. Early in the investigation, it was clear from the first six companies that their approaches to risk management were not system-wide across their entire corporate structure but siloed and rather fragmented. The companies' clear goal was to meet the ISM Code requirements. This led to refocusing this research on how to improve feedback on the safety management approaches being accomplished by providing a set of safety indicators. The companies studied tracked a small number of primarily lagging safety indicators. By expanding the set of safety indicators, especially leading indicators, this research strengthens the feedback process.

The STPA model of the control structure allowed the flow of SMS control actions to be tracked. Through this hazard analysis process, the set of unsafe control actions was determined for the complete range of safety actions being accomplished to satisfy the functions mandated in the ISM Code.

7.2 Innovations

This research has yielded three areas of innovation to improve the safety of ship operations. The first is the development of a model based on STPA used to generate a set of safety indicators. The STPA process was extended by several steps to create indicators of SMS performance. The second is the creation of a

prioritization process to create a set of key safety indicators for each company analysed. The third innovation was the generation of a generic set of safety indicators for use by any ship operator.

7.2.1 Extension of STPA

As explained in Figure 14 (Section 4.2, p.48), the basic steps developed by Professor Leveson for applying STPA to an analysis of an organization (Leveson & Thomas, 2018) had to be extended to create safety system indicators. The additional steps linked the STPA loss scenarios to a requirement to prevent the loss from occurring. These requirements were then tracked with a corresponding safety system indicator.

7.2.2 Creation of key safety indicators based on a STPA-SMS assessment

This research provides the operators of ships a set of system indicators they can employ to track the performance of their SMS. A prioritization scheme was created to focus on the safety management process indicators at Company A and B. Each operator is currently implementing the tracking of these performance indicators within their operating organizations. As developed in Section 4.2, the author proposes a further prioritization of the key indicators by applying Pareto's 80/20 thinking and Parmenter's 10-80-10 Rule to safety-critical transportation industries like shipping, rail, and air. Safety indicators were created in four areas based upon the pillars within the SMS template:

- Key Safety Policies and Indicators (KSPOIs)
- Key Safety Risk Indicators (KSRIs)
- Key Safety Assurance Indicators (KSAIs)
- Key Safety Promotion Indicators (KSPIs)

By splitting the 20% into these four areas, Stu's (4x5) x80 Rule was created. Through the prioritization process, Key Safety Indicators (KSIs) were created in each of these four areas. Thus the set of KSIs is formed from the KSAIs, KSPIs, KSPOIs and KSRIs.

7.2.3 Creation of an initial set of generic safety system indicators

From the STPA-SMS assessment models of the initial two companies researched, Table 26 (Section 5.3, p.94) shows an initial set of eleven generic key indicators (Priority 1) and twenty-seven regular indicators (Priority 2) developed by combining common results from both companies. The small number of indicators reflects that these indicators combine the results of two sets of subject matter experts reviewing the safety processes. In the future, as additional companies are analysed the generic set would become more refined and more focused as more user's experiences are incorporated. These initial results provide real insight into the critical safety indicators that need to be tracked at any ship operator. Each of these generic indicators captures the functioning of a critical area of the SMS. Many of the indicators are focused on tracking the quality of the processes being monitored. This is consistent with the fact that most of the hazards within the SMS deal with the effectiveness of the processes being implemented to manage safety.

7.3 Research strengths and limitations

A strength of the research approach was the use of a systemic hazard analysis process to create and prioritize the set of indicators. Another strength was that the analysis was performed on two diverse ship operators. This provides a broader perspective and allows the generic indicators developed to be applicable to both cruise and ferry operators. The author was afforded extensive interactions with both companies allowing detailed determination of the safety and risk management approaches. This access strengthened the research and helped validate that the modelling and results accurately reflect the procedures currently employed at each company.

A limitation is that the research generates a large number of indicators. To make the results more useful a subjective assessment process was developed that prioritized the resulting indicators. This process relied on the controllers within the organisation to perform the assessment.

7.4 Recommendations for future research

This research provides an initial path for the two companies studied to follow in implementing a set of safety indicators that can guide the improvement of their fleet safety. One area of future work is to prove the causal linkage between the leading and lagging indicators recommended from this research. This is a long-term project with several years' worth of quantitative data needed to verify the validity of these relationships.

In the future, each company must establish a tracking system to link the initial set of leading indicators to the accident and audit findings generated over the next several years. This validation approach would follow a method like what the American Bureau of Shipping (ABS) has published in several papers. The basic method tracks specific accident data to check that the leading indicator predicts movement in the lagging indicator (American Bureau of Shipping (ABS), 2012). Figure 28 shows the correlation between one indicator, the number of safety meetings held across a fleet of commercial cargo ships and work accidents. In this case, Restricted Work Accident Frequency (RWAF) is the total restricted work accident cases multiplied by 1 million, divided by the number of exposure (working) hours in the last year. There is a clear inverse correlation for this relationship, implying that this leading indicator provides an excellent measure of this aspect of the safety management approach at this shipping company. This is based on five years' worth of data for a commercial ship operating a fleet of cargo ships. The ABS approach uses a Spearman's' rho test to confirm the correlation. In this case, the inverse correlation shows that as the indicator being tracked increases there is a corresponding reduction in the number of accidents. A similar approach was shown by Tomlinson. (Tomlinson, 2011)

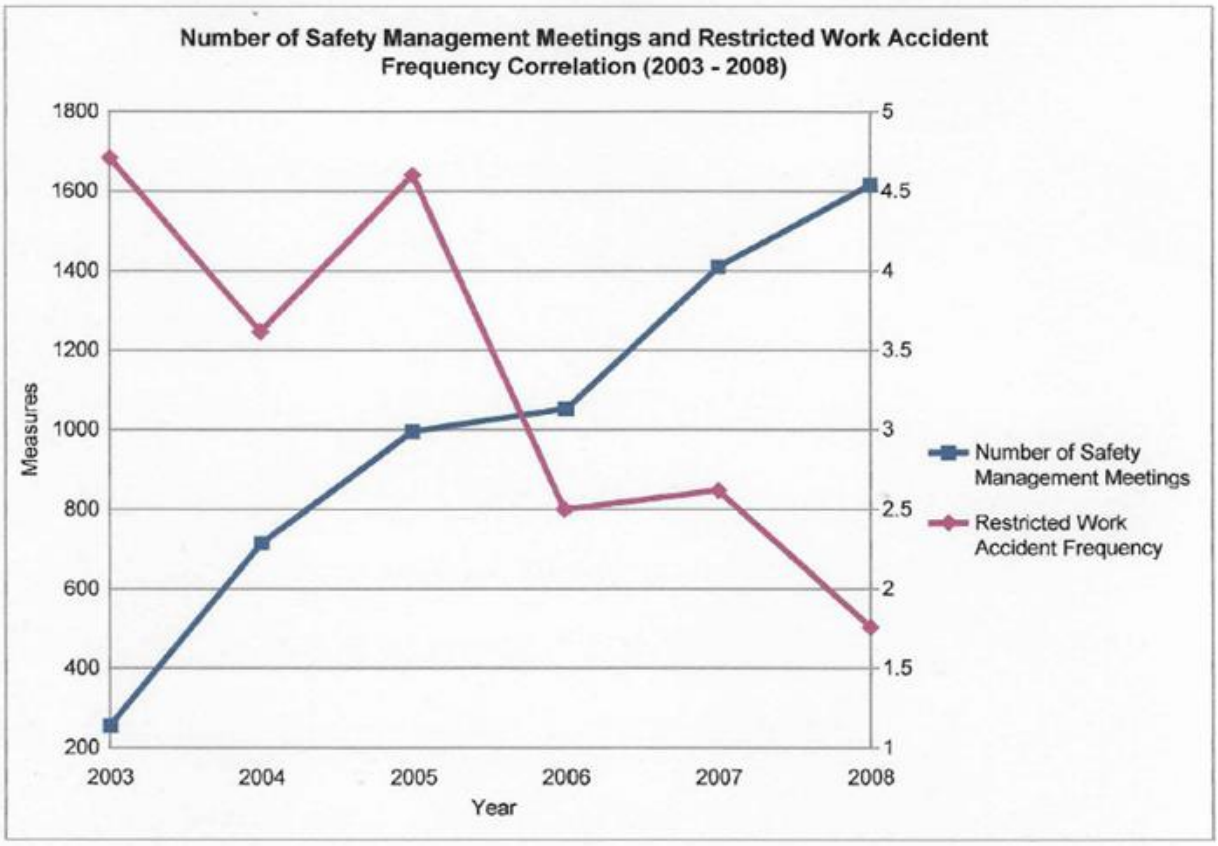

Figure 28: Correlation between safety management meetings and Restricted Work Accident Frequency

Another aspect of establishing these kinds of causal relationships is that over time deeper insight can be gained into the functioning of the SMS. If the causal relationship starts to diverge or change ((Dyreborg, 2009), then the company gains new knowledge of its safety management. In this example, if the number of safety meetings was to decrease and yet the accident frequency still decreased, some other change would have created this dynamic. With this knowledge, the safety team would need to research what is changing to understand how to modify the management approach and create revised indicators.

Over time the control actions change and so the set of indicators needed to track the new norms must be modified. With better implementation of Safety Assurance functions within the revised template created by this research for each company's SMS, continual improvement in the emergent property of safety will be accomplished. Although an initial set of generic performance indicators was created, future work with

additional companies should be completed. Increasing the sample size will bolster the credibility of these indicators as the key indicators to track.

Additional research is also needed in the prioritization of the indicators created by the STPA-SMS assessment. Other approaches, such as applying a weighting scheme based on the level of the controller within the organization were considered. STPA assessments of airline safety management systems have been accomplished (Karanikas, 2018) and could be used to guide future research. There is recent work to address the prioritization of results by Karanikas & Chatzimichalidou (Karanikas, 2018). Their paper proposes the use of continuous values for the behaviour of system components along with a weighing of each component relative to its hierarchical level in the organization as a means of prioritization. Over time the process of identifying and prioritizing the set of indicators will mature, but currently, this is a limitation of the state of the art.

Another area of future work is to better assess and monitor the performance of humans in the safety management process. The concept of resilience engineering has been used to explore additional factors that can be tracked to ascertain how well the safety culture is performing. Use of this by the airline industry provides insight into the path forward for research on improving the safety of ship operations. (Turan, 2016)

One final area that needs additional research is the implementation of risk management for ship operations. The ISM Code requires ship operators to assess all risks that may impact the safe operation of their fleets. As part of the Case studies, the author assessed the maturity of the risk processes in place at each of the companies. The results show that the risk processes are very immature and do not extend down to each ship in the fleet. There is no evidence of Enterprise or holistic risk management at the companies. Improving risk management at ship operators is another focus area for future work. Enterprise Risk Management (ERM) is being used in both the rail and airline sectors to further improve safety, which provides insight into the path forward for the maritime community to enhance its use of risk management to improve operations.

7.5 Summary – final thoughts

This research created sets of safety indicators for a ferry company and a cruise line to use to monitor the performance of their SMSs. The STPA modelling of each company's SMS allowed a very structured assessment of the current safety management approaches and created specific indicators tracking key safety functions. The thesis demonstrated that:

- Leveson's powerful STPA hazard analysis tool, with the extensions developed with this research, is an appropriate model to analyze SMS hazards and create safety indicators.
- By developing a revision to the SMS template that establishes four pillars of safety, the author's research identified shortcomings and points the way to improve safety at each ship operator.
- Stu's (4x5) x80 Rule provides a method to narrow the set of safety indicators that track the performance of a SMS.
- The highest priority safety indicators created a set of Key Safety Indicators (KSIs). These KSIs can then be reported up to senior management. By tracking the proposed set of Key Safety Indicators for ship SMS operations, ship operators have a new tool to improve ship operational safety. By tracking these indicators over time, a drift towards unsafe operations can be observed and remedial actions taken. Going forward, the companies can use the information from the indicators to develop interventions and prevention measures to eliminate hazards.

While focused on cruise and ferry operations, the general approach developed created a set of generic safety indicators that are applicable for any ship operator.

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Appendix

Appendix A – Company A STPA analysis results

Appendix A.1 – Company A Controller name and description

Controller Name	Controller Description
Audit and Risk Committee	Subcommittee of BOD
BOD	Board of Directors
CEO	Chief Executive Officer Company A
Chief Engineer	Manager of the ship engineering division
Company A	Executive level
Company A Acquisitions	CAA
Company A Operations	Shore-based management of fleet operations
Deck Department	Runs the hotel and safety operations onboard each ferry
Design Agent	Develops new ship and modernization design packages
Director HSQE	Head of Health, Safety, Quality and Environment group
Director Operations	Director of Marine Operations (Fleet)
Executive Team	The "C" level executives at Company A
Financial Director	Head of finance for Company A
Head of Deck Department	Manager of ship Deck Department
IMO	International Maritime Organization, part of the United Nations
Lloyds	Marine Regulatory Body-UK
Machinery Department	Machinery Department
Managing Director	Head of Operations
Master	Master of individual ship
Modernization Yard	the shipyard that updates ships
Recycling Yard	the yard that does recycling of ships
Risk Manager	Part of HSQE Organization
Safety Committee	Safety Committee
Shipyard	new construction yard
UK Government	Flag State
UK Ministry	Government administrator of ferry operations contract

Appendix A.2 – Company A Control Actions (CAs):

Locator	Company A Control Actions
A1-1	Strategic plan from the CEO down to the Operating level
A1-2	Executive-level guidance to operating organization level
A1-3	Managing Director guidance
A1-4	Provides corporate guidance on implementing ERM
A1-5	Audit and Risk subcommittee guidance on risk
A1-6	UK Government guidance on Safety and Risk
A1-7	UK Government guidance on Safety and Risk
A1-8	UK government recommendations for improving IMO regulations
A1-9	New regulations released
A2-1	Executive-level guidance
A2-2	Regulations
A4-1	Safety alerts issued
B1-1	Accident/near miss Report from the ship to Company A Operations
B1-2	Summary of accident and near-miss report information
B1-3	Accident/near miss report information provided to the BOD
B1-4	Summary Accident/near miss Report
B1-5	Contract deliverable identifying environmental hazards
B1-6	Hazard and risk deliverable from the shipyard
B1-7	Safety/hazard/risk analysis deliverable from the design agent for a new ship or modernization package.
B1-8	Hazards/risks/safety assessment deliverable from the recycling yard
B2-1	Reporting of risk assessments done by machinery department
B2-2	Deck department report on risks
B2-3	Risk Assessments from each ship
B2-4	Summary of risks compiled
B2-5	Summary of top risks.
B2-6	Summary of current corporate-wide risks.
B2-7	Summary of current corporate-wide risks.
B2-8	Summary of current corporate-wide risks.
B2-9	Summary of all corporate-wide risks
B2-10	Risk assessment deliverable from the Modernization Yard.
B2-11	Recycling yard's risk assessment deliverable.
C1-1	Summary report of LSA training
C1-2	Summary report of the release of hazardous materials
C1-3	Summary report of safety meeting held onboard ships
C1-4	Provides requested changes in operational procedures
C1-5	Master's annual recommended changes to SMS
C1-6	Annual SMS update to fleet

C1-7	Updates to Ship Operations manuals provided to the fleet.
C1-8	Annual SMS Update
C1-9	The contract for new construction or modernizations
C1-10	The contract for inspection services
C1-11	Contract deliverables require hazards and risks to be identified.
C1-12	Documents require design agent to produce deliver specifications and CONOPS that identify hazards and risks to safe operation.
C1-13	Operations contract requires safe operation of ships
C1-14	The contract requires hazards and risks to be identified and mitigated.
C1-15	The contract requires hazard and risk analysis.
C1-16	Engineering calculations and test reports
C1-17	Deliverables from the shipyard providing guidance on the safe operation of the ship.
C1-18	Lloyds assessment to award DOC.
C1-19	Lloyds approval of all drawings
C1-20	Surveys to keep in class
C1-21	Approval by Lloyds of plans and calculations.
C1-22	Approvals of plans and calculations
C1-23	Design agent supplies plans and calculations deliverables.
C1-24	New design and modernization construction specifications
C1-25	Design agent's estimate of the crew size on either new construction or modernization.
C1-26	Plans and calculations for new design or modernizations
C1-27	Deliverable
C1-28	Contract for operations
C1-29	The contract for new assets and modernizations
C1-30	Authority to operate
C1-31	Transport Scotland requests a change to the operations contract
C2-1	Development of an approach to planned maintenance.
C2-2	Deliverable from new construction and modernization yards.
C3-1	Ship requests a change
C3-2	Change requests from the fleet
C3-3	Approval of change requests via change orders
C3-4	Change order approval to design agent
C3-5	Approved changes to Modernization Yard
C3-6	Change order execution by the shipyard
C3-7	Design agent provides change requests, waivers and deviations
C3-8	Change orders for Modernization Yard
C4-1	Provide adequate resources for good safety and risk management.
C4-2	Provide resources for safety and risk management
C4-3	Resources provided for risk and safety management
C5-1	Accidents/near miss reports are submitted
C5-2	Accident/near miss reports submitted
C5-3	Accident/near miss reports are produced after an incident.

C5-4	Ship level safety assessments
C5-5	Ship level safety assessments
C5-6	Summary of ship level safety assessments
C5-7	Summary of indicators and key indicators
C5-8	Summary of performance information
C5-9	Guidance on the corporate path forward for risk and safety
C5-10	Summary of performance indicators
C6-1	SMS reviewed to make sure it is up to date.
C6-2	Shipboard safety reviews
C6-3	Ship level audits
C6-4	Fleet input on SMS to headquarters
C6-5	Fleet input to headquarters
C6-6	Request for audit support
C6-7	Request for audit support
C6-8	Support for audit analysis
C6-9	Summary of audits to BOD
C6-10	Government reviews
C6-11	Quarterly Financial Performance Report produced for Company A operations.
D1-2	Issue safety alerts
D2-1	Submit training requests
D2-2	Crew requests for training
D2-3	Fleet requests to the company
D2-4	Fleet safety training
D2-5	Development of training materials

Appendix A.3 - Company A Control Actions (CAs) by Controller:

Controller Name	Control Action Name	Description
Audit and Risk Committee	Audits	Summary of audits to BOD
Audit and Risk Committee	Regulations	UK Government guidance on Safety and Risk
Audit and Risk Committee	Risk Policy	Audit and Risk subcommittee guidance on risk
Audit and Risk Committee	Risk Register	Summary of all corporate-wide risks
BOD	Resources	Resources provided for risk and safety management
CEO	Accident/near miss report summary	Accident/near miss report information provided to the BOD
Chief Engineer	Accidents/near miss reports	Accidents/near miss reports are submitted
Chief Engineer	Risk Appetite	Executive-level guidance to operating organization level
Chief Engineer	Risk Assessment	Reporting of risk assessments done by machinery department

Chief Engineer	Training request	Crew requests for training
Company A	Accident/near miss Report	Summary Accident/near miss Report
Company A	Accident/near miss Report	Summary of the accident and near-miss report information
Company A	Resources	Provide resources for safety and risk management
Company A	Safety alerts	Issue safety alerts
Company A	Safety Alerts	Safety alerts issued
Company A	Safety Policy	Executive-level guidance
Company A	Strategic Plan	Strategic plan from the CEO down to the Operating level
Company A	Strategic Plan for safety and risk	Guidance on the corporate path forward for risk and safety
Company A Acquisitions	Change orders	Approval of change requests via change orders
Company A Acquisitions	Change orders	Approved changes to Modernization Yard
Company A Acquisitions	Change orders	Change order approval to design agent
Company A Acquisitions	Contract	The contract for inspection services
Company A Acquisitions	Contract	The contract for new construction or modernizations
Company A Acquisitions	Contract	The contract requires hazard and risk analysis.
Company A Acquisitions	Contract	The contract requires hazards and risks to be identified and mitigated.
Company A Acquisitions	Contract	Operations contract requires safe operation of ships
Company A Acquisitions	Contracts	Contract deliverables require hazards and risks to be identified.
Company A Acquisitions	Requirements, Specifications and CONOPS	Documents require design agent to produce deliver specifications and CONOPS that identify hazards and risks to safe operation.
Company A Operations	Emergency preparedness exercise	Emergency preparedness exercise done periodically to test the emergency centre at headquarters and the response from ships
Company A Operations	Key Indicators	Summary of indicators and key indicators
Company A Operations	Key Risk Indicators (KRIs)	Summary of top risks.
Company A Operations	Risk register	Summary of risks compiled
Deck Department	Accident/incident reports	Accident/near miss reports submitted
Deck Department	Annual Assessment of SMS	SMS reviewed to make sure it is up to date.
Deck Department	Change requests	Ship requests a change
Deck Department	Crew training	Submit training requests
Deck Department	Life savings drills	Fleet safety training
Deck Department	Life-saving appliance drills	Summary report of LSA training
Deck Department	Risk Assessments	Deck department report on risks
Deck Department	Safety assessments	Ship level safety assessments
Design Agent	Change requests, waivers and deviations	Design agent provides change requests, waivers and deviations

Design Agent	Manning	Design agent's estimate of the crew size on either new construction or modernization.
Design Agent	Plans and calculations	Plans and calculations for new design or modernizations
Design Agent	Plans and Calculations deliverables	Design agent supplies plans and calculations deliverables.
Design Agent	Safety/hazard/risk analysis	Safety/hazard/risk analysis deliverable from the design agent for a new ship or modernization package.
Design Agent	Specifications	New design and modernization construction specifications
Director HSQE	Audit	Support for audit analysis
Director HSQE	Audits	Request for audit support
Director HSQE	Key indicators	Summary of performance information
Director HSQE	Risk register	Summary of current corporate-wide risks.
Director HSQE	SMS Update	Annual SMS Update
Director HSQE	SMS Update	Annual SMS update to fleet
Director HSQE	Vessel Operations Updates	Updates to Ship Operations manuals provided to the fleet.
Director Operations	Audits	Request for audit support
Director Operations	Resources	Provide adequate resources for good safety and risk management.
Director Operations	Safety alerts	Issue safety alerts
Executive Team	Key Risk Indicators	Summary of performance indicators
Executive Team	Risk register	Summary of current corporate-wide risks.
Financial Director	Financial Performance	Quarterly Financial Performance Report produced for Company A operations.
IMO	Regulations update	New regulations released
IMO	Updated Regulations	IMO updates its regulation
Lloyds	Approvals	Approval by Lloyds of plans and calculations.
Lloyds	Approvals	Approvals of plans and calculations
Lloyds	Class Rules	Regulations
Lloyds	Surveys	Surveys to keep in class
Machinery Department	Safety Assessments	Ship level safety assessments
Managing Director	ERM Policy	Provides corporate guidance on implementing ERM
Managing Director	Safety Policy	Managing Director guidance
Master	Accident/Near miss report	Accident/near miss Report from the ship to Company A Operations
Master	Accident/near miss reports	Accident/near miss reports are produced after an incident.
Master	Annual assessment of SMS	Fleet input on SMS to headquarters
Master	Audits	Fleet input to headquarters
Master	Audits	Ship level audits
Master	Change requests	Change requests from the fleet

