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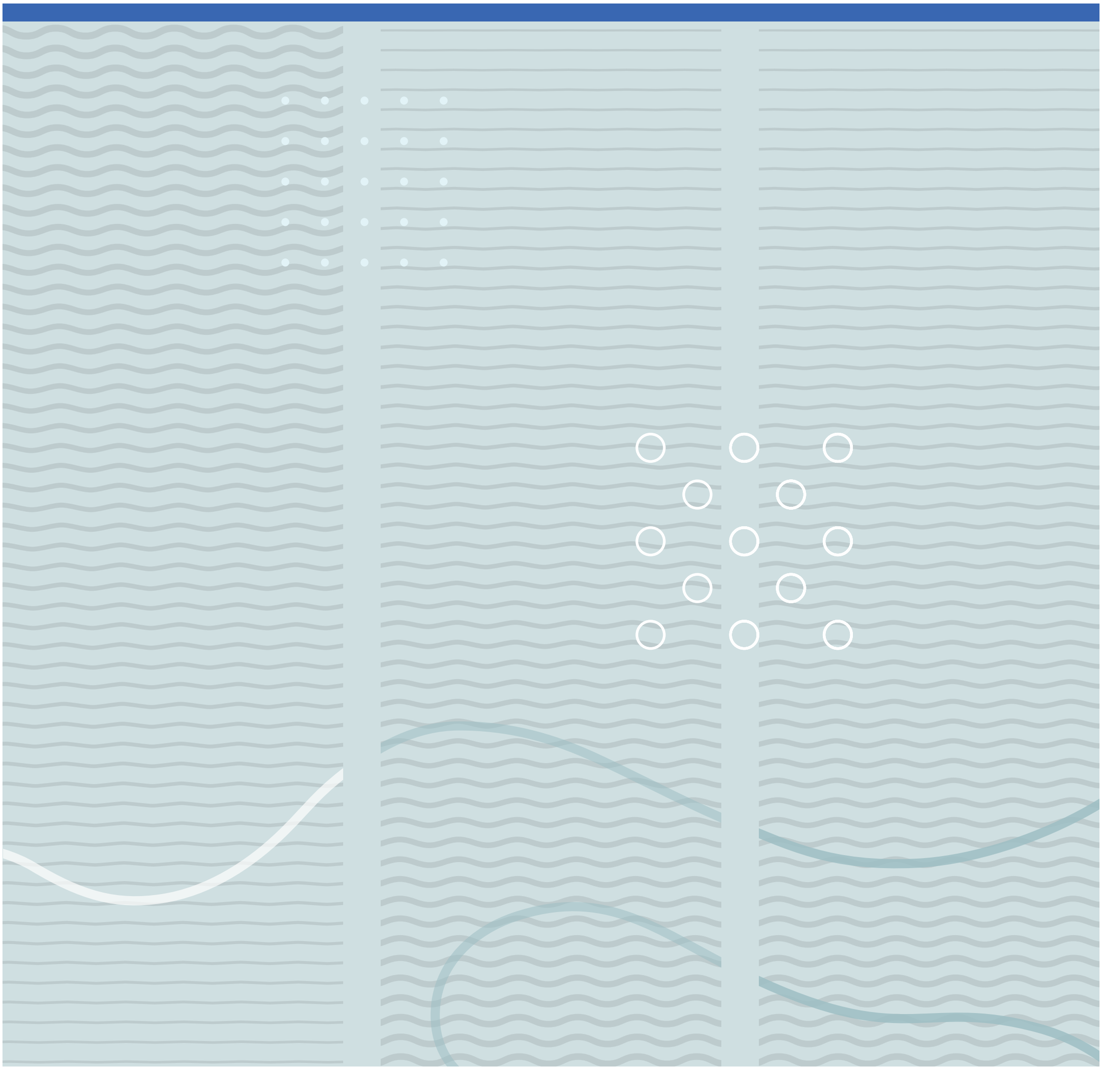
Tae-eun Kim

Maritime safety leadership

A study on leadership behaviors, an assessment instrument and future leadership for safety at sea



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A PhD dissertation in
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Preface

This thesis was prepared in partial fulfilment of the requirements for the joint Doctor of Philosophy (PhD) degree in Nautical Operations.

The main work of this thesis was carried out at the Department of Maritime Operations (IMA) at the University of South-Eastern Norway (USN), under the academic supervision of Professor Anne Haugen Gausdal and Professor Are Kristoffer Sydnes.

Pursuing a PhD degree was an important chapter of my life. It was a rewarding and challenging journey. Many ups and downs, pleasures and hardships. I was lucky to be guided and supported by wonderful mentors, colleagues and friends, whose advices, supports and encouragements have made this journey an intellectual enrichment, and a wonderful learning experience.

Vestfold, Norway

May 2020

Tae-eun Kim

Summary

Despite continual technological advancements and heightened safety standards in the merchant shipping industry, catastrophic accidents in recent years (e.g., Sanchi, Sewol ferry, Costa Concordia) have again reminded the world of the importance of safety in this industry. Investigation into maritime accidents has often revealed limited technical malfunctions but a series of organizational, managerial and leadership issues that influenced the safety culture and enabled the system to drift toward a state of higher risk.

Achieving and sustaining a safe workplace demands right and strong leadership. Considering the research conducted in various high-risk industrial settings (e.g., aviation, nuclear, healthcare, coal mining), the importance of leadership on safety has been well acknowledged and studied for many years (as elaborated in Section 2.3 and Table 8). However, there has been limited crossover of this body of work into the maritime arena. A leadership style characterized by a primary focus on promoting safety—*safety leadership*—has not been thoroughly explored in the maritime context. The current research lacks empirically tested theoretical models—with a validated and reliable scale—for describing and measuring safety leadership in daily operations. This, in turn, has limited our theoretical understanding and practice of maritime safety leadership.

In light of this knowledge gap, this thesis is carried out through a series of individual studies, with a total of 517 respondents from various merchant shipping sectors, aiming to explore and understand the safety leadership phenomenon in this context. This thesis presents five research articles, as briefly introduced in the following Figure (1). Article 1 is a background study to this PhD work, conducted to gain insights into maritime accidents and to understand the importance of human and organizational influences in maritime safety. Articles 2 and 3 are empirical studies that focus on exploring the effective safety leadership behaviors and influence tactics of shipboard officers. By considering the results derived from these two empirical studies, Article 4 focuses on developing the first Safety Leadership Self-Efficacy Scale (SLSES) in the merchant shipping context. The SLSES is developed through sequentially applying three interdependent analytical processes. Taken together, these empirical studies have resulted in a weighted model incorporating key safety leadership behavioral categories and a

safety leadership measurement scale that may facilitate the maritime researchers and practitioners to better understand, exercise and train safety leadership.

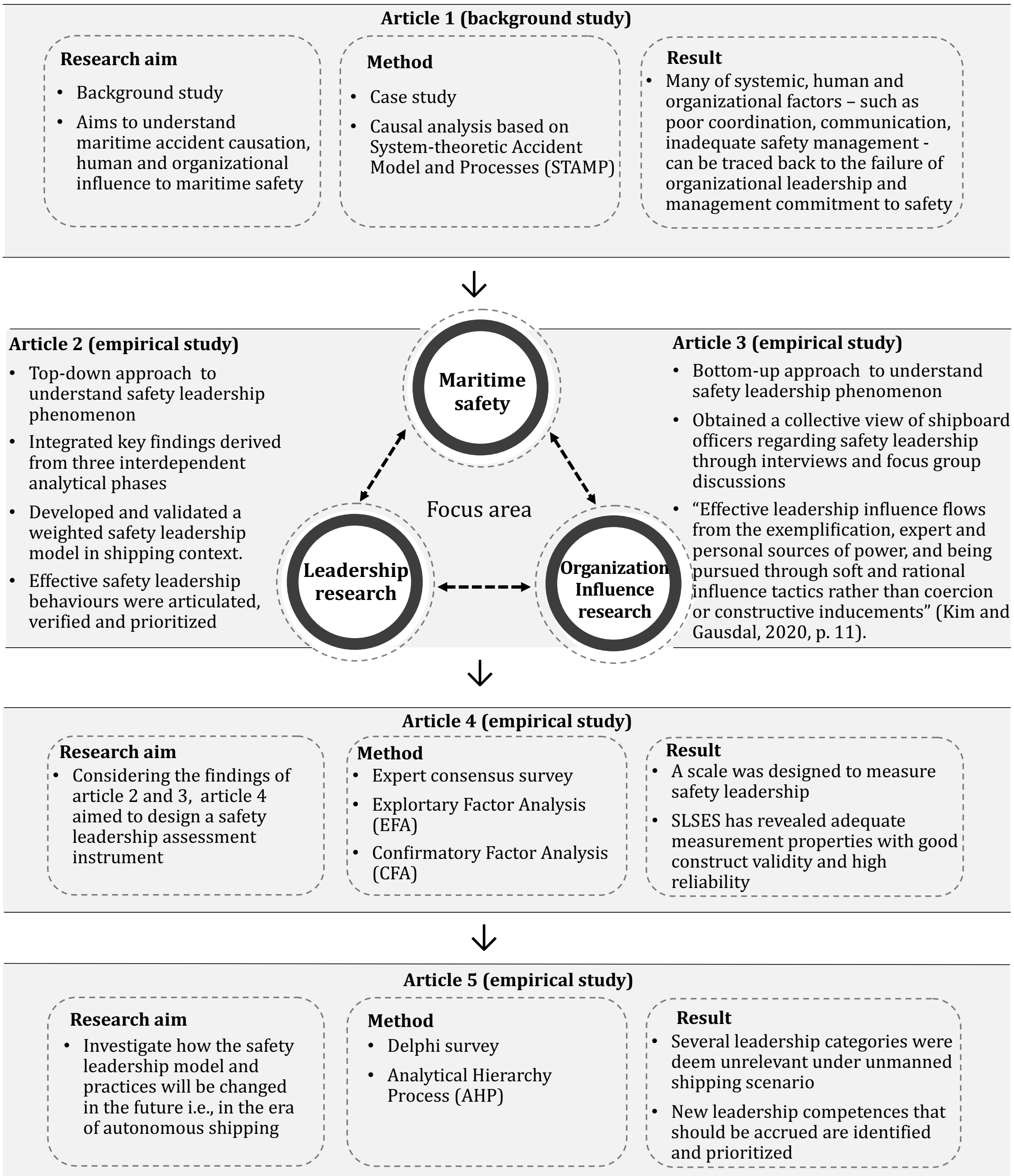

Figure (1). Summary of appended research articles

As global shipping sails into a more autonomous future, Article 5 presents an empirical analysis regarding if and how the leadership model will be changed in the future era of shipping. It identifies and prioritizes the leadership competences that should be developed by the personnel involved in autonomous ship operations. Each of these articles presents an independent but interlinked study supported by a variety of qualitative and/or quantitative research methods.

Amid all the pressing priorities in today's shipping business, the safety of the crews, passengers, cargos and ocean are the foremost moral and ethical obligations. It is one of the ultimate duties as well as challenges of today's leaders to effectively manage technology and lead people for safe and efficient ship operations. This thesis explored safety leadership behaviors and an assessment instrument as well as future leadership for safety at sea. The outcomes of this research have the following theoretical, policy and practical contributions to the maritime safety leadership field.

First, the thesis contributes to bridging a gap in the safety leadership literature, specifically the lack of an overall understanding of safety leadership in the maritime domain. It extends the existing safety leadership knowledge on how specific leaders' behaviors might affect subordinates' safety-related activities. It also provides an initial clarification regarding the leadership behaviors that are likely to motivate and promote different aspects of subordinates' safety behaviors. It further identifies which of these leadership behaviors is likely to have the most important impact on safety performance in ship operations.

Second, a measurement scale, the Safety Leadership Self-Efficacy Scale (SLSES), is formulated to serve as an instrument to facilitate an understanding of the safety leadership performance or potential of the current and future shipboard officers. Without measurement, we will have no visibility over performance and no direction for improvement. The SLSES formulated in this thesis contains 24 measurement items and three dimensions, including shipboard leaders' efficacy in safety management, motivation facilitation and safety initiatives. The scale can be used in practice by shipboard leaders to diagnose their own safety leadership levels, by subordinates to assess their leader's safety leadership performance, or by Maritime Education and Training (MET) institutes to perform more objective performance assessments. To the best of the author's knowledge, such an initiative is innovative in the current maritime safety leadership literature.

Third, no research to date has explored the impact of autonomous shipping on leadership behaviors and the leadership competence requirements specified on the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended. Article 5 of this thesis took the initiative to explore if the disruptive changes with regard to implementing Maritime Autonomous Surface Ships (MASS) will influence safety leadership behaviors and STCW leadership competence requirements. The results have shown that the current STCW leadership framework is not fully relevant for MASS. The leadership competences that should be accrued by the personnel involved in autonomous ship operations were discussed and prioritized according to their relative importance for safe operations under two different configurations of MASS.

This thesis could have policy implications for STCW Table A-II/2 (for masters and chief mates), Table A-III/2 (for chief engineer officers and second engineer officers), Table A-II/1 (for officers in charge of a navigational watch) and Table A-III/1 (for officers in charge of an engineering watch), as well as other tables that specify the same leadership Knowledge, Understanding and Proficiency (KUP). The results could contribute to professional seafarers, policy-makers and MET institutes interested in improving leadership training as well as other non-technical skill development programs. The findings generated and presented in this thesis may also, hopefully, shed light on further thoughts and research discussions for improving the safety of future ship operations.

Keywords: safety leadership, maritime industry, STCW, assessment instrument, MASS

Acknowledgements

Completing this PhD thesis, a product of several years' work, has been a truly memorable and challenging scholarly exercise for me. In my time of need and challenge, there were a great number of people who helped, supported and sustained me with their advice, guidance, friendship, good company and cheer. I wish to thank the constellation of those guiding stars for helping me in navigating the path of this PhD journey, and for making this adventure a meaningful and memorable mark in my life.

Foremost, it has been my incredible fortune to meet two experienced and dedicated supervisors: Professor Anne Haugen Gausdal and Professor Are Kristoffer Sydnes. From whom I received, not only high-quality advices, detailed and timely feedback to my thesis at different stages of its completion, but also constant support and sincere advice to my present and future academic development.

My deepest appreciation is given to Anne. Thank you for being my main supervisor for both of my master and PhD research, for patiently steering me in the right direction, and for always encouraging and supporting me when my work falls flat. This PhD journey with you, from its inception until this final remark, has been a rich and memorable learning experience for me.

A sincere gratitude also goes to my co-supervisor Are Kristoffer, thank you for your active involvement, stimulating discussions in every supervision meeting throughout this PhD process. The insightful review and advice you provided on early drafts were crucial in helping me bring this work to a higher scholarly level.

Along the journey of pursuing this PhD thesis, I have also received invaluable knowledge and support provided by many people from the academia, maritime industry and intergovernmental organization. In particular, I enjoyed the collaboration and nice discussions with Salman Nazir, Bjørn-Morten Batalden, and Steven Mallam in the writing process of Article 1, 4 and 5, respectively. It's been a pleasure collaborating with you and thanks for your contribution and support. To Hilde Sandhåland and Bjørn-Morten Batalden who were the committee members for my mid-term evaluation, as well as to Margareta Holtensdotter Lützhöft and Helle Asgjerd Oltedal who gave on-the-spot feedback during my mid-term presentation, I sincerely appreciated your evaluations and advices, as that has helped me to strengthen the quality and clarity of this work.

A research examining maritime safety leadership would hardly be completed without including the experience of individuals holding those positions. Great appreciations are owed to the CEOs, shipowners, board members, masters, maritime experts, shipboard officers, nautical subject lecturers and researchers – a total 517 respondents. They have contributed through providing “food for thought” to this PhD study, in form of interviews, group discussions or questionnaire surveys. The stories, experience and judgements they shared to me were the foundation for all the arguments presented here in this thesis.

A special note of thanks is given to Kitack Lim, IMO Secretary-General, as well as all team members in the Executive Office of the Secretary-General led by Arsenio Dominguez, who have given me a memorable working and learning experience during my PhD, and shown me a true definition of professionalism and leadership in world shipping. Grateful thanks are also due to Professor Dong-Wook Song at the World Maritime University, for mentoring and guiding me in my PhD and post-PhD endeavors, and for always enlightening me with a wealth of knowledge and experience.

I would also like to extend my appreciation to every colleague and leader here at IMA, thank you for your support and encouragement during this PhD process. To Paul Nikolai Smit, Martin Gregersen, Ketil Andre Sollien, Morten Bustgaard, Per Haavardtun, Per Eirik Undheim and Simen Hjellvik, thank you for generously setting aside time to help me with my questionnaires, for providing insider’s feedback and/or methodological advice. To PhD fellows at IMA, Atle, Jørgen, Laura, Amit, Mariia, Sathiya, Karen, thank you for the nice conversations and all social gatherings. Going through this PhD journey with you has made it more enjoyable.

Lastly, heartfelt thanks to my parents, family members and friends back home, whose unconditional support, cheers and endless love have been the fuel for all my scholarly efforts. Thank you ☺

Bakkenteigen,

Tae-eun Kim

Structure of Thesis

This thesis consists of two main parts:

Part I: This part introduces the theoretical background, research gaps and questions, as well as the methodology to be used during this PhD research. Main results generated from each study are presented and analyzed in light of its limitations, and possible areas for future research are indicated.

Part II: This part includes five journal articles prepared under this research topic. Article 1 is a background study to this thesis, Article 2 to 5 are empirical studies exploring maritime safety leadership. These articles are the main learning outcomes during my academic education in nautical operations.

List of Publications

Appended Articles:

Article 1

Kim, T., Nazir, S., Øvergård, K. I (2016). A STAMP-based causal analysis of the Korean Sewol ferry accident. *Safety Science.* 83: 93-101.

Article 2

Kim, T and Gausdal, AH (2017). Leading for safety: A weighted safety leadership model in shipping. *Reliability Engineering & System Safety* 165: 458-466.

Article 3

Kim, T and Gausdal AH (2020). Leaders' Influence Tactics for Safety: An Exploratory Study in the Maritime Context. *Safety* 6(1): 8

Article 4

Kim, T, Sydnes, Are K and Batalden, BM (2020). Development and validation of a Safety Leadership Self-Efficacy Scale (SLSES) in maritime context. *Safety Science*. 134

Article 5

Kim, T and Mallam, S (2020). A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations. *WMU Journal of Maritime Affairs*. 19:163–181

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PART I

1 Chapter: Introduction

"We have started on the right track to enduring safety improvements by looking at peoples' behaviors over the last decade, now is the time to focus on the behaviors of those who have the most impact on safety, culture, and business performance – our leaders" (Ross, 2011, p. 30)

This thesis on maritime safety leadership commences with an introduction of the industrial context, preliminary background information and research gaps that explain why the research problem under study exists. It sets the objective, defines the research questions to be explored and points out the value of this thesis.

1.1 Setting the scene: Background and context

With more than 80% of the world's trade carried by sea, merchant shipping has been considered one of the most globalized, important and interconnected industries of the modern era (Stopford, 2009; UNCTAD, 2019). Its importance in connecting continents, supporting international trade, supplying and sustaining today's global society and economy have made it indispensable to the world and to people's everyday lives (Grammenos, 2013; IAMU, 2015).

As the vanguard of globalization and one of the most important industries, merchant shipping has also widely been considered a high-risk industry (Perrow, 1999; Bergheim, Nielsen et al., 2015; Gausdal and Makarova, 2017; IMO, 2020). The sea always has perils and challenges for those who sail upon it. Although a number of regulatory responses, advanced ship designs and formal safety measures on vessels have steadily improved the safety level of ship operations over the years (Kontovas, Psaraftis et al., 2006; Kuronen and Tapaninen, 2009; Allianz, 2019), catastrophes in recent years—such as Sanchi, Sewol and Costa Concordia—have again reminded the world of the importance of safety in the maritime industry. These causalities and accidents have not only brought significant financial losses and environmental consequences but also enormous and immeasurable impacts on individuals, families and societies.