Master	Environmental Report	Summary report of the release of hazardous materials
Master	Planned maintenance	Development of an approach to planned maintenance.
Master	Risk Assessments	Risk Assessments from each ship
Master	Safety assessment	Summary of ship level safety assessments
Master	Safety meeting minutes	Summary report of safety meeting held onboard ships
Master	SMS Updates	Master's annual recommended changes to SMS
Master	Training requests	Fleet requests to the company
Master	Vessel Operation Updates	Provides requested changes in operational procedures
Modernization Yard	Change orders	Change orders for Modernization Yard
Modernization Yard	Hazards/risk/safety assessments	Deliverable
Modernization Yard	Risk Assessment	Risk assessment deliverable from the Modernization Yard.
Recycling Yard	Hazard report	Contract deliverable identifying environmental hazards
Recycling Yard	Hazards/risks/safety assessments	Hazards/risks/safety assessment deliverable from the recycling yard
Recycling Yard	Risk Assessment	Recycling yard's risk assessment deliverable.
Risk Manager	Risk register	Summary of current corporate-wide risks.
Safety Committee	Monthly Safety Review	Shipboard safety reviews
Shipyard	Change order	Change order execution by the shipyard
Shipyard	Contract	Lloyds assessment to award DOC.
Shipyard	Deliverables	Engineering calculations and test reports
Shipyard	Hazard Report	Hazard and risk deliverable from the shipyard
Shipyard	Operations and technical manuals	Deliverables from the shipyard providing guidance on the safe operation of the ship.
Shipyard	Plan approval	Lloyds approval of all drawings
Shipyard	Planned maintenance approach	Deliverable from new construction and modernization yards.
Shipyard	Training material	Development of training materials
UK Government	Audit/inspections	Government reviews
UK Government	Certifications	Authority to operate
UK Government	Regulation improvement	UK government recommendations for improving IMO regulations
UK Government	Regulations	UK Government guidance on Safety and Risk
UK Ministry	Contract	The contract for new assets and modernizations
UK Ministry	Contract	Contract for operations
UK Ministry	Contract Variation	UK Government requests a change to the operations contract

Appendix A.4 – Company A Unsafe Control Actions (UCAs)

Control Action Name	Unsafe Control Action Name	Description and [Hazard]	Context
Accident/incident reports	Accident/incident report	An accident/near miss report is not produced after an event. [SMSH-2]	Not Providing
Accident/incident reports	Accident/near-miss reports.	Accident/near miss reports are issued a long time after an event. [SMSH-2]	Too early or late
Accident/incident reports	Accident/near-miss reports.	The accident/near miss reveals new risks, mitigations are developed, but no resources are found available to implement them [SMSH-5]	Providing
Accident/incident reports	Accident/near-miss reports.	The accident/near miss reports fail to uncover root causes or establish a pattern. [SMSH-5]	Providing
Accident/incident reports	Accident/near-miss reports.	The accident/near miss reports reveal systems that need to change, but no decision is made as to how to deal with them [SMSH-5]	Providing
Accident/near miss Report	Accident and near-miss report issued late	By issuing the Accident/incident/near miss Report late, a mishap may reoccur. [SMSH-2]	Too early or late
Accident/near miss Report	Accident and near-miss report not issued	By not issuing an Accident/incident/near miss Report, the executive team does not learn from its mistakes and may repeat them. [SMSH-2]	Not Providing
Accident/near miss Report	Accident and near-miss summary do not provide actionable recommendations for improvements	Accident/incident/near miss Report is provided but the analysis of mishaps is superficial. [SMSH-5]	Providing
Accident/Near miss report	Accident/incident/near miss Report	Accident/incident/near miss Report is provided, but mishap analysis is superficial. [SMSH-5]	Providing
Accident/Near miss report	Accident/incident/near miss Report	By issuing the Accident/incident/near miss Report late, a mishap may reoccur. [SMSH-2]	Too early or late
Accident/Near miss report	Accident/incident/near miss Report	By not issuing an Accident/incident/near miss Report, the company does not learn from its mistakes and may repeat them. [SMSH-2]	Not providing
Accident/near miss Report	Accident/near miss Report is provided but lack detail of all incidents	Accident/incident/near miss Report is provided but shows unfavourable trends. [SMSH-5]	Providing
Accident/near miss Report	Accident/near miss Report not provided	By not issuing an Accident/incident/near miss Report, the company does not learn from its mistakes and may repeat them. [SMSH-2]	Not Providing
Accident/near miss Report	Accident/near miss Report provided late	By issuing the Accident/incident/near miss Report late, another similar accident/incident/near-miss may occur. [SMSH-2]	Too early or late

Accident/Near miss report	Master->CFL Operations	Accident/incident/near miss Report is provided, but mishap analysis is superficial. [SMSH-5]	Providing
Accident/near miss report summary	Accident/near miss report is not provided	By not issuing an Accident/incident/near miss Report, the BOD does not learn from its mistakes and may repeat them. [SMSH-2]	Not Providing
Accident/near miss report summary	Accident/near miss report is provided	Accident/incident/near miss report is approved by the Executive Team without proper review. [SMSH-5]	Providing
Accident/near miss report summary	Accident/near miss report is provided late	By issuing the Accident/incident/near miss Report late, a mishap may reoccur. [SMSH-2]	Too early or late
Accident/near miss reports	Accident/incident reports	Accident/ near miss reports are issued a long time after an event. [SMSH-2]	Too early or late
Accident/near miss reports	Accident/incident reports	An accident/ near miss report analysis is not carried out after an event. [SMSH-2]	Not Providing
Accident/near miss reports	Accident/incident reports	The accident/ near miss reports analysis reveals new risks, mitigations are developed, but no resources are found available to implement them [SMSH-5]	Providing
Accident/near miss reports	Accident/incident reports	The accident/ near miss reports reveal systems that need to change, but no decision is made as to how to deal with them [SMSH-5]	Providing
Accident/near miss reports	Accident/Incident/Near-miss reports	The accident/ near miss reports analysis fail to uncover root causes or establish a pattern. [SMSH-5]	Providing
Accidents/near miss reports	Accidents/near miss reports are poor quality	The accident/incident reports fail to uncover root causes or establish a pattern. [SMSH-3]	Providing
Accidents/near miss reports	Accidents/near miss reports do not cause a change to be executed.	The accident/incident reports reveal systems that need to change, but no decision is made as to how to deal with them [SMSH-3]	Providing
Accidents/near miss reports	Accidents/near miss reports do not cause resources to be spent to mitigate the issues.	The accident/incident reports reveal new risks, mitigations are developed, but no resources are found available to implement them [SMSH-5]	Providing
Accidents/near miss reports	Report not generated.	An accident/incident report is not carried out after an event. [SMSH-2]	Not Providing
Accidents/near miss reports	Report produced late.	Accident/incident reports are issued a long time after an event. [SSH6], [SMSH-2]	Too early or late
Annual Assessment of SMS	SMS assessment is provided	The assessment of SMS does not reveal existing safety risks [SMSH-5]	Providing
Annual Assessment of SMS	SMS assessment is provided	The assessment reveals existing flaws in SMS, but no decision is made as to how to deal with them [SMSH-5]	Providing
Annual Assessment of	SMS assessment is provided	The assessment reveals new flaws in SMS, measured developed, but no resources are	Providing

SMS		found available to implement them [SMSH-5]	
Annual Assessment of SMS	SMS assessment is provided late	SMS assessment is carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Annual Assessment of SMS	SMS assessment is provided late	SMS is carried out a long time after an incident/accident [SMSH-2]	Too early or late
Annual Assessment of SMS	SMS assessment not provided	SMS is not carried out after an incident/accident [SMSH-2]	Not Providing
Annual Assessment of SMS	SMS assessment not provided	The assessment of SMS cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Annual Assessment of SMS	SMS assessment not provided	The assessment of SMS cannot be carried out / completed because of lack of human resources [SMSH-2]	Not Providing
Annual assessment of SMS	SMS not updated	Lack of human resources [SMSH-2]	Not Providing
Annual assessment of SMS	SMS not updated	Assessment is not done [SMSH-2]	Not Providing
Annual assessment of SMS	SMS not updated	Review not done after an accident or near-miss [SMSH-2]	Not Providing
Annual assessment of SMS	SMS updated	The assessment of SMS does not reveal existing safety risks [SMSH-5]	Providing
Annual assessment of SMS	SMS updated	The assessment reveals existing flaws in SMS, but no decision is made as to how to deal with them [SMSH-5]	Providing
Annual assessment of SMS	SMS updated	The assessment reveals new flaws in SMS, measured developed, but no resources are found available to implement them [SMSH-5]	Providing
Annual assessment of SMS	SMS updated late	SMS review delayed [SMSH-2]	Too early or late
Approvals	Approvals granted late	By Lloyds providing the approvals late, the Shipyard fails to meet its delivery schedule. [SMSH-2]	Too early or late
Approvals	Approvals granted, but not all safety hazards identified.	Lloyds approves plans and calculations, but they fail to uncover safety issues. [SMSH-5]	Providing
Approvals	Approvals not granted.	By not providing approvals, the shipyard work is delayed and therefore delivery of the ship is delayed. [SMSH-2]	Not Providing
Approvals	Plans and calculations approved late.	Delivering approvals late means the construction of the ship will be delayed.	Too early or late

		[SMSH-2]	
Approvals	Plans and calculations approved, but not all safety hazards identified.	Lloyds approves plans and calculations but fails to uncover residual construction and safety issues. [SMSH-5]	Providing
Approvals	Plans and calculations not approved.	By not providing approvals, the construction and ship delivery are delayed [SMSH-5]	Not Providing
Audit	Audit	The audit is not conducted, thereby causing the ship to lose its operating certification. [SMSH-2]	Not Providing
Audit	Audit	Conducting the audit to late causes implementation of a fine, or loss of operating certification. [SMSH-2]	Too early or late
Audit	Audit	The audit is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audit/inspections	Audits or inspections conducted	The audit/inspection is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audit/inspections	Audits or inspections conducted late	Audit/inspection conducted late, thereby causing the company to lose its operating certification. [SMSH-2]	Too early or late
Audit/inspections	Audits or inspections not conducted	Audit/inspection is not conducted, thereby causing the company to lose its operating certification. [SMSH-2]	Not Providing
Audits	Audit	The audit is not conducted, thereby causing the ship to lose its operating certification. [SMSH-2]	Not Providing
Audits	Audit	Conducting the audit to late causes implementation of a fine, or loss of operating certification. [SMSH-2]	Too early or late
Audits	Audit	The audit is not conducted, thereby causing the ship to lose its operating certification. [SMSH-2]	Not Providing
Audits	Audit	The audit is not conducted, thereby causing the ship to lose its operating certification. [SMSH-2]	Not Providing
Audits	Audit	The audit is not conducted, thereby causing the ship to lose its operating certification. [SMSH-2]	Not Providing
Audits	Audit	Conducting the audit to late causes implementation of a fine, or loss of operating certification. [SMSH-52	Too early or late
Audits	Audit	Conducting the audit to late causes implementation of a fine, or loss of operating certification. [SMSH-2]	Too early or late

Audits	Audit	Conducting the audit to late causes implementation of a fine, or loss of operating certification. [SMSH-2]	Too early or late
Audits	Audit	The audit is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audits	Audit	The audit is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audits	Audit	The audit is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audits	Audit	The audit is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audits	Audit report not provided	The audit is not conducted, thereby allowing the internal controls of the organization to relax and cause potential problems. [SMSH-2]	Not Providing
Audits	Audit report provided	The audit is conducted but is a superficial check the box approach that fails to uncover hazards. [SMSH-5]	Providing
Audits	Audit report provided late	Conducting the audits too late causes the company to drift towards unsafe operations. [SMSH-2]	Too early or late
Certifications	SMS is approved late.	Delivering certifications late means ship operations may be stopped. [SMSH-1]	Too early or late
Certifications	SMS is approved, but flaws are not uncovered.	UK Government approves SMS, but the review is superficial. [SMSH-1]	Providing
Certifications	SMS is not approved.	UK Government, by not providing certification, means CMAL cannot operate its fleet. [SMSH-1]	Not Providing
Change order	Change is executed late.	The Shipyard responds to a Change order too late, so a known hazard, safety concern or risk situation goes unmitigated. [SMSH-2]	Too early or late
Change order	Change is executed but creates a hazard.	The change order is executed, but the Yard fails to analyse the hazards or risks that the change imparts. [SMSH-5]	Providing
Change order	Change is not executed.	The Shipyard fails to respond to a change order that allows a known hazard to go unmitigated. [SMSH-2]	Too early or late

Change orders	Approved change causes a hazard.	The change order is sent, but the Yard fails to analyse the hazards or risks that the change imparts. [SMSH-5]	Providing
Change orders	Change approved	The change request is sent, but shipyard fails to analyse the hazards or risks that the change imparts. [SMSH-5]	Providing
Change orders	Change approved late.	Change order released too late, so a known hazard, safety concern or risk situation goes unmitigated. [SMSH-2]	Too early or late
Change orders	Change not approved.	Not approving a change allows a known hazard to go unmitigated. [SMSH-2]	Not Providing
Change orders	Change order approved late.	CAA creates a hazard by not requesting a change that allows a known hazard to go unmitigated. [SMSH-2]	Too early or late
Change orders	Change order approved late.	Change order released too late, so a known hazard, safety concern or risk situation goes unmitigated. [SMSH-2]	Too early or late
Change orders	Change order is executed	The change order is sent, but the Design agent fails to analyse the hazards or risks that the change imparts. [SMSH-5]	Providing
Change orders	Change order is executed and causes a hazard.	The change order is executed, but the Yard fails to analyse the hazards or risks that the change imparts. [SMSH-5]	Providing
Change orders	Change order is executed late.	The Yard responds to a Change order too late, so a known hazard, safety concern or risk situation goes unmitigated. [SMSH-2]	Too early or late
Change orders	Change order is not executed.	The Yard fails to respond to a change order that allows a known hazard to go unmitigated. [SMSH-5]	Not Providing
Change orders	Change order not approved.	CAA creates a hazard by not requesting a change that allows a known hazard to go unmitigated. [SMSH-2]	Not Providing
Change orders	Change order not approved.	Company A creates a hazard by not requesting a change that allows a known hazard to go unmitigated. [SMSH-5]	Not Providing
Change requests	Change request delivered late.	Change request released too late, so a known safety problem goes unmitigated. [SMSH-2]	Too early or late
Change requests	Change request is	The change request is sent, but no action is	Providing

	delivered, but no action taken.	taken so hazardous conditions continues to exist. [SMSH-5]	
Change requests	Change request not delivered.	Not requesting a change allows a known hazard to go unmitigated. [SH1,2,3], [SMSH-5]	Not Providing
Change requests	Change request not sent.	Not requesting a change allows a known hazard to go unmitigated. [SMSH-2]	Not Providing
Change requests	Change request sent late.	Change request released too late, so a known safety problem goes unmitigated. [SMSH-2]	Too early or late
Change requests	Change requested, but no action is taken.	The change request is sent, but no action is taken so hazardous condition continues to exist. [SMSH-2]	Providing
Change requests, waivers, and deviations	Change requests, waivers and deviations approved late.	The Design Agent provides a change request, waiver, or a deviation too late, so a known hazard, safety concern or risk situation goes unmitigated. [SMSH-2]	Too early or late
Change requests, waivers, and deviations	Change requests, waivers and deviations are granted but safety hazard goes undetected.	The Change requests, waivers and deviations are executed, but Company A fails to respond to the requests in a timely manner. [SMSH-2]	Providing
Change requests, waivers and deviations	Change requests, waivers and deviations not approved.	The Design Agent fails to submit change requests, waivers and deviations so know design deficiencies go unmitigated. [SMSH-2]	Not Providing
Class Rules	Class Rules	Class Rules are released, but no new updates are included. [SMSH-1]	Provided
Class Rules	Class Rules not updated	By not issuing Class Rule updates, existing safety problems with the Rules will not be corrected. [SMSH-5]	Not Providing
Class Rules	Class Rules updated infrequently	By issuing the Class Rules late, design of new concepts may not be allowed on time causing late delivery of designs to owners/shipyards. [SMSH-5]	Too early or late
Contract	Contract	By not receiving the contract, CAA losses critical staffing impacting future operations due to loss of experience. [SMSH-5]	Not Providing
Contract	Contract	Contract awarded, but CAA's bid provides inadequate resources to staff the organization at a level to track the development of new ships, modernizations, and port revitalization. [SMSH-5]	Providing
Contract	Contract	Contracting late means CAA starts to lose experienced staff. [SMSH-5]	Too early or late
Contract	Contract	Contracting late means Company A Operation has less time to develop safe operating procedures based on sound SMS and risk	Too early or late

		management. [SMSH-4]	
Contract	Contract	Non-specific risk and safety guidance in the Contract mean Company A Operations may operate the fleet in an unsafe manner. [SMSH-4]	Not Providing
Contract	Contract	The CAA contract fails to identify all changes and hazardous materials that the Yard will have to deal with to scrap the ship. [SMSH-5]	Providing
Contract	Contract	The contract contains requirements for Company A Operations to identify risks to operations and implement a compliant SMS. [SMSH-5]	Providing
Contract	Contract awarded late.	Contracting late means Company A Operation starts to lose experienced staff. [SMSH-2]	Too early or late
Contract	Contract awarded, but adequate resources not available.	Contract awarded, but Company A Operations bid provides inadequate resources (time and materials) to implement safety and risk processes at a robust level. [SMSH-5]	Providing
Contract	Contract deliverables provided	The contract language requires the Yard to identify risks to operations and changes needed in the SMS to reflect the work being accomplished on the ship is weak. [SMSH-4]	Providing
Contract	Contract not awarded.	By not receiving the contract, Company A losses critical staffing impacting future operations due to loss of experience. [SMSH-5]	Not Providing
Contract	Contract not provided.	By not providing the contract, CAA is left with the potentially hazardous ship to dispose of. [SMSH-2]	Not Providing
Contract	Contract not provided.	By not providing the contract, the DOC is delayed, and the ship delivery is delayed [SMSH-2]	Not Providing
Contract	Contract not provided.	Not providing means CAA will not be allowed to operate the new ship or repaired/modernized ship due to lack of class certification. [SMSH-1]	Not Providing
Contract	Contract not provided.	Not providing requirements for hazard and risk analysis means the contract will not provide the baseline information for CAA to operate the new ship or repaired/modernized ship safely. [SMSH-2]	Not Providing
Contract	Contract provided but deliverables do not identify hazards and risks.	The contract contains requirements for Lloyds to identify unsafe design features, but the deliverables are not comprehensive and lack detail. [SMSH-5]	Providing
Contract	Contract provided late.	Contracting late means Lloyd's inspections and certifications are late and cause delays in the	Too early or late

		delivery or re-delivery of the ship(s) [SMSH-1]	
Contract	Contract provided late.	Contracting late means the DOC is delayed and thereby delaying the delivery of the ship [SMSH-2]	Too early or late
Contract	Contract provided late.	Contracting late means the Yard has less time to develop and implement a modernization package fully meeting SMS constraints with low risk. [SMSH-5]	Too early or late
Contract	Contract provided late.	Contracting late means the Yard has less time to develop and implement a recycling package fully meeting recycling laws, or potential new regulations could go into effect that limit competition. [SMSH-2]	Too early or late
Contract	Contract provided late.	Hazard and risk analysis is received too late, so new, modernized or repaired ship enters service with unknown hazards and risks. [SMSH-4]	Too early or late
Contract	Contract provided but does not contain strong hazard and risk analysis requirements.	The contract contains requirements for hazard and risk analysis, but the deliverables are not comprehensive and lack detail. [SMSH-5]	Providing
Contract	No contract provided.	By not providing specific risk and safety guidance in the Contract, the Yard may modify the ship and create new hazards or unsafe operating parameters. [SMSH-4]	Not Providing
Contract	SMS approved, but has residual hazards and risks for safe operations.	Contract awarded, but Lloyds verifies the SMS and provides a Document of Compliance (DOC) yet fails to find faults in the SMS that may cause accidents/incidents/near misses. [SMSH-5]	Providing
Contracts	Contract deliverables provided	The contract contains requirements for the Design Agent to identify unsafe design features, conduct hazard and risk analysis, but the deliverables are not comprehensive and lack detail. [SMSH-5]	Providing
Contracts	Contract not provided.	Not providing means CAA will not be able to keep the schedule for new construction, modernizations, or repairs. [SMSH-1]	Not Providing
Contracts	Contract provided late.	Contracting late means the Design Agent cannot support design, modernization, and repair schedules of the ship(s). [SMSH-5]	Too early or late
Crew training	Training request not provided	When training is not provided, the crew operates the ship unsafely [SMSH-2]	Not Providing
Crew training	Training request provided	The request is submitted, but no resources are found available to provide the training [SMSH-5]	Providing
Crew training	Training request provided	Training is approved, but no time is allotted in	Providing

		the ship's schedule to allow the training to occur [SMSH-5]	
Crew training	Training request provided late	Training is carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Deliverables	Deliverables lack good analysis of hazards and risks.	Calculations and test reports provided, but they are of low quality and allow the shipyard to incorporate hazardous or unsafe elements in the ship [SMSH-2]	Providing
Deliverables	Deliverables not provided.	By not providing the calculations and test reports, the shipyard may incorporate hazardous or unsafe elements in the ship. [SMSH-2]	Not Providing
Deliverables	Deliverables provided late.	Producing the calculations and test reports late means Company A cannot assess progress accurately and the Yard may be delayed by having to re-engineer or retest. [SMSH-2]	Too early or late
Emergency preparedness exercise	Emergency preparedness exercise conducted	The exercise is conducted but lacks realistic scenarios so is of limited value [SMSH-5]	Providing
Emergency preparedness exercise	Emergency preparedness exercise conducted late	By conducting the exercise late, a real emergency could happen prior to the training allowing the company to be unprepared [SMSH-2]	Too early or late
Emergency preparedness exercise	Emergency preparedness exercise not conducted	By not conducting the exercise the company is unprepared when an actual emergency occurs [SMSH-2]	Not Providing
Environmental Report	Environmental hazards identified, but no action taken to rectify.	The environmental report reveals existing deficiencies, but no decision is made as to how to deal with them [SMSH-5]	Providing
Environmental Report	Environmental hazards identified, but no resources are found to remedy.	The environmental report reveals new deficiencies, changes are developed, but no resources are found available to implement them [SMSH-5]	Providing
Environmental Report	Environmental hazards not reported.	Not reporting an environmental release of hazardous materials results in fines and legal action [SMSH-5]	Not Providing
Environmental Report	Environmental hazards reported late.	Not reporting an environmental release of hazardous materials results in fines and legal action [SMSH-5]	Too early or late
ERM Policy	ERM Policy too broad	The ERM policy is too broad and fails to direct the correct implementation of system-wide risk management. [SMSH-4]	Providing
ERM Policy	Late issuance of ERM Policy	The ERM policy is issued late so that resources are used incorrectly, focusing narrowly on risks, instead of companywide. [SMSH-2]	Too early or late

ERM Policy	Risk policy does not invoke ERM	By not issuing an ERM Policy, the HSE does not have guidance on system-wide risk management and continues to do a fragmented risk analysis. [SMSH-2]	Not Providing
Financial Performance	Quarterly Financial Performance report not provided	Quarterly Financial Performance Report produced for Company A operations is not produced. [SMSH-2]	Not Providing
Financial Performance	Quarterly Financial Performance report provided	Quarterly Financial Performance Report produced for Company A operations but is of low quality lacking complete financial information. [SMSH-5]	Providing
Financial Performance	Quarterly Financial Performance report provided late	Quarterly Financial Performance Report produced for Company A operations is produced late. [SMSH-2]	Too early or late
Hazard Report	Hazard report delivered late	Shipyard provides the Hazard Report late, so design team allows some hazards to be embedded into the design and therefore in the construction. [SMSH-2]	Too early or late
Hazard Report	Hazard report fails to identify all hazards	The Hazard Report fails to identify all hazards, so costs rise, and schedule is delayed by the shipyard. [SMSH-5]	Providing
Hazard Report	Hazard report not delivered	Hazard report is not provided by the shipyard, leading to hazards going undiscovered and unmitigated during design and construction. [SMSH-2]	Not Providing
Hazard report	Report fails to identify all hazards	The hazard and risk assessment fail to identify all hazards, so cost to recycle rises. [SMSH-5]	Providing
Hazard report	Report fails to provide the hazard assessment	Risk and hazard assessment by the Yard is not provided or is incomplete. [SMSH-5]	Providing
Hazard report	Report on risks and hazards is delivered late	Yard fails to meet schedule for delivering the hazard and risk assessment [SMSH-2]	Too early or late
Hazards/risk/safety assessments	Hazard/risk/safety assessments are incomplete and do not identify all issues.	Yard submits hazards/risks/safety assessments, but they are low quality creating construction and safety issues. [SMSH-5]	Providing
Hazards/risk/safety assessments	Hazard/risk/safety assessments are not provided.	By not providing hazards/risks/safety assessments to CAA detailed design and construction may incorporate faults. [SMSH-2]	Not Providing
Hazards/risk/safety assessments	Hazard/risk/safety assessments are provided late.	Delivering hazards/risks/safety assessments late to CAA means that detailed design and modernization of the ship will be delayed. [SMSH-2]]	Too early or late
Hazards/risks/safety assessments	Recycling Yard fails to provide Hazards/risks/safety assessments.	By not providing hazards/risks/safety assessments to Company A demolition is delayed [SMSH-2]	Not Providing
Hazards/risks/safe	Recycling Yard provides the	Delivering hazards/risks/safety assessments	Too early or

ty assessments	Hazards/risks/safety assessment late.	late to CMAL means demolition will be delayed. [SMSH-2]	late
Hazards/risks/safety assessments	Recycling Yard provides the Hazards/risks/safety assessment, but it does not identify all the issues.	Yard submits hazards/risks/safety assessments, but they are low quality creating demolition issues. [SMSH-5]	Providing
Key indicators	Key indicators	Key Indicators are not produced, allowing poor performance to go undetected. [SMSH-2]	Not Providing
Key indicators	Key indicators	Key indicators are provided late, so poor performance goes undetected for some time. [SMSH-2]	Too early or late
Key indicators	Key indicators	Key Indicators do not contain all key data elements, just a check the box exercise. [SMSH-4]	Providing
Key Indicators	Key indicators not provided	Key Indicators are not produced, allowing poor performance to go undetected. [SMSH-2]	Not Providing
Key Indicators	Key indicators provided	Key Indicators do not contain all key data elements, just a check the box exercise. [SMSH-4]	Providing
Key Indicators	Key indicators provided late	Key indicators are provided late, so poor performance goes undetected for some time. [SMSH-2]	Too early or late
Key Risk Indicators	Key Indicators	Key Indicators are not produced, allowing poor performance to go undetected. [SMSH-2]	Not Providing
Key Risk Indicators	Key Indicators	Key indicators are provided late, so poor performance goes undetected for some time. [SMSH-2]	Too early or late
Key Risk Indicators	Key Indicators	Key Indicators do not contain all key data elements, just a check the box exercise. [SMSH-5]	Providing
Key Risk Indicators (KRIs)	KRIs are incomplete.	KRI's do not contain all key indicators, just a check the box exercise. [SMSH-5]	Providing
Key Risk Indicators (KRIs)	KRIs are not produced.	KRI's are not produced, so some critical risks go unmitigated. [SMSH-2]	Not Providing
Key Risk Indicators (KRIs)	KRIs are produced late.	KRIs provided late, so an Enterprise risks reside in the organization [SMSH-2]	Too early or late
Life savings drills	LSA drill conducted	The drill is conducted, and a fault causes an accident [SMSH-5]	Providing
Life savings drills	LSA drill conducted late	Lifesaving appliance drills are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Life savings drills	LSA drill not conducted	When training is not provided, the crew cannot operate the lifesaving equipment during a real crisis. [SMSH-2]	Not Providing
Life-saving appliance drills	Lifesaving Appliance	The life-saving appliance drill does not reveal existing deficiencies [SMSH-5]	Providing

Life-saving appliance drills	LSA deficiencies identified, but no action taken.	The assessment reveals existing deficiencies, but no decision is made as to how to deal with them [SMSH-5]	Providing
Life-saving appliance drills	LSA deficiencies identified, but no resources found to mitigate.	The assessment reveals new deficiencies, changes are developed, but no resources are found available to implement them [SMSH-5]	Providing
Life-saving appliance drills	LSA drills not performed on schedule.	Life-saving appliance drills are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Life-saving appliance drills	LSA drills not performed.	The life-saving appliance drills cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Life-saving appliance drills	LSA drills not performed.	The life-saving appliance drills cannot be carried out / completed because of lack of human resources [SMSH-2]	Not Providing
Manning	Manning estimate is inaccurate.	Design Agent submits a low manning estimate causing a redesign later in the detail design process. [SMSH-5]	Providing
Manning	Manning estimate not provided.	By not providing the manning estimate, detailed design is delayed [SMSH-2]	Not Providing
Manning	Manning estimate provided late.	Delivering the manning estimate late means the detailed design will be delayed. [SMSH-2]	Too early or late
Monthly Safety Review	Safety meeting held	The Monthly meeting reveals new safety issues, but they are not acted upon (implementation) [SMSH-5]	Providing
Monthly Safety Review	Safety meeting held	The on-board monthly meeting is held, but no action is taken on outstanding safety issues. [SMSH-5]	Providing
Monthly Safety Review	Safety meeting held late	The late meeting leads to recurrence of identified safety issue; done less frequently than required [SMSH-2]	Too early or late
Monthly Safety Review	Safety meeting not held	No monthly safety review is held, so no action on outstanding safety issues [SMSH-2]	Not Providing
Operations and technical manuals	Deliverables fail to identify hazards and risk to safe operations.	The Shipyard provides the Operations and Technical Manuals, but the quality is low so hazardous operations or maintenance actions may occur. [SMSH-4]	Providing
Operations and technical manuals	Deliverables not provided.	By not providing the Operations and Technical Manuals, the crew will not be able to operate and maintain the ship. [SMSH-4]	Not Providing
Operations and technical manuals	Deliverables provided late.	Producing the Operations and Technical Manuals late means CAA may not operate or maintain the ship at delivery. [SMSH-4]	Too early or late
Plan approval	Plans are approved, but all hazards and risks to safe operations are not identified.	Shipyard submits the plans for approval, but Lloyds fails to uncover residual construction and safety issues. [SMSH-5]	Providing

Plan approval	Plans are not provided.	By not providing the plans for approval, the construction and ship delivery are delayed [SMSH-2]	Not Providing
Plan approval	Plans are provided late for approval.	Delivering plans late means the Lloyds is delayed and thereby delaying construction of the ship. [SMSH-2]	Too early or late
Planned maintenance approach	Procedures not provided.	Not providing the planned maintenance approach information means the crew is unable to maintain the ship and triggers an accident/incident/near miss. [SMSH-2]	Not Providing
Planned maintenance approach	Procedures provided cause an accident.	The planned maintenance approach is developed, but the quality is low so performing the maintenance triggers an accident/incident/near miss. [SMSH-5]	Providing
Planned maintenance approach	Procedures provided late.	The Shipyard is late delivering the preventative maintenance approach, which causes the crew to trigger an accident/incident/near miss. [SMSH-2]	Too early or late
Planned maintenance	Following planned maintenance causes an accident.	The planned maintenance approach is followed, but performing the maintenance triggers an accident/incident/near miss. [SMSH-5]	Providing
Planned maintenance	No planned maintenance used.	Not providing planned maintenance allows a failure that causes an accident/incident/near miss. [SMSH-2]	Not Providing
Planned maintenance	Planned maintenance is performed late.	Planned maintenance is carried out, but not done according to plan, thereby creating an unsafe condition. [SMSH-5]	Too early or late
Plans and calculations	Plans and calculations do not identify all hazards and safety issues.	Design Agent submits plans and calculations, but they are low quality creating construction and safety issues. [SMSH-5]	Providing
Plans and calculations	Plans and calculations not provided.	By not providing plans and calculations to Lloyds for approval on schedule, detailed design and construction are delayed [SMSH-5]	Not Providing
Plans and calculations	Plans and calculations provided late.	Delivering plans and calculations late to Lloyds means that detailed design and construction of the ship will be delayed. [SMSH-2]	Too early or late
Plans and Calculations deliverables	Plans and calculations not provided.	By not providing plans and calculations, construction and ship delivery are delayed [SMSH-2]	Not Providing
Plans and Calculations deliverables	Plans and calculations provided fail to identify all safety issues.	Design Agent submits plans and calculations, but they are low quality creating construction and safety issues. [SMSH-5]	Providing
Plans and Calculations deliverables	Plans and calculations provided late.	Delivering plans and calculations late means the construction of the ship will be delayed. [SMSH-2]	Too early or late

Regulation improvement	Recommendations are issued but do not provide needed changes	UK Government provides recommended changes to the Safety and Risk regulations, but the comments are too broad. [SMSH-5]	Providing
Regulation improvement	Recommendations not provided	By not providing recommendations, the UK Government fails to guide improvement in safe operations of ship operators. [SMSH-2]	Not Providing
Regulation improvement	Regulations input	The recommendations for updates to regulations regarding changes to safe ship operations are delayed allowing unsafe practices to continue. [SMSH-1]	Too early or late
Regulations	Regulation is not provided	By not updating regulations on SMS, the UK Government fails to guide improvement in safe operations of ship operators. [SMSH-1]	Not Providing
Regulations	Regulation is provided	Safety and Risk policies are too broad and fail to provide explicit guidance for a robust SMS. [SMSH-4]	Providing
Regulations	Regulation issued late	The updates to regulations regarding SMS use are delayed allowing unsafe practices to continue. [SMSH-1]	Too early or late
Regulations	Risk Policy is too broad	The Risk Policy is too broad and fails to direct the correct implementation of system-wide risk management. [SMSH-4]	Providing
Regulations	Risk Policy not provided	By not issuing the Risk Policy, the Audit and Risk Committee does not provide guidance to Corporate on their assessment of system-wide risk management and continues to do a fragmented risk analysis. [SMSH-2]	Not Providing
Regulations	Risk Policy provided late	The Audit and Risk Committee's Risk Policy is issued late so that resources are used incorrectly, focusing narrowly on risks, instead of companywide. [SMSH-2]	Too early or late
Regulations update	New regulations fail to improve safety	IMO provides updated regulations that fail to improve SMS requirements. [SMSH-5]	Providing
Regulations update	No new regulations to improve safety are released in a timely fashion	By not providing an updated regulation, the IMO fails to guide improvement in safe operations of ship operators. [SMSH-5]	Not Providing
Regulations update	Time between the release of new regulations is too long	The updates to regulations regarding changes to safe ship operations are delayed allowing unsafe practices to continue. [SMSH-5]	Too early or late
Requirements, Specifications and CONOPS	Deliverables	Not providing high-quality requirements, specifications and CONOPS means new construction, modernizations or repairs may be unsafe or not meet Company A's needs. [SMSH-5]	Not Providing
Requirements, Specifications and	Deliverables	Providing requirements, specifications and CONOPS late means the Design Agent cannot	Too early or late

CONOPS		support design, modernization, and repair schedules of the ship(s). [SMSH-2]	
Requirements, Specifications and CONOPS	Deliverables	The requirements, specifications and CONOPS contain requirements provided to the Design Agent to identify unsafe design features, conduct hazard, and risk analysis, but the deliverables are not comprehensive and lack detail. [SMSH-5]]	Providing
Resources	Resources not provided.	Resources are not provided which allows inadequate mitigation of a known hazard. [SMSH-2]	Not Providing
Resources	Resources not provided.	Resources are not provided which allows inadequate risk management across the company. [SMSH-2]	Not Providing
Resources	Resources not provided.	Resources are not provided which allows inadequate training or a known hazard to go unmitigated across the fleet. [SMSH-2]	Not Providing
Resources	Resources provided	Resources are provided, but the ship fails to mitigate known hazards and risks in a timely fashion. [SMSH-5]	Providing
Resources	Resources provided late.	Resources are not provided which allows inadequate training or a known hazard to go unmitigated across the fleet. [SMSH-2]	Too early or late
Resources	Resources provided late.	Resources are provided late which allows a known hazard to exist. [SMSH-2].	Too early or late
Resources	Resources provided late.	Resources provided late, so risk process is not as robust as it could have been. [SMSH-2]	Too early or late
Resources	Resources provided, but hazards are not identified or mitigated.	Resources are provided by the CEO, but the Company A Operations group fails to balance safety and risk management with other priorities allowing for the safety culture to decline. [SMSH-5]	Providing
Resources	Resources provided, but hazards still go unidentified and unmitigated.	Resources are provided by the BOD, but the Audit and Risk Committee fails to balance risk management with other priorities allowing for the risk process to decline. [SMSH-5]	Providing
Risk Appetite	Risk Appetite	By not issuing a Risk Appetite, the Operations group does not have guidance on the priority for resource expenditures to buy down risk. [SMSH-2]	Not providing
Risk Appetite	Risk Appetite	Risk Appetite is issued late so that resources are used incorrectly, focusing on the wrong risks and safety issues. [SMSH-2]	Too early or late
Risk Appetite	Risk Appetite	Risk Appetite is too conservative and fails to direct the correct expenditure of resources to mitigate risk. [SMSH-5]	Providing

Risk Assessment	Risk assessment provided late.	Risk assessments are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Risk Assessment	Risk Assessment accomplished, but not all hazards identified.	The assessment reveals new risks, but Yard fails to mitigate prior to the start of recycling [SMSH-5]	Providing
Risk Assessment	Risk assessment identifies risks, but nothing is done to mitigate	The assessment reveals existing risks, but no decision is made as to how to deal with them [SMSH-5]	Providing
Risk Assessment	Risk assessment identifies risks, but nothing is done to mitigate	The assessment reveals new risks, mitigations are developed, but no resources are found available to implement them [SMSH-5]	Providing
Risk Assessment	Risk assessment incomplete	The assessment does not reveal existing risks [SMSH-5]	Providing
Risk Assessment	Risk assessment incomplete.	Risk assessment is not carried out after an incident/accident [SMSH-2]	Not Providing
Risk Assessment	Risk assessment is late.	Yard provides the risk assessments late, so Company A has no time to mitigate prior to start of recycling. [SMSH-2]	Too early or late
Risk Assessment	Risk assessment is provided late.	Risk assessments are carried out a long time after an incident/accident [SMSH-2]	Too early or late
Risk Assessment	Risk assessment not produced.	Risk assessment is not provided to Company A acquisitions as part of the Recycling Yard's deliverables. [SMSH-2]	Not Providing
Risk Assessment	Risk assessment not provided.	The risk assessment cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Risk Assessment	Risk assessment not provided.	The risk assessment cannot be carried out / completed because of lack of human resources [SMSH-2]	Not Providing
Risk Assessment	Risk assessments not produced.	Risk assessment is not provided to Company A as part of the Yard modernization information. [SMSH-2]	Not Providing
Risk Assessment	Risk assessments produced late.	Yard provides the risk assessments late, so CAA has no time to mitigate problems during design or construction [SMSH-2]	Too early or late
Risk Assessment	Yard fails to mitigate identified risk during modernization development and execution.	The assessment reveals new risks, but Yard fails to mitigate during design and modernization. [SMSH-5]	Providing
Risk Assessments	Risk Assessment	The assessment does not reveal existing risks [SMSH-5]	Providing
Risk Assessments	Risk assessments are late.	Risk assessments are carried out a long time after an incident/accident [SMSH-2]	Too early or late
Risk Assessments	Risk assessments are	Risk assessments are carried out at longer	Too early or

	performed infrequently.	intervals (assessed every 1+ years) [SMSH-2]	late
Risk Assessments	Risk assessment not performed.	Risk assessment is not carried out after an incident/accident [SMSH-2]	Not providing
Risk Assessments	Risk Assessment of poor quality.	The assessment does not reveal existing risks [SMSH-5]	Providing
Risk Assessments	Risk assessments are not reviewed due to lack of personnel.	The risk assessment cannot be carried out / completed because of lack of human resources [SMSH-2]	Not providing
Risk Assessments	Risk Assessments done but not mitigated.	The assessment reveals existing risks, but no decision is made as to how to deal with them [SMSH-5]	Providing
Risk Assessments	Risk Assessments done but not mitigated.	The assessment reveals new risks, mitigations are developed, but no resources are found available to implement them [SMSH-5]	Providing
Risk Assessments	Risk Assessments done but not mitigated.	The risk assessment cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Risk Assessments	Risk Assessments are done late.	Risk assessments are carried out a long time after an incident/accident [SMSH-2]	Too early or late
Risk Assessments	Risk Assessments are done late.	Risk assessments are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Risk Assessments	Risk Assessments identity problems and mitigation, but no funding is provided.	The assessment reveals new risks, mitigations are developed, but no resources are found available to implement them [SMSH-5]	Providing
Risk Assessments	Risk Assessments identity problems, but no mitigation is attempted.	The assessment reveals existing risks, but no decision is made as to how to deal with them [SMSH-5]	Providing
Risk Assessments	Risk Assessments not done.	Risk assessment is not carried out after an incident/accident [SMSH-2]	Not Providing
Risk Assessments	Risk Assessments not done.	The risk assessment cannot be carried out / completed because of lack of human resources [SMSH-5]	Not Providing
Risk Assessments	Risk Assessments are incomplete.	The risk assessment cannot be carried out / completed because of lack of data/information [SMSH-2]	Providing
Risk Register	Risk mitigations are not prioritized.	Risk register review does not focus the Audit and Risk Committee on proper prioritization of risks, so corporate resources do not mitigate the highest risks. [SMSH-2]	Providing
Risk register	Risk register is incomplete.	Risk register does not contain all risks, just a check the box exercise. [SMSH-2]	Providing
Risk register	Risk register is incomplete.	Risk register does not contain all risks, just a check the box exercise. [SSH5]	Providing
Risk register	Risk register is incomplete.	Risk register review does not focus upper management on proper prioritization of risks, so corporate resources do not mitigate the highest risks. [SMSH-5]	Providing

Risk register	Risk register is not produced.	By not issuing a Risk Register, the Executive Team does not have guidance on the priority for resource expenditures to buy down risk [SMSH-2]	Not Providing
Risk register	Risk register is not produced.	By not producing the risk register, know risks are left unmitigated and cause an accident/incident/near miss. [SSH5]	Not Providing
Risk register	Risk register is not produced.	By not producing the risk register, known risks are left unmitigated and cause an accident/incident/near miss. [SMSH-2]	Not Providing
Risk Register	Risk register is not produced.	By not producing the risk register, known risks are left unmitigated and cause an accident/incident/near miss. [SMSH-2]	Not Providing
Risk register	Risk register is produced late.	Risk register provided late, so a known risk goes unmitigated. [SMSH-2]	Too early or late
Risk register	Risk register is produced late.	Risk register provided late, so a risk goes unmitigated. [SSH5].	Too early or late
Risk register	Risk register is produced late.	Risk register provided late, which does not allow upper management time to verify and update the prioritization of the risks, so a risk goes unmitigated. [SMSH-2]	Too early or late
Risk register	Risk register not produced	By not producing the risk register, known risks are left unmitigated and cause an accident/incident/near miss. [SMSH-2]	Not Providing
Risk register	Risk register produced	Risk register does not contain all risks, just a check the box exercise. [SMSH-5]	Providing
Risk register	Risk register produced late	Risk register provided late, so a risk goes unmitigated. [SMSH-2]	Too early or late
Risk Register	Risk register produced late.	Risk register provided late, which does not allow the Audit and Risk Committee time to verify and update the prioritization of the risks, so a risk goes unmitigated. [SMSH-2]	Too early or late
Safety Alerts	Safety Alerts issued late	By issuing a Safety Alert late, a known safety concern is not mitigated, causing an accident/incident/near miss. [SMSH-2]	Too early or late
Safety alerts	Safety alert	By issuing the Safety Alert late, a safety issue continues and causes an accident/incident/near miss. [SMSH-2]	Too early or late
Safety alerts	Safety alert	By not issuing a Safety Alert, a known safety concern is not mitigated. [SMSH-2]	Not Providing
Safety alerts	Safety alert	Failure to issue the safety alert allows an accident to occur. [SMSH-2]	Not Providing
Safety alerts	Safety alert	Safety alert issuance is delayed causing an accident. [SMSH-2]	Too early or late
Safety alerts	Safety alert	Safety Alerts lack specificity to work on every ship, thereby creating an unplanned risk or hazard. [SMSH-5]	Providing

Safety alerts	Safety alert	The safety alert contains information not compatible with a particular ship. [SMSH-5]	Providing
Safety Alerts	Safety Alert issued but contains incorrect information	Safety Alerts lack specificity to work on every ship, thereby creating an unplanned risk or hazard. [SMSH-5]	Providing
Safety Alerts	Safety Alerts not issued	By not issuing a Safety Alert, a known safety concern is not mitigated. [SMSH-2]	Not Providing
Safety assessment	Safety assessment not provided	The safety assessment cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Safety assessment	Safety assessment not provided	The safety assessment cannot be carried out / completed because of lack of human resources [SMSH-2]	Not Providing
Safety assessment	Safety assessment not provided	Safety assessment is not carried out after an incident/accident [SMSH-2]	Not Providing
Safety assessment	Safety assessment provided	The assessment does not reveal existing safety risks [SMSH-5]	Providing
Safety assessment	Safety assessment provided	The assessment reveals existing safety issues, but no decision is made as to how to deal with them [SMSH-5]	Providing
Safety assessment	Safety assessment provided	The assessment reveals new safety flaws, measured developed, but no resources are found available to implement them [SMSH-5]	Providing
Safety assessment	Safety assessment provided late	Safety assessments are carried out a long time after an incident/accident [SMSH-2]	Too early or late
Safety assessment	Safety assessment provided late	Safety assessments are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Safety assessments	Safety assessment	Safety assessment is not carried out after an incident/accident [SMSH-2]	Not Providing
Safety assessments	Safety assessment	Safety assessments are carried out a long time after an incident/accident [SMSH-2]	Too early or late
Safety assessments	Safety assessment	Safety assessments are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Safety assessments	Safety assessment	The assessment does not reveal existing safety risks [SMSH-5]	Providing
Safety assessments	Safety assessment	The assessment reveals existing safety issues, but no decision is made as to how to deal with them [SMSH-5]	Providing
Safety assessments	Safety assessment	The assessment reveals new safety flaws, measures developed, but no resources are found available to implement them [SMSH-5]	Providing
Safety assessments	Safety assessment	The safety assessment cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Safety assessments	Safety assessment	The safety assessment cannot be carried out / completed because of lack of human resources [SMSH-5]	Not Providing