Safety in ship operations depends on many factors (Mearns, Flin et al., 2001; Hetherington, Flin et al., 2006; Hsu, Huang et al., 2015). Analysis into maritime accidents has revealed a series of causal factors (Schröder-Hinrichs, Hollnagel et al., 2012; Kim, Nazir et al., 2016). In many cases, there are very limited contributions from technical failures or machinery malfunctions but significant human, organizational and managerial issues in safety management and accident prevention that enabled the system to drift toward a higher state of risk (Chauvin, Lardjane et al., 2013; Kim, Nazir et al., 2016). Continuous advancements in ship design and navigation technologies have gradually increased the reliability of technical systems on board today's vessels and reduced the probability of technical failures, which in turn gives more attention and light to the underlying influence of human and organizational factors in accident causation (O'Dea and Flin, 2003; Hetherington, Flin et al., 2006; Schröder-Hinrichs, Baldauf et al., 2011).

Behind the errors that are revealed during the investigation in the aftermath of an accident, a series of cultural issues and dysfunctional interactions or coordination often exist within the systems, so that an error-prone condition is created (Rasmussen, 1990; Leveson, 2011). Many of those systemic errors, such as poor supervision and safety monitoring, lack of communication and teamwork, or inadequate safety management and coordination, can often be traced back to the failure of leadership to formulate a good safety culture and systemic safety solutions (Flin and Yule, 2004; Dekker, 2014; Kim, 2016; Kim, Nazir et al., 2016). As Leveson (2011) stated, "Safety starts with management leadership and commitment for safety. Without this, the efforts of others in the organization are almost doomed to failure. Leadership creates culture, which drives behavior" (p. 177).

Leadership's commitment to safety—reflected in safety concern, budget allocation, priority-setting, etc.—is considered an important differentiating factor between high- and low-accident companies (Kjellén, 1982), having a positive direct influence on the formulation of safety values and planning and executing the Safety Management System (SMS) (Aksorn and Hadikusumo, 2008; Hsu, Li et al., 2010; Tabish and Jha, 2015; Eskandari, Jafari et al., 2017). It also has crucial importance for safety culture (Flin and Yule, 2004), safety climate (Mullen and Kelloway, 2009) and subordinates' safety compliance and participation behaviors (Roger, Flin et al., 2011; Du and Sun, 2012; Fernández-Muñiz, Montes-Peón et al., 2014; Kim and Gausdal, 2017). To improve and sustain subordinates' motivation for safety, it is important that leaders are equipped with certain communication, motivational and management skills that may differ from those required to fulfill general task-oriented goals (O'Dea and Flin, 2003). Some maritime researchers (Oltedal and McArthur, 2011) have also observed a positive association between the respondent's perception of their manager's leadership skills and increased reporting frequency. Without the right leadership in place, good SMS is less likely to succeed and sustain.

These research findings have clarified and substantialized the importance of leadership intervention for safety-related outcomes and have also increased the credibility for safety leadership training and development.

1.2 Research gaps, objectives and questions

Although extensive research in various hazardous industrial contexts has identified leadership as a key factor for safety, there has been little crossover of this body of work into the maritime arena (Theotokas, Lagoudis et al., 2014). Leadership that is characterized by a primary focus on influencing safety—*safety leadership*—has rarely been investigated thoroughly in the merchant shipping context alongside general leadership styles.

To ensure mariners are equipped with the necessary leadership competences, leadership training has been included as a mandatory competence requirement for shipboard officers at both the operational and management levels, under the Manila Amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended (IMO, 2017; Oltedal and Lützhöft, 2018). The responsibility to fulfill this requirement falls on the MET institutions in each jurisdiction to develop and implement leadership training programs with or without consideration of the International Maritime Organization (IMO) leadership model course (Mori, 2014). Often, leadership skills were taught through Bridge Resource Management (BRM) courses (Oltedal and Lützhöft, 2018). BRM was developed primarily based on aviation Crew Resource Management (CRM) as well as generic leadership knowledge, with few sector-specific adjustments and scientific adaptations to the maritime context (Barnett, Gatfield et al., 2003; Oltedal and Lützhöft, 2018).

Whether such leadership training has its intended effect has been debated (O'Connor, 2011), as "sector-specific characteristics may render an approach used in aviation less suitable for the maritime sector" (Oltedal and Lützhöft, 2018, p. 80). Prior research has noted that the BRM training intervention did not have a significant effect on the attitudes and knowledge of officers (O'Connor, 2011). One reason for this is that leadership research is lacking in this particular industrial context (O'Connor, 2011; Mori, 2014).

What becomes evident when reviewing the literature (see Table 8) is the lack of consistent thrust in studying the leadership behaviors of shipboard officers for current and future ship operations. Current research also needs a reliable and valid safety leadership measurement instrument to facilitate the recognition of safety leadership performance and the scientific development of safety leadership competence. The generic leadership models (e.g., transformational and transactional leadership theory (Bass and Stogdill, 1990), Leader-Member Exchange (Gerstner and Day, 1997)) encompass a wide range of styles, traits and behaviors. However, to facilitate the empirical training and development of shipboard officers, the propositions of these general leadership theories may be too abstract to be implemented in the training strategies (Kim, 2016). They also provide limited indication of the important leadership competences that should be accrued by the personnel involved in ship operations. These ambiguities, in turn, limit the effectiveness of leadership training. Furthermore, very few academic discussions (e.g., Kitada, Baldauf et al., 2018) have been held on the potential impact of MASS on leadership for future ship operators, and no research to date has evaluated the applicability and relevance of STCW leadership requirements under different MASS operational scenarios.

Based on these identified knowledge gaps, the research problem is that there is a lack of knowledge regarding safety leadership in the maritime context, despite its importance for ship operations. The objective of this thesis is therefore to explore and understand safety leadership phenomena in merchant shipping to broaden our theoretical understanding of maritime safety leadership and to guide practitioners in establishing best leadership practices. To address this objective, this thesis has centered on the following research questions:

Research question #1: What are the key safety leadership behaviors that should be demonstrated at each managerial level in shipping organizations?

1.a. What are the key safety leadership behaviors in high-risk organizations? How can the safety leadership contribution be understood through the lens of systems thinking?

1.b. Are the key safety leadership behaviors in high-risk organizations transferable/applicable to shipping organizations?

1.c. What is the relative significance of each safety leadership behavior in determining the overall safety performance for shipping organizations?

Research question #2: What are the interpersonal influence tactics employed by shipboard leaders that successfully influenced their subordinates' safety compliance and participation behaviors in ship operations?

Research question #3: What are the indicators of good safety leadership, and how can the safety leadership efficacy of the current and future shipboard officers be measured?

Research question #4: What are the leadership implications of autonomous shipping?

4.a. What is the applicability of current leadership competence requirements for MASS operations?

4.b. What are the future leadership competences that should be accrued by the personnel involved in MASS operations?

Each of these research questions is linked to a specific research aim that has been addressed and investigated by a series of studies, as illustrated in Figure 1.

Article 1 (background study)

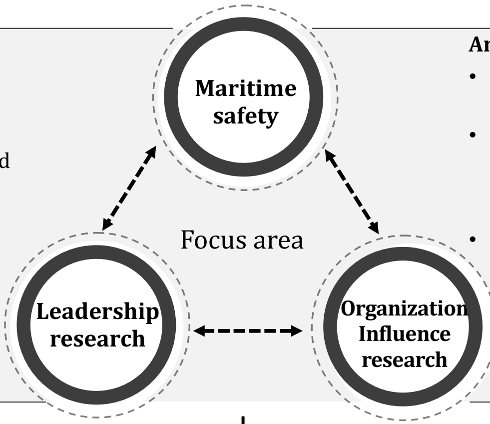
Research aim
- Background study
- Aims to understand maritime accident causation, human and organizational influence to maritime safety

Method
- Case study
- Causal analysis based on System-theoretic Accident Model and Processes (STAMP)

Result
- Many of systemic, human and organizational factors – such as poor coordination, communication, inadequate safety management - can be traced back to the failure of organizational leadership and management commitment to safety

Research question#1 & 2
- What are the key safety leadership behaviors that should be demonstrated at each managerial level in shipping organizations?
- What are the interpersonal influence tactics employed by shipboard leaders that successfully influenced their subordinates' safety compliance and participation behaviors in ship operations?

Article 2 (empirical study)
- Top-down approach to understand safety leadership phenomenon
- Integrated key findings derived from three interdependent analytical phases
- Developed and validated a weighted safety leadership model in shipping context.
- Effective safety leadership behaviours were articulated, verified and prioritized



Article 3 (empirical study)
- Bottom-up approach to understand safety leadership phenomenon
- Obtained a collective view of shipboard officers regarding safety leadership through interviews and focus group discussions
- "Effective leadership influence flows from the exemplification, expert and personal sources of power, and being pursued through soft and rational influence tactics rather than coercion or constructive inducements" (Kim and Gausdal, 2020, p. 11).

Research question #3:
- What are the indicators of good safety leadership, and how can the safety leadership efficacy of the current and future shipboard officers be measured?

Article 4 (empirical study)

Research aim
- Considering the findings of article 2 and 3, article 4 aimed to design a safety leadership assessment instrument

Method
- Expert consensus survey
- Explortary Factor Analysis (EFA)
- Confirmatory Factor Analysis (CFA)

Result
- A scale was designed to measure safety leadership
- SLSES has revealed adequate measurement properties with good construct validity and high reliability

Research question #4:
- What are the leadership implications of autonomous shipping?
  - 4.a. What is the applicability of current leadership competence requirements for MASS operations?
  - 4.b. What are the future leadership competences that should be accrued by the personnel involved in MASS? operations?

Article 5 (empirical study)

Research aim
- Investigate how the safety leadership model and practices will be changed in the future i.e., in the era of autonomous shipping

Method
- Delphi survey
- Analytical Hierarchy Process (AHP)

Result
- Several leadership categories were deem unrelevant under unmanned shipping scenario
- New leadership competences that should be accrued are identified and prioritized

Figure 1. Research questions, methodological choices and results

1.3 Structure of the thesis

This thesis presented five journal articles in Part II. Information regarding each of the articles is presented in the following Table 1.

Table 1. Appended articles

Article Title	Authors	Journal	Index	Status
Article 1: A STAMP-based causal analysis of the Korean Sewol ferry accident	Tae-eun Kim Salman Nazir Kjell Ivar Øvergård	Safety science	SCI (E)[1] NSD level 2	Published
Article 2: Leading for safety: A weighted safety leadership model in shipping	Tae-eun Kim Anne Haugen Gausdal	Reliability Engineering & System Safety	SCI (E) NSD level 2	Published
Article 3: Leaders' Influence Tactics for Shipboard Safety – An Exploratory Study	Tae-eun Kim Anne Haugen Gausdal	Safety	e-SCI[2] NSD level 1	Published
Article 4: Developing and Validating a Safety Leadership Self-Efficacy Scale (SLSES) in Maritime Context	Tae-eun Kim Are Kristoffer Sydnes Bjørn-Morten Batalden	Safety science	SCI (E) NSD level 2	Published
Article 5: A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations	Tae-eun Kim Steven Mallam	WMU Journal of Maritime Affairs	e-SCI NSD level 1	Published

The following Chapter 2 will introduce the literature background to familiarize the readers with this topic. Maritime safety, leadership and influence theories, as well as existing research on safety leadership will be provided. Chapter 3 details the methodological choice as well as the strategies for data collection and analysis. Each of the research methods mentioned in Figure 1, their usages and contributions in exploring the research questions will be described. The main results will be presented and analyzed in Chapter 4 in light of the objective of this thesis. Chapter 5 concludes this thesis with an overview of the research contributions, views the findings in the light of its limitations, and provides an outlook and recommendations for future work.

[1] SCI (E): Science Citation Index Expanded

[2] e-SCI: Emerging Sources Citation Index

2 Chapter: Theory and Regulatory Background

This chapter introduces and elaborates on each of the knowledge areas relevant for the exploration of the research questions described in Chapter 1. It presents two relevant maritime regulations and leadership theories as well as the latest research results related to maritime safety leadership in order to provide the theoretical background and debates relevant to this research topic.

2.1 Maritime safety

Safety has long been considered an important aspect of shipping due to the high potential for human, financial, legal and reputational consequences (Perrow, 1999; Kim and Gausdal, 2017). The professional mariners who operate commercial vessels today are the key on-scene decision-makers, problem-solvers, safety and security managers whose technical competence, ship-handling knowledge, management and leadership skills have been crucial in making today's commercial shipping more safe, secure and efficient (Schröder-Hinrichs, Hollnagel et al., 2013; Barnett, 2017). However, the consequences of leadership failures—as observed in many catastrophic accidents in history, such as those of the Green Lily, Costa Concordia, Bow Mariner, and Sewol ferry—have also illustrated the potential for severe consequences.

The majority of maritime accident investigations have concluded that human errors are the primary cause (Rothblum, 2000; Toffoli, Lefevre et al., 2005; Allianz, 2019). We expect good decisions, good command and leadership from the operators and are grievously disappointed if they fail to provide it, especially in critical situations (Kim and Gausdal, 2017). The traditional safety approach has focused on increasing reliability by reducing the chance of errors in human operators and other system components (Leveson, 2011). However, this safety approach has been criticized (Hollnagel, Woods et al., 2012; Leveson, Dulac et al., 2012), as the technological systems that we operate today in this dynamic, socio-technical, complex digital world cannot be effectively controlled by only pursuing reliability (Leveson, 2011). Making all components highly reliable does not necessarily make the overall operation safe (Leveson, 2011; Kim, Nazir et al., 2016). More and more system interaction accidents have happened, as compared to component failures (Leveson, 2011). The interdependencies and interactions among different actors, such as human operators, technical systems, and other system components have become increasingly critical for safe and efficient operations (Perrow, 1999). Several researchers have advanced the safety approaches by expanding the focus to the system as a whole (Rasmussen, 1997; Leveson, 2011; Hollnagel, 2012). The decisions made by the human operators are influenced by the context in which they occur, the design of the technologies they use, the dynamic work processes they need to control, and the social, organizational and cultural environments in which they work (Reason, 1990; Woods, Dekker et al., 2010). To effectively improve safety and to prevent human errors from future occurrence, it is crucial not only to control and seek to eliminate individual errors to ensure reliability but also to bring structural changes, design out the potential hazards and formulate a safe working environment so that real improvements can be made (Kim, Nazir et al., 2016). All these efforts will demand strong leadership and organizational commitment.

2.1.1 Relevant international maritime regulations

Safety at sea depends on the professionalism and competence of seafarers. It also depends greatly on how the management activities (e.g., safety management, maintenance planning and crew training) are performed on shore to ensure the safer deployment of ships in a well-crewed, seaworthy and good maintenance condition. Two important IMO instruments are particularly relevant to this safety leadership research.

The International Safety Management (ISM) Code

Following several high-profile maritime disasters (e.g., the MS Herald of Free Enterprise in 1987, Doña Paz in 1987, Exxon Valdez in 1989, Braer in 1993 and Estonia in 1994), an important instrument, the International Safety Management (ISM) Code, was introduced by the IMO to embody its pursuit of addressing critical human element and organizational issues in maritime safety (IMO, 2002; Anderson, 2003; Batalden and Sydnes, 2014). The code was made mandatory through the International Convention for the Safety of Life at Sea, 1974 (IMO, 2004). The ISM Code was applied in 1998 for all passenger ships, oil tankers, chemical tankers, gas carriers, bulk carriers and cargo high-speed craft of 500 gt and upwards (Ringbom, 2008). With respect to all other cargo ships and mobile offshore units of 500 gt and upwards, the date of implementation was July 2002 (Ringbom, 2008; Kristiansen, 2013).

Since the adoption of the ISM Code, international shipping companies have been required to design, develop and execute an SMS that aligns with the company's policies and relevant national and international legislative requirements (IMO, 2014) in order to minimize the risks associated with people, property and the environment (Celik, 2009; Lindøe, Engen et al., 2011). The established SMS should detail the important safety policies and procedures that need to be followed to ensure the safe functioning of ships at the sea, and it plays a key role in ship operations (Anderson, 2005). Nevertheless, the ISM Code does not include details regarding how this SMS should be achieved (Batalden and Sydnes, 2014). The effectiveness of an SMS, and consequently the safety performance, depends to a large extent on how the leaders both on board and ashore would establish the SMS, value and approach its implementation (MCA, 2004; Bhattacharya, 2012). As stated in the preamble to the ISM Code, "In matters of safety and pollution prevention, it is the commitment, competence, attitudes and motivation of individuals at all levels that determines the end result" (IMO, 2014).

The safety goals would not be accomplished without leadership commitment, individual competence, collaborative work and the safe functioning of the systems. Correspondingly, it is important to develop and enhance leadership skills conducive to safety for leaders on both sea and shore in a shipping organization.

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended

The STCW 1978, as amended, sets the minimum qualification standards for global seafarers (IMO, 2017). Since its introduction in 1978, the convention has been revised several times to keep pace with technological developments and new competence requirements for seafarers. During the last major revision, the STCW 2010 Manila

Amendments, "Leadership and Teamwork" was inserted as a compulsory competence requirement in Part A of the Code for those who would like to be certified or renew their certificates (Mejia, 2010; IMO, 2011). This implies that leadership skills are mandatory not only for the management-level shipboard officers (e.g., masters, chief mates, chief engineers) but also the operation-level officers (e.g., officers in charge of a navigational or engineering watch) (IMO, 2011). The rationale behind the amendment rests upon the increasing importance of the human element in ensuring safety in ship operations, as well as the acknowledgment of the important role shipboard leaders play in this risky and isolated working environment. The required leadership competences, as stated in STCW 1978, as amended, are summarized in Table 2.

Table 2. Leadership competence requirements for management and operational level onboard conventional merchant ships as set out in STCW Table A-II/2, Table A-III/2, Table A-II/1 and Table A-III/1 (IMO, 2017; Kim and Mallam, 2020)

Target	Knowledge, Understanding and Proficiency (KUP)
STCW required leadership competence for both management and operational level onboard conventional merchant ships	Knowledge of shipboard personnel management and training
	Knowledge of related international maritime conventions and recommendations, and national legislation
	Ability to apply task and workload management, including: .1 planning and coordination .2 personnel assignment .3 time and resource constraints .4 prioritization
	Knowledge and ability to apply effective resource management: .1 allocation, assignment, and prioritization of resources .2 effective communication on board and ashore .3 decisions reflect consideration of team experience .4 assertiveness and leadership, including motivation .5 obtaining and maintaining situation awareness
	Knowledge and ability to apply decision-making techniques: .1 situation and risk assessment .2 identify and generate options .3 select course of action .4 evaluation of outcome effectiveness
	Development, implementation, and oversight of standard operating procedures (*only for management level)

To ensure that seafarers acquire competence as set out in the convention, an IMO model course on leadership is provided (IMO, 2014), and the MET institutes in each member state offer training courses and programs for nautical and technical officers. The requirement applies to international seagoing officers but, to the author's knowledge, has also been incorporated into many domestic maritime regulations. Shipboard officers at the management level are the designated leaders who wish to lead effectively in a culturally diverse, dynamic but closed social environment while gaining respect, participation and compliance from their crew members.

The intention of leadership training is to raise the competence level of shipboard officers with regard to leadership, teamwork and management skills. However, as effective leadership practices and behaviors have not been thoroughly explored in this specific industrial context, the course materials and training programs developed were mainly based upon the trainers' personal experiences and CRM courses, which were initially developed in the aviation industry for cockpit crews but modified for application in a maritime setting (O'Connor, 2011). This situation formulated a critical need for research into safety leadership phenomena in maritime context to enrich the teaching resources and survey instruments to address this knowledge gap.