Safety Assessments	Safety assessment not provided	Safety assessment is not carried out after an incident/accident [SMSH-2]	Not Providing
Safety Assessments	Safety assessment not provided	The safety assessment cannot be carried out / completed because of lack of data/information [SMSH-2]	Not Providing
Safety Assessments	Safety assessment not provided	The safety assessment cannot be carried out / completed because of lack of human resources [SMSH-2]	Not Providing
Safety Assessments	Safety assessment provided	The assessment does not reveal existing safety risks [SMSH-5]	Providing
Safety Assessments	Safety assessment provided	The assessment reveals existing safety issues, but no decision is made as to how to deal with them [SMSH-5]	Providing
Safety Assessments	Safety assessment provided	The assessment reveals new safety flaws, measured developed, but no resources are found available to implement them [SMSH-5]	Providing
Safety Assessments	Safety assessment provided late	Safety assessments are carried out a long time after an incident/accident [SMSH-2]	Too early or late
Safety Assessments	Safety assessment provided late	Safety assessments are carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Safety meeting minutes	Safety meeting minutes not produced.	Not reporting safety meeting minutes allows a known hazard to go unmitigated. [SMSH-2]	Not Providing
Safety meeting minutes	Safety meeting minutes produced but no action taken.	The safety meeting minutes reveal existing deficiencies, but no decision is made as to how to deal with them [SMSH-5]	Providing
Safety meeting minutes	Safety meeting minutes produced late.	Safety meeting minutes released too late, longer intervals (assessed every 1+ years), so a known safety problem goes unmitigated. [SMSH-2]	Too early or late
Safety meeting minutes	Safety meeting minutes produced, but no resources found to mitigate the issues.	The safety meeting minutes new deficiencies, changes are developed, but no resources are found available to implement them [SMSH-5]	Providing
Safety Policy	Safety Plan	By issuing the Safety Plan late, active management of safety is negatively affected inside the company. [SMSH-5]	Too early or late
Safety Policy	Safety Policy	The Safety Policy is issued late so that resources are used incorrectly, focusing on the wrong risks and safety issues. [SMSH-52]	Too early or late
Safety Policy	Safety Policy	By not issuing a Safety Policy, the company's approaches to safety are not coordinated. [SMSH-2]	Not Providing
Safety Policy	Safety Policy	By not issuing a Safety Policy, the HSE does not have guidance on the priority for resource expenditures to buy down risk. [SMSH-2]	Not providing
Safety Policy	Safety Policy	Safety Policy has not been updated, so the plan is outdated regarding the changing cruise and	Providing

		ferry operating environment. [SMSH-5]	
Safety Policy	Safety Policy	The Safety Policy is too broad and fails to direct the correct expenditure of resources to establish and improve the Safety Culture. [SMSH-5]	Providing
Safety/hazard/risk analysis	Safety/hazard/risk analysis is delivered late.	The Design agent provides the Safety/hazard/risk analysis late, so Company A (via the shipyard) allows some hazards to be embedded into the design and therefore in the construction. [SMSH-2]	Providing
Safety/hazard/risk analysis	Safety/hazard/risk analysis is not delivered.	The Safety/hazard/risk analysis is not provided by the design agent, leading to hazards going undiscovered and unmitigated during detail design and construction. [SMSH-2]	Not providing
Safety/hazard/risk analysis	Safety/hazard/risk analysis is of poor quality.	The Safety/hazard/risk analysis fails to identify all hazards, so costs rise, and schedule is delayed by the shipyard. [SMSH-5]	Providing
SMS Update	SMS updates are not provided.	Not providing the SMS updates allows a known hazard to go unmitigated. [SMSH-4]	Not Providing
SMS Update	SMS updates are provided late.	SMS updates released too late, longer intervals (assessed every 1+ years), so known safety problem go unmitigated. [SMSH-4]	Too early or late
SMS Update	SMS updates are provided, but incomplete.	The SMS updates are provided, but the quality is low, so unsafe conditions persist onboard. [SMSH-5]	Providing
SMS Update	SMS updates not provided.	Not providing the SMS updates allows a known hazard to go unmitigated. [SMSH-4]	Not Providing
SMS Update	SMS updates provided but do not capture all changes.	The SMS updates are provided, but the quality is low, so unsafe conditions persist onboard. [SMSH-4]	Providing
SMS Update	SMS updates provided late.	SMS updates released too late, longer intervals (assessed every 1+ years), so known safety problem go unmitigated. [SMSH-4]	Too early or late
SMS Updates	SMS Update	Not providing the SMS updates allows a known hazard to go unmitigated. [SMSH-2]	Not Providing
SMS Updates	SMS Update	SMS updates released too late, longer intervals (assessed every 1+ years), so a known safety problem goes unmitigated. [SMSH-2]	Too early or late
SMS Updates	SMS Update	The SMS updates are provided, but no training or resources accompany the changes, so unsafe conditions persist onboard. [SMSH-4]	Providing
Specifications	Specifications are delivered late.	Delivering Specifications late means the construction of the ship will be delayed. [SMSH-2]	Too early or late
Specifications	Specifications are not delivered.	By not providing Specifications, construction and ship delivery are delayed [SMSH-2]	Not Providing
Specifications	Specifications create safety	Design Agent submits Specifications, but they	Providing

	issues.	are low quality creating construction and safety issues. [SMSH-5]	
Strategic Plan	Strategic Plan	By not requiring ERM in the Strategic Plan, only a subset of risks affecting the company is identified. [SMSH-4]	Not providing
Strategic Plan	Strategic Plan	Strategic Plan does not contain the requirement for using Enterprise Risk Management (ERM), just a generic risk management approach to check the IMO box requirement. [SMSH-5]	Providing
Strategic Plan	Strategic Plan	Strategic Plan requires ERM but is issued late so that risks are allowed to affect the company. [SMSH-2]	Too early or late
Strategic Plan for safety and risk	Safety Strategy	Safety and risk Strategy only has minor changes, so the update does not reflect the new operating environment. [SMSH-4]	Providing
Strategic Plan for safety and risk	Safety Strategy,	By not updating the Safety Strategy, the existing approaches do not change and adapt to the changes in the operating environment. [SMSH-4]	Not Providing
Strategic Plan for safety and risk	Safety Strategy,	Safety and risk Strategy is issued late so that existing safety issues are allowed to affect the company. [SMSH-2]	Too early or late
Surveys	Survey accomplished late.	By Lloyds conducting the survey late Company A may lose the use of this ship as it is out of class. [SMSH-2]	Too early or late
Surveys	Survey fails to uncover all hazards.	Lloyds conducts the survey, but they fail to uncover safety issues. [SMSH-5]	Providing
Surveys	Survey not accomplished.	By not conducting the survey, Company A losses the use of the particular ship. [SMSH-2]	Not Providing
Training material	Training materials not provided	If the Shipyard fails to provide training materials, the crew will not be able to operate the ship safely. [SMSH-2]	Not Providing
Training material	Training materials provided	The training materials are provided but are of low quality and do not address the key safety and operational issues. [SMSH-5]	Providing
Training material	Training materials provided late	The Shipyard provides the training materials late, so the crew does not benefit from the information developed. [SMSH-5]	Too early or late
Training request	Training request not provided	When training is not provided, the crew operates the ship unsafely [SMSH-2]	Not Providing
Training request	Training request provided	The request is submitted, but no resources are found available to provide the training [SMSH-5]	Providing
Training request	Training request provided	Training is approved, but no time is allotted in the ship's schedule to allow the training to occur. [SMSH-5]	Providing

Training request	Training request provided late	Training is carried out at longer intervals (assessed every 1+ years) [SMSH-2].	Too early or late
Training requests	Training request not submitted	When training is not provided, the crew operates the ship unsafely [SMSH-2]	Not Providing
Training requests	Training request submitted	The request is submitted, but no resources are found available to provide the training [SMSH-5]	Providing
Training requests	Training request submitted	Training is approved, but no time is allotted in the ship's schedule to allow the training to occur. [SMSH-5]	Providing
Training requests	Training request submitted late	Training is carried out at longer intervals (assessed every 1+ years) [SMSH-2]	Too early or late
Updated Regulations	Updated regulation issued late	By issuing the updated regulation late, unsafe conditions on ships continue [SMSH-1]	Too early or late
Updated Regulations	Updated regulation is not issued	By failing to update the regulation, ship safety is not improved [SMSH-1]	Not Providing
Updated Regulations	Updated regulation issued	Updated regulation is issued, but fails to improve safety [SMSH-1]	Providing
Vessel Operation Updates	Ship Operations Manual recommended changes are made late.	Ship operation manual recommended updates released too late, longer intervals (assessed every 1+ years), so a known safety problem goes unmitigated. [SMSH-2]	Too early or late
Vessel Operation Updates	Ship Operations Manual recommended changes are not made.	Not providing the ship operation manual updates allows a known hazard to go unmitigated. [SMSH-2]	Not Providing
Vessel Operation Updates	Ship Operations Manual recommended changes made, but nothing happens	The recommended ship operations manual updates are provided, but no training or resources accompany the changes, so unsafe conditions persist onboard. [SMSH-5]	Providing
Vessel Operations Updates	SMS update not provided	Not providing the SMS updates allows a known hazard to go unmitigated. [SMSH-4]	Not Providing
Vessel Operations Updates	SMS update provided	The SMS updates are provided, but the quality is low, so unsafe conditions persist onboard. [SMSH-5]	Providing
Vessel Operations Updates	SMS update provided late	SMS updates released too late, longer intervals (assessed every 1+ years), so known safety problem go unmitigated. [SMSH-4]	Too early or late

Appendix A.5 – Company A Priority 1 Safety System Indicators (SSIs):

Indicator Type	System Indicator Name	Description
Assurance	Audit	Number of new findings each review cycle shall be tracked and reviewed annually.
Assurance	Audit	Number of repeat findings each review cycle shall be tracked and reviewed annually.
Assurance	Audit	The quality of the audit process should be assessed annually and reported.
Assurance	Audit assessment	The quality of the audit process should be assessed annually and reported.
Assurance	Change order	Number of change orders that are not acted upon by the Yard in thirty days, reported monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Yard in thirty days, reported monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Design Agent in thirty days, reported monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Yard in thirty days, reported monthly.
Assurance	Change requests	Number of change requests, waivers and deviations that are not acted upon by Company A Acquisitions in thirty days, reported monthly
Assurance	Contract	Number of days late after the scheduled delivery of the Contract to Company A Acquisitions shall be tracked and reported monthly
Assurance	Environmental report	Number of environmental deficiencies open and unresolved reported weekly.
Assurance	Planned maintenance	Number of planned maintenance activities scheduled, but not completed, reported monthly.
Assurance	Planned maintenance	Number of incidents caused by planned maintenance should be tracked on a yearly basis.
Assurance	Resources	Level of funding for risk and safety mitigation efforts shall be tracked monthly.
Assurance	Resources	Crew manning levels shall be tracked weekly.
Assurance	Resources	Number of unfilled crew onboard ships tracked monthly.
Assurance	Safety assessment	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported on a monthly basis.
Assurance	Safety assessment	Track number of safety assessments conducted on a monthly basis, including the number of hazards found
Assurance	Safety assessment	Number of accident/incident/near miss reports with no decision to fix the issues highlighted, reported monthly.
Assurance	Safety assessment	Number of accident/incident/near miss reports with no decision to fix the issues highlighted, reported monthly.
Assurance	Safety meeting	Number of times ship fails to hold the Monthly safety reviews, reported monthly.
Assurance	Safety meeting minutes	Master reports monthly/annually on the total number of safety deficiencies and the number not being dealt with.
Assurance	SMS	Number of days late after the scheduled delivery of approvals from the UK

		Government shall be tracked and reported monthly.
Assurance	SMS	Number of flaws identified in the SMS by Deck and Engineering and submitted to the Master shall be reported at the completion of the review.
Assurance	SMS assessment	Percentage of ship's Masters that submit SMS comments on time.
Assurance	SMS assessment	Percentage of unresolved comments steadily grows. The trigger is 10%.
Assurance	SMS Update	Number of changes to the SMS should be tracked and reported on annually.
Policy & Objectives	ERM Policy	The ERM policy is too broad and fails to direct the correct implementation of system-wide risk management.
Policy & Objectives	Risk Appetite	Time between updates to the Risk Appetite document shall be tracked and reported annually.
Policy & Objectives	Safety Policy	The time in months since the Safety Policy was updated, reported on a yearly basis.
Policy & Objectives	Safety Strategy,	Number of times that the Safety Strategy is not produced shall be tracked and reported.
Policy & Objectives	Update issued late	The lateness of the issuance of IMO regulations shall be tracked and reported monthly
Promotion	Key indicators	Number of audits done on Key Indicators per year reported annually.
Promotion	Key Indicators	Number of audits findings that indicate Key indicators are used in decision making.
Promotion	LSA drill	Number of accidents occurring during training drills on the lifesaving appliances.
Promotion	LSA drill	Percentage of lifesaving appliance drills accomplished on schedule fleet-wide.
Promotion	Quarterly Financial Performance report	The quality of the Quarterly Financial Performance Report shall be assessed in reported annually.
Promotion	Resources	Amount of funding available for training tracked monthly.
Promotion	Safety alerts	Quality of Safety Alerts shall be assessed annually.
Promotion	Training request	Number of approved training requests not accomplished on a monthly basis.
Promotion	Training request	Number of training requests not approved reported monthly.
Promotion	Training request	Number of approved training scenarios not accomplished on a monthly basis.
Risk	Resources	BOD appoints a lead risk person for the Audit and Risk Committee.
Risk	Resources	Number of known KRI's created and tracked on a monthly basis.
Risk	Accident/incident/ near miss Report	Quality of Accident/incident/near miss Reports should be assessed annually.
Risk	Accident/Incident/ Near-miss reports	Number of accident/incident/near miss reports that are open, with no conclusion as to root cause identified summarized and tracked on a monthly basis.
Risk	Accident/near-miss reports.	The ratio of open versus closed accident/incident/near miss reports reported monthly.
Risk	Analysis	Average time to decide on whether to act on an accident/incident/near miss report recommendation for a change in the SMS shall be tracked and

		reported on monthly.
Risk	KRI	The quality of the KRIs shall be assessed and findings reported annually.
Risk	Resources	Number of know risks and hazards that go unmitigated tracked on a monthly basis
Risk	Resources	Risk mitigation funding shall be tracked and reported on monthly.
Risk	Risk Assessment	Quality of risk assessments should be assessed annually.
Risk	Strategic Plan	Percentage of the company using ERM as their method of Risk Management.

Appendix A.6– Company A Priority 2 Safety System Indicators (SSIs):

Indicator Type	System Indicator Name	Description
Assurance	Approvals	Number of days late after the scheduled delivery of approvals from Lloyds shall be tracked and reported monthly.
Assurance	Approvals	Number of comments on each plan shall be tracked and reported on monthly.
Assurance	Audit report	Number of audits not conducted shall be tracked and reported quarterly.
Assurance	Change order	Average time for the Yard to decide to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Average time for the Yard to decide to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Average time for the Yard to decide to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change order	Average time to decide to respond to an approved a change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Number of change orders backlogged to be definitized shall be tracked monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change request	Number of change orders that are not acted upon by the Shipyard in thirty days, reported monthly.
Assurance	Change request	Average time to decide to respond to an approved a change order with a priced change shall be tracked and reported on monthly.
Assurance	Change request	Number of change requests not processed shall be tracked and reported monthly.
Assurance	Change request	Number of change requests that are not acted upon by Company A in thirty days, reported monthly.
Assurance	Change request	Average time to decide on whether to approve a change request shall be tracked and reported on monthly.
Assurance	Change request	Number of change orders backlogged shall be tracked monthly.
Assurance	Change requests	Number of change requests, waivers and deviations backlogged shall be tracked monthly.

Assurance	Change requests	Average time for the Yard to decide to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Assurance	Contract	Number of days late in releasing the contract shall be tracked and reported monthly.
Assurance	Contract	Number of days late after the scheduled delivery of the Contract to Lloyds shall be tracked and reported monthly.
Assurance	Contract	Number of days late after the scheduled delivery of the Contract to Company A shall be tracked and reported monthly.
Assurance	Contract	Number of days late after the scheduled delivery of the requirements/specifications shall be tracked and reported monthly.
Assurance	Contract	Track and report the number of design deficiencies.
Assurance	Contract	Track and report the number of design deficiencies.
Assurance	Deliverables	Number of days late after the scheduled delivery of engineering calculations and test results shall be tracked and reported monthly.
Assurance	Deliverables	Company A shall track the number of deficiencies identified with Operations and Technical Manuals on a monthly basis.
Assurance	Deliverables	Number of days late after the scheduled delivery of Operations and Technical Manuals shall be tracked and reported monthly.
Assurance	Deliverables	Yard produces comprehensive SMS operational changes before redelivery of the ship to the fleet.
Assurance	Deliverables	Number of days late after scheduled award of contract reported monthly.
Assurance	Environmental report	Number of environmental deficiencies shall be reported weekly.
Assurance	Environmental report	Total number of environmental incidents and timeliness of the release of the report summarized in a weekly report to the Master.
Assurance	Environmental report	Number of environmental releases reported weekly.
Assurance	LSA	Total number of safety deficiencies found during weekly/monthly LSA tests.
Assurance	LSA deficiencies	Average time to fix safety deficiencies found through LSA testing must be reported monthly.
Assurance	LSA drills	Deck department tracks the number of LSA tests cancelled due to poor documentation.
Assurance	LSA drills	Deck Department reports monthly on the number of late or cancelled LSA tests.
Assurance	LSA testing	Deck Department reports on the number of open safety deficiencies identified by LSA testing monthly.
Assurance	Planned maintenance	Number of planned maintenance activities not completed each month,
Assurance	Planned maintenance	Number of incidents caused by planned maintenance should be tracked on a yearly basis.
Assurance	Plans	Number of comments on each plan shall be tracked and reported on monthly.
Assurance	Plans	Number of days late after the scheduled delivery of the plans to Lloyds shall be tracked and reported monthly.
Assurance	Plans and	The quality of the plans and calculations submitted shall be assessed and

	calculations	the results shall be tracked and reported.
Assurance	Plans and calculations	Number of comments on plans and calculations shall be tracked and reported on monthly.
Assurance	Plans and calculations	Number of days late after the scheduled delivery of plans and calculations shall be tracked and reported monthly to Company A.
Assurance	Plans and calculations	Number of plans and calculations submitted late to Lloyds shall be tracked by Company A Acquisitions monthly.
Assurance	Resources	Amount of funding available for training tracked monthly.
Assurance	Resources	Number of unfilled crew onboard ship tracked on a monthly basis
Assurance	Resources	Crew manning levels shall be tracked monthly.
Assurance	Safety assessment	Track number of safety assessments conducted on a monthly basis, including the number of hazards found.
Assurance	Safety assessment	Number of cancelled safety assessments due to lack of information/data shall be tracked and reported monthly.
Assurance	Safety assessment	Number of cancelled safety assessments due to lack of resources shall be tracked and reported monthly.
Assurance	Safety assessment	Ratio of open versus closed accident/incident/near miss reports reported monthly.
Assurance	Safety assessment	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported on a monthly basis across the whole fleet.
Assurance	Safety assessment	Ratio of planned versus accomplished safety assessments shall be reported monthly for the whole fleet.
Assurance	Safety assessment	Ratio of planned versus accomplished safety assessments shall be reported monthly.
Assurance	Safety meeting	Number of newly identified safety issues not addressed within 30 days.
Assurance	Safety meeting	Number of safety deficiencies open and unresolved reported weekly.
Assurance	Safety meeting	Number of safety meeting minutes delivered late every month.
Assurance	Safety meeting	Number of monthly safety meetings held on time, provided in a monthly report.
Assurance	Safety meetings	Number of safety meeting minutes not submitted as a percentage of the total fleet's input/reports.
Assurance	SMS review	Number of flaws identified in the SMS by Deck and Engineering and submitted to the Master shall be reported at the completion of the review.
Assurance	SMS update	Number of SMS updates not submitted on time shall be reported monthly.
Assurance	SMS update	Number of SMS revisions delivered late shall be tracked and reported annually.
Assurance	SMS updates	SMS updates shall be provided on time.
Assurance	Specifications	Number of days late after the scheduled delivery of the specifications shall be tracked by Company A.
Assurance	Specifications	Number of comments on specifications shall be tracked and reported on monthly.
Assurance	Survey	Number of comments on each survey shall be tracked and reported on monthly.
Assurance	Survey	Number of days late after the scheduled delivery of the surveys from

		Lloyds shall be tracked and reported monthly.
Policy & Objectives	Class rules	Class Rules are released, but no new updates are included
Policy & Objectives	ERM Policy	By not issuing an ERM Policy, the HSE does not have guidance on system-wide risk management and continues to do
Policy & Objectives	Risk appetite	Number of days late for Risk Appetite revision is tracked on an annual basis.
Policy & Objectives	Risk Policy	The Risk Policy is too narrow and fails to direct the correct implementation of system-wide risk management.
Policy & Objectives	Safety policy	Number of days late for Safety Policy revision is tracked on an annual basis.
Policy & Objectives	Safety Policy	Length in time in months since the last update of the Safety Policy.
Policy & Objectives	Safety Strategy	Number of significant changes to the Safety Strategy ship be tracked and report on annually.
Policy & Objectives	Update not issued	Frequency of regulation updating should be tracked and reported
Policy & Objectives	Updated regulation issued	Number of updates issued by IMO shall be tracked and reported annually.
Promotion	Key Indicators	Number of audits findings that indicate Key indicators are not used in decision making.
Promotion	Key Indicators	Number of days late for the Key Indicator report shall be tracked and reported on monthly.
Promotion	Key indicators	Ration of the number of key indicators versus five-year average plotted monthly.
Promotion	Key indicators	Number of days late for the Key Indicator report shall be tracked and reported on monthly.
Promotion	Key indicators	Number of days late for the Key Indicator report shall be tracked and reported on monthly.
Promotion	Key indicators	Number of audits done on Key Indicators per year reported annually.
Promotion	LSA drill	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.
Promotion	Quarterly Financial Performance report	The number of times the Quarterly Financial Report is not produced shall be tracked and reported annually.
Promotion	Quarterly Financial Performance report	The number of times the Quarterly Financial Report is not produced shall be tracked and reported annually.
Promotion	Safety alert	Average time to release a Safety Alert must be tracked.
Promotion	Training material	Number of days late for training material shall be tracked and reported monthly.
Promotion	Training materials	Percentage of training materials delivered on schedule is tracked monthly.
Promotion	Training materials	Number of issues/mistakes found by CMAL when reviewing the Shipyard provided training materials shall be tracked and reported monthly.

Promotion	Training request	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.
Promotion	Training request	Number of training requests not approved reported monthly.
Promotion	Training request	Number of approved training requests not accomplished on a monthly basis.
Promotion	Training request	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.
Promotion	Training request	Number of training requests not approved reported monthly.
Promotion	Training	Number of times training is delayed shall be tracked and reported monthly
Risk	Resources	BOD appoints a lead risk person for the Audit and Risk Committee.
Risk	Resources	Number of known KRI's created and tracked on a monthly basis.
Risk	Accident/incident report	Number of accident/incident/near miss produced, and number open reported monthly.
Risk	Accident/incident reports	Number of accident/incident/near miss reports with no decision to fix the issues highlighted, reported monthly.
Risk	Accident/incident reports	Ratio of open versus closed accident/incident/near miss reports reported monthly.
Risk	Accident/incident reports	Number of accident/incident/near miss reports that are open, with no conclusion as to root cause identified.
Risk	Accident/incident reports	Number of accident/incident/near miss reports with no decision to fix the issues highlighted reported monthly
Risk	Accident/incident reports	Average time to decide on whether to act on an accident/incident/near miss reports shall be tracked and reported on monthly.
Risk	Accident/incident reports	Number of accident/incident/near miss reports completed, and number open reported monthly.
Risk	Accident/incident/ near miss Report	Number of days late in the issuance of the Accident/incident/near miss Report is tracked and reported monthly.
Risk	Accident/incident/ near miss Report	Number of times Accident/incident/near miss Report is not issued tracked and reported annually.
Risk	Accident/incident/ near miss Report	Number of times Accident/incident/near miss Report is not issued shall be tracked and reported annually.
Risk	Accident/incident/ near miss Report	Number of days late in the issuance of the Accident/incident/near miss Report is tracked and reported monthly.
Risk	Accident/incident/ near miss Report	Quality of Accident/incident/near miss Reports should be assessed annually.
Risk	Accident/incident/ near miss Report	Number of days late in the issuance of the Accident/incident/near miss Report is tracked and reported monthly.
Risk	Accident/incident/ near miss Report	Quality of Accident/incident/near miss Reports should be assessed annually.
Risk	Analysis	Number of accident/incident/near miss reports with no decision to fix the issues highlighted reported monthly.
Risk	Analysis	Ratio of open versus closed accident/incident/near miss reports reported monthly.
Risk	Analysis	Number of accident/incident/near miss reports that are open, with no conclusion as to root cause identified.
Risk	Analysis	Number of accident/incident/near miss reports produced and number

		open reported monthly.
Risk	Contract	Number of rejected hazard, safety and risk deliverables.
Risk	Contract	Number of hazards, safety and risk deliverables that are received late shall be tracked and reported monthly.
Risk	Deliverables	Number of critical hazards identified and reported monthly.
Risk	Hazard analysis	Number of days the hazard analysis is late being provided by the Recycling Yard shall be tracked and reported.
Risk	Hazard report	Number of days the hazard analysis is late being provided to the Shipyard shall be tracked and reported monthly.
Risk	Hazard/risk/safety assessments	Number of hazards, risk and safety assessments submitted late to Company A Acquisitions shall be tracked and reported monthly.
Risk	Hazards/risks/safety assessments	Number of hazards, risk and safety assessments submitted late to Company A acquisitions shall be tracked and reported monthly.
Risk	KRIs	The average number of days past due for the KRIs shall be reported monthly.
Risk	KRIs	Number of times KRIs are not produced should be tracked and reported on annually.
Risk	Resources	Level of funding for risk mitigation efforts shall be tracked monthly.
Risk	Resources	Level of funding for risk and safety mitigation efforts shall be tracked monthly.
Risk	Risk assessment	The ratio of the number of risk assessments versus the total number of near misses, incidents and accidents should be tracked/plotted on a monthly basis.
Risk	Risk assessment	The total number of incomplete risk assessment should be reported on a monthly basis.
Risk	Risk assessment	The total number of incomplete risk assessment should be reported on a monthly basis.
Risk	Risk assessment	A summary report of the number of risk assessments conducted should be produced annually.
Risk	Risk assessment	A summary report of the total number of risk assessments should be produced annually.
Risk	Risk assessment	The quality of the risk assessments based on the total number accomplished versus the average for the previous three years shall be calculated and reported annually.
Risk	Risk assessment	Number of days the risk assessment is late being provided to the Modernization Yard shall be tracked and reported monthly.
Risk	Risk assessments	The total number of risk assessments should be tracked/plotted on a monthly/quarterly/annual basis.
Risk	Risk assessments	The number of risk assessments conducted late should be tracked and reported monthly.
Risk	Risk mitigation	Average funding per mitigation plan and total risk mitigation funding shall be reported monthly.
Risk	Risk register	Average number of days past due for the risk register shall be reported monthly.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.

Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Risk register	Average number of days since the last prioritization of the risk register shall be reported monthly.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Risk register	Average number of days past due for the risk register shall be reported monthly.
Risk	Safety/hazard/risk analysis	Number of days the Safety/hazard/risk analysis is late being provided to Company A shall be tracked and reported monthly.
Risk	Safety/hazard/risk analysis	The quality of the Safety/hazard/risk analysis shall be assessed when the deliverable is provided, and results reported annually.
Risk	Strategic Plan	The quality of the Strategic Plan in the area of risk management shall be assessed on a yearly basis.
Risk	Summary risk assessment	Quality of the Summary Assessment Report based on the number of risks unchanged from the previous report should be assessed annually.

Appendix A.7– Company A Priority 3 Safety System Indicators (SSIs):

Indicator Type	System Indicator Name	Description
Assurance	Resources	Approved and actual manpower shall be tracked and reported monthly.
Assurance	Approvals	Number of changes required on resubmittals to get approval shall be tracked and reported on monthly.
Assurance	Approvals	Number of days late after the scheduled delivery of the surveys from Lloyds shall be tracked and reported monthly.
Assurance	Change request	Number of change requests that are not acted upon by the Master in thirty days, reported monthly.
Assurance	Change request	Average time to decide on whether to approve a change request shall be tracked and reported on monthly.
Assurance	Contract	Number of days late after scheduled award of contract reported monthly.
Assurance	Contract	Number of days late after scheduled award of contract reported monthly.
Assurance	Contract	SMS passes audits on time, with no significant findings.
Assurance	LSA drills	Deck Department reports monthly/annually on all delayed or incomplete LSA tests.
Assurance	Manning estimate	Number of days late after the scheduled delivery of the manning estimate shall be tracked by Company A Acquisitions.
Assurance	Operations Manual update	Number of Ship Operation Manual updates delivered late shall be tracked and reported monthly.
Assurance	Operations Manual	Number of days past due for Ship Operation Manual update shall be

	update	tracked.
Assurance	Planned maintenance	Number of planned maintenance approaches not provided shall be tracked and reported monthly.
Assurance	Planned maintenance	The number of planned maintenance approaches not delivered shall be tracked each month
Assurance	Safety assessment	Number of accident/incident/near miss reports with no decision to fix the issues highlighted, reported monthly.
Assurance	Safety assessment	Ratio of open versus closed accident/incident/near miss reports reported monthly for the whole fleet.
Assurance	Safety assessment	Ratio of planned versus accomplished safety assessments shall be reported monthly for the whole fleet.
Assurance	Safety assessment	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported on a monthly basis across the whole fleet.
Assurance	Safety assessment	Number of cancelled safety assessments due to lack of resources shall be tracked and reported monthly
Assurance	Safety assessment	Track resources spent on fixing hazards identified in safety assessments and report on monthly.
Assurance	Safety assessment	Track resources spent on fixing hazards identified in safety assessments and report on monthly.
Assurance	Safety assessment	Director of Service Delivery shall track the number of cancelled safety assessments due to lack of information/data on a monthly basis.
Assurance	Safety assessment	Number of cancelled safety assessments due to lack of resources shall be tracked and reported monthly.
Assurance	Safety assessment	Ratio of open versus closed accident/incident/near miss reports reported monthly for the whole fleet.
Assurance	Safety assessment	Track number of safety assessments conducted on a monthly basis, including the number of hazards found.
Assurance	Safety assessment	Track resources spent on fixing hazards identified in safety assessments and report on monthly.
Assurance	Safety assessment	Director of Service Delivery shall track the number of cancelled safety assessments due to lack of information/data on a monthly basis.
Assurance	Safety meeting	Percentage of safety issues unresolved after 30 days steadily increases. Initial trigger is at 10%.
Assurance	Ship Operations Manual updates	Number of changes to the Ship Operations Manual should be tracked and reported on annually.
Assurance	SMS assessment	Data must be provided to the Deck and Engineering Departments so they can conduct the annual SMS assessment.
Assurance	SMS review	Total number of changes to SMS, versus number approved tracked on a monthly basis.
Assurance	SMS Update	Number of revisions to the SMS are tracked and reported annually.
Assurance	SMS Update	Training to implement changes to the SMS should be tracked and reported on annually.
Assurance	SMS updates	Training to implement changes to the SMS should be tracked and reported on annually.
Policy &	Class rule update	Length in time in months since the last update of the Class Rules.

Objectives		
Policy & Objectives	ERM Policy	Number of days late for ERM Policy revisions are tracked on an annual basis.
Policy & Objectives	Regulations	Number of days late for SMS Regulation revisions are tracked on an annual basis.
Policy & Objectives	Regulations	Number of days late for SMS Regulation revisions are tracked on an annual basis.
Policy & Objectives	Risk appetite	Frequency of updating the corporate risk appetite is tracked and reported on an annually.
Policy & Objectives	Risk Policy	Number of days late for Risk Policy revisions are tracked on an annual basis.
Policy & Objectives	Safety Policy	Number of days late for Safety Policy revision is tracked on an annual basis.
Policy & Objectives	Safety policy	Time since the last issuance of the Safety Policy (in days) shall be tracked and reported.
Policy & Objectives	Safety Strategy,	Late delivery of the Safety Strategy shall be tracked and reported monthly.
Policy & Objectives	Strategic Plan	Number of days late for Strategic Plan revision is tracked on an annual basis.
Policy & Objectives	Updated regulations	The time in months since the ISM Code was updated, reported on a yearly basis.
Promotion	Resources	Training, safety and risk mitigation funding shall be tracked and reported on monthly.
Promotion	Safety Alert	Average number of Safety Alerts issued per month shall be tracked and reported quarterly.
Promotion	Safety alert	Average time to release a Safety Alert must be tracked.
Promotion	Safety Alert	Number of days late for Safety Alert revision is tracked on an annual basis.
Promotion	Training request	Track the delay in the Director of Service Delivery approving the training schedule.
Promotion	Training request	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.
Risk	Resources	Number of unmitigated risks shall be tracked and reported on a monthly basis.
Risk	Accident/incident reports	Track resources spent on an accident/incident/near miss changes/mitigations and report on monthly.
Risk	Accident/incident/near miss Report	Number of times Accident/incident/near miss Report not issued is tracked and reported annually.
Risk	Accident/incident/near miss Report	Number of times Accident/incident/near miss Report is not issued tracked and reported annually.
Risk	Accident/incident/near miss Report	Number of days late in the issuance of the Accident/incident/near miss Report is tracked and reported monthly.
Risk	Accident/incident/near miss Report	Accident/incident/near miss trends shall be analysed and reported monthly.
Risk	Resources	Number of know risks and hazards that go unmitigated tracked on a monthly basis.

Risk	Risk assessment	An annual summary report documenting the ratio of the number of risk assessments versus the total number of near misses, incidents and accidents should be produced.
Risk	Risk assessment	Total number of unfunded and unstaffed risk assessments should be reported on a monthly basis.
Risk	Risk assessment	The ratio of the number of risk assessments versus the total number of near misses, incidents and accidents should be tracked/plotted on a monthly basis.
Risk	Risk assessment	Average funding per mitigation plan and total risk mitigation funding shall be reported monthly.
Risk	Risk assessment	Total number of unfunded and unstaffed risk assessments should be reported on a monthly basis.
Risk	Risk assessment	The total number of risk assessments should be tracked/plotted on a monthly/quarterly/annual basis.
Risk	Risk assessment	Number of days the risk assessment is late being provided to the Recycling Yard shall be tracked and reported monthly.
Risk	Risk assessment	The number of risk assessments conducted should be tracked.
Risk	Risk mitigation	The summary of the average funding per mitigation plan and total risk mitigation funding shall be reported monthly.
Risk	Risk register	Average number of days since the last prioritization of the risk register by the BOD shall be reported monthly.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Risk register	Average number of days past due for the risk register shall be reported monthly.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Summary risk assessment	Average funding per mitigation plan and total risk mitigation funding shall be reported monthly.
Risk	Summary risk assessment	A summary report of the total number of unfunded and unstaffed risk assessments should be reported on a monthly basis

Appendix A.8 – Company A System Safety Requirements (SSRs)

Unsafe Control Action Name	Priority	Safety System Requirement Name	Description
Audit	3	Audit	Deck and Machinery Departments audits must be completed within five days of being tasked.
Audit	3	Audit	Status of audits shall be reported within one week of the due date.
Accident and near-miss report issued late	2	Accident/incident/ near miss Report	Accident/incident/near miss Report shall be issued on schedule.
Accident and near-miss report not complete	1	Accident/incident/ near miss Report	The Accident/incident/near miss Report shall be issued on schedule.
Accident and near-miss summary do not provide actionable recommendations for improvements	2	Accident/incident/ near miss Report	Analysis of accident/incident/near-miss data shall be of high-quality uncovering root causes of problems and providing guidance for changes to operations.
Accident/incident report	2	Accident/incident report	Accident/incident/near miss reports shall be provided within two weeks of the event.
Accident/incident reports	2	Accident/incident reports	Track number of approved changes fixing hazards identifies via the accident/incident/near miss reports shall be reviewed by the Master within one week of receipt.
Accident/incident reports	3	Accident/incident reports	Accident/incident/near miss reports shall be provided within two weeks of the event.
Accident/incident reports	3	Accident/incident reports	Director of Service Delivery shall decide on whether to approve an accident/incident/near miss report within two weeks of receipt.
Accident/incident reports	3	Accident/incident reports	Each Master needs to track and report monthly on the number of closed versus open accident/incident/near-miss reports.
Accident/incident/near miss Report	1	Accident/incident/ near miss Report	Analysis of accident/incident/near-miss data shall be of high-quality uncovering root causes of problems and providing guidance for changes to operations.
Accident/incident/near miss Report	1	Accident/incident/ near miss Report	The Accident/incident/near miss Report shall be issued on schedule.
Accident/incident/near miss Report	2	Accident/incident/ near miss Report	The Accident/incident/near miss Report shall be issued on schedule.
Accident/Incident/Near-miss reports	1	Accident/Incident/ Near-miss reports	Director of Delivery Services needs to insist on a complete investigation of accident/incidents/near misses to determine a root cause.
Accident/near miss report is not provided	2	Accident/incident/ near miss Report	The Accident/incident/near miss Report shall be issued on schedule.

Accident/near miss report is provided	2	Accident/incident/ near miss Report	Analysis of accident/incident/near-miss data shall be of high-quality uncovering root causes of problems and providing guidance for changes to operations.
Accident/near miss Report is provided but lack detail of all incidents [SH1,2,3]	1	Accident/incident/ near miss Report	If accident/incident/near-miss trends are unfavourable, then Company A shall proactively provide remedial plans to improve the situation.
Accident/near miss report is provided late	2	Accident/incident/ near miss Report	Accident/incident/near miss Report shall be issued on schedule.
Accident/near miss Report not provided	2	Accident/incident/ near miss Report	The Accident/incident/near miss Report shall be issued on schedule.
Accident/near miss Report provided late	2	Accident/incident/ near miss Report	Accident/incident/near miss Report shall be issued on schedule.
Accident/near-miss reports.	2	Accident/incident reports	Master shall decide on whether to approve a change request within 30 days of being notified of an existing hazard or problem that needs to be corrected.
Accident/near-miss reports.	1	Accident/incident reports	Master needs to respond to insist on a complete investigation of accident/incidents/near misses to determine a root cause.
Accident/near-miss reports.	1	Accident/near-miss reports.	Master needs to track and report monthly on the number of closed versus open accident/incident/near-miss reports.
Accident/near-miss reports.	3	Accident/incident reports	Vetting of the accident/incident/near miss reports shall be reviewed by the Master within one week of receipt.
Accidents/near miss reports are poor quality	2	Analysis	Master needs to respond to insist on a complete investigation of accident/incidents/near misses to determine a root cause and make recommendations on how to improve the SMS.
Accidents/near miss reports do not cause a change to be executed.	2	Analysis	Master shall decide on whether to approve a change request within 30 days of being notified of an existing hazard or problem that needs to be corrected.
Accidents/near miss reports do not cause resources to be spent to mitigate the issues.	1	Analysis	Vetting of the accident/incident/near miss reports shall be reviewed by the Master within one week of receipt.
Approvals granted late	2	Approvals	Lloyds shall deliver surveys on schedule.
Approvals granted, but not all safety hazards identified.	1	Approvals	Lloyds shall provide high-quality approvals that have identified safety issues.
Approvals not granted.	2	Approval	Lloyds shall provide the approvals to the shipyard on schedule.
Approved change causes a hazard.	1	Change order	Yard needs to respond to all change orders within thirty days.

Audit	2	Audit	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the audit coverage consistently uncover new findings.
Audit	1	Audit	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the audit coverage consistently uncover new findings.
Audit	1	Audit	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the audit coverage consistently uncovers new findings.
Audit	1	Audit	Status of audits shall be reported within one week of the due date.
Audit	1	Audit	Status of audits shall be reported within one week of the due date.
Audit	2	Audit	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the audit coverage consistently uncover new findings.
Audit	2	Audit	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the audit coverage consistently uncover new findings.
Audit	2	Audit	Risk Manager's assessment must be completed within one week of being tasked
Audit	2	Audit	Status of audits shall be reported within one week of the due date.
Audit	2	Audit	Status of audits shall be reported within one week of the due date.
Audit	3	Audit	Deck and Machinery Departments audits must be completed within five days of being tasked.
Audit	3	Audit	Deck and Machinery Departments audits must be completed within five days of being tasked.
Audit	3	Audit	Director of Service Deliver audit must be completed within five days of being tasked.
Audit report not provided	1	Audit	Audit and Risk Committee's assessment must be completed within one month of being tasked.
Audit report provided	2	Audit	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the audit coverage consistently uncover new findings.
Audit report provided late	2	Audit	Status of audits shall be reported within one week of the due date.
Audits or inspections conducted	1	Audits or inspections	Quality of audits shall be monitored periodically to ensure that the breadth and depth of the

			audit coverage consistently uncover new findings.
Audits or inspections conducted late	2	Audits or inspections	Status of audits/inspections shall be reported within one week of the due date.
Audits or inspections not conducted	2	Audits or inspections	UK Government audits/inspections must be completed within five days of being tasked.
Change approved	1	Change request	Shipyard needs to respond to all change orders within thirty days.
Change approved late.	1	Change request	A change order must be processed within 30 days of receipt by the Shipyard.
Change is executed late.	2	Change order	A change order must be processed within 30 days of receipt by the Yard.
Change is executed but creates a hazard.	1	Change order	Yard needs to respond to all change orders within thirty days.
Change not approved.	1	Change request	Company A shall track the backlog of change requests to the Shipyard that have not been converted to change orders.
Change order approved late.	1	Change order	A change order must be processed within 30 days of receipt by the Design Agent.
Change order approved late.	2	Change order	Average time for the Yard to decide to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Change order is executed	1	Change order	Design Agent needs to respond to all change orders within thirty days.
Change order is executed and causes a hazard.	1	Change order	Yard needs to respond to all change orders within thirty days.
Change order is executed late.	2	Change order	A change order must be processed within 30 days of receipt by the Yard.
Change order is not executed.	2	Change order	Company A shall track the backlog of change orders to the Shipyard that has not been definitized.
Change order not approved.	1	Change order	Company A shall track the backlog of change requests to the Design Agent that have not been converted to change orders.
Change order not approved.	1	Change order	Company A shall track the backlog of change requests to the Design Agent that have not been converted to change orders.
Change request delivered late.	1	Change request	A change request must be submitted within 30 days of a safety hazard being identified.
Change request is delivered, but no action taken.	3	Change request	Master needs to respond to all change requests within thirty days.
Change request not delivered.	1	Change request	Deck and machinery departments shall submit change requests within 30 days of being notified of an existing hazard or problem that needs to be corrected.
Change request not sent.	3	Change request	Master shall submit change requests within 30

			days of being notified of an existing hazard or problem that needs to be corrected.
Change request sent late.	3	Change request	A change request must be submitted within 30 days of receipt by the Master.
Change requests, waivers and deviations approved late.	2	Change requests	Change requests, waivers and deviations shall be submitted by the Design Agent as soon as practical
Change requests, waivers and deviations are granted but safety hazard goes undetected.	1	Change requests	Company A needs to respond to all change requests, waivers, and deviations within thirty days.
Change requests, waivers and deviations not approved.	2	Change requests	The Design Agent shall provide change requests, waivers, and deviations as soon as practicable.
Change requested, but no action is taken.	1	Change request	Company A needs to respond to all change requests within thirty days.
Class Rules	2	Class rules	Lloyds shall produce updates to Class Rules that fix know safety issues.
Class Rules not updated	2	Class rule update	The Class Rules shall be updated periodically to remove safety issues.
Class Rules updated infrequently	1	Class rules update	Class Rule revision is issued on schedule
Contract	2	Contract	Company A's contract group shall ensure the contract requiring rigorous SMS and risk management procedures.
Contract	1	Contract	Contract for Company A operations shall be issued and signed on schedule.
Contract	1	Contract	Company A shall implement a robust SMS risk analysis process to operate the fleet.
Contract	1	Contract	Company A shall provide adequate resources to hire adequate experienced staff.
Contract	1	Contract	Company A shall identify all hazardous materials and conditions in the contract so that the recycling yards can bid accurate costs and schedules.
Contract	1	Contract	UK Government shall award the contract to Company A on schedule.
Contract	2	Contract	UK Government shall award the contract on schedule.
Contract awarded late.	1	Contract	UK Government shall award the contract to CFL on schedule.
Contract awarded, but adequate resources not available.	1	Contract	Company A shall provide adequate resources to implement a robust safety and risk management process.
Contract deliverables provided	1	Contract	The Design Agent shall perform comprehensive hazard, risk and safety analysis for class compliance

Contract deliverables provided	1	Deliverables	Company A shall include robust contract language ensuring that changes to the SMS and the risk system due to the modernizations are captured and provided in the change information provided to the ship's force.
Contract not awarded.	2	Contract	UK Government shall award the contract on schedule.
Contract not provided.	0	Contract	Company A's contract group shall award Lloyd's support contract on schedule.
Contract not provided.	1	Contract	Company A's contract shall contain a comprehensive set of requirements for hazard, safety, and risk deliverables.
Contract not provided.	2	Contract	Company A shall issue the contract for awarding the recycling of a ship on schedule.
Contract not provided.	2	Contract	Company A's contract group shall award the Design Agent's contract on schedule.
Contract not provided.	2	Contract	The Shipyard shall provide the contract for the DOC on schedule.
Contract provided but deliverables do not identify hazards and risks.	1	Contract	Lloyds shall perform comprehensive hazard, risk and safety analysis for class compliance
Contract provided late.	2	Contract	Contract for Lloyd's support shall be awarded on schedule.
Contract provided late.	1	Contract	Contract for Company A operations shall contain sound requirements for the Yard to analyse the safety and risk impacts caused by the modernization.
Contract provided late.	2	Contract	Contract for the Design Agent's support shall be awarded on schedule.
Contract provided late.	2	Contract	Contracts for recycling shall be awarded on schedule.
Contract provided late.	2	Contract	Hazards, safety, and risk deliverables need to be submitted on schedule.
Contract provided late.	2	Contract	The shipyard shall deliver the contract to Lloyds on schedule.
Contract provided but does not contain strong hazard and risk analysis requirements.	1	Contract	Shipyard shall perform comprehensive hazard, risk, and safety analysis.
Deliverables	1	Deliverables	The Design Agent shall perform comprehensive hazard, risk and safety analysis based on the information provided in the requirements, specifications and CONOPS.
Deliverables	2	Deliverables	Company A's design group shall provide requirements, specifications and CONOPS on schedule
Deliverables	2	Deliverables	Contract for the Design Agent's support shall be awarded on schedule.

Deliverables fail to identify hazards and risk to safe operations.	1	Deliverables	The Shipyard shall analyse shall provide high-quality Operations and Technical Manuals.
Deliverables lack good analysis of hazards and risks.	1	Deliverables	The Shipyard shall analyse all engineering calculations and test results for hazards and risks so they can be mitigated during detailed design and construction.
Deliverables not provided.	2	Deliverables	The Shipyard shall provide all engineering calculations and test results on schedule.
Deliverables not provided.	3	Deliverables	The Shipyard shall provide all Operations and Technical Manuals on schedule.
Deliverables provided late.	2	Deliverables	The shipyard shall deliver engineering calculations and test results on schedule.
Deliverables provided late.	3	Deliverables	The shipyard shall deliver Operations and Technical Manuals on schedule.
Environmental hazards identified, but no action taken to rectify.	1	Environmental report	Deficiencies identified in environmental reports must be addressed within 24 hours.
Environmental hazards identified, but no resources are found to remedy.	2	Environmental report	Resources (funding and time) shall be provided to resolve environmental deficiencies within 24 hours.
Environmental hazards not reported.	2	Environmental report	Environmental release of hazardous materials shall be reported in accordance with Flag State requirements.
Environmental hazards reported late.	2	Environmental report	Environmental reports shall be forwarded within 24 hours of the occurrence of the incident.
ERM Policy too broad	2	ERM Policy	The ERM policy shall provide specific guidance to guide the implementation of a system-wide risk assessment process.
Following planned maintenance causes an accident.	1	Planned maintenance	Company A management shall track any adverse incidents caused by successfully following the planned maintenance approach.
Hazard report delivered late	2	Hazard report	The Shipyard shall deliver the hazard analysis to Company A on schedule.
Hazard report fails to identify all hazards	1	Hazard report	The quality of the Shipyard's hazard analysis must be assessed to ensure all possible hazards are identified and provided to the Yard.
Hazard report not delivered	2	Hazard report	The Shipyard shall provide a hazard analysis as part of the Recycling Package prepared for bid by shipyards.
Hazard/risk/safety assessments are incomplete and do not identify all issues.	1	Hazard/risk/safety assessments	The Yard shall deliver high-quality hazards, risk, and safety assessments documents.
Hazard/risk/safety assessments are not provided.	2	Hazard/risk/safety assessments	Yard shall provide hazards, risk and safety assessments on schedule.

Hazard/risk/safety assessments are provided late.	2	Hazard/risk/safety assessments	The Yard shall deliver the hazards, risk, and safety assessments on schedule.
Key Indicators	1	Key Indicators	Executive Team shall track the timeliness of the Key Indicators (Performance, Safety, Risk and Financial)
Key Indicators	1	Key Indicators	Results of the application of Key Indicators need to be audited periodically to ensure the indicators are used by management to make decisions
Key indicators	2	Key indicators	Company A Operations shall track the lateness of the Key Indicator report.
Key indicators	2	Key indicators	Company A operations shall track the timeliness of the Key Indicators (Performance, Safety and Financial)
Key indicators	2	Key indicators	Key Indicators need to be audited periodically to ensure the quality of the indicators remains high.
Key Indicators	2	Key Indicators	The CEO shall track the lateness of the Key Indicator report.
Key indicators not provided	2	Key indicators	Company A operations shall track the timeliness of the Key Indicators (Performance, Safety and Financial)
Key indicators provided	1	Key indicators	Key Indicators need to be audited periodically to ensure the quality of the indicators remains high.
Key indicators provided late	2	Key indicators	Company A Operations shall track the lateness of the Key Indicator report.
KRIs are incomplete.	1	KRI	The KRI's quality must be assessed periodically to ensure the best mix of appropriate Enterprise risks are identified.
KRIs are not produced.	2	KRIs	The KRIs report shall be produced on schedule.
KRIs are produced late.	2	KRIs	Number of days late for producing the KRIs shall be tracked.
Late issuance of ERM Policy	2	ERM Policy	The ERM policy is issued on schedule.
Lifesaving Appliance	2	LSA	Deck Department needs to track the number of LSA deficiencies found during each test.
LSA deficiencies identified, but no action taken.	2	LSA testing	Deck Department shall decide on how to deal with LSA deficiencies within seven days of becoming aware of a safety-related issue.
LSA deficiencies identified, but no resources found to mitigate.	1	LSA deficiencies	Company A must track how long it takes to fix safety deficiencies after being discovered by LSA testing.
LSA drill conducted	1	LSA drill	Training for the safe operation of the lifesaving appliances must be accomplished prior to the crew operating the equipment during a drill.

LSA drill conducted late	2	LSA drill	Master shall ensure the completion of lifesaving appliance drills on schedule.
LSA drill not conducted	2	LSA drill	Master shall ensure that lifesaving appliance training is accomplished on schedule.
LSA drills not performed on schedule.	2	LSA drills	LSA testing shall be conducted according to the SMS periodicity.
LSA drills not performed.	2	LSA drills	Deck department shall have up to date data on all LSA systems, including the latest changes.
LSA drills not performed.	2	LSA drills	Deck Department shall provide adequate resources to conduct all scheduled LSA tests.
Manning estimate is inaccurate.	1	Manning estimate	Design Agent shall provide a quality manning estimate with no need to change the manning levels later
Manning estimate not provided.	3	Manning estimate	Design Agent shall provide the manning estimate to Company A on schedule.
Manning estimate provided late.	3	Manning estimate	The Design Agent shall deliver the manning estimate to Company A on schedule.
New regulations fail to improve safety	2	Updated regulations	The IMO shall provide specific recommended changes to the regulations for SMS.
No contract provided.	2	Contract	Company A's contract group shall ensure the contract requires rigorous SMS and risk management procedures.
No new regulations to improve safety are released in a timely fashion	1	Updated regulations	SMS regulations shall be updated periodically to continuously improve the ship SMS approach.
No planned maintenance used.	1	Planned maintenance	Planned maintenance activities shall be completed according to the schedule
Planned maintenance is performed late.	2	Planned maintenance	Planned maintenance shall be completed on schedule.
Plans and calculations approved late.	2	Approvals	Lloyds shall deliver the plans to the Design Agent on schedule.
Plans and calculations approved, but not all safety hazards identified.	1	Approvals	Lloyds shall provide approved plans that have identified residual construction problems and safety issues.
Plans and calculations do not identify all hazards and safety issues.	1	Plans and calculations	The Design Agent shall deliver high-quality plans and calculations.
Plans and calculations not approved.	2	Approval	Lloyds shall provide approvals to the Design Agent on schedule.
Plans and calculations not provided.	2	Plans and calculations	Design Agent shall provide plans and calculations to CMAL on schedule.
Plans and calculations not provided.	2	Plans and calculations	Design Agent shall provide plans and calculations to Lloyds on schedule.
Plans and calculations provided fail to identify all safety issues.	1	Plans and calculations	Design Agent shall provide produce quality plans and calculations with few residual construction problems and safety issues.

Plans and calculations provided late.	2	Plans and calculations	The Design Agent shall deliver plans and calculations on schedule.
Plans and calculations provided late.	2	Plans and calculations	The Design Agent shall deliver the plans and calculations to Company A on schedule.
Plans are approved, but all hazards and risks to safe operations are not identified.	1	Plans	Lloyds shall provide approved plans that have identified and resolved residual construction problems and safety issues.
Plans are not provided.	2	Plans	The Shipyard shall provide the plans to the shipyard on schedule.
Plans are provided late for approval.	2	Plans	The shipyard shall deliver the plans to Lloyds on schedule.
Procedures not provided.	2	Planned maintenance	The planned maintenance approach shall be provided according to the schedule.
Procedures provided cause an accident.	2	Planned maintenance	Company A shall track any adverse incidents caused by successfully following the planned maintenance approach.
Procedures provided late.	2	Planned maintenance	The planned maintenance approach shall be completed on schedule.
Quarterly Financial Performance report not provided	2	Quarterly Financial Performance report	The Quarterly Financial Performance Report shall be produced.
Quarterly Financial Performance report provided	2	Quarterly Financial Performance report	The Quarterly Financial Performance Report shall be of high quality.
Quarterly Financial Performance report provided late	2	Quarterly Financial Performance report	The Quarterly Financial Performance Report shall be produced on schedule.
Recommendations are issued but do not provide needed changes	2	Changes to regulations	The UK Government shall provide specific recommended changes to the regulations for SMS.
Recommendations not provided	2	Change to regulations	SMS regulations shall be updated periodically to continuously improve the ship SMS approach.
Recycling Yard fails to provide Hazards/risks/safety assessments.	2	Hazards/risks/safety assessments	Risk assessment quality must be assessed periodically to ensure all possible risks are identified by the reviewers.
Recycling Yard provides the Hazards/risks/safety assessment late.	2	Hazards/risks/safety assessments	The Yard shall deliver the hazards, risk, and safety assessments on schedule.
Recycling Yard provides the Hazards/risks/safety assessment, but it does not identify all the issues.	1	Hazard risks and safety assessments	The Yard shall deliver high-quality hazards, risk, and safety assessments documents.
Regulation is not provided	2	Regulations	SMS regulations shall be updated periodically to continuously improve the ship SMS approach.
Regulation is provided	3	Safety and Risk policies	The Safety and Risk Regulations shall provide specific guidance to guide the implementation of a system-wide SMS.

Regulation issued late	2	Regulations	The regulations on SMS are issued periodically on schedule.
Regulations input	1	\Regulations	The regulations on SMS are issued periodically on schedule.
Report fails to identify all hazards	1	Hazard analysis	The quality of the Yard's hazard analysis must be assessed to ensure all possible hazards are identified and provided to the Yard.
Report fails to provide the hazard assessment	2	Hazard analysis	Yard shall provide a hazard analysis as part of the proposal to CMAL.
Report not generated.	3	Analysis	Accident/incident/near miss reports shall be provided within two weeks of the event.
Report on risks and hazards is delivered late	2	Hazard analysis	The Recycling Yard shall deliver the hazard analysis schedule.
Report produced late.	3	Analysis	Chief engineer needs to track and report monthly on the number of closed versus open accident/incident/near miss reports recommendations.
Resources not provided.	1	Resources	Director of Service Delivery shall provide adequate resources (funding and manpower) to mitigate existing hazards and problems.
Resources not provided.	2	Resources	BOD shall provide adequate resources (funding and manpower) to the Audit and Risk Committee to mitigate existing risks.
Resources not provided.	2	Resources	Corporate Company A shall provide adequate resources (funding and manpower) to mitigate existing hazards and problems.
Resources provided	3	Resources	Master needs to prioritize resources to tackle worse problems or hazards first.
Resources provided late.	2	Resources	The Audit and Risk Committee needs to receive resources on schedule.
Resources provided late.	3	Resources	Resources must be provided on schedule.
Resources provided late.	3	Resources	Resources must be provided on schedule.
Resources provided, but hazards are not identified or mitigated.	1	Resources	Company A needs to prioritize resources to tackle worse problems or hazards first.
Resources provided, but hazards still go unidentified and unmitigated.	1	Resources	The Audit and Risk Committee needs to prioritize resources to tackle worse problems or hazards first.
Risk Appetite	1	Risk appetite	Company A management shall update the company's risk appetite considering changes in the operating environment.
Risk Appetite	2	Risk Appetite	A Risk Appetite shall be produced and be included in the company's approach to risk management.
Risk Appetite	3	Risk appetite	Risk Appetite is issued on schedule.
Risk Assessment	1	Risk Assessment	Risk assessment quality must be assessed

			periodically to ensure all possible risks are identified by the reviewers.
Risk assessment provided late.	3	Risk assessments	A risk assessment shall be carried out at least annually.
Risk Assessment accomplished, but not all hazards identified.	2	Risk assessment	The quality of Company A's risk assessments must be assessed to ensure all possible risks are identified and provided to the Yard.
Risk assessment is late.	2	Risk assessment	A risk assessment shall be carried out on time.
Risk assessments are performed infrequently.	2	Risk assessment	A risk assessment shall be carried out at least annually.
Risk assessment identifies risks, but nothing is done to mitigate	2	Risk assessment	Mitigation plans must be developed for all newly identified risks within one month of submittal.
Risk assessment identifies risks, but nothing is done to mitigate	2	Risk mitigation	Funding for risk mitigation plans needs to be tracked.
Risk assessment incomplete	1	Risk assessment	Risk assessment quality must be assessed periodically to ensure all possible risks are identified by the reviewers.
Risk assessment incomplete.	1	Risk assessment	A risk assessment shall be carried out after a near miss, an incident, or an accident.
Risk assessment is late.	2	Risk assessment	Company A shall deliver the risk assessment to the Recycling Yard on schedule.
Risk assessment is provided late.	1	Risk assessments	A risk assessment shall be carried out at least annually.
Risk assessment not performed.	1	Risk assessment	A summary report for risk assessments shall be produced after a near miss, an incident, or an accident.
Risk assessment not produced.	1	Risk assessment	Company A shall provide a risk assessment as part of the Recycling Package prepared for bid by shipyards
Risk assessment not provided.	3	Risk assessment	All data needed to perform a risk assessment should be provided in a timely manner.
Risk assessment not provided.	3	Risk assessment	Resources (staff and funding) needed to perform a risk assessment should be provided in a timely manner.
Risk Assessment of poor quality.	3	Summary risk assessment	The Summary risk assessments quality must be assessed periodically to ensure all possible risks are identified by the reviewers.
Risk assessments are not reviewed due to lack of personnel.	2	Summary risk assessment	Resources (staff and funding) needed to create a summary risk assessment should be provided in a timely. Manner
Risk Assessments done but not mitigated.	0	Risk assessment	Mitigation plans must be developed for all newly identified risks within one month of submittal.
Risk Assessments done but not mitigated.	2	Risk assessment	Funding for risk mitigation plans needs to be tracked.

Risk Assessments done but not mitigated.	3	Risk assessment	All data needed to perform a risk assessment should be provided in a timely manner.
Risk Assessments are done late.	1	Risk assessment	A risk assessment shall be carried out at least annually.
Risk Assessments are done late.	2	Risk assessment	A risk assessment shall be carried out at least annually.
Risk Assessments identity problems and mitigation, but no funding is provided.	2	Summary risk assessment	Total Funding for all risk mitigation plans needs to be tracked.
Risk Assessments identity problems, but no mitigation is attempted.	1	Summary risk assessment	The total number of mitigation plans developed for the summary of newly identified risks shall be tracked monthly.
Risk Assessments not done.	2	Risk assessment	A risk assessment shall be carried out after a near miss, an incident, or an accident.
Risk Assessments not done.	2	Risk assessment	Resources (staff and funding) needed to perform a risk assessment should be provided in a timely manner.
Risk assessments not produced.	2	Risk assessment	Company A shall provide a risk assessment as part of the Modernization Package prepared for bid by shipyards.
Risk assessments produced late.	2	Risk assessment	Company A shall deliver the risk assessment to the Modernization Yard on schedule.
Risk Assessments are incomplete.	2	Risk mitigation	Funding for all risk mitigation plans needs to be summarized and tracked.
Risk mitigations are not prioritized.	1	Risk register	The risk register quality must be assessed periodically to ensure management's prioritization reveals the key risks.
Risk policy does not invoke ERM	1	ERM Policy	ERM shall be required to be included as the company's approach to risk management.
Risk Policy is too broad	1	Risk Policy is	The Risk Policy shall provide specific guidance to guide the implementation of a system-wide risk assessment process.
Risk Policy not provided	2	Risk Policy	ERM shall be required to be included as the company's approach to risk management.
Risk Policy provided late	2	Risk Policy	The Risk Policy is issued on schedule.
Risk register is incomplete.	1	Risk register	The risk register quality must be assessed periodically to ensure all possible risks are identified by the reviewers.
Risk register is incomplete.	2	Risk register	The risk register quality must be assessed periodically to ensure all possible risks are identified by the reviewers.
Risk register is incomplete.	2	Risk register	The risk register quality must be assessed periodically to ensure management's prioritization reveals the key risks.
Risk register is not produced.	1	Risk register	The issuance of the Risk Register shall be tracked.

Risk register is not produced.	1	Risk register	The verification of senior management's prioritization of the Risk Register shall be tracked.
Risk register is not produced.	1	Risk register	The verification of the BOD's prioritization of the Risk Register shall be tracked.
Risk register is not produced.	2	Risk register	The issuance of the Risk Register shall be tracked.
Risk register is produced late.	1	Risk register	Number of days late for each risk register shall be tracked.
Risk register is produced late.	2	Risk register	Number of days late for each risk register shall be tracked.
Risk register is produced late.	2	Risk register	Number of days late for producing each risk register shall be tracked.
Risk register not produced	2	Risk register	The issuance of the Risk Register shall be done on schedule.
Risk register produced	1	Risk register	The risk register shall be of high quality and holistic.
Risk register produced late	2	Risk register	Number of days late for each release of the risk register shall be tracked.
Risk register produced late.	2	Risk register	Number of days late for each risk register shall be tracked.
Safety Alerts issued late	2	Safety Alert	Safety Alert shall be issued on schedule.
Safety alert	1	Safety alert	Company A must issue Safety Alerts within 24 hours of becoming aware of a safety-related issue.
Safety alert	1	Safety alert	Company A must issue Safety Alerts within 24 hours of becoming aware of a safety-related issue.
Safety alert	1	Safety alert	Director of Service Delivery must track how long it takes to release a Safety Alert from the time it became aware of the safety issue.
Safety alert	1	Safety alert	Safety Committee on each ship needs to review all Safety Alerts within 24 hours to make sure they apply to their ship.
Safety alert	2	Safety alert	Company A must track how long it takes to release a Safety Alert from the time it became aware of the safety issue.
Safety alert	2	Safety alert	Safety Committee on each ship needs to review all Safety Alerts within 24 hours to make sure they apply to their particular ship.
Safety Alert issued but contains incorrect information	1	Safety alerts	Safety alerts should be focused and specific so they can be effective
Safety Alerts not issued	2	Safety Alert	The Safety Alert shall be issued on schedule.
Safety assessment	1	Safety assessment	Master needs to insist on high-quality safety assessments.

Safety assessment	1	Safety assessment	Master needs to require a safety assessment after every accident/incident/near miss.
Safety assessment	2	Safety assessment	Director of Service Delivery shall decide on how to resolve the safety issues identified within two weeks of receipt.
Safety assessment	2	Safety assessment	Master shall provide adequate resources to conduct all safety inspections on schedule.
Safety assessment	3	Safety assessment	Information/data needed to conduct a safety assessment shall be provided as needed.
Safety assessment	3	Safety assessment	Master needs to require a safety assessment after every accident/incident/near miss.
Safety assessment	3	Safety assessment	Master needs to track and report on the number of safety assessments planned versus accomplished.
Safety assessment	3	Safety assessment	Track number of approved changes fixing hazards identified via safety assessments reviewed by the Master
Safety assessment not provided	2	Safety assessment	Director of Service Delivery shall provide adequate resources to conduct all safety inspections on schedule.
Safety assessment not provided	3	Safety assessment	Information/data needed to conduct a safety assessment shall be provided as needed.
Safety assessment not provided	2	Safety assessment	Director of Service Delivery needs to require a safety assessment after every accident/incident/near miss.
Safety assessment not provided	2	Safety assessment	Director of Service Delivery shall provide adequate resources to conduct all safety inspections on schedule.
Safety assessment not provided	3	Safety assessment	Director of Service Delivery needs to require a safety assessment after every accident/incident/near miss.
Safety assessment not provided	3	Safety assessment	Information/data needed to conduct a safety assessment shall be provided as needed.
Safety assessment provided	1	Safety assessment	Director of Service Delivery shall decide on whether to approve an accident/incident/near miss report within two weeks of receipt.
Safety assessment provided	1	Safety assessment	Director of Service Delivery shall decide on whether to approve an accident/incident/near miss report within two weeks of receipt.
Safety assessment provided	2	Safety assessment	Track number of approved changes fixing hazards identified via safety assessments reviewed by the Master.
Safety assessment provided	3	Safety assessment	Director of Service Delivery needs to insist on high-quality safety assessments.
Safety assessment provided	3	Safety assessment	Director of Service Delivery needs to insist on high-quality safety assessments.
Safety assessment provided	3	Safety assessment	Track number of approved changes fixing

			hazards identified via safety assessments reviewed by the Master
Safety assessment provided late	2	Safety assessment	Director of Service Delivery needs to require a safety assessment after every accident/incident/near miss.
Safety assessment provided late	3	Safety assessment	Director of Service Delivery needs to require a safety assessment after every accident/incident/near miss.
Safety assessment provided late	3	Safety assessment	Director of Service Delivery needs to track and report on the number of safety assessments planned versus accomplished
Safety assessment provided late	3	Safety assessment	Director of Service Delivery needs to track and report on the number of safety assessments planned versus accomplished.
Safety meeting held	2	Safety meeting	All new safety issues need to be addressed before the next monthly meeting.
Safety meeting held	2	Safety meeting	Response to on-board safety issues must occur within 30 days of ship's submittal to Company A Operations
Safety meeting held	2	Safety meeting	Response to on-board safety issues must occur within 30 days of ship's submittal to Company A Operations
Safety meeting held late	2	Safety meeting	Existing safety issues must be resolved with 30 days of their documentation.
Safety meeting minutes not produced.	2	Safety meetings	Safety meeting minutes shall be submitted monthly.
Safety meeting minutes produced but no action taken.	1	Safety meeting minutes	Deficiencies identified in the safety report must be addressed within 30 days.
Safety meeting minutes produced late.	2	Safety meeting	Safety meeting minutes need to be submitted on schedule every month.
Safety meeting minutes produced, but no resources found to mitigate the issues.	1	Safety meeting	Resources (funding and time) shall be provided to resolve safety deficiencies within 30 days.
Safety meeting not held	1	Safety meeting	Monthly on-board safety meetings must be held within seven days of planned dates.
Safety Plan	3	Safety Policy	Safety Policy or revision is issued on schedule.
Safety Policy	1	Safety Policy	The Safety Policy shall be issued and revised periodically.
Safety Policy	1	Safety policy	The Safety Policy shall provide specific guidance to improve the Safety Culture in the operating environment.
Safety Policy	2	Safety Policy	Company A management shall require periodic updating of the Safety Policy.
Safety Policy	2	Safety policy	Safety Policy is issued on schedule.
Safety Policy	2	Safety policy	The Safety Policy shall establish the priority for buying down risks.

Safety Strategy	3	Safety Strategy	Safety Strategy changes shall be comprehensive to reflect the continuing evolution in operations.
Safety Strategy,	1	Safety Strategy,	Director of HSQE shall provide the updated Safety Strategy on schedule.
Safety Strategy,	2	Safety Strategy,	Safety Strategy must be provided on schedule.
Safety/hazard/risk analysis is delivered late.	1	Safety/hazard/risk analysis	The Design Agent shall deliver the Safety/hazard/risk analysis to Company A on schedule.
Safety/hazard/risk analysis is not delivered.	2	Safety/hazard/risk analysis	The Design agent shall provide a safety/hazard/risk analysis as part of the deliverables.
Safety/hazard/risk analysis is of poor quality.	1	Safety/hazard/risk analysis	The quality of the Design Agent's safety/hazard/risk analysis must be of high quality.
Ship Operations Manual recommended changes are made late.	1	Operation Manual update	Operation Manual updates need to be submitted on schedule.
Ship Operations Manual recommended changes are not made.	3	Operations Manual update	Operations Manual update shall be provided annually.
Ship Operations Manual recommended changes made, but nothing happens	1	MVOM updates	Company A management shall track all changes to the Operations Manual and make sure ships are trained in how to accomplish the changes recommended in a timely fashion.
SMS approved, but has residual hazards and risks for safe operations.	1	SMS	Lloyds shall provide a high-quality assessment of the SMS for the DOC.
SMS assessment is provided	1	SMS review	Before the SMS review, the following up to date information has to be available: RA results, barrier statuses (outstanding safety issues), the impact of approved change on-board with an assessment of the needed changes to the SMS.
SMS assessment is provided	2	SMS review	The Master must receive inputs from the senior Deck and Machinery Department officers within one month of tasking, or his review will lack depth and credibility.
SMS assessment is provided	3	SMS review	If no formal version control is in place the Master may be commenting on an out of date version of the SMS.
SMS assessment is provided	3	SMS review	Master has to have adequate competence in ISM Code and SMS, RA (risk assessment), and safety barrier management.
SMS assessment is provided	3	SMS review	Master's workload must allow time to perform the annual review of the SMS
SMS assessment is provided late	1	SMS assessment	Review of the SMS must be accomplished within one month of the planned date.