2.2 Leadership and influence theories

Burns (1978, p. 2) remarked that "leadership is one of the most observed and least understood phenomena on earth." In addition to the complexity of the phenomenon, "there are almost as many definitions of leadership as those who have attempted to define the concept" (Bass and Stogdill, 1990, p. 11). How we define the concept will guide how we study it (Hunt, 2004). It is therefore worthy, in this safety leadership study, to discuss several key leadership theories and the leadership definition used for this research.

2.2.1 The nature and definition of leadership

Leadership is one of the most examined phenomena in social science (Antonakis, Cianciolo et al., 2004). It is a phenomenon evident in humankind and animal species

(Bass and Stogdill, 1990) and has critical importance for group, organizational and societal functioning (Antonakis, Cianciolo et al., 2004). The term "leader" was conceptualized before biblical times and noted in the 1300s, whereas the term "leadership" appeared during the late 1700s (Stogdill, 1974; King, 1990). Scientific research on the topic of leadership was not very active until the twentieth century (Stogdill and Bass, 1981) but flourished afterwards, with intensive research exploring what makes an effective leader and how leadership influences performance.

The initial thought on leadership was largely based on the impact of exceptional influential individuals, heroes, kings and politicians in the history of the world (Carlyle, 1846; King, 1990). Their superior attributes, intellects, personalities and courage seemed to determine their influence in history (Carlyle, 1846). Thomas Carlyle expressed his view on leadership by stating that "the history of the world is but the biography of great men" (Carlyle, 1846). Early ideas about leadership centered around this notion that leadership is an inborn talent of individuals, whose influence potential depends primarily on traits and other innate personal qualities. It is assumed that only the person who possesses this personality and these traits can ever be a great leader. Leaders, under this rationale, are born, not made (Bass and Stogdill, 1990; Tubbs and Schulz, 2006). However, this notion has received substantial criticism from many influential scientists. Among many, sociology pioneer Herbert Spencer, in his book *The Study of Sociology* (1873), made a forceful argument:

> You must admit that the genesis of a great man depends on the long series of complex influences which has produced the race in which he appears, and the social state into which that race has slowly grown . . . Before he can remake his society, his society must make him. (p. 166)

Moreover, the evidence became clear for researchers that there is no common list of traits among leaders, and it is unrealistic to predict leadership potential solely on the basis of personal traits (Johns and Moser, 1989). Leadership research after World War II moved from trait theory to the human relations school of thought (Greenwood, 1996) and emphasized "influence" more than traits or other intrapersonal characteristics (Stogdill, 1975). Researchers noted that leadership should be considered a learned skill and has little to do with innate personal qualities and genetic endowment (Organ, 1996).

A number of authors (e.g., Katz and Kahn, 1966; Burns, 1978; Bass and Stogdill, 1990) have approached leadership influence from various aspects and offered various definitions of leadership. Katz and Kahn (1966) defined leadership as "any act of influence on a matter of organizational relevance" (p. 334). Burns (1978) defined leadership as "inducing followers to act for certain goals that represent the values and the motivations—the wants and needs, the aspirations and expectations—of both leaders and followers" (p. 19). Greenwood (1996) viewed leadership as "the process of influencing people to direct their efforts toward the achievement of some particular goal or goals" (p. 4).

Leadership has been defined in different ways, but in principle, most of the theorists agree that leadership is an influencing process (Antonakis, Cianciolo et al., 2004; Yukl, 2013). In this thesis, leadership is also viewed as an influencing process between leaders and followers. If leadership is about influence, it is then important to cultivate and maximize the use of influence in order to become an effective leader, and the same for an effective safety leader. As explored by Yukl (2013) (see Figure 2), the source of leaders' influence is not only associated with the leaders' traits, skills or personal characteristics but also the behaviors and influence processes demonstrated to their followers, which could influence the followers' attitudes and behaviors and, consequently, the performance outcomes.

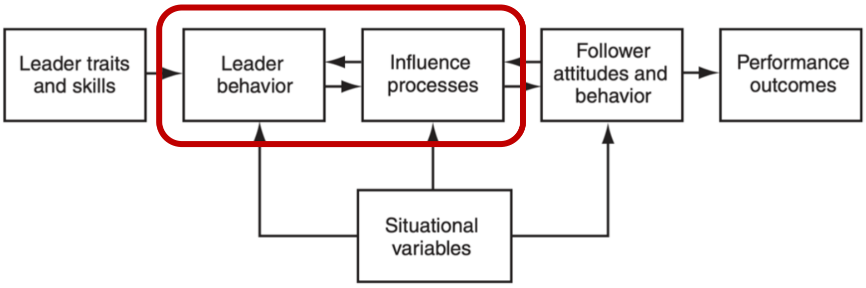


Figure 2. Leadership variables and causal relationships (adapted from Yukl, 2013, p. 11)

A person's value system, personality type, traits or other experiences (such as accident exposure) can be used to explain one's motivation to initiate a leadership attempt and demonstrate certain leadership behaviors or influence tactics (Conchie and Moon, 2010;

Yukl, 2013). However, such individual antecedents are hard to change through short-term training programs and are not practical to incorporate into regulations and industrial practices. This thesis therefore focuses on two leadership variables, leader behaviors and influence processes, as the main areas of exploration.

2.2.2 Key leadership theories

Transformational and transactional leadership theories dominate in general leadership studies, and they are arguably the most popular theories in leadership research in this century (McCleskey, 2014). Burns (1978) conceptualized leadership as either transformational or transactional. He viewed leadership as a proactive process of influence and change toward a greater common vision (Clark and Harrison, 2018). Transactional leaders are those who lead through social exchange (e.g., rewards and punishments), whereas transformational leaders are those who inspire and empower their followers to achieve performance beyond expectations (Burns, 1978).

Bass (1985) advanced this transformational and transactional leadership theory and presented a full-range leadership model (Bass, 1985) that incorporated both aspects of "old" elements (e.g., roles, task elements) and "new" leadership elements (e.g., charisma, vision) (Antonakis, 2012). Subordinates were placed at the center of this leadership strategy. Leaders are required to demonstrate a combination of leadership practices with the use of charisma, ability and vision. Transformational leadership comprises four facets, namely idealized influence (i.e., leaders as examples for their followers to imitate), inspirational motivation (i.e., followers are encouraged to achieve beyond their individual goals), intellectual stimulation (i.e., leaders inspire followers to think creatively and innovatively) and individualized consideration (i.e., leaders demonstrate respect and personal concern to followers) (Bass and Avolio, 1993).

Transactional leadership comprises two facets: contingent reward (i.e., rewards and recognition for good behaviors) and management by exception (i.e., proactive and emphasizing prevention) (Avolio, 1999). Another leadership theory that has been used in safety leadership research is the Leader–Member Exchange (LMX) theory, a relationship-based approach focusing on the dyadic relationship between leaders and followers

(Hofmann and Morgeson, 1999). Both LMX and transactional leadership theory consider that leadership exists not only in the individuals and/or the situation, but more in the relationship developed through social interaction and role differentiation (King, 1990). The quality of the dyadic relationship developed by the leaders will influence the followers' behaviors and performance, which is a reflection of one's leadership effectiveness. Transformational and transactional leadership are the dominating theories both in the field of general leadership studies and in safety leadership research (Clarke, 2013; Tao, Yang et al., 2020). This study builds on this theoretical base and assumes that transformational and transactional leadership are fundamental to understanding maritime safety leadership.

2.2.3 Influence research

As argued by many leadership theorists (Stogdill, 1975; Burns, 1978), leadership should be seen as an influence process between or among individuals rather than an inner characteristic or inborn talent of an individual. Leadership effectiveness is determined by the influence the leader possesses and how resourceful he or she is in executing that influence to persuade subordinates (Yukl, 2013). Leadership research has studied unidirectional and multidirectional influence, including downward, upward and lateral influence (Yukl, 2013). Downward influence attempt is often referred to as use of leadership influence, in which the leader is assumed to be the key agent while his or her subordinates are conceived as passive receivers of influence. Under this rationale, improving leadership potential and effectiveness would depend on how good the leaders are at using influence methods and tactics. Several studies (e.g., Kipnis, Schmidt et al., 1980; Schriesheim and Hinkin, 1990; Yukl and Falbe, 1990; Schermerhorn and Bond, 1991) have explored these influence tactics and strategies in order to increase the understanding of influence processes, as the use of appropriate influence strategies or tactics could pave the way to leadership effectiveness.

The approach to influencing followers can be further divided into hard, soft and rational tactics (Kim and Gausdal, 2020). Soft influence tactics (e.g., inspirational appeals, consultation, ingratiation) are related to transforming followers' value systems into alignment with the goals, which reflects a transformational leadership style (Emans, Munduate et al., 2003). On the other hand, exchange and persuasion are considered rational influence tactics and are closely aligned with transactional leadership (Clarke and Ward, 2006). Hard influence tactics (such as pressure and legitimating) draw on one's authority and positional power to force followers into compliance in an impersonal way (Mullaney, 2013). The use of rational persuasion and coalition were found to be directly effective in enhancing subordinates' safety participation and involvement (Clarke and Ward, 2006). These research findings from general organizational influence research will be used as the theory foundation for Article 3, in which shipboard leaders' influence tactics for safety will be interpreted and analyzed in light of these previous studies.

2.3 Safety leadership research

Safety leadership has been defined as "a process of interaction between leaders and followers to achieve organizational safety goals" (Wu, 2005). Leadership influence on safety performance "is both theoretically logical and empirically supported" (Hoffmeister, Gibbons et al., 2014, p. 69).

Several researchers (Butler and Jones (1979); Dunbar (1975) Simard and Marchand (1994); Hofmann and Morgeson (1999); Zohar (2002)) have spearheaded the field of safety leadership research by providing empirical evidence for recognizing the importance of leadership for safety. Later studies have further proved that organizations in which leaders take an active role in promoting safety have better safety reporting (O'Dea and Flin, 2001; Vredenburgh, 2002), better safety culture and climate (Zohar, 2003; Farrington-Darby, Pickup et al., 2005) and better safety records (Hofmann, Jacobs et al., 1995; de Koster, Stam et al., 2011; Lekka and Healey, 2012). Maritime accident analysis research has also revealed that leadership and organizational failures (e.g., insufficient support, inadequate priority and safety value) can be an important contributing factor to maritime accidents (Kim, Nazir et al., 2016). Leadership research has also shown that accidents can be effectively prevented or reduced with supervisors' engagement in safety leadership behaviors(Conchie and Moon, 2010), as followers' safety compliance and participation behaviors are highly influenced by the leaders' behaviors they are modeling (Griffin and Neal, 2000). Cooper (2010) identified that senior, middle and front-line managers' safety leadership accounts for 86% of the variations in employees' safety behaviors and the corrective action rate in the construction industry.

A meta-analysis has revealed that both transformational and transactional leadership styles have beneficial effects for followers' safety behaviors (Clarke, 2013). Leaders' behaviors associated with a transformational leadership style have been consistently found to be important predictors of safety outcomes (Fernández-Muñiz, Montes-Peón et al., 2017). The effect is evident in terms of increased safety behaviors, workers' rule compliance, safety motivation (Barling, Loughlin et al., 2002), decreased unsafe behaviors and industrial injury rates (Zohar, 2002, 2003). In the study conducted by Barling, Loughlin et al. (2002), transformational leadership associated behaviors were found to predict occupational injuries through the effects of perceived safety climate, safety consciousness and the conduction of safety-related events. Transformational leadership has been identified as an even more important predictor of safety performance compared to hazard reduction systems (de Koster, Stam et al., 2011). Transactional leadership has also been found as a strong predictor for safety performance, as leaders' supervision, monitoring and provision of contingent consequences (i.e., reward/punishment) are necessary to maintain performance reliability, especially during routine job operations (Lu and Yang, 2010; Martínez-Córcoles and Stephanou, 2017).

A high-quality LMX relationship positively influences safety communications, safety commitment and subsequent accidents (Hofmann and Morgeson, 1999). The exchange relationship is also significantly related to followers' safety-related citizenship behaviors (e.g., initiating safety-related change, safety-related helping, voice, stewardship and whistle-blowing) (Hofmann, Morgeson et al., 2003), reduced safety-related events and enhanced workplace safety (Michael, Guo et al., 2006). Followers' safety commitment and engagement are highly influenced by perceived organizational support as well as the quality of interpersonal relationships (Eid, Mearns et al., 2012). Ginsburg, Chuang et al.

(2010) found that organizational leadership for safety also significantly influenced the learning outcomes from minor, moderate and major near-misses, which are valuable inputs for an organization to update its safety management practices and generate corrective/preventive action. In the merchant shipping context, a positive association between the followers' perception of their manager's leadership skills and the frequency of incident reporting is also recognized (Oltedal and McArthur, 2011).

In essence, safety leadership has been perceived as an important external source that could influence or regulate followers' safety behaviors (Griffin and Hu, 2013). Safety leadership competence is critical in determining followers' degree of safety compliance and participation (Clarke, 2013), having a strong causal relationship with safety climate (Wu, Chen, & Li, 2008) and impact on overall safety outcome, namely a reduced number of work-related injuries and incidents (Mullen & Kelloway, 2009; Ross, 2011). In spite of the different industrial contexts and research approaches, certain leadership behavioral categories repeatedly appeared during the literature review, indicating their strong implications for positive safety outcomes. These common behavioral categories will be presented and analyzed in Chapter 4.

In sum, the previous safety leadership research conducted in a general high-risk industrial context (Section 2.3), in addition to the aforementioned generic leadership theories and organizational influence research (Section 2.2), formed an important theoretical basis for the author to analyze and discuss the data generated from this thesis.

3 Chapter: Research Methodology

Appropriate research design and method selection are essential prerequisites to drawing valid conclusions and inferences. In pursuit of the research questions as specified in the introduction, this thesis was designed by incorporating both qualitative and quantitative approaches to explore the safety leadership phenomenon in the merchant shipping context. This chapter will provide detailed descriptions regarding the methods selected for each empirical study. Methodological challenges and ethical considerations pertaining to this thesis will also be discussed. Please note that the methods for the particular studies are presented in full in the appended articles.

3.1 Social science research methods

Scientific research philosophy and reasoning

The belief about how the data should be collected and analyzed for the study of a phenomenon is referred to as the *research philosophy* (Saunders, 2011). The philosophy selected and adopted in a study contains important assumptions regarding the way in which the researchers view the world and how knowledge can be created (Crossan, 2003; Holden and Lynch, 2004; Saunders, 2011). There are five main research philosophical perspectives: pragmatism, positivism, critical realism, interpretivism and postmodernism (Saunders, 2011). According to Saunders (2011), pragmatism, by using a variety of research methods, focuses on improving practices and supports the concepts only if they could support action. Positivism considers the world as a closed system wherein a cause-and-effect relationship can be observed; it is often applied in the physical and natural sciences. Critical realism focuses on exploring the underlying mechanisms to offer an explanation of how and why the social phenomena are structured. Interpretivism, as a subjectivist philosophy, seeks to explore the lived experiences of individuals or groups and incorporate the perspectives and interpretations of both informants and researchers into the research. Postmodernism seeks to question the previous ways of thinking and values the subjective perspectives of collective individuals and communities. The choice of research philosophy is mostly determined by the research problem under study (Saunders, 2011). Since this research is concerned with exploring safety leadership behaviors and the influence process as well as seeking a way to measure safety leadership behaviors in a real-life context, a pragmatism perspective is adopted as the research philosophy, with a combination of both positivist and interpretivist positions to approach the research questions.

During the scientific process, three reasoning approaches can be used: deductive, inductive and abductive (Walton, 2014). Positivist studies usually adopt deductive reasoning, which moves from a general rule to a more specific conclusion, commonly called a "top-down" approach (Crowther and Lancaster, 2012). Inductive reasoning moves from specific observations to broader generalizations in light of the accumulated evidence, which is more aligned with a "bottom-up" approach and is highly associated with the interpretivism philosophy (Sternberg, 1986). Abductive reasoning, as a mixture of inductive and deductive approaches, begins with incomplete observations and moves toward the likeliest possible explanation (Walton, 2014). This thesis uses these three reasoning approaches with the following research methodologies to acquire knowledge and build a fuller understanding of the research problem.

Methodological approach

Qualitative, quantitative and mixed-methods are the three main approaches to human and social science research (Bernard and Bernard, 2013). The qualitative approach is concerned with understanding human behaviors and social phenomena from the perspectives of informants (Yin, 2015). The quantitative approach aims to test hypotheses through the generation of numerical data to uncover patterns and relationships that can be projected to a larger population (Bernard and Bernard, 2013). Those who engage in the quantitative approach focus on hypothesis testing and seeking generalizable results with a large sample size. Those who engage in the qualitative approach seek to generate theories through exploring the lived experiences of humans through naturalistic research methods such as interview, observations and field study to explore and understand the underlying reasons, opinions and meaning individuals or groups ascribe to the problem under study (Yin, 2015). The decision regarding which research approach to use—quantitative, qualitative or mixed-methods—lies within the essence of the research question (Eisenhardt and Graebner, 2007). Quantitative research methods are suited to verifying an existing set of defined variables of an established theory, while a qualitative approach is especially useful to explore the "how" or "why" of a phenomenon rather than "how many" or "how much" (Eisenhardt, 1989). In this thesis, a mixed-methods approach (Denscombe, 2008) was used, which incorporates the elements of both quantitative and qualitative approaches to obtain a more complete understanding of the research questions. The methodological choice for each article is summarized in Table 3 and will be introduced individually in the following Section 3.2.

Table 3. Methodological choice for each research study

Article Title	**Approach**	**Method/Statistical technique**	**Data**
Article 1: A STAMP-based causal analysis of the Korean Sewol ferry accident	Qualitative	Case study	Accident materials
Article 2: Leading for safety: A weighted safety leadership model in shipping	Qualitative/ Quantitative	Systematic literature review Delphi method Analytic hierarchy process (AHP)	24 respondents[3]
Article 3: Leaders' Influence Tactics for Shipboard Safety – An Exploratory Study	Qualitative	Interviews Focus group	41 participants[4]
Article 4: Developing and Validating a Safety Leadership Self-Efficacy Scale (SLSES) in Maritime Context	Quantitative	Content validity study Exploratory factor analysis (EFA) Confirmatory factor analysis (CFA)	416 respondents
Article 5: A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations	Qualitative/ Quantitative	Delphi method AHP	36 respondents

[3] Respondent refers to a person who has answered structured/semi structured questionnaires (Morse, 1991)

[4] Participant refers to a person who has taken an active role in qualitative inquiries (Morse, 1991)

3.2 Research methodology and data analysis process

In total, eight different research methods and analysis processes were used in this thesis, including case study, systematic literature review, Delphi method, Analytical Hierarchy Process (AHP), interview and focus group discussion using Individual, Group And Plenary (IGP) method, content validity study, as well as statistical methods such as exploratory and confirmatory factor analysis. The following sections will explain each of these methods and analysis processes, how they have been used sequentially and how respondents were recruited for each study.

Case study

Case study involves the in-depth investigation of single or multiple cases to acquire profound and detailed information related to the phenomena under investigation (Eisenhardt, 1989; Silverman, 2013; Yin, 2017). Case study is an appropriate research strategy to generate theory (Yin, 1981; Eisenhardt, 1989), and it is particularly useful when the relevant behavior cannot be manipulated (Rowley, 2002) and when the boundaries between the phenomenon and context are not clearly evident (Yin, 1981). By conducting an in-depth study of the selected cases, the possibility of understanding the latent and underlying issues is high (Thomas, 2011; Miles, Huberman et al., 2013), which could complement the mainstream deductive research that focuses more on a large number of context-stripped cases and statistical significance (Miles, Huberman et al., 2013).

Article 1, as a background study to this thesis, is interested in understanding why a maritime accident happened, which factors affected safety in ship operations and how to prevent a similar loss in the future. The nature of these inquiries demanded an in-depth study to explore the underlying issues and gain a comprehensive understanding (Rowley, 2002). Therefore, this background study employed a case study design (Yin, 1981) to understand the underlying causal factors and construct an explanation of the 2014 Sewol ferry tragedy—one of the worst maritime catastrophes in history.

In this accident, the captain was one of the few that abandoned the ship and failed to provide evacuation plans or instructions, which trapped more than 300 passengers inside the capsizing vessel. Despite the fact that a number of causal factors directly and indirectly contributed to this accident, the master's leadership failure was obviously one of the most critical issues that should be further explored (Kwon, 2016). In using this as a case, a systematic causal analysis was conducted following the Systems-Theoretic Accident Model and Processes (STAMP) (Leveson, 2011), as it enables the researcher to generate a broader view of accident mechanisms (Leveson, 2011; Kim and Nazir, 2016). The process of STAMP-based accident causal analysis is detailed in Table 4.

Table 4. Accident analysis steps based on STAMP (adapted from Kim, et al 2016 based on Leveson, 2011)

Step No.	Description of Steps
1	Identify the system(s) and hazard(s) involved in the accident
2	Identify the system safety constraints and system requirements associated with that hazard(s)
3	Document the safety control structure in place to control the hazard and enforce the safety constraints
4	Determine the proximate events leading to the accident
5	Analyze the accident at the physical system level
6	Moving up the levels of the safety control structure, determine how and why each successive higher level contributed to the inadequate control at the lower level
7	Analyze overall communications and coordination contributors to the accident
8	Determine if there were any changes to the system hierarchical safety control structure over time that migrated the system to a less safe position and contributed to the accident
9	Develop recommendations

STAMP encourages a holistic causal analysis that expands the focus beyond the immediate physical failures to a systemic view through examining both linear and non-linear factors and interactions at all control levels that could influence the safety level of the system (Leveson, 2011). Using this STAMP accident analysis process, this case study examined the entire accident process and identified a series of important systemic factors involved.

As the author has no direct access to primary data from the victims of the Sewol ferry accident, a variety of secondary data were used in this case study process, including the original official investigation reports that contained detailed descriptions regarding the ship particulars, accident timeline, testimonies, errors involved, logbooks, recorded electronic information and interview data from all key personnel involved (KMST, 2014; MOF, 2014). Previous research (e.g., Cho and Yoon, 2015; Hwang, 2015; Zhang and Wang, 2015) detailing this accident was also considered during the analysis process. These documents provided sufficient background information to conduct a STAMP analysis and meet the quality requirement of secondary data research, as they are from official sources (Hox and Boeije, 2005). Further, as explained by several researchers (Yin, 1981; Rowley, 2002; Bowen, 2009), these documents can be used as appropriate empirical data and sources of evidence for case studies.

Systematic literature review

A systematic literature review has been considered as a research method (Snyder, 2019), it "locates existing studies, selects and evaluates contributions, analyses and synthesizes data, and reports the evidence in such a way that allows reasonably clean conclusions to be reached" (Denyer and Tranfield, 2009, p. 671). It was applied in Article 2 to synthesize and reflect on the existing research findings on the topic of safety leadership. The research articles were checked against two pre-determined criteria for their eligibility: each (1) must be a peer-reviewed journal article, and (2) must examine the impact of specific safety leadership styles or behaviors on safety outcome(s). In the light of the theoretical data derived from the systematic literature review, two researchers performed an inductive coding process to condense the varied safety leadership behaviors into summarized leadership behavioral categories. The inductive coding process can be summarized as follows based on the suggestions of Thomas (2006) and Creswell (2002): (1) perform an initial examination of the textual data; (2) identify information segments; (3) label the segments to form categories; (4) reduce the overlapping categories and redundancies; and (5) create a model incorporating the most important categories.

Following this process, a systematic coding process of the literature was performed by two researchers independently and reached 88% similarity regarding the codes.

A summary of the current literature relevant to safety leadership in various industrial settings was provided during this systematic literature review, as presented in Chapter 4 Table 8. The summarized leadership behavioral categories were also used as a point of departure for discussions and evaluations among experts during the Delphi study in Article 2.

Delphi method

The Delphi method is a structured and interactive communication technique used to congregate expert opinions on a specific topic (Linstone and Turoff, 1975; Rowe and Wright, 2001). It has been widely utilized in various research fields to identify the key issues pertaining to the subject matter from the experts' perspectives. It typically involves several iterative communication rounds in which the expert panel is asked to answer a series of questions until reaching consensus (Hsu and Sandford, 2007). The responses from the experts are synthesized after the first Delphi round and shared with the experts afterward for a second round of communication. The method has been applied with various modifications to shorten the communication process and to avoid non-relevant responses (e.g., Binkley, Finch et al., 1993).

The frequency of the communication rounds varies depending on the purpose of the research (Erffmeyer, Erffmeyer et al., 1986; Rowe and Wright, 2001). Previous studies (e.g., Binkley, Finch et al., 1993) have demonstrated the sufficiency of using single-round Delphi to gain a collective view among experts on a specific issue, replacing the initial round, however, with a systematic literature review (Binkley, Finch et al., 1993). Considering the purpose of Article 2 and the breadth of leadership behaviors, Article 2 utilized a modified Delphi method through a single-round questionnaire to gauge the level of agreement among shipping experts on a temporary taxonomy of safety leadership behaviors, which constituted the second round of the traditional Delphi method. Article 5, included in this thesis, employed a two-round Delphi process, as there is not sufficient literature to be used as a basis.

Analytical Hierarchy Process (AHP)

AHP (Saaty, 1979; Vaidya and Kumar, 2006) was utilized as the subsequent stage of Delphi to determine the importance ranking of the safety leadership behavioral categories through pairwise comparisons by a group of experts. AHP is a multi-criteria decision-making method and one of the most accurate approaches for quantifying the weights of criteria (Wind and Saaty, 1980; Saaty and Vargas, 1985; Saaty, 1990; Islam and Saaty, 2010). It converts the evaluation into numerical values so that the relative importance of various alternatives can be calculated. AHP has been utilized in both Articles 2 and 5; the procedures are presented in Table 5.

Table 5. Analytic Hierarchy Process (AHP) (adapted from (Taylor III, 2002))

Step No.	Description
1	Establishing pairwise comparison matrix for each safety leadership behavior
2	Establishing the normalized matrix
3	Calculating the eigenvector of each safety leadership behavior category
4	Calculating global priority of each behavior
5	Determining the final ranking according to the value acquired
6	Evaluate and check the consistency of judgements

Saaty (1979) proposed utilizing the Consistency Index (CI) and Consistency Ratio (CR) to check the consistency of judgments. CI can be calculated through $(\lambda_{max}-n)/(n-1)$. CR is calculated by dividing the CI with a random index (Saaty and Vargas, 2012), which reflects how consistent the judgments have been relative to completely random judgments. As a rule of thumb, CR should be less than .1 to be considered as acceptable judgments (Zahedi, 1986; Saaty, 1987); this applies to both Articles 2 and 5.

Interview, focus group and Individual, Group and Plenary (IGP) method

Article 3 employed a qualitative research design to explore safety leadership behaviors based on a bottom-up approach using semi-structured interviews and focus group discussions. Qualitative inquiries offer the opportunity to explore meanings attached to the experience. This form of inquiry has strength to reveal phenomena in a more detailed way to yield rich insights and gain a better understanding of interactions, attitudes and behaviors (Maxwell, 2008; Yin, 2015).

A semi-structured interview is defined by Longhurst (2003) as follows:

> A verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions. Although the interviewer prepares a list of predetermined questions, semi-structured interviews unfold in a conversational manner offering participants the chance to explore issues they feel are important. (p. 103)

This is similar to focus groups, as they are both conversational and informal (Longhurst, 2003). In Article 3, an interview guide was developed for both interviews and focus group discussions. I, as an interviewer and focus group discussion facilitator, played a role to keep the conversation on topic but allowed the interviewees and focus groups to discuss the questions from as many angles as they wanted. I also asked probing questions (Legard, Keegan et al., 2003) during the interviews and focus group discussions to clarify the ideas and assist the respondents in providing more thoughts and details.

There is no well-established guideline for determining a non-probabilistic sample size (Guest, Bunce et al., 2006). Some studies (e.g., Burrows & Kendall, 1997) have recommended a minimum of three to four focus group discussions for a research topic (O. Nyumba, Wilson et al., 2018). In this study (Article 3), 11 semi-structured interviews and four independent focus group discussions were conducted, and the sample sizes were deemed adequate, as we did not see any new theoretical insights emerge from the last few new responses, which could be an indicator that it has come closer to the goal of saturation (Dworkin, 2012). The focus group further employed the IGP method (Gausdal, 2015), which consisted of four communication phases, including material-reading (e.g., distributing informed consent form and questions to be discussed) and individual reflection, followed by group reflection/presentations as well as plenary discussions (Gausdal, 2015). The data generated were analyzed through directed content analysis (Insch, Moore et al., 1997; Hsieh and Shannon, 2005; Krippendorff, 2012) and coding (Miles, Huberman et al., 2014), in light of the existing theories, to identify themes that appeared frequently and consistently from the qualitative data as well as to draw inferences for analytical conclusions. The results that appeared in the data but were not connected to previous theories were used to form new themes.

Researchers have brought attention to the need to consider contextual factors in understanding and analyzing the interview and focus group data, as the context and group dynamics might affect the data collected (Carey and Asbury, 2016). During the individual interview process, the interviewer and interviewee interact and construct meanings jointly (Garton and Copland, 2010). Several variables (such as noise and voice) might affect the interview process. All interviews in Article 3 were conducted at a time and place of the interviewee's convenience, without any disturbances. The focus and scope of the research question to be asked were also carefully planned and tested prior to the main data collection. The IGP method itself facilitates the interactions within the focus group and tries to bring more than the sum of its respondents' comments. The synergy of the group would therefore be useful to enrich the data generation.

Content validity study

Content validity is an important procedure in scale development studies (DeVellis, 2016). It refers to the degree to which an instrument has an appropriate sample of items to measure the construct (i.e., safety leadership efficacy). A content validity index (CVI) contains I-CVI for the content validity of individual items and S-CVI for evaluating the content validity of a scale. Wynd, Schmidt et al. (2003) recommended including Cohen's coefficient kappa (K) to supplement the CVI, as the CVI does not consider the possibility of inflated values due to chance agreement. The K value should be above 0.74 to be considered excellent; between 0.60 and 0.74 is good, between 0.40 and 0.59 is fair and below 0.40 is poor (Cicchetti and Sparrow, 1981). Generally, researchers recommend that a scale with excellent content validity should have I-CVIs above 0.78 (Shi, Mo et al., 2012). A scale-level content validity index, i.e., S-CVI/UA and S-CVI/Ave, should be 0.8 and 0.9 or higher (Shi, Mo et al., 2012). A content validity study was applied in the scale development process in Article 4, with the purpose to check the degree to which the scale has an appropriate sample of items for the construct being measured.

Factor analysis

Factor analysis is a widely utilized statistical technique for data reduction and for identifying and confirming the common factors or latent constructs that can account for the patterns of observed correlations (Hayton, Allen et al., 2004; Costello and Osborne, 2005). As commented upon by Nunnally (1978) and cited by Thompson and Daniel (1996), “factor analysis is at the heart of the measurement of psychological constructs” (p. 198). It helps to establish the underlying dimensions between measured variables and latent constructs and to test and inform the refinement of theories (Perron and Gillespie, 2015).

There are two main categories of factor analysis: exploratory and confirmatory (Worthington and Whittaker, 2006). Exploratory factor analysis (EFA) allows the researcher to explore whether the items could be reduced to a smaller number of meaningful factors (Samoilenko and Osei-Bryson, 2017). Confirmatory factor analysis (CFA), on the other hand, is used to test whether the data fits a hypothesized measurement model (Samoilenko and Osei-Bryson, 2017). Both are commonly applied in scale development research (Worthington and Whittaker, 2006). EFA was used during the scale development process in Article 4 with the purpose to reduce the item pool to a smaller set of summary variables and to identify the latent factors that could explain the covariation among the measured variables. A latent factor is a dimension or construct that is a condensed statement of the relationship between several variables (Kline, 2014).

First, sampling adequacy was checked with Kaiser-Meyer-Olkin (KMO) (Kaiser, 1970; Kaiser and Rice, 1974) and Bartlett’s Test of Sphericity (Bartlett, 1950) to determine how suited the data were for the purpose of factor analysis. The KMO should be above .50, and Bartlett’s Test of Sphericity should be significant at the .05 level in order to be considered suitable for factor analysis (Williams, Onsman et al., 2010).

There are several techniques for factor extraction, or the process of identifying the latent factors that best characterize a set of variables (Kahn, 2006). Principal Component Analysis (PCA), Maximum Likelihood (ML), Principal Axis Factoring (PAF), generalized least squares and unweighted least squares are commonly used methods for factor extraction (Williams, Onsman et al., 2010). In this study, ML was used for factor extraction, as it offers more reliable estimation for scale development research (Worthington and Whittaker, 2006). The overall variance explained and the scree test were considered together with the eigenvalue during factor extraction (Costello and Osborne, 2005; Williams, Onsman et al., 2010). Orthogonal rotation (e.g., quartimax, varimax, equimax) is often used during EFA (Williams, Onsman et al., 2010); however, it is hard to expect that the factors are completely uncorrelated to each other. The oblique rotation (i.e., promax) method was used in this study, as it allows for factor correlation (Kahn, 2006) and offers more accurate results for research involving human behaviors (Williams, Onsman et al., 2010). Loadings and cross-loadings were used as the criteria for item deletion. Items with factor loading lower than .5 and high cross-loading (>.4) (Hatcher, 1994) will be eliminated. The Cronbach's alpha coefficients of the extracted factors should be more than the minimum value of 0.70 (Nunnally, 1994).

Following up on the result derived from the EFA stage, CFA is employed to test the relationship between the factors and measured variables and confirm whether the data fit a hypothesized measurement model. EFA looks for patterns, while CFA conducts statistical hypothesis testing on proposed models (Samoilenko and Osei-Bryson, 2017). The most current approach in conducting CFA is to use Structural Equation Modelling (SEM) (Worthington and Whittaker, 2006). SEM is a powerful confirmatory technique because it allows the researcher greater control over the form of constraints placed on items and factors when analyzing a hypothesized model. Further, SEM can also be used to examine competing models to assess the extent to which one hypothesized model fits better in comparison to alternative models (Worthington and Whittaker, 2006). This process plays an important role in validating the model and finding the reliability of the scale.

The acceptable fit of the hypothesized model is evidenced by the following indicators (Hooper, Coughlan et al., 2008): (1) absolute fit indices, such as $\chi 2$, Root Means Square Error Of Approximation (RMSEA), Goodness-Of-Fit Index (GFI) and the Adjusted Goodness-Of-Fit Statistic (AGFI), Root Mean Square Residual (RMR) and Standardized Root Mean Square Residual (SRMR); (2) incremental fit indices, such as the Normed-Fit Index (NFI) and Comparative Fit Index (CFI); and (3) parsimony fit indices, such as the

Parsimony Goodness-Of-Fit Index (PGFI) and the Parsimonious Normed Fit Index (PNFI). Regarding the indices to be reported, researchers have mentioned that it is not necessary to report every index (Hooper, Coughlan et al., 2008).

In Article 4, acceptable model fit was evaluated by several commonly used fit indexes including RMSEA (< 0.06), CFI (>.90), TFI (>.90) and SRMR (<0.08) (Hu and Bentler, 1999; Hooper, Coughlan et al., 2008; Kline, 2015). Reliability was assessed using Cronbach's alpha (α >.6), composite reliability (CR >.7) and average variance extracted (AVE >.5) (Fornell and Larcker, 1981; Nunnally, 1994; Ahmad, Zulkurnain et al., 2016).

3.3 Sampling process of empirical studies

To ensure research quality and to derive reasonable conclusions, this thesis recruited a total of 517 participants and respondents from various merchant shipping sectors. The expert panel in Article 2 had 24 respondents to identify, confirm and weigh the appropriateness, applicability and relative importance of different safety leadership behavioral categories in the context of merchant shipping. Forty-one participants were involved in Article 3, either through interviews or focus group discussions. In Article 4, a total of 416 respondents have answered the online questionnaires. Thirty-six respondents were recruited for the last article of this thesis (Article 5) to evaluate and predict the future leadership competence requirements in the era of autonomous shipping. All of the participants and respondents have relevant working experience in the maritime industry while holding a good level of knowledge and expertise to provide valuable information on the research questions. The sampling process for each of these four studies is described in the following sections.

Scholars have suggested that the studies using Delphi and AHP should have 15 to 20 experts to obtain a representative pool of judgments (Ludwig, 1997; Hsu and Sandford, 2007). Both Article 2 and Article 5 had more than 20 experts participating, which indicated a good sample size for conducting this type of study. The 24 respondents in Article 2 were leaders and managers working in various merchant shipping sectors. These respondents were invited and recruited through professional networks and social platforms and were asked to evaluate and weigh the appropriateness, applicability and relative importance of the identified safety leadership behaviors in the context of merchant shipping. Approximate 61% of them had over 10 years' work experience in this industry while holding leadership positions such as CEO, deputy managing director, vessel executive, fleet manager, technical superintendent, captain, chief engineer, etc., and 34.78% of the experts had more than 20 years of experience in shipping, constituting a reasonable expert panel for this study to generate appropriate findings.

Article 3 consisted of 11 individual semi-structured interviews and four focus group discussions with 30 shipboard officers. All participants possessed relevant experience as shipboard officers with managerial or operational responsibilities. They were identified and recruited through my and my supervisor's professional network and connections, as well as the professional seafarers who attended the Onboard Management Training (OBMT) course at the Department of Maritime Operations at the University of South-Eastern Norway. A majority of the participants (48.78%) had more than 20 years of experience in leadership roles as ship masters and deck department senior officers.

The research process of Article 4 was divided into three stages, including a content validity study, an EFA and a CFA study. A total of 20 respondents (i.e., subject matter experts) answered the content validity survey; 60% were university professors, lecturers and researchers in maritime subjects, and 40% worked within the merchant shipping industry. A total of 396 shipboard officers were involved in the factor analysis in Article 4. They were randomly recruited from the global merchant shipping industry with the help of several maritime institutes, including the Norwegian Shipowners' Association, professors working at the universities involved in the Norwegian National Joint PhD program in Nautical Operations, and the Korean Institute of Maritime and Fisheries Technology. According to Izquierdo Alfaro, Olea Díaz et al. (2014), 73.3% of the studies applying EFA and CFA used the same sample. In this Article 4, 150 samples were used for EFA, 246 new samples were added for CFA to test the measurement model. Since the communalities for all items in EFA are high (all above 0.7), "sample size have relatively little impact on quality of the solution, meaning that accurate recovery of population solutions can be obtained using a fairly small sample" (MacCallum, Widaman et al., 1999,

p. 90). For the CFA, there were 396 samples for 26 items, the subjects-to-variables ratio is 15. The sample size is in accordance with the general sampling recommendations (Worthington and Whittaker, 2006).

The questionnaires were administrated on Qualtrics™ using two languages, English and Korean. It was designed with anonymous and forced-response functions, which means that each question needed to be answered before proceeding to the next one, and thus no missing values were recorded in the dataset. Excel, SPSS v25 and RStudio were used for data analysis. A majority of the respondents in the survey were from major merchant shipping sectors, such as tankers, roll-on/roll-off and bulker carriers, and having senior or junior leadership positions such as master, chief engineer, or deck or engineering department officer.