SMS assessment is provided late	3	SMS assessment	Review of the SMS must be accomplished within one month of an accident/incident/near miss.
SMS assessment not provided	2	SMS assessment	New flaws identified at each review cycle must be addressed within two months.
SMS assessment not provided	2	SMS assessment	Request for annual SMS review by Master must be generated and received.
SMS assessment not provided	3	SMS assessment	Adequate staffing must be supplied on each ferry to provide enough resources for standard reviews in a timely fashion.
SMS is approved late.	1	SMS	UK Government shall deliver the SMS certification on schedule.
SMS is approved, but flaws are not uncovered.	1	SMS	UK Government shall certify the SMS after finding all known safety issues.
SMS is not approved.	2	SMS	UK Government shall provide SMS certification of the SMS on schedule.
SMS not updated	2	SMS	Adequate staffing must be supplied on each ferry to provide enough resources for standard reviews in a timely fashion.
SMS not updated	2	SMS	New flaws identified at each review cycle must be addressed within one month.
SMS not updated	3	SMS	Data must be provided to the Deck and Engineering Departments so they can conduct the annual SMS assessment.
SMS not updated	3	SMS	Request for annual SMS review by Master must be generated and received.
SMS Update	2	SMS updates	Company A management shall track all changes to the SMS and make sure ships are trained in how to accomplish the changes recommended in a timely fashion.
SMS Update	1	SMS Update	Company A management shall track all changes to the SMS and make sure ships are trained in how to accomplish the changes recommended in a timely fashion.
SMS Update	2	SMS Update	SMS updates need to be released on schedule.
SMS updated	1	SMS	Director of Service Delivery must respond to newly discovered SMS flaws within one month.
SMS updated	2	SMS	Before the SMS review, the following up to date information must be available: RA results, barrier statuses (outstanding safety issues), the impact of approved change on-board with an assessment of the needed changes to the SMS.
SMS updated	2	SMS	Version control of the SMS must be in place, so comments are made on the correct document.
SMS updated	3	SMS	Changes recommended from the review shall be incorporated into the SMS within 30 days.
SMS updated	3	SMS	Master has to have adequate competence in

			ISM Code and SMS, RA (risk assessment), and safety barrier management.
SMS updated	3	SMS	The Master must receive inputs from the senior Deck and Machinery Department officers within one month of tasking, or his review will lack depth and credibility.
SMS updated late	2	SMS	New flaws identified at each review cycle must be addressed within one month.
SMS updates are not provided.	2	SMS update	SMS updates shall be submitted on schedule.
SMS updates are provided late.	2	SMS update	SMS updates need to be submitted on schedule.
SMS updates are provided, but incomplete.	1	SMS Update	Director of HSQE shall provide a high-quality revision to the SMS to fix known issues.
SMS updates not provided.	2	SMS updates	SMS updates shall be provided
SMS updates provided but do not capture all changes.	2	SMS updates	The SMS updates shall be of high quality.
Specifications are delivered late.	2	Specifications	The Design Agent shall deliver the specifications to Company A on schedule.
Specifications are not delivered.	2	Specifications	Design Agent shall provide specifications to CMAL on schedule.
Specifications create safety issues.	1	Specifications	Design Agent shall produce quality specifications with few residual construction problems and safety issues.
Strategic Plan	1	Strategic plan	Company A management shall require sophisticated risk management, including ERM.
Strategic Plan	1	Strategic Plan	The Strategic Plan shall require ERM to be included in the company's approach to risk management.
Strategic Plan	2	Strategic Plan	Strategic Plan or revision to the plan requiring ERM is issued on schedule.
Survey accomplished late.	2	Survey	Lloyds shall deliver surveys on schedule.
Survey fails to uncover all hazards.	1	Survey	Lloyds shall provide high-quality surveys that identify all safety issues.
Survey not accomplished.	2	Survey	Lloyds shall provide the surveys to CMAL on schedule.
Time between the release of new regulations is too long	3	Updated regulations	IMO shall update the ISM Code periodically to reflect the latest approaches to safety and risk management.
Training materials not provided	2	Training materials	Company A Acquisitions shall insure that the Shipyard provides quality training materials on schedule.
Training materials provided	2	Training materials	The Shipyard shall prepare high-quality training materials delivered on schedule.
Training materials provided late	3	Training materials	Shipyard shall produce the training materials on schedule.

Training request not provided	2	Training request	Master should approve all necessary training requests.
Training request not provided	2	Training request	Master should approve all necessary training requests.
Training request not submitted	2	Training request	Director of Service Delivery should approve all necessary training requests.
Training request provided	1	Training request	Master shall provide adequate time in the ship's schedule to allow for all approved training.
Training request provided	2	Training request	Master shall provide adequate time in the ship's schedule to allow for all approved training.
Training request provided	2	Training request	Master shall provide resources for needed training requests
Training request provided	2	Training request	Master shall provide resources for needed training requests.
Training request provided late	2	Training request	Training shall take place meeting the approved schedule.
Training request provided late	3	Training	Training shall take place meeting the approved schedule.
Training request submitted	1	Training request	Director of Service Delivery shall provide resources for needed training requests.
Training request submitted	2	Training request	Director of Service Delivery shall provide adequate time in the ship's schedule to allow for all approved training.
Training request submitted late	2	Training request	The training schedule shall be approved on schedule.
Updated regulation issued late	2	Update issued late	The IMO shall issue updates to regulations on schedule
Updated regulation is not issued	2	Update not issued	By failing to update their regulation, no improvement in safety management is gained.
Updated regulation issued	2	Updated regulation issued	IMO shall issue updated regulation, but change that improves safety
Yard fails to mitigate identified risk during modernization development and execution.	1	Risk assessment	The quality of Company A's risk assessments must be assessed to ensure all possible risks are identified and provided to the Yard

Appendix A.9 - Company A Key Safety Assurance Indicators

Source UCA	Indicator	Type	Measure	Controller
	Safety Assurance			
C1-2-2- SI1	Environmental report	Lead	The number of environmental deficiencies open and unresolved reported weekly.	UK Ministry
C1-29-3- SI1	Contract	Lead	Number of days late after the scheduled delivery of the Contract to Company A Acquisitions shall be tracked and reported monthly	UK Ministry
C1-30-3- SI2	SMS	Lead	The number of days late after the scheduled delivery of approvals from the UK Government shall be tracked and reported monthly.	UK Government
C1-3-1- SI1	Safety meeting minutes	Lead	Master reports monthly/annually on the total number of safety deficiencies and the number not being dealt with.	Master
C1-8-1- SI1	SMS Update	Lead	The number of changes to the SMS should be tracked and reported on annually.	Director HSQE
C2-1-1- SI1	Planned maintenance	Lead	The number of incidents caused by planned maintenance should be tracked yearly.	Master
C2-1-2- SI1	Planned maintenance	Lead	The number of planned maintenance activities scheduled, but not completed, reported monthly.	Master
C3-4-1- SI1	Change order	Lag	The number of change orders that are not acted upon by the Design Agent in thirty days, reported monthly.	Company A Acquisitions

C3-5-1-SI1	Change order	Lead	The number of change orders that are not acted upon by the Yard in thirty days, reported monthly.	Company A Acquisitions
C3-6-1-SI1	Change order	Lead	The number of change orders that are not acted upon by the Yard in thirty days, reported monthly.	Shipyard
C3-7-1-SI1	Change requests	Lead	Number of change requests, waivers and deviations that are not acted upon by Company A Acquisitions in thirty days, reported monthly	Design agent
C3-8-1-SI1	Change order	Lead	The number of change orders that are not acted upon by the Yard in thirty days, reported monthly.	Modernization Yard
C4-1-2-SI1	Resources	Lead	Level of funding for risk and safety mitigation efforts tracked monthly.	Director of operations
C4-1-2-SI2	Resources	Lead	Crew manning levels shall be tracked weekly.	Director of operations
C4-2-1-SI2	Resources	Lead	The number of unfilled crew onboard ships tracked monthly.	Company A
C5-4-1-SI1	Safety assessment	Lead	Track number of safety assessments conducted monthly, including the number of hazards found	Deck Department
C5-4-6-SI1	Safety assessment	Lead	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported monthly.	Deck Department
C5-5-2-SI1	Safety assessment	Lead	The number of accident/incident/near miss reports with no decision to fix the issues highlighted, reported monthly.	Safety Committee
C6-4-2-SI1	Safety assessment	Lead	The number of flaws identified in the SMS by Deck and Engineering and submitted to the Master shall be reported after the review.	Master

C6-1-7- SI1	SMS assessment	Lag	Percentage of ship's master's that submit SMS comments on time.	Deck Department
C6-1-7- SI2	SMS assessment	Lead	Percentage of unresolved comments steadily grows. The trigger is 10%.	Deck Department
C6-2-3- SI1	Safety meeting	Lead	The number of times ship fails to hold the Monthly safety reviews, reported monthly.	Safety Committee
C6-4-2- SI1	SMS	Lead	The number of flaws identified in the SMS by Deck and Engineering and submitted to the Master shall be reported after the review.	Master
C6-5-1- SI1	Audit	Lead	The quality of the audit process should be assessed annually and reported.	Master
C6-7-1- SI1	Audit assessment	Lead	The quality of the audit process should be assessed annually and reported.	Director HSQE
C6-8-1- SI1	Audit	Lead	The number of repeat findings each review cycle shall be tracked and reviewed annually.	Director HSQE
C6-9-1- SI1	Audit	Lag	The number of new findings for each review cycle shall be tracked and reviewed annually.	Audit and Risk Committee

Appendix B – Company B STPA analysis results

Appendix B.1 – Company B Controller name and description

Controller Name	Controller Description
Bermuda Government	Flag state for 9 of 10 Company B ships
BOD	Board of Directors for Company B
BOD-Audit and Risk Committee	Proposed new subcommittee of the BOD
CE	Chief Engineer onboard ship
CEO	Chief Executive Officer
CMO	Chief Maritime Officer
CRO	Chief Risk Officer
Design Agent	prepares plans, specs and data for modernization and new construction
Director New Builds	Company B Coordinator of new builds
Director of New Build	lead for new ship construction at Company B
Director of Safety & Environmental	Company B manager responsible for the safety and environmental compliance
Director, Risk Engineering	Risk manager for Company B - Corporate Level
DPA	Designated Person Ashore
EVP Maritime	Head of Maritime operations at Company B
EVP Maritime	Overall responsibility for the Brand operation, modernization, and new builds
EVP Maritime Policy & Analysis	Executive Vice President of Policy & Analysis Corporate Level
Fleet Director(s)	Shoreside management of ship repairs, modernisations at Company B
Head Deck Department	Head of Deck Department onboard ship
HSC	shipboard Health and Safety Committee
IMO	International Maritime Organization
Lloyds	UK Regulatory agent
Master	Captain of a ship in Company B fleet
Modernization Yard	Shipyard providing repair and modernization services
President	President of Company B
Project Director	Company B Director of modernizations and repairs
R&A	Risk & Audit Department
Recycling Yard	facility to decommission/recycle a ship
Senior Manager of Safety	lead safety person at Company B
Shipyard	building facility for new construction ships
Sr. VP Ship Building	Head of new construction for Company B
Staff Captain	Deputy Captain - head of Deck Department
SVP Nautical Operations	Head of marine operations for Company B

UK Government	Flag state for 1 of 10 Company B ships
VP Asset Management	Head of Asset Management for Company B
VP Governance	Responsible for operation of Company B Fleet, plus DPA
VP Risk and Operational Support	Company B Head of risk management and operational support

Appendix B.2 – Company B Control Actions (CAs):

Controller Name	Control Action Name	Description
Bermuda Government	Audits, inspections, and certificates	External audits and inspections of Company B ships (except Britannia)
Bermuda Government	Regulation improvement	Recommendations to improve the ISM Code
Bermuda Government	Regulations	Flag state regulations for risk and safety management
BOD	Resources	Resources provided for risk and safety management (corporate level)
BOD	Risk appetite	Annual guidance on key risk areas of risk, holistically for company.
BOD	Risk management policy	BOD guidance on the use of holistic risk across the entire organization
BOD-Audit and Risk Committee	Risk management policy	Audit and Risk Committee guidance to the BOD on the use of holistic risk management across all of the organization
CE	Accident/near miss Report	Accident and near-miss information from the ship Department level
CE	Change request	Ship Department requests a change
CE	Crew training	Request for Crew training
CE	Environmental report	Report on the release of hazardous materials
CE	Risk assessment	Risk assessments developed at the ship's department level
CE	Safety assessment	Assess the safety of new or modernized systems
CE	SMS Annual assessment	Input to the Master's review of the SMS
CEO	Key indicators	Key indicators (KPIs, KSIs, KRIs and KFIs)
CEO	Risk appetite	Annual guidance on key risk areas of risk, holistically for company. Set by senior management.
CEO	Risk appetite	Annual guidance on key risk areas of risk, holistically for company. Set by senior management.
CEO	Safety Policy	Overarching company safety guidance
CEO	Strategic Plan	Strategic plan from the CEO down to the Operating level via CMO. Provides a roadmap for corporate changes.
CMO	Emergency preparedness	Periodic testing of the Brand's readiness for an emergency

CMO	Key indicators	Key indicators (KPIs, KSIs, KRIs and KFIs)
CMO	Safety policy updates	Periodic updates to the company safety policy
CMO	Strategic Plan	Strategic plan from the CMO down to the Operating level. Provides a roadmap for corporate changes.
CRO	Risk register	ERM report listing all risks Company B faces
Design Agent	Change requests, waivers, and deviations	Design agent provides change requests, waivers, and deviations
Design Agent	Manning estimate	Design agent's estimate of the crew size on either new construction or modernization.
Design Agent	Plans and calculations	Design agent supplies plans and calculations deliverables.
Design Agent	Plans and calculations	Plans and calculations for new design or modernizations
Design Agent	Safety/hazard/risk analysis	Safety/hazard/risk analysis deliverable from the design agent for a new ship or modernization package.
Design Agent	Specifications	New design and modernization construction specifications
Director of New Build	Change orders	Approval of change requests via change orders
Director of New Build	Change orders	Change order approval to design agent
Director of New Build	Contract	Contract deliverables require hazards and risks to be identified.
Director of New Build	Contract	Contract for inspection services
Director of New Build	Contract	Contract for new construction
Director, Risk Engineering	Enterprise Risk Management	Combination of Brand level risks with corporate-level risks to generate an ERM report
Director, Risk Engineering	Risk assessment	Summary report of all risk appraisals done throughout all brands
Director, Risk Engineering	Risk register	Listing of all enterprise risks
EVP Maritime	Key indicators	Key indicators (KPIs, KSIs, KRIs and KFIs) for CUK are developed
EVP Maritime	Resources	Budget for safety and risk management
EVP Maritime Policy & Analysis	Accident, near-miss report	Summary report issued to all brands summarizing lessons learned
EVP Maritime Policy & Analysis	Safety Flash	Safety Flash issued
HSC	Accident/near miss Report	Accident and near-miss information from the ship level
HSC	Monthly safety meeting	HSC meeting on each ship
HSC	Safety assessment	Safety assessment after changes
IMO	Regulations	New regulations released
IMO	Regulations (update)	IMO updates the ISM Code
Lloyds	Approvals	Approval of plans and calculations

Lloyds	Class rules update	Update of the classification societies rules for safety and risk
Lloyds	Plans and calculation approvals	Approval of plans and calculations
Lloyds	Surveys	Surveys to keep in class
Master	Change request	Change requests from the fleet (planned)
Master	Change request	Request to modify an existing operational (HESS) process
Master	Environmental report	Report on the release of hazardous materials
Master	Key indicators (balanced scorecard)	Key indicators (KPIs, KSIs, KRIs and KFIs)
Master	Key Indicators (Balanced Scorecard)	Key Indicators (KPIs, KSIs, KRIs, and KFIs)
Master	Planned maintenance	Development of an approach to planned maintenance.
Master	Risk assessment	Master's report on risk assessments
Master	Risk register	Summary of ship risks compiled
Master	SMS updated	Annual review of the SMS
Modernization Yard	Change orders	Change orders for Modernization Yard
Modernization Yard	Hazards/risk/safety assessments	Deliverables
Modernization Yard	Operations and technical manuals	Deliverables from the shipyard providing guidance on the safe operation of the ship.
President	Resources	Budget for safety and risk management
President	Risk appetite	Risk appetite guidance for Company B
Project Director	Contract	Contract requires hazards and risks to be identified and mitigated.
R&A	Audit Report	Report of audit findings to the BOD
R&A	Internal audit	Internal audits of CUK
Recycling Yard	Ship recycling hazard analysis	Ship recycler must perform a hazard analysis of the potential issues caused by the breaking up of each particular ship.
Shipyard	Planned maintenance	Deliverable from new construction yards.
Shipyard	Change order	Change order execution by the shipyard
Shipyard	Contract	Lloyds assessment to award DOC.
Shipyard	Operations and technical manuals	Deliverables from the shipyard providing guidance on the safe operation of the ship.
Shipyard	Plan and calculations submission	Submission to Lloyds for approval of all drawings and calculations
Shipyard	Safety/hazard/risk analysis	Safety/hazard/risk analysis deliverable from the shipyard for a new ship or modernization package.
Shipyard	Training material	Development of training materials
Staff Captain	Accident and near-miss Report	Accident and near-miss information from the ship Department level
Staff Captain	Accident/near miss	Accident and incident analysis reports
Staff Captain	Annual assessment of SMS	Input to the Master's annual SMS assessment

Staff Captain	Change requests	Request to change existing operations
Staff Captain	Crew training	Submit training requests
Staff Captain	Lifesaving appliance (LSA) drills	Conduct of LSA training
Staff Captain	Risk assessment	As new risks are determined, assessments are conducted to determine the proper mitigation effort.
UK Government	Audits, inspections, and certificates	External audits and inspections of ships
UK Government	Regulation improvement	Recommendations to improve the ISM Code
UK Government	Regulations	Flag state regulations for risk and safety management
VP Asset Management	Accident, near-miss report	Incident information from fleet operations, modernizations, and new construction
VP Asset Management	Accident, near-miss report	Summary report on CUK
VP Asset Management	Change orders	Approved changes to Modernization Yard
VP Asset Management	Change orders	Change order execution by a shipyard
VP Asset Management	Contract	Contract requires hazard and risk analysis.
VP Asset Management	Crew training	Submit crew training request
VP Asset Management	Environmental report	Report on the release of hazardous materials
VP Asset Management	Risk assessments	Risk appraisals are done on new or revised equipment or procedures
VP Governance	Audits, inspections	Flag and Port State audits and inspections
VP Governance	Contract	Contract deliverables require hazards and risks to be identified.
VP Governance	Resources	Budget for safety and risk management at the ship level
VP Governance	Safety Flash input	Safety Flash input issued
VP Governance	SMS Update	Updates to the SMS
VP Risk and Operational Support	Risk register	Summary of Brand's risks compiled

Appendix B.3 – Company B Priority 1 Safety System Indicators (SSIs):

Indicator Type	System Indicator Name	Description
Assurance	Audit	Status of overdue audits close-outs shall be reported within one week of the due date.
Assurance	Audit	Number of audits conducted late shall be tracked and reported weekly.
Assurance	Audit	The quality of the audit process should be assessed annually and reported.
Assurance	Change order	Number of change orders without a hazard and risk assessment shall be tracked and reported monthly.
Assurance	Environmental report	Number of environmental deficiencies shall be reported weekly.

Assurance	Environmental report	Total number of environmental fines levied shall be tracked and reported weekly.
Assurance	Key indicator report	The quality of the key indicators shall be assessed and reported annually.
Assurance	Operations and Technical Manuals	Number of Operations and Technical Manuals delivered shall be tracked and reported monthly.
Assurance	Planned maintenance	Number of planned maintenance activities scheduled, but not completed, reported monthly.
Assurance	Planned maintenance	Number of incidents caused by planned maintenance should be tracked on a yearly basis.
Assurance	Plans and calculations	Number of days late delivering the plans and calculations to Lloyds shall be tracked and reported monthly.
Assurance	Repeat audit findings	Audit report tracking the repeat audit findings uncovered on a monthly basis for whole brand.
Assurance	Resources	Number of unfilled crew onboard ships tracked on a monthly basis.
Assurance	Resources	Amount of funding available for training tracked monthly.
Assurance	Resources	Crew manning levels shall be tracked monthly.
Assurance	Resources	Approved and actual manpower shall be tracked and reported monthly.
Assurance	Safety assessment	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported on a monthly basis across the whole fleet.
Assurance	Safety assessment	Ratio of planned versus accomplished safety assessments shall be reported monthly for the whole fleet.
Assurance	Safety assessment	The number of open safety assessments shall be tracked and reported monthly.
Assurance	Safety meeting report	Number of safety meeting minutes not submitted as a percentage of the total fleet's input/reports.
Assurance	Safety meeting report	Number of safety meeting minutes delivered late every month.
Assurance	Survey	Number of days late after the scheduled delivery of the surveys from Lloyds shall be tracked and reported monthly.
Policy & Objectives	Emergency processes testing	Number of emergency system tests conducted yearly versus planned, tracked and reported quarterly.
Policy & Objectives	New regulations	Number of times the ISM Code is updated in a 10 year period.
Policy & Objectives	Regulations	Length in months between updates of the SMS regulations shall be tracked and reported annually.
Policy & Objectives	Safety policy updates	The quality of the Safety Policy updates shall be assessed on a scale of 1 to 5
Policy & Objectives	Strategic plan	Percentage of the company using ERM as their method of Risk Management.
Policy & Objectives	Strategic Plan	Percentage of the company using ERM as their method of Risk Management.
Promotion	LSA drill	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.

Promotion	LSA drill	Number of accidents occurring during training drills on the lifesaving appliances.
Promotion	Resources	Amount of funding available for training tracked monthly.
Promotion	Safety Flash	Average number of Safety Flashes issued per month shall be tracked and reported quarterly.
Promotion	Safety Flash	Average number of Safety Flashes issued per month shall be tracked and reported quarterly.
Promotion	Safety Flash	Quality of Safety Flashes shall be assessed annually.
Promotion	Training materials	Number of days late for training material shall be tracked and reported monthly.
Promotion	Training materials	Number of issues/mistakes found by Company B VP Asset Management when reviewing the Shipyard provided training materials shall be tracked and reported monthly.
Promotion	Training request	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.
Promotion	Training request	Number of training requests approved shall be tracked and reported monthly.
Promotion	Training request	Number of training requests not approved reported monthly.
Promotion	Training request	Number of approved training requests not accomplished on a monthly basis.
Promotion	Training request	Number of training requests not approved reported monthly.
Risk	Accident/incident/near miss Report	Number of specific lessons learned shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Number of times Company B fails to submit the Accident/incident/near miss Report on the schedule shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Number of HSCs that fail to deliver an Accident/incident/near miss Report shall be tracked and reported quarterly.
Risk	Resources	Level of funding for risk and safety mitigation efforts shall be tracked monthly.
Risk	Resources	Risk mitigation funding shall be tracked and reported on monthly.
Risk	Resources	Training, safety, and risk mitigation funding shall be tracked and reported on monthly.
Risk	Resources	Level of funding for risk and safety mitigation efforts shall be tracked monthly.
Risk	Risk appetite	Frequency of updating the corporate risk appetite is tracked and reported on an annually.
Risk	Risk appetite	The number of times the BOD fails to issue the Risk Appetite shall be tracked and reported annually.
Risk	Risk appetite	Number of months late in issuing the Risk Appetite shall be tracked and reported quarterly.
Risk	Risk appetite	Number of times the CEO fails to issue the Risk Appetite to the BOD shall be tracked and reported annually.
Risk	Risk assessment	An annual summary report documenting the ratio of the number of risk assessments versus the total number of near

		misses, incidents and accidents should be produced.
Risk	Risk assessment	A summary report of the total number of risk assessments and the percentage delivered late should be produced annually.
Risk	Risk assessment	Number of new risks identified without mitigation plans shall be tracked and reported monthly.
Risk	Risk assessment	The number of risk assessments conducted late should be tracked and reported monthly.
Risk	Risk assessment	An assessment of the quality of the ERM report shall be made and reported annually.
Risk	Risk assessment	Total number of unfunded and unstaffed risk assessments should be reported on a monthly basis.
Risk	Risk assessments	The total number of risk assessments should be tracked/plotted on a monthly/quarterly/annual basis.
Risk	Risk assessments	Total number of unfunded and unstaffed risk assessments should be reported on a monthly basis.
Risk	Risk management policy	Results of ERM audit shall be produced annually.
Risk	Risk Mitigation	Number of unmitigated risks shall be tracked and reported on a monthly basis.
Risk	Risk register	Quality of the Risk register shall be assessed, and findings reported annually.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Risk register	Average number of days past due for the risk register shall be reported monthly.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Risk register	Average number of days past due for the risk register shall be reported quarterly.
Risk	Safety/hazard/risk analysis	The number of times the Design agent fails to provide a safety/hazard/risk analysis as part of the deliverables shall be tracked and reported.
Risk	Safety/hazard/risk analysis	Number of days the Safety/hazard/risk analysis is late being provided to Company B shall be tracked and reported monthly.