Article 5 was endowed with two methodological phases integrating the Delphi technique and AHP, with two sequential surveys to collect empirical data from 36 respondents. The respondents were SMEs who possessed relevant experience in maritime leadership training, maritime research or practice. The first six experts were selected based on professional networks and asked to forward the questionnaire to other experts with relevant experience and expertise for the subject of this research, which corresponded to a snowball sampling process (Biernacki and Waldorf, 1981). Different from Article 2, this study applied two rounds of a Delphi survey to gather as well as verify the consensus from the panelists. The data were analyzed through an abductive coding process, considering the STCW leadership requirements as well as previous research to identify commonalities that represent future leadership competence. An AHP questionnaire was designed and distributed in the second round for prioritizing and ranking leadership competence and identifying leadership competences that, according to the informants, play the principal roles in the future of autonomous shipping.

3.4 Validity, reliability and quality of research

Validity refers to the appropriateness of the inferences made from the results—in other words, the extent to which the results accurately measure what the research intended to measure (Heale and Twycross, 2015). Reliability refers to the extent to which the results can be reproduced if the research is repeated under the same conditions (Kothari, 2004). There are four main types of validity: content validity, construct validity (including discriminant and convergent validity), face validity and criterion validity (including concurrent and predictive validity) (Cronbach and Meehl, 1998; Kimberlin and Winterstein, 2008). Taherdoost (2016) made a comprehensive summary (please see Table 6) regarding the validity components and techniques for enhancing the validity and reliability of a questionnaire study.

Table 6. Validity and reliability definitions and suggested techniques (Taherdoost, 2016, p. 34)

Validity Component	Definition	Type	Technique Suggested
Face Validity	The extent that measurement instrument items linguistically and analytically look like what is supposed to be measured	Recommended	Post hoc theory, expert assessment of items; Cohen's Kappa Index (CKI)
Content Validity	The extent that measurement instrument items are relevant and representative of the target construct	Highly recommended	Literature review; expert panels or judges; CVRs; Q-sorting
Construct Discriminant validity	the extent that measures of different constructs diverge or minimally correlate with one another	Mandatory	MTMM; PCA; CFA; PLS AVE; Q-sorting
Construct Convergent validity	The extent that different measures of the same construct converge or strongly correlate with one another	Mandatory	MTMM; PCA; CFA; Q-sorting
Criterion Predictive Validity	the extent that a measure predicts another measure	Mandatory	Regression Analysis, Discriminant Analysis
Criterion Concurrent Validity	the extent that a measure simultaneously relates to another measure that it is supposed to relate	Mandatory	Correlation Analysis
Criterion Postdictive Validity	The extent that a measure is related to the scores on another, already established in past.	Mandatory	Correlation Analysis
Reliability Internal consistency	the extent to which a measurement of a phenomenon provides stable and consist result	Mandatory	Cronbach's a; correlations; SEM reliability coefficients

Content validity looks at whether the instrument adequately covers all important and representative content with respect to the variable (Cronbach and Meehl, 1998; Heale and Twycross, 2015). It can be enhanced through conducing a systematic literature review, inviting subject matter experts to join the research process and calculating the content validity ratio (CVR) (Lawshe, 1975; Sireci, 1998; Taherdoost, 2016). Construct validity defines the degree to which a test measures what it claims (Heale and Twycross, 2015). For instance, if a person has a high score on a leadership survey, this person should truly have a high degree of leadership. Criterion validity indicates the extent to which a measure is related to an outcome (Heale and Twycross, 2015). Content and criterion-related validity contribute to the evidence of construct validity (Kimberlin and Winterstein, 2008). Reliability in quantitative research can be assessed through Cronbach's α and correlations (Taherdoost, 2016). The following table summarizes how validity and reliability were established for each study included in this thesis.

Table 7. Strategies employed for increasing validity and reliability of each study

Criteria	Article 1	Article 2	Article 3	Article 4	Article 5
Method selected	Case study STAMP	SLR Delphi method AHP	Interview Focus group	Content validity study Questionnaire survey	Delphi method AHP
Validity	• Used the existing theory to guide the case study process • Established a chain of evidence • Mapped the interactions and causal relationships • Explained the data analysis process • Used multiple sources of evidence	• Systematically synthesized the existing research findings and used them as the basis • Received expert opinion and described their profiles in detail • Calculated content validity ratio (CVR) • Direct quotation to support findings	• Varied typology (interviews, focus group discussions) • Feedback and interactive contact with the participants • Explained the characteristics of the participants • Direct quotation to support findings • Provided thick descriptions	• Received expert opinion to increase content validity • Fitness indexes achieved the level of acceptance • Assessed discriminant validity • Described the sample in detail • Random selection of shipboard officers to avoid biases	• Feedback and interactive contact with the respondents • Experts had opportunity to refine the researcher's understanding and/or findings • Described the sample in detail • Direct quotation to support findings
Reliability	• Employed a clear accident analysis procedure that can be repeated • Reported the documents used for analysis • Three maritime researchers reviewed and agreed	• Two researchers involved in the coding process • Calculated the degree of agreement • Cross-checked the findings with other similar research • Specified the analytical procedures	• Two researchers involved in the content analysis process • Compared the results with previous research findings • Specified the analytical procedures	• Calculated Cronbach's α • Calculated composite reliability (CR >.7) • Calculated average variance extracted (AVE >.5) • Obtained consensus from three maritime researchers • Specified the analytical procedures	• Two researchers involved in the coding process and agreed on the findings • Specified the analytical procedures • Calculated degree of agreement among experts

Ensuring the validity and reliability of a qualitative study also involves conducting the investigation in an ethical manner (Merriam, 2015). Unlike quantitative methodology, the primary instrument for data collection, interpretation and analysis in a qualitative study is the researcher him/herself (Yin, 2015). The researcher's personal values, judgments and ideological preferences may shape the research design and the interpretation of the results (Eisenhardt, 1989), which may also lead to biased conclusions as a result of information processing biases (Eisenhardt, 1989). To minimize this bias, two or three researchers were involved in each research process to minimize the subjectivity involved in the interpretation process. The degree of agreement was also calculated and presented. Each article has also reported the full range of the research findings, with diversified perspectives that may also cover the negative findings that were contrary to the assumptions.

Validity and reliability measures reflect the research quality (Seale, 1999; Heale and Twycross, 2015). As synthesized in Table 7, this thesis applied various measures as recommended by researchers (see Table 6) to maximize the research validity and reliability. Each study based the research on a chain of inferential reasoning supported by relevant literature and provided detailed description regarding the research process, samples and methods.

Although the results hold promise as a starting point for understanding maritime safety leadership, the results must also be viewed in light of their limitations. These limitations regarding the validity and reliability issues of this thesis are further explained in Section 4.6, in which future work directions are also suggested.

3.5 Research ethics

Conducting ethically sound research is essential and fundamental for scientific inquiry (Chalmers, 2013). This thesis followed the Norwegian national research ethics committee's guidelines for ethical research. Notification of the PhD project has been given to the Norwegian Centre for Research Data (NSD), and NSD approval for research has been obtained; please see Appendix I. All participants and respondents' information has been handled in compliance with the Personal Data Act.

This maritime safety leadership thesis is interested in learning best practices, leadership experiences from those who are willing to share and give advices to current and future generations of seafarers to improve safety leadership competence. It does not pose any physical dangers, health hazards or psychological harm to the participants and respondents. No identifiable personal data is needed or collected. All indirect personal information (e.g., email conversation, conversation records on LinkedIn) were deleted from the computer after the data collection. All collected data in this thesis have been anonymized in accordance with the NSD requirement.

Prior to the interview and focus group discussions, the researcher explained the purpose of the study, the confidentiality rules and the voluntary nature of participants' involvement. An information letter was formulated as informed consent in accordance with the NSD's suggestion (please see Appendix II), and they were informed of their right to withdraw at any time. Participants were also asked to provide feedback regarding the perceived value and their interview experience. No respondent indicated any complaints regarding the data collection practices or any discomfort with my presence in the group discussions. The questionnaires was designed with "anonymize responses" function on Qualtrics, which does not collect any email or IP addresses. All respondents were given an information letter regarding the nature of the research and their rights before they proceeded further in the survey. Although no personal information was collected, the responses received during this thesis have been treated as strictly confidential and were not divulged to anyone other than the researchers. Furthermore, the data collected in the project have only been used for the purposes for which they were collected.

The merchant maritime industry has long been considered as a male-dominated industry, with only 2% female seafarers working on board ships (MacNeil and Ghosh, 2017). Even fewer women work as shipboard officers. The reality of the gender imbalance in the maritime industry poses a significant challenge for the researcher in recruiting female respondents. The sample inevitably involved uneven gender distribution. However, gender biases are also part of the population of the merchant maritime industry. Correcting the gender balance in the sample size would potentially lead to a misrepresentation of the population. Therefore, gender issues were not focused on in this thesis.

Furthermore, the project follows the Vancouver rules (Masic, 2012, p. 146) for co-authorship, which specify that the authorship credit shall be based on:

1. Substantial contributions to the design and planning of the research, acquisition of data, or analysis and interpretation of data;
2. Drafting the article or revising it critically with important intellectual content;
3. Final approval of the version to be published.

All persons named as authors in the articles included in this PhD project have satisfied the authorship criteria mentioned above. Individuals and institutes that have provided advice or feedback, or who helped with the data collection, have been acknowledged.

4 Chapter: Results and Discussions

This chapter presents, analyzes and discusses the results of this thesis with reference to the theories presented in Chapter 2. It elaborates on how the results connect to existing theories and how the empirical studies are integrated to contribute to the understanding of safety leadership in ship operational context. The main results generated in each research article are presented and analyzed in light of its limitations. Possible areas for future research are indicated. Please note that the results and discussions are presented in full in the appended articles.

4.1 Results and discussions of Article 1

In the background study, a STAMP-based causal analysis of the 2014 Sewol ferry accident was conducted. The ship (see figures below) capsized on the morning of 16th April 2014 during a frequent voyage from Incheon to Jeju Island in Korea, leading to the deaths of 304 passengers and crew, most of whom were second-year high school students (KMST, 2014; Kim, Nazir et al., 2016).

Figure 3. Sewol ferry (KMST, 2014, p. 8)

The ship's master irresponsibly abandoned the ship without giving appropriate evacuation instructions, which consequently delayed a plausible evacuation and trapped the passengers in the cold waters (Kim, Haugen et al., 2016; Kim, Nazir et al., 2016). This leadership failure magnified the crisis loss and triggered a long-lasting national trauma. According to the official investigation report (KMST, 2014), the ship was modified in 2012 to expand the cargo and passenger capacity, which raised the ship's center of gravity and made the ship dangerously top-heavy (Suh and Kim, 2017). Furthermore, the ship departed from the port in a significantly overloaded condition with improperly secured cargos and an insufficient amount of ballast (Kim, Nazir et al., 2016). These risk factors, in combination with the environmental circumstances (e.g., strong underwater current), brought the vessel into a high-risk state.

At the time of the accident, the ship was controlled by a third mate and a helmsman (Kim, Nazir et al., 2016). Two 5-degree commands were issued, which caused a sudden heeling motion of the ship, causing it to lean sharply to port and consequently shifting the improperly secured cargo. In addition to the added effect of the insufficient ballast and fast underwater current, the list gradually increased until it capsized (KMST, 2014; Kim, Nazir et al., 2016). The master and crew members on board failed to give timely evacuation commands to the passengers, and the available life rafts were not properly launched (Kim, Nazir et al., 2016).

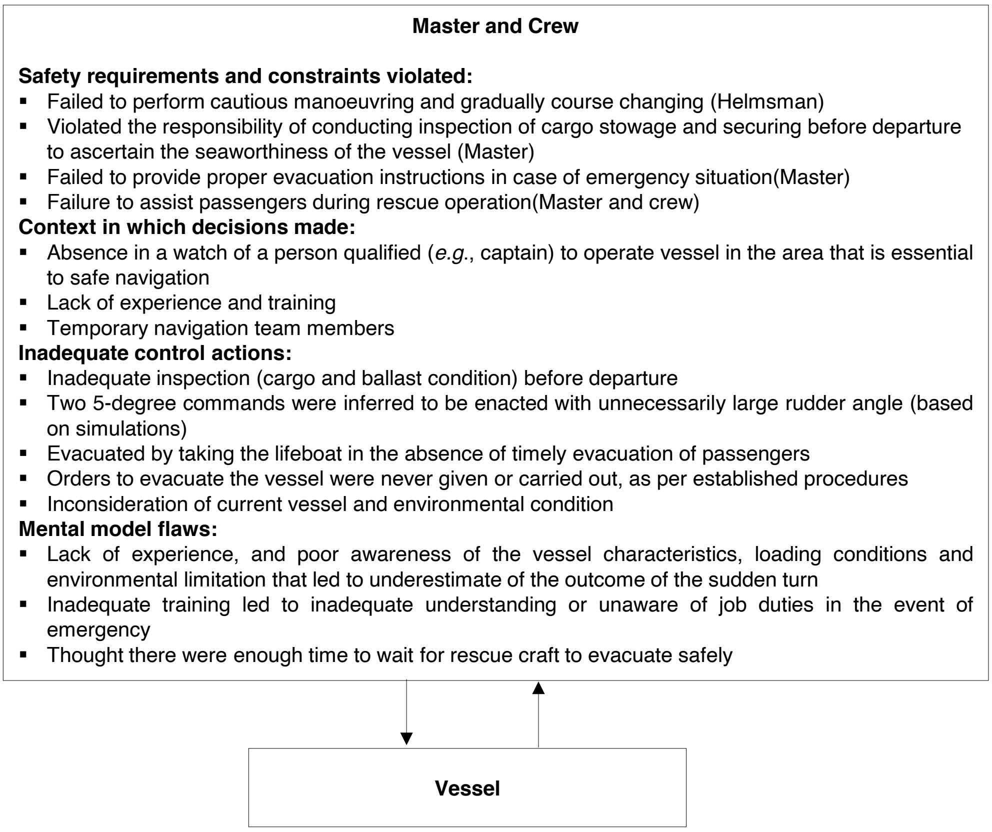


Figure 4. Analysis at the ship master and crew level (adapted from Kim, Nazir et al. (2016))

An in-depth study of this case revealed a series of direct and indirect factors contributing to this huge death toll. An analysis at the crew level, as briefly illustrated in Figure 4, reveals several flawed decisions and inappropriate control actions, including failure to perform cautious maneuvering, failure to conduct adequate inspection to prevent cargo movement, failure to provide evacuation instructions on time, and failure to initiate teamwork and coordination during a rescue operation (Kim, Nazir et al., 2016). These show severe shortcomings in the competence of the shipboard leaders to apply leadership, management and teamwork skills. However, many of these flawed control actions from the shipboard level can be explained by analyzing the safety control actions performed by the ship-owning company.

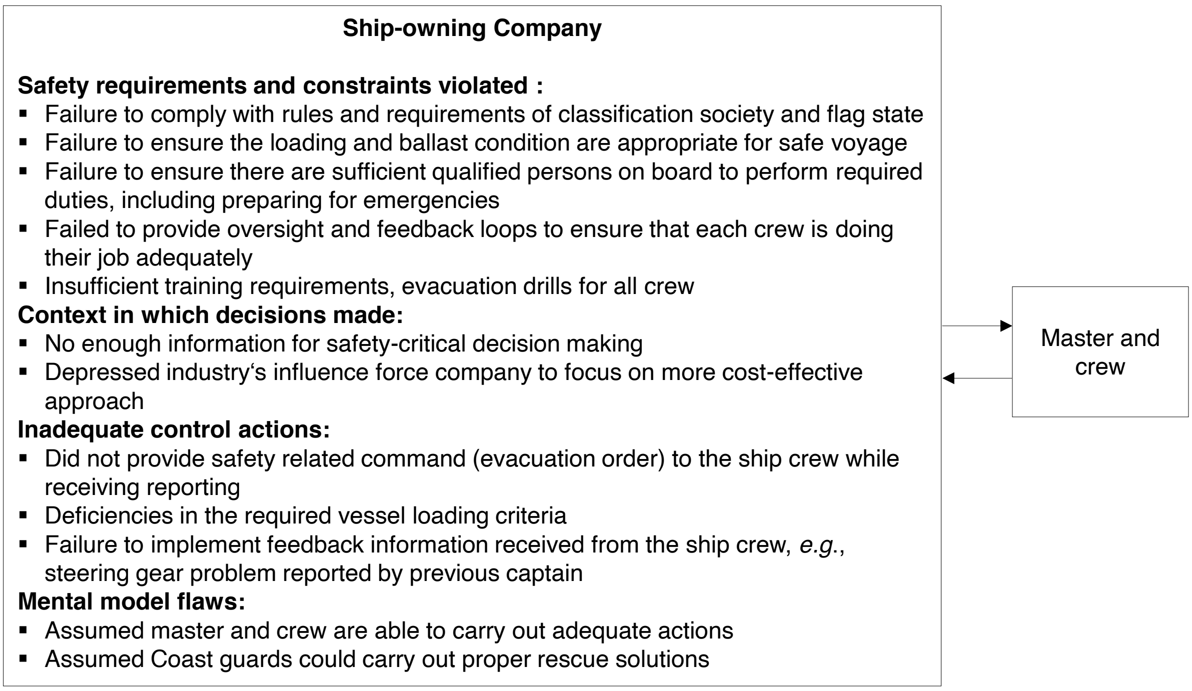


Figure 5. Analysis at the ship-owning company level (adapted from Kim, Nazir et al. (2016))

The company failed to provide well-trained personnel on board to perform required duties and failed to provide sufficient safety monitoring and oversight (Kim, Nazir et al., 2016). By analyzing at the ship-owning company level (please see Figure 5), it is evident that the management lacked safety concerns and failed to establish a well-functioning safety control mechanism. Their negligent training, organizational support and budget allocation inadvertently placed them and the vessel at undue risk and further influenced the safety behaviors onboard the ship. Research has revealed that a lack of organizational support is one of the main impeding factors for seafarers' participation in safety (Mearns and Reader, 2008; Bhattacharya, 2009; Berg, 2013). Many of the systemic factors, such as lack of training and inappropriate common practices, can be traced back to the failure of safety leadership (Flin and Yule, 2004; Berg, 2013).

The Sewol ferry accident analysis has facilitated the realization that, among all contributing factors for safe and efficient ship operations, safety leadership commitment at all organizational levels has fundamental importance. It demonstrates a need for studying the safety leadership phenomenon in the maritime domain, as it is important for the shipboard officers to have sufficient leadership competence to lead the crew during the sea voyage. Considering the severe human, financial, legal and reputational consequences of a maritime accident, the shipboard officers' leadership in terms of safety is worthy of academic consideration. This background study was therefore the motivation for the author to look into safety leadership in the maritime domain.

4.2 Results and discussions of Article 2

Article 2 presents an empirical study that explores safety leadership behaviors in the maritime context. Through sequentially applying three interdependent research techniques, namely inductive analysis of the literature review findings, modified Delphi and AHP analysis, Article 2 attempts to articulate, confirm and prioritize effective safety leadership behaviors in the maritime context with an expert panel. The results generated through the systematic literature review are presented in Table 8.

Table 8. A synthesis of key leadership behaviors affecting safety performance (results from Kim and Gausdal, 2017, pp. 460, 461, 462)

Author(s)	High-risk Industry context	Related Leadership theory	Type of managers	Identified leadership behaviors affecting safety performance
Clarke and Ward (2006)	Manufacturing	Transformational	Immediate supervisor	• Promote involvement in decision making
		Transactional		• Generating enthusiasm for safety • Using logical arguments and factual evidence • Using co-workers to create pressure for the subordinates to comply
Hofmann and Morgeson (1999)	Manufacturing	Leader-Member exchange	Group leaders	• Engage in communication pertaining to safety issues • Promote more open and frequent communication and feedback
Parker, Yule et al. (2012)	Healthcare	Not specified	Surgeon	• Guiding and supporting • Communicating and coordinating • Task management behaviors
Flin and Yule (2004)	Healthcare	Transactional	Supervisor	• "Monitoring and reinforcing workers' safe behaviors" • "Participating in frontline workers' safety activities" p. 46
		Transformational		• "Being supportive of safety initiatives" • "Encouraging subordinate involvement in safety initiatives" p. 46
Lu and Tsai (2008)	Container shipping	Not specified	Supervisor	• Caring about crew safety • Encouraging safe behaviors • Keeping crew informed of the safety rules and providing necessary safety information
Martínez-Córcoles, Gracia et al. (2011)	Nuclear industry	Empowering leadership	Immediate supervisor	• "Showing what should be achieved and why; explaining not only what should be done, but also the reasons, contributing to giving more sense to the task" • "Promoting subordinates' self-effectiveness and increasing the feeling that they can accomplish the task" • "Offering examples of good practices that subordinates can imitate" • "Developing subordinates' abilities, which will allow them to steadily increase their contributions" • "Providing positive emotional support by recognizing good work and taking care of the members' welfare" • "Organizing work to enable subordinates to achieve success and derive personal satisfaction from the work, increasing subordinates' perception of auto-efficacy, and inspiring them to achieve increasingly higher goals" p. 1126
Conchie et al. (2011)	Construction	Not specified	Supervisor	• Demonstrating benevolence by caring and concerning for subordinates' safety and welfare
Hoffmeister, Gibbons et al. (2014)	Construction	Transformational	Supervisor	• Instilling pride in subordinates • Expressing safety values to subordinates

Table 8 continued (results from Kim and Gausdal, 2017, pp. 460, 461, 462)

Author(s)	High-risk Industry context	Related Leadership theory	Type of managers	Identified leadership behaviors affecting safety performance
Hofmann and Stetzer (1998)	Large utility organization	Not specified	Supervisor	• Facilitating open communication on safety
Wu, Chang et al. (2011)	Petrochemical	Not specified	Supervisor	• (Safety caring) To respect and trust subordinates, to care about subordinates' needs and empathize with their problems • (Safety coaching) To stimulate subordinates' abilities, to share opinions, and allow subordinates to participate in decision making • (Safety controlling) To set the rules by which the organization runs, to use their power to give a reward or a punishment and to review subordinates' behaviors
Flin and Yule (2004)	Healthcare	Transactional	Managers-frontline	• "Becoming involved in safety initiatives" p. 46
		Transformational		• "Emphasizing safety over productivity" • "Adopting a decentralized style" • "Relaying the corporate vision for safety to supervisors" p. 46
Conchie and Moon (2010)	Construction	Not specified	Manager-supervisor	• Promoting role autonomy
O'Dea and Flin (2001)	Oil and gas	Not specified	Site managers	• Facilitating open and participative relationship with subordinates through "consulting" and "joining" behaviors
Wu, Lin et al. (2010)	Tele-communications	Not specified	Operations manager	• Acquiring safety information through a monitoring system (Safety monitoring) • Continuously circulating information so that subordinates receive important updates (Safety disseminating) • Frequently attending safety committee meetings (Safety representing)
Petersen (2000)	No targeted industry	Not specified	Middle managers	• Ensuring the quality of subordinate, supervisor or team performance in respect to safety matters • Engaging in visible actions that demonstrate the importance of safety
Yang, Wang et al. (2009)	Healthcare	Consideration leadership	Top management	• Exhibiting concern for the safety of the subordinates
		Initiating structure leadership		• Establishing an organization system for safety activities, audits and communication
McFadden, Henagan et al. (2009)	Healthcare	Transformational	Top management	• Making safety a primary priority • Devoting necessary resources to safety initiatives

Table 8 continued (results from Kim and Gausdal, 2017, pp. 460, 461, 462)

Lu and Yang (2010)	Container terminal operations	Transactional	Senior management	• "Creating a clear mission, responsibility and goal to set standards of behavior for subordinates" • "Setting up a safety system to correct workers' safety behaviors" p. 124
		Transformational		• Role modelling • Stressing the importance of safety equipment • Emphasizing interests in acting on safety policies • Praising employees' safety behaviors Encouraging employees' participation in safety decision
Roger, Flin et al. (2011)	Energy industry	Not specified	Senior managers/ Health and safety professionals	• "Emphasizing safety as an organizational priority" • "Establishing clear communication for safety" • "Participating in safety activities" • "Setting and maintaining safety standards" • "Maintaining risk awareness" • "Motivating and supporting the workforce" p. 1145
Du and Sun (2012)	Coalmines	Transactional	Senior managers	• (Safety monitor) Setting up clear goals and safety systems in order to ensure the safe behaviors of subordinates
		Transformational		• (Safety motivation) Creating a motivation system to encourage employees' safety behaviors
Yule, Flin et al. (2007)	Power-generating	Not specified	Senior managers	• Provide resources for training of the workforce • Encourage supervisors' involvement in safety activities
Bhattacharya (2012)	Shipping	Not specified	Top management	• Promoting high level of trust between employers and seafarers
Wu, Fang et al. (2015)	High speed railway construction	Transformational and transactional	Owner	• (Safety influence and role modelling) Establishing employees' trust and loyalty to leaders by exhibiting idealized influence and role modelling in safety • (Safety motivation and coaching) Providing meaning and challenge to their work, encouraging the subordinates to envision future state • (Safety caring and individual respect) Paying attention to the safety of the subordinates, providing help when needed. Establishing harmonious relationship with subordinates while maintaining effective communication channels. • (Safety controlling and performance management) Allocating safety responsibility and establishing standards and expectations for safety performance.

As shown in the review, leadership styles and behaviors conducive for safety have been well-studied in high-risk industries; however, few studies have been conducted in the merchant shipping sector. One way to identify effective safety leadership behaviors is to explore the scientific findings accumulated in other high-risk industrial contexts and seek to extrapolate and validate their application in the maritime context. Article 2 therefore begins by synthesizing the existing research findings to delineate an initial safety leadership model. Certain leadership behaviors for safety repeatedly appeared at each level of management during the review, indicating their strong connections with positive safety outcomes.

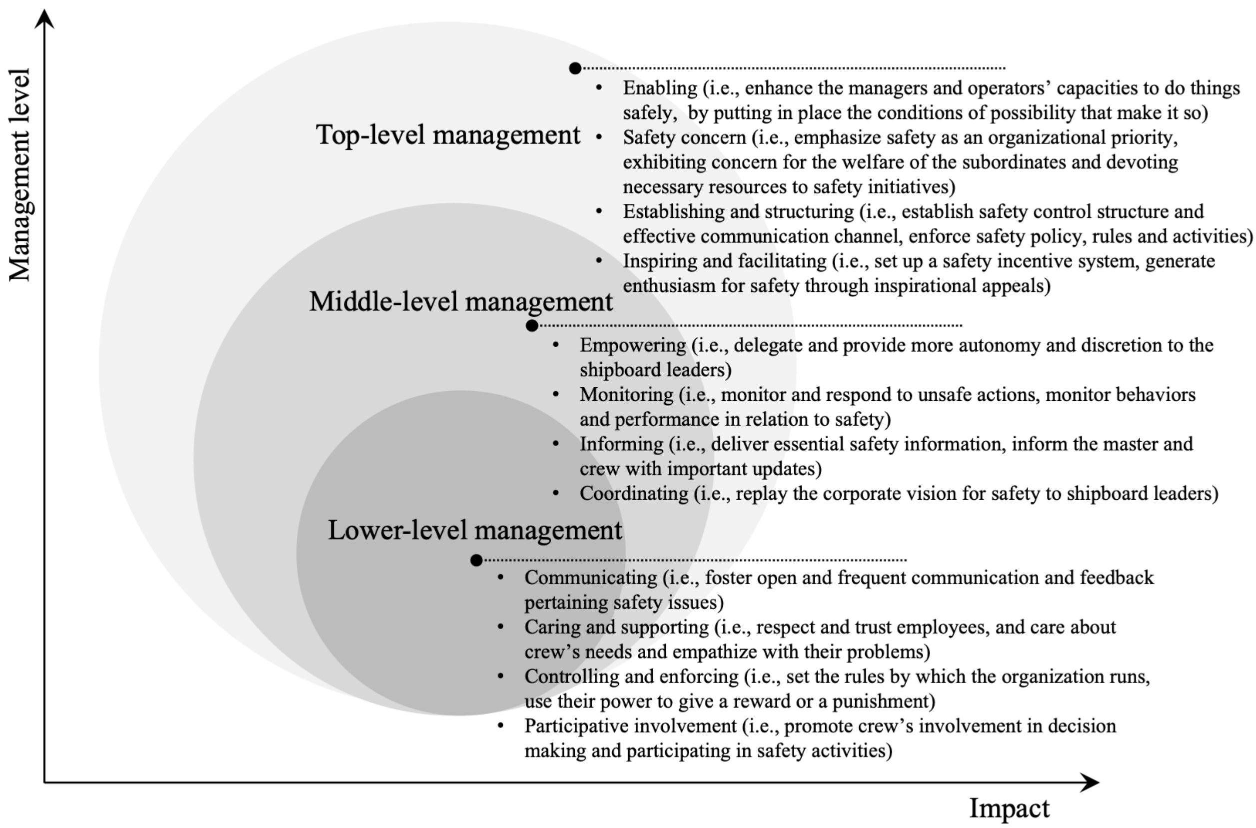


Figure 6. Initial safety leadership model

Through an inductive coding analysis of the behaviors generated from each research study examining effective safety leadership behaviors, 12 behavioral categories were generated to integrate the key findings from the literature, as shown in Figure 6, which tied to different aspects of transformational and transactional leadership theory (Barling, Loughlin et al., 2002; Bass and Riggio, 2006; Clarke, 2013). The theme of inspiring and facilitating is associated with the inspirational motivation component of the transformational leadership style, where leaders inspire and motivate their followers to meet goals and perform beyond expectations. Caring and supporting, and communicating about safety concerns and issues, are more aligned with the individualized consideration component of transformational leadership, where leaders attend to each subordinate's needs and try to support them in demonstrating the desired safety behaviors. Empowering, participative involvement to promote subordinates' involvement in decision-making is associated with the intellectual stimulation aspect of transformational leadership. Controlling and enforcing, informing, coordinating and monitoring behavioral categories are more aligned with the focus of transactional leadership, in which the emphasis is placed on maintaining routine and promoting subordinates' compliance through management actions and process monitoring.

All these safety leadership behavioral categories have been evaluated by the expert panel in the Delphi process, with the purpose to verify whether these categories are sufficient, appropriate and important to be considered as good safety leadership functions for each management level in shipping. As shown in Figure 7, most were confirmed by the experts in the Delphi process with a high level of agreement, but the controlling and enforcing aspects of leadership behaviors were rejected.

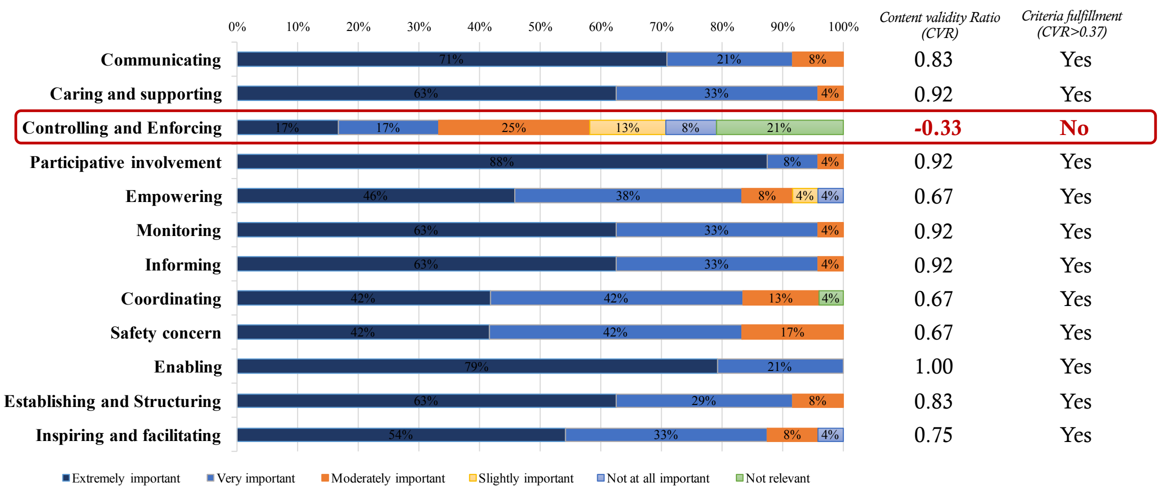


Figure 7. Degree of agreement on each safety leadership behavior (adapted from Kim (2016))

The question of which of these aspects of safety leadership have the most impact on safety performance in ship operations has been explored through AHP. As shown in Table 9, shipboard-level leaders' participative involvement was perceived by the expert panel as having the highest relative importance to safety performance in ship operations. Top-level management's establishing- and structuring-related behaviors for allocating safety responsibilities and establishing safety values and standards also received a high level of adherence. At the middle-management level (e.g., fleet managers, technical superintendents), the safety-informing behavioral category has frequently appeared in the literature, and it was perceived that it has the most impact on safety performance at the middle-management level (Kim and Gausdal, 2017). It contains several safety leadership behaviors, such as delivering essential safety information, updating the master and crews with the latest information and accurately communicating safety issues and concerns from the front line to the top-level management to provide a true lens on safety performance.

Table 9. Final weighted safety leadership model (adapted from Kim and Gausdal, 2017)

Managerial level	Safety leadership behavioral category	Calculated relative significance	Rank
Lower-level (shipboard-level) management (LM)	Communicating	0.113	4
	Caring and supporting	0.090	6
	Participative involvement	0.158	1
Middle-level management (MM)	Empowering	0.036	11
	Monitoring	0.059	9
	Informing	0.119	3
	Coordinating	0.054	10
Top-level management (TM)	Enabling	0.101	5
	Safety concern	0.068	8
	Establishing and structuring	0.122	2
	Inspiring and facilitating	0.079	7

Safety in merchant shipping has been widely considered as the product of compliance with safety rules and regulations (Cartner, Fiske et al., 2009). However, what is seen as effective safety leadership in this study does not favor autocratic and centralized behaviors. The safety leadership behavioral categories at the shipboard level reflect a primary focus on the exercise of transformational leadership, which is inconsistent with the results of several other studies in other high-risk industrial settings (Clarke and Ward, 2006; Dartey-Baah and Addo, 2018). In the maritime context, most of the work tasks in daily ship operations are routinized, it can be inferred that the need for strong vertical leadership is therefore often minimal. The crew members onboard, regardless of their rank, are skilled workers who are required to have a raft of practical and technical skills to perform specialized tasks and to be part of the team (Lane, 1990; Visvikis and Panayides, 2017). The main leadership role on board ships today seems not only to be a commander to ensure safety in both normal and abnormal situations, but also to be a facilitator to leverage the capabilities of knowledge-based team members and to build a sense of community through more horizontal (transformational) aspects of leadership, as indicated in the results. The leadership effort at the shipboard level seems to be directed toward maximizing the potential of the crew team as a whole and to formulate a safe working atmosphere, rather than simply projecting downward influence and seeking compliance. Effective shipboard leadership devolves the decision-making power to the crew members by allowing them to be actively involved in decision-making and safety interventions rather than simply playing the passive role of recipient. This point echoes other evidence from research that suggests the decentralization of authority is the most effective way in which management can promote safety, and a participative way of leading is a key predictor of crew members' safety motivation, participation and compliance (Simard and Marchand, 1995; Flin and Yule, 2004; Yang, Wang et al., 2009).

Both the transformational leadership aspects of idealized influence and inspirational motivation (e.g., empowering, inspiring and facilitating), as well as a transactional leadership style (e.g., establishing and structuring, monitoring and coordinating), can be observed from the leadership behaviors for safety at the middle and top levels of management. These results are supported by several studies (Lu and Yang, 2010; Du and Sun, 2012; Wu, Fang et al., 2015) arguing that both transformational and transactional leadership are required for generating and implementing safety management measures at the higher management levels. The results also support the arguments of Cox, Pearce et al. (2003); Muller, Sankaran et al. (2015) and Pearce (2004), who stressed that both vertical (i.e., transactional) and horizontal (i.e., transformational) leadership focuses could supplement but not replace each other. However, a stronger focus on the exercise of transactional leadership can be observed for the middle and top management in shipping organizations. Considering the nature of shipping, the remote working conditions do not permit frequent face-to-face communication or interpersonal interaction between the senior-level management and the crews onboard ships. This may, in turn, constrain the opportunities and mechanisms through which transformational leadership can be fully exercised.

This study endeavored to gain an overall picture regarding this field. Through using three interrelated methods, key safety leadership behaviors at three main organizational levels were identified, assessed and weighed according to the judgment of the expert panel. The results should also be interpreted with caution. The initial leadership model was derived through condensing the research findings generated from other high-risk industrial contexts. To complement the top-down-driven research findings in this Article 2, the study described in Article 3 was conducted to delve deeper into the maritime context and to explore how leaders can effectively persuade for safety compliance and participation.

4.3 Results and discussions of Article 3

Article 3 employed a qualitative research design using interviews and focus group discussions with a total of 41 shipboard officers from various sectors to look into leaders' influence tactics for safety. It brings together the organizational influence theories and safety research (as detailed in Chapter 2) to empirically explore how leaders can effectively persuade subordinates to attain a good level of safety compliance and safety participation onboard ships. Influence is the mechanism through which a leader enacts his or her leadership, which has been considered an essential element of leadership (Feser, 2016). The data generated through interviews and focus group discussions were analyzed through an abductive reasoning approach using a directed content analysis process (Krippendorff, 2012) to view and code the data in light of previous influence theories.

The results revealed that both transformational and transactional leadership styles are important aspects of effective safety leadership at the shipboard level. Different practices of influence have a differential effect on subordinates' safety compliance and safety participation behaviors. In light of the downward influence tactics identified hitherto in general influence tactics research (see Chapter 2) (Yukl and Tracey, 1992; Yukl, Chavez et al., 2005), this study identifies persuasive coaching, role modeling and pressure as most effective in influencing safety compliance, while consultation and exchange are the core tactics employed by shipboard leaders that effectively influence crew members' safety participation behaviors in ship operations.