Appendix B.4 – Company B Priority 2 Safety System Indicators (SSIs)

Indicator Type	System Indicator Name	Description
Assurance	Audit	Number of audits not conducted shall be tracked and reported annually.
Assurance	Audit report	The quality of the audit process should be assessed annually and reported.
Assurance	Audit report	Number of times the Audit Report is not issued shall be tracked and reported annually.

Assurance	Audit report	Number of times the Audit Report is not issued on time shall be tracked and reported annually.
Assurance	Change order	Number of change orders released late by Company B shall be tracked and reported monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Shipyard in thirty days, reported monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change order	Number of changes orders still undefinitized shall be tracked and reported monthly.
Assurance	Change order	Change orders not executed shall be tracked and reported monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Yard in thirty days, reported monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change order	Average time for the Yard to decide to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Yard in thirty days, reported monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change order	Average time for the Yard to respond to an approved change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change order	Number of change orders backlogged shall be tracked monthly.
Assurance	Change order	Number of change orders that are not acted upon by the Design Agent in thirty days, reported monthly.
Assurance	Change order	Average time to decide to respond to an approved a change order with a priced change shall be tracked and reported on monthly.
Assurance	Change order	Average time to decide to respond to an approved a change order with a priced change shall be tracked and reported on monthly.
Assurance	Change request	Average time to decide on whether to approve a change request shall be tracked and reported on monthly.
Assurance	Change request	Number of change requests submitted monthly shall be tracked and reported monthly.
Assurance	Change request	Number of change requests that are not acted upon by Company B VP Governance within thirty days, reported monthly.
Assurance	Change request	Average time to decide on whether to approve a change request shall be tracked and reported on monthly.
Assurance	Change request	Number of change requests not processed shall be tracked and reported monthly.
Assurance	Change request	Number of change requests that are not acted upon by the Master in thirty days, reported monthly.
Assurance	Change request	Number of change requests that are not acted upon by Company B VP Governance within thirty days, reported monthly.
Assurance	Change request	Average time to decide on whether to approve a change request shall be tracked and reported on monthly.
Assurance	Change request	Number of change requests submitted monthly shall be tracked and reported monthly.

Assurance	Change request	Number of change requests that are not acted upon by the Master in thirty days, reported monthly.
Assurance	Change request	Number of change requests submitted shall be tracked and reported on monthly.
Assurance	Change requests, waivers, and deviations	Number of days late for change requests, waivers and deviations shall be tracked and reported monthly.
Assurance	Change requests, waivers, and deviations	Number of responses taking longer than 30 days shall be tracked and reported monthly.
Assurance	Contract	Number of days late after scheduled award of contract reported monthly.
Assurance	Contract	Number of days late releasing the contract shall be tracked and reported on monthly.
Assurance	Contract	Track and report the number of design deficiencies.
Assurance	Contract	Number of rejected hazards, safety, and risk deliverables.
Assurance	Contract	Number of days late after scheduled award of contract reported monthly.
Assurance	Contract	Number of hazards, safety and risk deliverables that are received late shall be tracked and reported monthly.
Assurance	Contract	Track and report the number of design deficiencies.
Assurance	Contract	Number of rejected hazards, safety, and risk deliverables.
Assurance	Contract	Number of hazards, safety and risk deliverables that are received late shall be tracked and reported monthly.
Assurance	DOC	Number of days late awarding the contract to Lloyds for the DOC shall be tracked and reported monthly.
Assurance	Environmental report	Number of environmental deficiencies shall be reported weekly.
Assurance	Environmental report	Number of environmental deficiencies shall be reported weekly.
Assurance	Environmental report	Number of environmental releases reported weekly.
Assurance	Environmental report	Number of environmental releases reported weekly.
Assurance	Environmental report	Number of environmental deficiencies open and unresolved reported weekly.
Assurance	Environmental report	Number of fines incurred shall be tracked and reported weekly.
Assurance	Environmental report	Number of environmental deficiencies open and unresolved reported weekly.
Assurance	Key indicator report	The number of days late for producing the Key indicator report shall be tracked and produced annually.
Assurance	Key indicator report	The quality of the key indicators shall be assessed and reported annually.

Assurance	Key indicator report	Number of times the Key indicator report is not produced shall be tracked and reported annually.
Assurance	Key indicator report	Number of times the Key indicator report is not produced shall be tracked and reported annually.
Assurance	Key indicator report	The number of days late for producing the Key indicator report shall be tracked and produced annually.
Assurance	Key indicator report	The number of days late for producing the Key indicator report shall be tracked and produced annually.
Assurance	Key indicator report	Number of times the Key indicator report is not produced shall be tracked and reported annually.
Assurance	Key indicator report	The quality of the key indicators shall be assessed and reported annually.
Assurance	Key indicators	Number of days late for the Key Indicator report shall be tracked and reported on monthly.
Assurance	Key indicators	The quality of the Key Indicators shall be assessed, and findings reported annually.
Assurance	Key indicators	Number of times the Key Indicators are not provided shall be tracked and reported quarterly.
Assurance	Key indicators	Number of days late for releasing the Key Indicators shall be tracked and reported monthly.
Assurance	Key indicators	Number of audits done on Key Indicators per year reported annually.
Assurance	Key indicators	Ratio of the number of key indicators versus five-year average plotted monthly.
Assurance	Manning	The number of days late for the manning estimate shall be tracked and reported monthly.
Assurance	Operations and Technical Manuals	Number of Operations and Technical Manuals delivered shall be tracked and reported monthly.
Assurance	Operations and Technical Manuals	The quality of the Operations and Technical Manuals shall be assessed upon delivery.
Assurance	Operations and Technical Manuals	Number of Operations and Technical Manuals delivered late shall be tracked and reported monthly.
Assurance	Operations and Technical Manuals	Number of Operations and Technical Manuals delivered late shall be tracked and reported monthly.
Assurance	Planned maintenance	Number of accidents or incidents caused when using the planned maintenance approach delivered shall be tracked and reported monthly.
Assurance	Planned maintenance	Number of planned maintenance activities not completed each month,
Assurance	Planned maintenance	Number of days late for delivery of the planned maintenance approach shall be tracked and reported monthly.
Assurance	Plans and calculations	Number of changes required on resubmittals to get approval shall be tracked and reported on monthly.
Assurance	Plans and	The quality of the plans and calculations submitted shall be assessed and

	calculations	the results shall be tracked and reported.
Assurance	Plans and calculations	Number of days late after the scheduled delivery of the surveys from Lloyds shall be tracked and reported monthly.
Assurance	Plans and calculations	Number of plans and calculations submitted late to Lloyds shall be tracked by Company B VP Asset Management monthly.
Assurance	Plans and calculations	Number of plans and calculations delivered shall be tracked and reported monthly.
Assurance	Resources	Number of unfilled crew onboard ship tracked on a monthly basis
Assurance	Resources	Resources expended per month shall be tracked and reported quarterly.
Assurance	Resources	Number of known KRI's created and tracked on a monthly basis.
Assurance	Resources	Crew manning levels shall be tracked monthly.
Assurance	Resources	Level of funding and manpower shall be tracked and reported monthly.
Assurance	Safety assessment	Number of cancelled safety assessments due to lack of resources shall be tracked and reported monthly.
Assurance	Safety assessment	Number of accident/incident/near miss reports with no decision to fix the issues highlighted, reported monthly.
Assurance	Safety assessment	Master shall track the number of cancelled safety assessments due to lack of information/data on a monthly basis.
Assurance	Safety assessment	Ratio of open versus closed accident/incident/near miss reports reported monthly for the whole fleet.
Assurance	Safety assessment	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported on a monthly basis.
Assurance	Safety assessment	Percentage of safety assessments conducted versus the total number of accidents/incidents/near misses reported on a monthly basis.
Assurance	Safety assessment	Track number of safety assessments conducted on a monthly basis, including the number of hazards found.
Assurance	Safety meeting report	HSC reports monthly/annually on the total number of safety deficiencies and the number not being dealt with.
Assurance	SMS review	Number of flaws identified in the SMS by Deck and Engineering and submitted to the Master shall be tracked and reported after the review.
Assurance	SMS review	Total number of changes to SMS, versus number approved tracked on a monthly basis.
Assurance	SMS updates	The SMS update shall be provided on schedule.
Assurance	SMS updates	The SMS update shall be provided on schedule.
Assurance	Specifications	Number of days late after the scheduled delivery of the specifications shall be tracked by Company B VP Asset Management
Assurance	Survey	Number of comments on each survey shall be tracked and reported on monthly.
Policy & Objectives	Changes to regulations	Length of time between providing comments to the IMO shall be tracked.
Policy & Objectives	Changes to regulations	Length of time between providing comments to the IMO shall be tracked.
Policy & Objectives	Changes to regulations	Length of time between providing comments to the IMO shall be tracked.
Policy & Objectives	Emergency processes	Number of emergency system tests conducted late shall be tracked and reported quarterly.

	testing	
Policy & Objectives	Emergency processes testing	Number of emergency system tests conducted yearly tracked and reported quarterly.
Policy & Objectives	New regulations	Number of updates issued as a trailing 10-year average.
Policy & Objectives	Regulation update	The time in months since the ISM Code was updated, reported on a yearly basis.
Policy & Objectives	Regulations	Number of days late for SMS Regulation revisions are tracked on an annual basis.
Policy & Objectives	Regulations	Number of days late for SMS Regulation revisions are tracked on an annual basis.
Policy & Objectives	Resources	BOD appoints a lead risk person for the Audit and Risk Committee.
Policy & Objectives	Safety Policy	Time since the last issuance of the Safety Policy (in days) shall be tracked and reported.
Policy & Objectives	Safety Policy	Length in time in months since the last update of the Safety Policy.
Policy & Objectives	Safety Policy	Number of days late for Safety Policy revision is tracked on an annual basis.
Policy & Objectives	Strategic Plan	The quality of the Strategic Plan in the area of risk management shall be assessed on a yearly basis.
Policy & Objectives	Strategic Plan	Number of days late for Strategic Plan revision is tracked on an annual basis.
Policy & Objectives	Strategic Plan	Number of days late for Strategic Plan revision is tracked on an annual basis.
Policy & Objectives	Strategic Plan	The quality of the Strategic Plan in the area of risk management shall be assessed on a yearly basis.
Policy & Objectives	Updated regulations	IMO shall update the ISM Code periodically to reflect the latest approaches to safety and risk management.
Policy & Objectives	Updated regulations	The time in months since the ISM Code was updated, reported on a yearly basis.
Policy & Objectives	Updates to class rules	Length in time in months since the last update of the Class Rules.
Policy & Objectives	Updates to class rules	Number of months between Class Rule revisions shall be tracked and reported annually.
Policy & Objectives	Updates to class rules	Length of time between updates of the rules shall be tracked.
Promotion	LSA drill	Percentage of lifesaving appliance drills accomplished on schedule fleet-wide.
Promotion	Safety Alert	Number of days late in the issuance of Safety Alerts shall be reported monthly.
Promotion	Safety Flash	Quality of Safety Flashes shall be assessed annually.
Promotion	Safety Flash	Late delivery of the Safety Flash causes allows an accident/incident or near miss to occur.
Promotion	Safety Flash	Number of days late for Safety Flash revision is tracked on an annual

		basis.
Promotion	Training materials	Percentage of training materials delivered on schedule is tracked monthly.
Promotion	Training request	Number of times training is delayed shall be tracked and reported monthly.
Promotion	Training request	Number of training requests not approved reported monthly.
Promotion	Training request	Number of training requests not approved reported monthly.
Promotion	Training request	Number of training requests submitted late shall be tracked and reported monthly.
Promotion	Training request	Number of times training is delayed shall be tracked and reported monthly.
Promotion	Training request	Plot the curves of expenditures on training and the number of accidents/incidents/near misses on a monthly basis.
Risk	Accident/incident/near miss Report	Number of times Company B fails to submit the Lessons Learned Report shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Quality of Accident/incident/near miss Reports should be assessed annually.
Risk	Accident/incident/near miss Report	Number of times the Staff Captain issues the Accident/incident/near miss Report late shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Number of times the CE issues the Accident/incident/near miss Report late shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Number of times the Staff Captain fails to provide the Accident/incident/near miss Report shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Number of times the Staff Captain issues the Accident/incident/near miss Report late shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	Number of times Accident/incident/near miss Report is not issued shall be tracked and reported annually.
Risk	Accident/incident/near miss Report	Quality of Accident/incident/near miss Reports should be assessed annually.
Risk	Accident/incident/near miss Report	Number of days late in the issuance of the Accident/incident/near miss Report is tracked and reported monthly.
Risk	Accident/incident/near miss Report	Number of times the CE fails to provide the Accident/incident/near miss Report shall be tracked and reported quarterly.
Risk	Accident/incident/near miss Report	The number of times the Accident/incident/near miss Report is issued late shall be tracked and reported quarterly.

Risk	Accident/incident/near miss Report	Number of times Accident/incident/near miss Report is not issued shall be tracked and reported annually.
Risk	Accident/near miss Report	Number of Accident/near miss Reports not provided shall be tracked and reported monthly.
Risk	Accident/near miss Report	Number of Accident/near miss Reports issued late shall be tracked and reported monthly.
Risk	ERM Report	Number of times the ERM Report is provided late shall be tracked and reported quarterly.
Risk	ERM Report	Number of times the ERM Report is not provided on schedule shall be tracked and reported quarterly.
Risk	Hazard analysis	Number of low-quality hazard analysis from Recycling Yards shall be assessed and reported quarterly.
Risk	Hazard analysis	Number of days late for delivery of the hazard analysis shall be tracked and reported monthly
Risk	Hazard/risk/safety assessments	Number of days the Safety/hazard/risk analysis is late being provided to Company B VP Asset Management shall be tracked and reported monthly.
Risk	Hazard/risk/safety assessments	The quality of the Safety/hazard/risk analysis shall be assessed when the deliverable is provided, and results reported annually.
Risk	Resources	Number of know risks and hazards that go unmitigated tracked on a monthly basis.
Risk	Resources	Late delivery of resources shall be tracked and reported monthly.
Risk	Resources	Level of funding for risk mitigation efforts shall be tracked monthly.
Risk	Resources	Number of know risks and hazards that go unmitigated tracked on a monthly basis
Risk	Risk appetite	The change in focus at Company B shall be tracked and reported annually.
Risk	Risk appetite	The number of times the BOD issues the Risk Appetite late shall be tracked and reported annually.
Risk	Risk appetite	The change in focus over time shall be tracked and reported annually. Concern is to track whether the focus areas remain constant/stagnant.
Risk	Risk appetite	The number of times the CEO fails to issue the Risk Appetite shall be tracked and reported annually.
Risk	Risk appetite	The number of times the CEO issues the Risk Appetite late shall be tracked and reported annually.
Risk	Risk appetite	Key risk areas are tracked and reported for each ship.
Risk	Risk appetite	Number of days late in releasing the Risk Appetite shall be tracked and reported monthly.
Risk	Risk assessment	Number of risk mitigation plans produced shall be tracked and reported quarterly.
Risk	Risk assessment	The total number of risk assessments should be tracked/plotted on a monthly/quarterly/annual basis.
Risk	Risk assessment	Number of risk mitigation plans produced shall be tracked and reported quarterly.
Risk	Risk assessment	Total number of incomplete risk assessment should be reported on a

		monthly basis.
Risk	Risk assessment	Number of risks identified by risk assessments that have no resources or mitigation plans tracked and reported monthly.
Risk	Risk assessment	Total number of incomplete risk assessment should be reported on a monthly basis.
Risk	Risk assessment	Quality of the Summary Assessment Report based on the number of risks unchanged from the previous report should be assessed annually.
Risk	Risk management policy	Release of ERM update shall be tracked and reported annually.
Risk	Risk register	Number of times the risk register is not published shall be reported quarterly.
Risk	Risk register	Time between audits of the risk process in days should be tracked and reported annually.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Risk register	Average number of days past due for the risk register shall be reported monthly.
Risk	Risk register	Average number of days past due for the risk register shall be reported monthly.
Risk	Risk register	Number of times the risk register is not published shall be reported annually.
Risk	Safety/hazard/risk analysis	The number of times the Design agent fails to provide a safety/hazard/risk analysis as part of the deliverables shall be tracked and reported.
Risk	Safety/hazard/risk analysis	The quality of the Safety/hazard/risk analysis shall be assessed when the deliverable is provided, and results reported annually.
Risk	Safety/hazard/risk analysis	The quality of the Safety/hazard/risk analysis shall be assessed when the deliverable is provided, and results reported annually.
Risk	Safety/hazard/risk analysis	Number of days the Safety/hazard/risk analysis is late being provided to Company B shall be tracked and reported monthly.

Appendix B.5 – Company B Priority 3 System Safety Indicators (SSIs)

Indicator Type	System Indicator Name	Description
Assurance	Audit	Number of new findings each review cycle shall be tracked and reviewed annually.
Assurance	Contract	Number of days late releasing the contract shall be tracked and reported monthly.
Assurance	Plans and calculations	Number of days late after the scheduled delivery of plans and calculations shall be tracked and reported monthly to Company B
Assurance	Plans and calculations	Number of comments on plans and calculations shall be tracked and reported on monthly.
Assurance	Safety assessment	Master fails to provide resources to respond to a safety assessment finding,

		allowing an incident to occur.
Assurance	SMS updates	Number of times SMS updates are provided late shall be tracked and reported annually.
Assurance	SMS updates	The quality of the CE's inputs to the SMS update should be assessed annually.
Assurance	SMS updates	The assessment of SMS cannot be carried out / completed because of lack of data/information.
Assurance	SMS updates	The quality of the CE's inputs to the SMS update should be assessed annually.
Assurance	SMS updates	The assessment of SMS cannot be carried out / completed because of lack of data/information.
Assurance	SMS updates a	The quality of the SMS updates shall be assessed annually and reported.
Assurance	SMS updates a	Number of times SMS updates are not provided shall be tracked and reported annually.
Assurance	Specifications	Number of comments on specifications shall be tracked and reported on monthly.
Policy & Objectives	Risk management policy	Number of days past due for the issuance of the risk management policy shall be reported annually.
Risk	Accident/incident/ near miss Report	Quality of the HSC generated Accident/incident/near miss Report shall be assessed annually.
Risk	Accident/incident/ near miss Report	Quality of the Accident/incident/near miss Reports provided to the HSC shall be assessed annually.
Risk	Accident/near miss Report	The quality of the Accident/near miss Report shall be assessed and reported annually.
Risk	Contract	Quality of contract package's identification of hazardous materials shall be assessed prior to release.
Risk	Risk assessment	A risk assessment shall be carried out after a near miss, an incident or an accident.
Risk	Risk management policy	Number of days past due for the issuance of the risk management policy shall be reported monthly.
Risk	Risk register	The quality of the risk process on a scale of 1 to 5 should be tracked and reported annually.

Appendix B.6 Company B – Key Safety Risk Indicators (KSRI)

	Safety Risk			
A1-1-2- SI1	Strategic plan	Lead	Percentage of the company using ERM as their method of Risk Management.	CEO
A1-2-2- SI1	Strategic Plan	Lead	Percentage of the company using ERM as their method of Risk Management.	CMO

B2-11-1-SI1	Risk management policy	Lead	Results of ERM audit shall be produced annually.	BOD
B2-1-1-SI1	Risk appetite	Lead	Frequency of updating the corporate risk appetite is tracked and reported on an annually.	CEO
B2-1-2-SI1	Risk appetite	Lead	The number of times the CEO fails to issue the Risk Appetite to the BOD shall be tracked and reported annually.	CEO
B2-1-3-SI1	Risk appetite	Lead	Number of months late in issuing the Risk Appetite shall be tracked and reported quarterly.	CEO
B2-14-2-SI1	Risk assessment	Lag	An annual summary report documenting the ratio of the number of risk assessments versus the total number of near misses, incidents and accidents should be produced.	CE
B2-14-3-SI1	Risk assessment	Lag	A summary report of the total number of risk assessments and the percentage delivered late should be produced annually.	CE
B2-15-1-SI1	Risk assessment	Lead	The number of new risks identified without mitigation plans shall be tracked and reported monthly.	Staff Captain
B2-15-3-SI1	Risk assessment	Lead	The number of risk assessments conducted late should be tracked and reported monthly.	Staff Captain
B2-2-2-SI1	Risk appetite	Lead	The number of times the BOD fails to issue the Risk Appetite shall be tracked and reported annually.	BOD
B2-3-2-SI1	Risk appetite	Lead	The number of times the CEO fails to issue the Risk Appetite shall be tracked and reported annually.	CEO
B2-3-3-SI1	Risk appetite	Lead	The number of times the CEO issues the Risk Appetite late shall be tracked and reported annually.	CEO

B2-5-1- SI1	Risk assessment	Lead	An assessment of the quality of the ERM report shall be made and reported annually.	Director, Risk Engineering
B2-6-1- SI1	Risk register	Lead	Quality of the Risk register shall be assessed, and findings reported annually.	Director, Risk Engineering
B2-6-3- SI1	Risk register	Lead	The average number of days past due for the risk register shall be reported quarterly.	Director, Risk Engineering
B2-8-2- SI1	Risk register	Lead	The number of times the risk register is not published shall be reported annually.	Master
B2-8-3- SI1	Risk register	Lead	The average number of days past due for the risk register shall be reported monthly.	Master
B2-9-2- SI1	Risk assessments	Lead	The total number of unfunded and unstaffed risk assessments should be reported monthly.	Master
B2-9-3- SI1	Risk assessments	Lag	The total number of risk assessments should be tracked/plotted on a monthly/quarterly/annual basis.	Master
C4-2-3- SI3	Risk Mitigation	Lead	The number of unmitigated risks shall be tracked and reported monthly.	VP Governance

Appendix C

Types of Performance Indicators (PIs)	**Characteristics**	**Frequency of Measurement**	**Number of Measures**
Key Performance Indicators (KPIs) focus on repeat audits, accident report root cause analysis and change management in the organization	Tells how well the various parts of the organization are performing	Monthly, Quarterly	Up to 5%
Performance Indicators (PIs) are broader indicators of safety performance assessments of accidents, audits, preventative maintenance, and training performance		24/7, daily, Weekly, Monthly, Quarterly	No more than 20%
Key Risk Indicators (KRIs) are focused on risk management processes, establishing a risk appetite, and conducting risk assessments	Risk indicators are forward-looking measures that guide teams in where to focus mitigation efforts to reduce risk	Monthly, Quarterly	Up to 5%
Risk Indicators (RIs) are broader indicators of potential areas that will impact operational safety or financial performance.		Weekly	No more than 20%
Key Safety Indicators (KSIs) focus on operational safety measures, including the number of safety meeting onboard, quality of the minutes, SMS updates, safety alerts	Safety indicators are forward-looking measures that guide where potential unsafe actions may occur	Monthly, Quarterly	Up to 5%
Safety Indicators (SIs) provide broader tracking of training, available manpower, LSA training		Weekly	No more than 20%
Key Financial Indicators (KFIs) are focused on critical safety areas like budgets for safety training, risk management and safety	These financial measures provide guidance on the overall performance of the company, tend to be lagging indicators	Weekly, Monthly, Quarterly	Up to 5%
Financial Indicators (FIs) are broader indicators of safety areas like preventative maintenance budgets, risk mitigation funding and training.		Weekly	No more than 20%