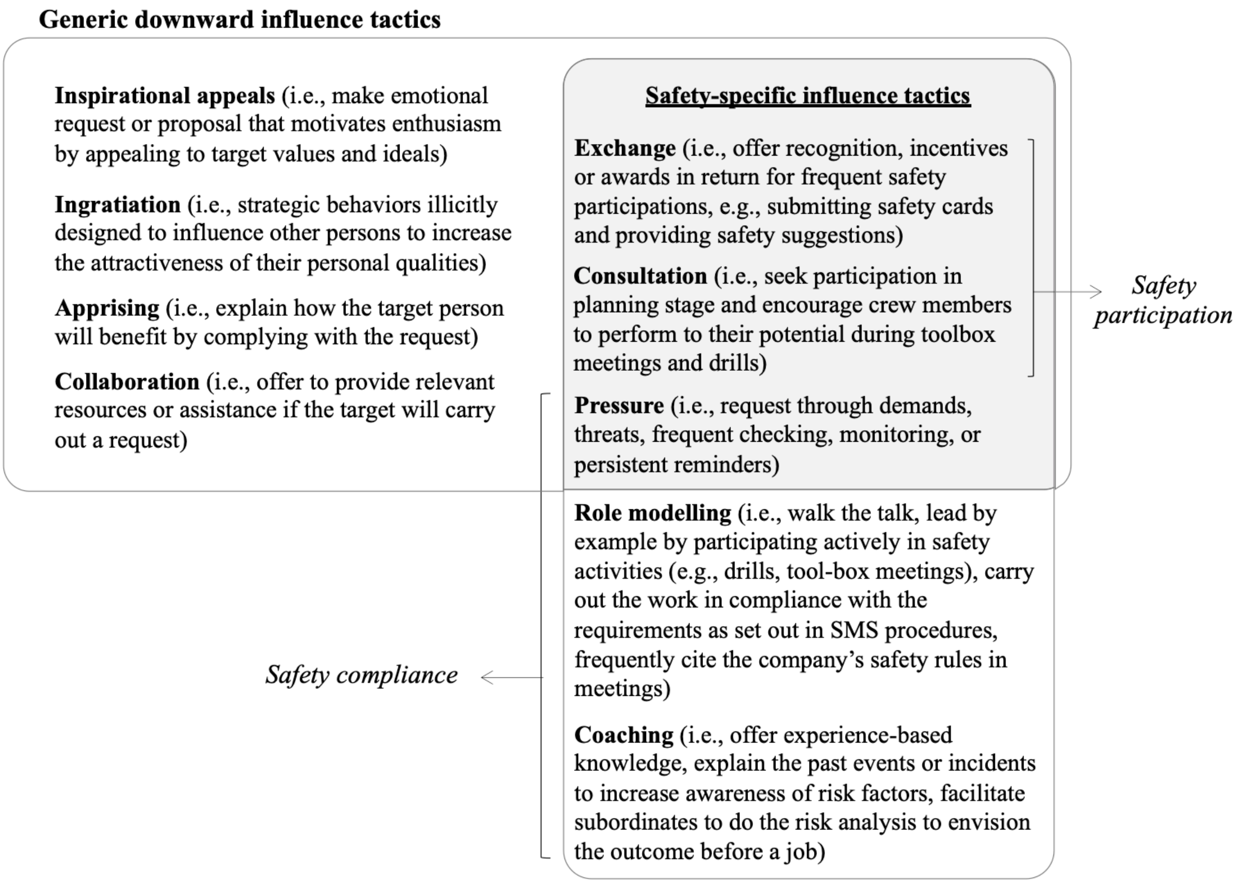


Figure 8. Influence tactics for safety behaviors (adapted from Kim and Gausdal, 2020)

Maritime safety leadership is an influence relationship. It flows from expert, exemplification and personal sources of power (Kim and Gausdal, 2020). Whether to initiate a leadership event is associated with the leader's safety commitment and learning orientation and the criticality of the problem as well as the desired relational outcome of a leadership attempt (Kim and Gausdal, 2020). When taking initiative for a crew's safety participation and non-compliance behaviors (e.g., taking shortcuts or ignoring safe procedures), the respondents described a variety of downward influence tactics, as illustrated in Figure 8, to facilitate the crew members overcoming knowledge and motivation barriers. These influence tactics integrate the elements of both transformational and transactional leadership styles. The use of exchange and pressure were closely aligned with transactional leadership, whereas role modeling, consultation and coaching reflected a transformational leadership focus. As elaborated in Article 3 (Kim and Gausdal, 2020), the results also indicated that the more relationship-oriented the leaders' behaviors, the more effective their safety leadership would be in improving subordinates' safety practices. This result also supported another study conducted in air traffic control, which found that the leadership style for safety favors a high relationship and low task orientation (Arvidsson, Johansson et al., 2007).

The results further corroborated that both transformational and transactional leadership styles are effective in influencing safety compliance and participation behaviors in a ship-operational context (Kim and Gausdal, 2020). This point slightly conflicts with an earlier study (O'Dea and Flin, 2003) which found that a transactional leadership style is more relevant to lower-level management, while a transformational style may be more related to the functions of more senior-level management.

Considering this result in light of Article 2, both articles reveal that safety leadership at the shipboard level has a primary focus on transformational leadership. This result must be interpreted by considering the context of the shipping industry and the managerial position of the shipboard leaders. Research has shown that senior management–level shipboard leaders (e.g., masters, chief-engineers) feel that their authority is being undermined by increasing administrative burdens and governance from shore-based managers under the ISM Code (Little, 2004; MCA, 2004). The safety management activities and safety-related decisions in daily operations are generally well-specified in the SMS as established onshore. The safety performance is closely monitored and guided by the Designated Person Ashore (DPA), as required in the ISM Code (Chen, 2000), which may not allow the shipboard officers to set the rules and to provide rewards or punishments to the crew members. Therefore, a transactional leadership focus is not preferable to transformational leadership at the shipboard level.

These two initial studies (Articles 2 and 3) on maritime safety leadership have several limitations that call for further investigation. First, several contextual factors, such as respondents' nationalities, cultural backgrounds and gender variables, were not taken into consideration. Maritime safety leadership research has not yet tapped into this level of detail to explore if and how gender, cultural values and shipping sector specific characteristics would affect safety leadership behaviors and preferences. Nevertheless, it is an important area to explore, as demonstrated in many studies in the general leadership research field (Dorfman, Howell et al., 1997; House, Wright et al., 1997). This issue will be further discussed in Section 4.6.

The results and understandings generated in Article 3, together with the safety leadership behaviors recognized in Article 2, could contribute to an understanding of the overall safety leadership needed in the merchant shipping context, which will be considered as a partial basis for building an assessment model.

4.4 Results and discussions of Article 4

Article 4 focused on developing the first SLSES in the merchant shipping context. The initial item pool was constructed by considering the effective safety leadership behaviors and influence tactics recognized in Articles 2 and 3 while considering other inputs from literature and three maritime safety researchers. This scale development process was further divided into three stages, including a content validation study with 20 subject matter experts, an Exploratory Factor Analysis (EFA) and a Confirmatory Factor Analysis (CFA) study. During the first stage, a content validity assessment process was engaged with a group of maritime experts (N = 20) to evaluate the appropriateness of each item for measuring the safety leadership of shipboard officers. This process provided an initial content validation check of all measurement items. The results are summarized in Table 10.

Table 10. Results from content validity study in Article 4 (Result from Kim, Sydnes et al., 2021)

Notation	*Item description*	*Importance* Rating 3,4,5	*Importance* Rating 1 or 2	*I-CVI*	*Pc*	*K*
I1	Have the ability to foresee risks	18	2	0,9474	0,0002	0,95
I2	Able to make changes in personnel and task assignments to ensure safe and efficient operations	18	2	0,9474	0,0002	0,95
I3	Have the ability to change the operation to improve safety	20	0	1,0526	0,0000	1,05
I4	Have the ability to establish new rules and work procedures to improve safety	19	1	1,0000	0,0000	1,00
I5	Capable of gathering safety information to make necessary changes	19	1	1,0000	0,0000	1,00
I6	Encourage learning as a basis for improving safety	19	1	1,0000	0,0000	1,00
I7	Able to identify hazards proactively	19	1	1,0000	0,0000	1,00
I8	Able to proactively manage safety risks	19	1	1,0000	0,0000	1,00
I9	Able to use formal authority to ensure crew members adhere to the safety procedures and policies	19	1	1,0000	0,0000	1,00
I10	Ensure achievable safety goals are set	19	1	1,0000	0,0000	1,00
I11	Prioritize safety over other business targets and activities	19	1	1,0000	0,0000	1,00
I12	Follow up crew members to ensure that tasks are completed in a timely and efficient manner	16	4	0,8421	0,0046	0,84
I13	Make concrete plans and programs for the safety activities	18	2	0,9474	0,0002	0,95
I14	Have sufficient knowledge of the technical performance of the vessel	20	0	1,0526	0,0000	1,05
I15	Provide expert knowledge to crew members	18	2	0,9474	0,0002	0,95
I16	Have the capacity to manage the technical skills of the crew members	19	1	1,0000	0,0000	1,00
I17	When undesirable incidents occur, be able to follow the established procedures to deal with the situation	20	0	1,0526	0,0000	1,05
I18	When undesirable incidents occur, be able to improvise to handle the situation effectively	18	2	0,9474	0,0002	0,95
I19	Able to develop effective teams to operate safely	20	0	1,0526	0,0000	1,05
I20	Allocate resources adequately to ensure safe and efficient operation	20	0	1,0526	0,0000	1,05
I21	Able to ensure necessary safety precautions are being carried out by conducting regular supervision	17	3	0,8947	0,0011	0,89
I22	Participate actively in workforce safety activities and initiatives	18	2	0,9474	0,0002	0,95

Notation	Item description	Importance		I-CVI	Pc	K
		Rating 3,4,5	Rating 1 or 2			
I23	Able to make sound decisions and the right choices	19	1	1,0000	0,0000	1,00
I24	Able to mobilize the resources to make effective decisions in a timely manner	18	2	0,9474	0,0002	0,95
I25	Confident that crew members will follow up leaders' decisions	18	2	0,9474	0,0002	0,95
I26	Able to initiate and engage in toolbox sessions during safety meetings on board	18	2	0,9474	0,0002	0,95
I27	Involve crew members actively in recommending revisions to established procedures	19	1	1,0000	0,0000	1,00
I28	Able to delegate work tasks effectively and encourage crew members to accept responsibility for safety	18	2	0,9474	0,0002	0,95
I29	Actively listen to the crew members, and promote their involvement in decision making	19	1	1,0000	0,0000	1,00
I30	Seriously consider the subordinates' suggestions and initiatives for improving safety	19	1	1,0000	0,0000	1,00
I31	Able to successfully foster effective collaboration among crew members	18	2	0,9474	0,0002	0,95
I32	Able to foster positive attitudes and mutual respect among crew members	18	2	0,9474	0,0002	0,95
I33	Monitor performance and ensure that safety procedures are followed by crew members	18	2	0,9474	0,0002	0,95
I34	Use appropriate sanctions to respond to unsafe actions	16	4	0,8421	0,0046	0,84
I35	Able to closely observe crew performance during safety drills on board, and highlight shortcomings and good work	18	2	0,9474	0,0002	0,95
I36	Encourage crew members to create peer pressures to avoid safety complacency	15	5	0,7895	0,0148	0,79
I37	Treat all crew members with dignity and respect	20	0	1,0526	0,0000	1,05
I38	Willing to deal with resistance from crew members in an open and constructive manner	20	0	1,0526	0,0000	1,05
I39	Concerned with how crew members perceive justice and seek to lead in a fair manner	18	2	0,9474	0,0002	0,95
I40	Appear honest and credible to others	19	1	1,0000	0,0000	1,00
I41	Challenge their own and the team's performance against safety objectives to avoid complacency	16	4	0,8421	0,0046	0,84
I42	Set high safety standards for vessel operations	18	2	0,9474	0,0002	0,95
I43	Pioneer in achieving high safety standards	15	5	0,7895	0,0148	0,79
I44	Use logical arguments and factual evidence to ensure crew members' compliance with safety rules/procedures	17	3	0,8947	0,0011	0,89

Notation	*Item description*	*Importance* Rating 3,4,5	Rating 1 or 2	*I-CVI*	*Pc*	*K*
I45	Use good seamanship in leading and training the crew	19	1	1,0000	0,0000	1,00
I46	Have the necessary competence to provide proper directions to the crew	20	0	1,0526	0,0000	1,05
I47	Provide feedback on task performance frequently	16	4	0,8421	0,0046	0,84
I48	Foster open and frequent communication among crew members on safety issues	19	1	1,0000	0,0000	1,00
I49	Able to clearly articulate the desired safety behaviors and work practices	18	2	0,9474	0,0002	0,95
I50	Have the cultural awareness to communicate effectively with all crew members	19	1	1,0000	0,0000	1,00
I51	Circulate important safety information among crew members	19	1	1,0000	0,0000	1,00
I52	Able to lead by example, and communicate the importance of safety through both words and actions	20	0	1,0526	0,0000	1,05
I53	Care about crew member' safety, express compassion and empathy where appropriate	20	0	1,0526	0,0000	1,05
I54	Provide recognition and incentives to crew members for promoting positive safety on board ship	18	2	0,9474	0,0002	0,95
I55	Provide positive emotional support and take care of the crew's welfare	17	3	0,8947	0,0011	0,89
I56	Make the crew more confident to accomplish their tasks	17	3	0,8947	0,0011	0,89
I57	Encourage people to report errors, near-misses or other safety-related information without fear of the consequences	20	0	1,0526	0,0000	1,05
I58	Confident in ensuring the motivation of crews to follow Safety Management Systems (SMS)	18	2	0,9474	0,0002	0,95
I59	Will not bend safety rules to achieve performance targets	18	2	0,9474	0,0002	0,95
I60	Willing to reflect on, and revise leader's decisions based on feedback from the crew	18	2	0,9474	0,0002	0,95
I61	Explain and justify the activities to be performed to give more purpose to the task	15	5	0,7895	0,0148	0,79
I62	Able to galvanize the crews' support to achieve safety standards and goals	17	3	0,8947	0,0011	0,89
I63	Aware of their influence and know what leadership strategies or tactics are needed to ensure safety in various situations	17	3	0,8947	0,0011	0,89
I64	Capable of sourcing the pertinent information for decision making	18	2	0,9474	0,0002	0,95
I65	Capable of keeping safety information updated	19	1	1,0000	0,0000	1,00

The I-CVI of each item reached above 0.79, and the CVI of the overall scale produced a result of S-CVI/Ave = 0.96, which indicated a good level of content validity. No items could be excluded in the initial content validity stage. The second stage of Article 4 used EFA to examine the loadings of individual items and to determine the extent to which the remaining items together could explain the variance of the construct. Table 11 presents the results from the EFA.

Table 11. Results from Exploratory Factor Analysis (Result from Kim, Sydnes et al., 2021)

Factor label	**Items**	**Loading**	**Communalities**	
			Initial	**Extracted**
Factor 1: Efficacy in Safety Motivation Cronbach's α=.971	I57	.859	.779	.720
	I58	.834	.770	.752
	I56	.811	.800	.756
	I40	.782	.703	.614
	I63	.742	.724	.652
	I49	.673	.841	.816
	I48	.673	.865	.833
	I39	.671	.774	.709
	I53	.617	.772	.737
	I37	.578	.757	.660
	I46	.560	.807	.739
	I44	.546	.798	.726
	I50	.544	.766	.723
	I60	.534	.721	.674
Factor 2: Efficacy in Safety Management Cronbach's α=.933	I30	.729	.834	.846
	I29	.725	.838	.808
	I18	.718	.722	.695
	I2	.675	.610	.486
	I24	.531	.797	.743
	I8	.523	.748	.662
Factor 3: Efficacy in Safety Initiative Cronbach's α=.923	I26	.846	.794	.798
	I47	.730	.719	.671
	I43	.653	.716	.684
	I27	.651	.798	.769
	I35	.602	.774	.672
	I10	.587	.681	.581

As presented in Article 4, the factorability of the items was first examined. The KMO was .962, and Bartlett's test of sphericity was also significant ($\chi2$ (325) = 4175.945, $p < .000$), which indicated the existence of a strong relationship between the variables for a meaningful factor analysis (Kaiser, 1970; Kaiser and Rice, 1974). The iterative analysis process yielded the extraction of three factors, namely efficacy in safety management, efficacy in taking safety initiatives and efficacy in motivation facilitation.

Thirty-nine out of the 65 items were eliminated due to insignificant loading or high cross-loading, with 26 items to be considered for inclusion in a hypothesized factor structure for the safety leadership efficacy scale, which accounts for 74.821% of the variance (Kim, Sydnes et al., 2021). The overall reliability, Cronbach's α of the scale with 26 items, was .979. Cronbach's α for self-efficacy in safety management reached .933, with .971 for safety motivation facilitation and .923 for leaders' efficacy in taking safety initiatives. This result was followed up with a CFA with 396 samples to verify the hypothesized measurement structure, as illustrated in Figure 9.

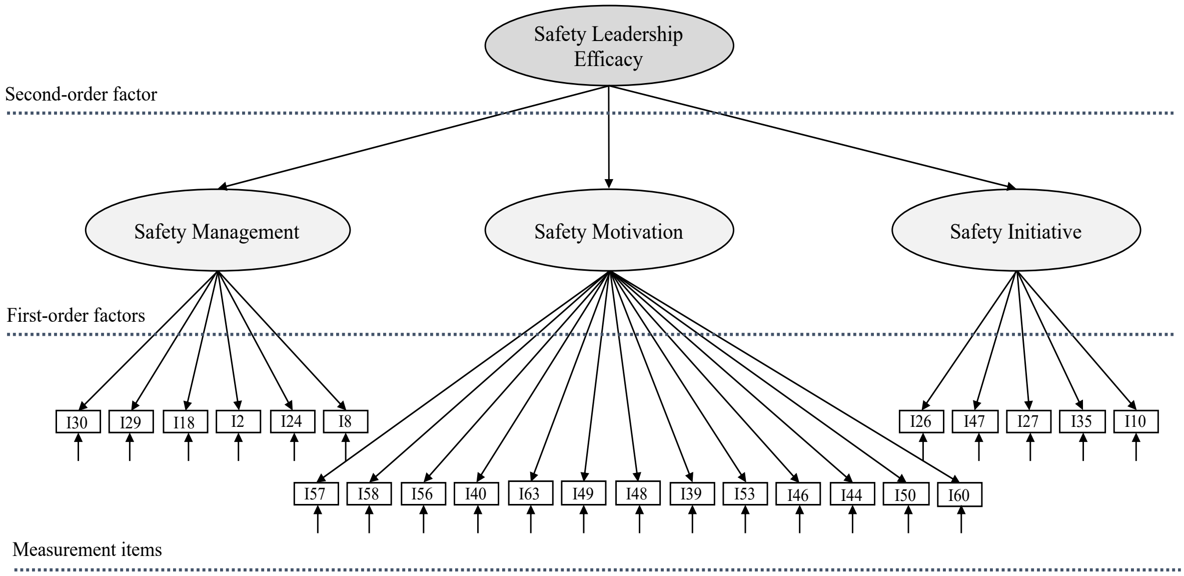


Figure 9. Final CFA model (Result from Kim, Sydnes et al., 2021)

During the third stage, the CFA process, two items, I37 and I43, were further dropped. The analysis was performed using 396 samples without any missing values in the dataset. The remaining 24 items contained in this scale have an adequate statistical measurement property and good reliability. The goodness-of-fit indices were χ^2_{MLR} (249, N = 396) = 493.904 ($p<.001$), R-CFI = .947, R-TLI = .941, CFI = .944, TLI = .938, RMSEA = .050 (90% CI, [.045,.055]) and standardized RMR = .034. The final CFA result is presented in Table 12.

Leaders' efficacy in safety motivation facilitation was measured using 13 items to assess the extent to which the shipboard officers could use social skills to influence, encourage, motivate and build relationships with the crew members. The shipboard officers' competence in safety management was measured with six items and looked into the extent to which they could identify, manage and handle risky and hazardous situations during ship operations. Efficacy in taking safety initiatives was measured with five items by looking at the extent to which shipboard officers could demonstrate specific, discrete verbal and nonverbal leadership behaviors and initiations to encourage their subordinates' involvement in safety activities.

Table 12. Results from Confirmatory Factor Analysis (Result from Kim, Sydnes et al., 2021)

Notation	Item	Estimate		R^2	S.E.	z-value	P(>|z|)	Cronbach Alpha
		B	β					
Efficacy in safety motivation facilitation			*0.946					.954
I57	Encourage people to report errors, near-misses or other safety-related information without fear of the consequences	1.000	0.767	0.588			1.116	
I58	Confident in ensuring the motivation of crews to follow Safety Management Systems (SMS)	1.096	0.794	0.631	0.065	16.925	0.000	
I56	Make the crew more confident to accomplish their tasks	1.020	0.804	0.646	0.053	19.186	0.000	
I40	Appear honest and credible to others	0.978	0.739	0.546	0.053	18.547	0.000	
I63	Aware of their influence and know what leadership strategies or tactics are needed to ensure safety in various situations	0.994	0.799	0.639	0.074	13.384	0.000	
I49	Able to clearly articulate the desired safety behaviors and work practices	1.085	0.849	0.721	0.069	15.628	0.000	
I48	Foster open and frequent communication among crew members on safety issues	1.083	0.826	0.683	0.069	15.650	0.000	
I39	Concerned with how crew members perceive justice and seek to lead in a fair manner	0.988	0.762	0.580	0.062	15.860	0.000	
I53	Care about crew member' safety, express compassion and empathy where appropriate	0.952	0.771	0.594	0.056	17.033	0.000	
I46	Have the necessary competence to provide proper directions to the crew	1.154	0.807	0.651	0.076	15.095	0.000	
I44	Use logical arguments and factual evidence to ensure crew members' compliance with safety rules/procedures	0.990	0.804	0.646	0.056	17.597	0.000	
I50	Have the cultural awareness to communicate effectively with all crew members	1.063	0.722	0.521	0.083	12.761	0.000	

I60	Willing to reflect on, and revise leader's decisions based on feedback from the crew	0.916	0.760	0.578	0.074	12.457	0.000	
Efficacy in safety management			*0.961					.906
I30	Seriously consider the subordinates' suggestions and initiatives for improving safety	1.000	0.806	0.650			1.076	
I29	Actively listen to the crew members, and promote their involvement in decision making	1.078	0.814	0.662	0.074	14.596	0.000	
I18	When undesirable incidents occur, be able to improvise to handle the situation effectively	1.092	0.791	0.625	0.093	11.704	0.000	
I2	Able to use formal authority to ensure crew members adhere to the safety procedures and policies	1.047	0.707	0.500	0.096	10.918	0.000	
I24	Able to mobilize the resources to make effective decisions in a timely manner	1.098	0.861	0.741	0.083	13.213	0.000	
I8	Able to proactively manage safety risks	0.977	0.745	0.555	0.069	14.096	0.000	
Efficacy in safety initiative			*0.963					.887
I26	Able to initiate and engage in toolbox sessions during safety meetings on board	1.000	0.801	0.641			1.279	
I47	Provide feedback on task performance frequently	0.953	0.769	0.591	0.063	15.040	0.000	
I27	Involve crew members actively in recommending revisions to established procedures	0.963	0.807	0.651	0.038	25.197	0.000	
I35	Able to closely observe crew performance during safety drills on board, and highlight shortcomings and good work	0.931	0.814	0.662	0.050	18.646	0.000	
I10	Ensure achievable safety goals are set	0.760	0.723	0.523	0.054	14.156	0.000	
	SLSES TOTAL							**.971**

In comparison to other safety leadership scales (Wu, Chen et al., 2008; Du and Sun, 2012), the SLSES has a specific focus on maritime safety. The items could reflect the key KUP stated in the STCW leadership requirements for shipboard officers at both the management and operational levels (please see Table 2), but elaborated on the STCW leadership requirements by including the key safety leadership behaviors identified through two previous empirical articles included in this thesis. This gives a more comprehensive measurement of the safety leadership of shipboard officers.

Research has recognized that effective leadership requires leaders to be skilled in the use of influence (Yukl and Falbe, 1990) and to have a good level of self-efficacy toward their own leadership behaviors and capabilities (Anderson, Krajewski et al., 2008). The

SLSES incorporated the items that could help in assessing these leadership aspects and can aid in the understanding and prediction of the safety leadership of shipboard leaders. According to previous studies, leaders with higher leadership efficacy are more likely to initiate and engage in leadership attempts (Paglis and Green, 2002), use leadership skills and have better effectiveness compared to those with lower self-efficacy (Anderson, Krajewski et al., 2008). Follow-up studies should consider conducting correlational statistics between the respondents' SLSES scores and other relevant safety indicators (e.g., incident/near-miss reporting rate, injury rate). Given that this is the first scientific safety leadership-efficacy measurement scale in maritime context, it may provide a distinct contribution to theory-building and empirical research.

4.5 Results and discussions of Article 5

Articles 2–4 have generated an understanding of safety leadership practices and designed a measurement scale for assessing the safety leadership efficacy of shipboard officers. The research is based on the assumption that a ship is operated by a team of human operators and that their collaborations, teamwork, safety participation and compliance have important implications for the safety and reliability of ship operations. As technology advances by gradually replacing many human roles in operations, a skeptic could ask—as we are living in an era of unprecedented technological change, and the maritime industry is talking intensively about MASS where humans are not needed on board—could these leadership findings be outdated?

In the last article of this thesis, another empirical study was conducted to project future leadership requirements through exploring and analyzing how different degrees of autonomy might affect safety leadership. This article starts with a presentation regarding the status of automation development for the shipping industry, the current recommended safety leadership practices, and how these will be changed and adapted in light of two major degrees of autonomy: manned MASS and unmanned and remotely controlled MASS. Current safety leadership behavioral competence requirements are evaluated through two rounds of Delphi expert consensus. The results are summarized in Table 13.

Table 13. Degree of agreement regarding the relevance of each leadership Knowledge, Understanding And Proficiency (KUP) for MASS (Kim and Mallam, 2020)

Notation	Common Knowledge, understanding and proficiency (KUP) of leadership for both management and operational level onboard merchant ships	Relevant under manned MASS?	Relevant under remotely controlled MASS?	Comparison
KUP 1	Knowledge of shipboard personnel management and training	Yes (92%)	No (63%)	-29%
KUP 2	Knowledge of related international maritime conventions and recommendations, and national legislation	Yes (100%)	Yes (88%)	-12%
KUP 3	Ability to apply task and workload management including planning and coordination, personnel assignment, time and resource constraints, prioritization	Yes (100%)	Yes (100%)	0%
KUP 4	Knowledge and ability to apply effective resource management	Yes (92%)	No (79%)	13%
	.1 Ability to allocate, assign, and prioritize resources	Yes (96%)	No (79%)	17%
	.2 Ability to initiate and maintain effective communication on board and ashore	Yes (100%)	No (79%)	21%
	.3 Ability to make decisions reflect consideration of team experience	Yes (100%)	No (79%)	21%
	.4 Assertiveness and leadership, including motivation	Yes (96%)	No (67%)	29%
	.5 Ability to obtain and maintain situation awareness	Yes (100%)	Yes (88%)	12%
KUP 5	Knowledge and ability to apply decision-making techniques	Yes (100%)	Yes (92%)	8%
	.1 Knowledge and ability to conduct situation and risk assessment	Yes (100%)	Yes (88%)	12%
	.2 Knowledge and ability to identify and generate options	Yes (100%)	Yes (83%)	17%
	.3 Knowledge and ability to select course of action	Yes (92%)	Yes (92%)	0%
	.4 Knowledge and ability to evaluation of outcome effectiveness	Yes (88%)	Yes (88%)	0%
KUP 6	Development, implementation, and oversight of standard operating procedures	Yes (92%)	Yes (92%)	0%
B1	Caring and supporting (i.e., respect and trust employees, and care about crew's needs and empathize with their problems)	Yes (92%)	No (71%)	21%
B2	Controlling and enforcing (i.e., set the rules by which the teams/organization runs, use their power to give a reward or a punishment)	Yes (100%)	No (71%)	29%
B3	Participative involvement (i.e., promote crew's involvement in decision making and participating in safety activities)	Yes (100%)	No (71%)	29%

The degree of agreement has shown that all forms of leadership competence (including leadership behaviors and knowledge requirements) still seem relevant and important for manned MASS. However, if the ship is remotely controlled without crew on board, the leadership model will be slightly changed. Several key leadership competences, such as knowledge of shipboard personnel management and training, caring and supporting behaviors, participative involvement and controlling and enforcing behaviors, were deemed no longer relevant. Based on the results presented in Table 13, the panelists were invited to confirm the findings and also to complete an AHP questionnaire to prioritize leadership competences for both remote-control operators and shipboard officers on highly automated ships. The final prioritized list of leadership competence requirements is presented in Table 14, according to their relative importance for safe and efficient operation.

Table 14. Future leadership competence required for shipboard officers (Kim and Mallam, 2020)

Category	Notation	Leadership requirement for shipboard leaders on manned MASS	Weight	Importance ranking
Required leadership competence for shipboard officers on manned MASS	KUP 5	Knowledge and ability to apply decision-making techniques	0,1554	1
	New KUP	Knowledge and ability to acquire, handle and comprehend large amount of system information	0,1454	2
	B3	Participative involvement (i.e., promote crew's involvement in decision making and participating in safety activities)	0,1105	3
	B1	Caring and supporting (i.e., respect and trust employees, and care about crew's needs and empathize with their problems)	0,1029	4
	KUP 4	Knowledge and ability to apply effective resource management	0,1007	5
	KUP 6	Development, implementation, and oversight of standard operating procedures	0,0913	6
	KUP 3	Ability to apply task and workload management	0,0912	7
	B2	Controlling and enforcing (i.e., set the rules by which the teams/organization runs, use their power to give a reward or a punishment)	0,0795	8
	KUP 2	Knowledge of related international maritime conventions and recommendations, and national legislation	0,0622	9
	KUP 1	Knowledge of shipboard personnel management and training	0,0608	10

Required leadership competence for remote control operators of unmanned MASS	KUP 4.5	Ability to obtain and maintain situation awareness	0,3088	1
	New KUP	Knowledge and ability to acquire, handle and comprehend large amount of system information	0,2385	2
	KUP 5	Knowledge and ability to apply decision-making techniques	0,1904	3
	KUP 6	Development, implementation, and oversight of standard operating procedures	0,1027	4
	KUP 3	Ability to apply task and workload management	0,0830	5
	KUP 2	Knowledge of international maritime conventions and recommendations, and related national legislation	0,0766	6

In the manned MASS configuration, the ship would be able to make routine decisions based on its autonomous operating systems, as the ship can at times be unsupervised. It can be expected that the decision points that come to the crews are more likely to involve unusual or abnormal situations that could not be sufficiently dealt with by an autonomous operating system (Kim and Mallam, 2020). This would challenge the crews to deal with more complex technical problems in a timely manner through interpreting a large amount of system information that may not have been faced frequently, or at all, in conventional ship operations (Kim and Mallam, 2020). Consequently, system understanding, process mapping and the ability to synthesize information rapidly to acquire an in-depth understanding of the automation system and its behaviors would be fundamental to adequate follow-up control actions. The Delphi process has revealed that in addition to the existing KUPs, the knowledge and ability to acquire, handle and comprehend a large amount of system information would be crucial to add as a new KUP to the STCW leadership requirements.

The AHP result indicates that for shipboard leaders on highly automated ships, the knowledge and ability to apply decision-making techniques (KUP 5), and the knowledge and ability to acquire, handle and comprehend a large amount of system information (new KUP), were deemed most critical to be developed by future shipboard officers, whereas knowledge regarding shipboard personnel management and training will become the least relevant and important (Kim and Mallam, 2020). For remote-control operators on unmanned ships, the ability to obtain and maintain situational awareness is perceived as the most critical leadership competence requirement for safe and efficient operation.

Furthermore, the knowledge and ability to acquire, handle and comprehend a large amount of system information has also reached a high level of perceived importance.

Many researchers have discussed the benefits as well as the challenges of implementing remote and unmanned control solutions for the safety and efficiency of future ship operations (Kooij, Loonstijn et al., 2018; Porathe, Hoem et al., 2018; Mallam, Nazir et al., 2019). Although the development and implementation of automation technology are partly intended to deliver cost savings by an increase in vessel safety and efficiency as well as reliability by removing human failures, automation will also potentially bring a set of new and unknown risks to the shipping system (Porathe, Hoem et al., 2018; Ringbom, 2019). Using highly intelligent algorithms and their burgeoning decision-making potential also implies that future ship operators, both shipboard officers and remote-control operators, need to update their knowledge and skills in order to keep abreast of technological changes. The results support other studies (Ringbom, 2019; Sharma, Kim et al., 2019) by suggesting the mandatory minimum requirements for seafarers should be significantly revised in future versions of the STCW to meet the challenges presented by technological disruption.

4.6 Research limitations and future work

This thesis is subject to some limitations. In light of the methodology described in Chapter 3 and the research findings presented in this chapter, some constraints of this thesis deserve note.

First, the representativeness, validity and reliability of the findings generated from all articles would have been enhanced with larger sample sizes. Future research to validate the findings with more balanced and larger representation of the global merchant shipping industry is needed. Further, the safety leadership model derived through Article 2 can be applied to any high-risk industry, as the initial hierarchy model was built upon the literature conducted in various high-risk industrial contexts (Kim and Gausdal, 2017). However, the AHP results presented here can only be applied to the context of merchant shipping as it was judged by an expert panel from this particular industrial context. Future studies can investigate the priority sets from different shipping sectors, and the differences may provide a basis for identifying the contextual effects. In addition to this, as the AHP model assumes independencies among the alternatives, future research can also contribute to exploring the independencies and correlations through statistical analysis as well as the causal relationship between each safety leadership behavior and the related safety outcome (e.g., near-misses reporting, number of non-conformity).

Second, the analysis presented in this thesis was built upon the literature (as presented in Table 8) that has explored the causal relationship between specific leadership styles and safety performance, and the empirical research part of the Article 2 and 3 relied on the evaluations, experiences, stories, incidents provided from the leaders' perspective. This is one way to study leadership phenomena (Bernstein, 2018). Future research can take another perspective to explore how safety leadership behaviors and influence tactics can be perceived on the other side of the dyads (e.g., followers) to extend the findings presented here. The results can then be compared with those presented in this thesis.

Third, this research focused on extracting a general and succinct understanding of safety leadership in maritime arena, yet several variables, such as nationality, cultural values and personability, sector-specific characteristics, were not taken into consideration during the data collection and analysis process. These variables have also not been considered in the leadership competence requirement in STCW 1978, as amended (IMO, 2017). Intra-personal characteristics and cultural values have profound influence in shaping decisions, work-related attitudes and behavioral patterns (Jung, Bass et al., 1995; Jung and Avolio, 1999). Previous research has indicated that culture dimensions (e.g., power distance, uncertainty avoidance, collectivism and long-term orientation) could influence seafarers' safety attitudes and behaviors (Lu, Hsu et al., 2016). It is therefore worthwhile to conduct future research in this area to obtain a fuller picture of the safety leadership process and to consider the influence of individuals' values on the selection and implementation of safety leadership influence strategies.

In the context of the dynamic shipping industry, it can be inferred that the relative importance of each leadership behavior for safety is also context-dependent. Sector specific characteristics may also influence the practices of safety leadership, as the risk factors and level of safety criticality are different across different shipping sectors (e.g., general cargo ships, tankers, cruise ships, bulk carriers). This opens up another area of research to explore the differences in leadership practices among different shipping sectors to tailor the leadership styles and practices for safe and efficient operations.

Lastly, effective leadership, which is considered an important ingredient for safe operation today, will play an increasingly important role in the era of autonomous shipping to address complex demands in the dynamic and complex operational environment where multiple degrees of autonomy are present at sea. Researchers should expand the exploration regarding the leadership requirements under different MASS scenarios to effectively prepare seafarers for safe and efficient ship operations in the future.

5 Chapter: Conclusions

This chapter reflects on the main research findings and contributions of this thesis by revisiting the research questions raised in the introductory chapter. The results from each article and how they contribute to the literature, practice and/or policy are briefly summarized in Figure 10 and further elaborated in the following sections. This chapter restates the thesis, concludes the thesis with an overview of the research contributions and provides an outlook for future research in the field of safety leadership.

5.1 Revisiting the research questions

***Research question #1**: What are the key safety leadership behaviors that should be demonstrated at each managerial level in shipping organizations?*

1.a What are the key safety leadership behaviors in high-risk organizations? How to understand the safety leadership contribution in the lens of systems thinking?

1.b Are the key safety leadership behaviors in high-risk organizations transferable/applicable to shipping?

1.c What is the relative significance of each safety leadership behavior in determining the overall safety performance for shipping organizations?

It is recognized in this research that effective safety management requires a collective effort from all organizational levels. Passionate, effective leadership is a prerequisite for safe performance. An inductive analysis of the empirical studies in different high-risk industries on the topic of safety leadership has yielded an initial understanding of a range of critical safety leadership behaviors at each organizational level.

To address subquestion 1.a, the review has identified that lower-level managers' communicating (LM1), caring and supporting (LM2), controlling and enforcing (LM3) and participative involvement (LM4), and the middle level's empowering (MM1), monitoring (MM2), informing (MM3) and coordinating behaviors (MM4), are the key leadership behavioral categories that could exert positive influence over subordinates with increased safety behaviors. Four safety leadership behavioral categories, including enabling (TM1), safety concern (TM2), establishing and structuring (TM3), and inspiring and facilitating (TM4), among the top-level management were synthesized through an inductive analysis of the empirical studies within various industrial settings that yielded similar findings (Kim, 2016). These leadership behaviors appeared to be the means by which managers can exert positive influence over their subordinates pertaining to safety-related activities.

To address subquestion 1.b, the research looked into if the key safety leadership behaviors in high-risk organizations are transferable/applicable to shipping context. The results have shown that among these 12 identified safety leadership behavioral categories, eleven categories identified in other high-risk industrial contexts were confirmed by the maritime experts to be also appropriate and important to be applied in this specific context of shipping industry. However, controlling and enforcing behaviors have been perceived to be less effective to be demonstrated by shipboard leaders in daily ship operations, but may require in the emergency or abnormal situations when firm control or an authoritarian approach is needed (Kim and Gausdal, 2017). As further elaborated in the article, to be able to balance authority and approachability would be a clear leadership skill and shall be used adaptively depending on the criticality of the leadership situations.

In light of subquestion 1.c, shipboard-level leaders' participative involvement was perceived to have the highest relative importance to the safety performance of ship operations by the expert panel in the AHP analysis. Top-level management's establishing and structuring behaviors also received a high level of adherence, as these are important to enable and ensure safety as the top priority and to reflect safety values in the overall organizational structure and policies. Leaders' informing behaviors, such as delivering essential safety information or updating the master and crews with the latest information, have frequently appeared in the literature (see Table 8), and it was perceived that this has the most importance in middle-level management (e.g., fleet managers, technical superintendents).

The dynamic nature of a ship's operational environment may imply that the relative importance of each leadership behavior and leadership objective is also highly context-dependent. It was suggested in this study to continuously adapt and monitor the safety leadership performance and ensure its effectiveness. This model may contribute to a succinct understanding of safety leadership behavior at each management level and may also be used as a benchmark for developing the leadership competence of new or less experienced managers.

Research question #2*: What are the interpersonal influence tactics employed by shipboard leaders that successfully influenced their subordinates' safety compliance and participation behaviors in ship operations?*

Although considerable research has demonstrated the importance of leadership on safety, as synthesized in Article 2, less is known about the specific leadership actions and means of persuasion that promote different kinds of safety performance in subordinates. In this study, a qualitative approach was taken to identify specific safety leadership influence behaviors and to investigate how they might motivate two distinct aspects of safety performance i.e., safety compliance and safety participation.

The study highlights that "effective leadership influence flows from the exemplification, expert and personal sources of power, and being pursued through soft and rational influence tactics rather than coercion or constructive inducements" (Kim and Gausdal, 2020, p. 11). It identifies that persuasive coaching, role modeling, pressure, consultation and exchange tactics were the essential means of persuasion leading to greater safety compliance and participation behaviors. When encouraging the crew members to adhere to safety procedures and rules, coaching, role modeling and pressure tactics were found to be more effective in generating changes compared to hard influence tactics such as pressure or sanctions. It also emphasized individual learning to increase crew members' awareness of problems and self-efficacy in engaging in safety-related activities. Exchange and consultation were interaction- and relationship-oriented, encouraging better two-way communication, which is more likely to influence active safety participation behaviors among the crew members.

Furthermore, this study found that leadership style for safety in a ship-operational context has a high relationship and low task-oriented behavioral orientation (Kim and Gausdal, 2020), and it is also linked to both of the components in transformational and transactional leadership. This contributes additional evidence to the literature that both transformational and transactional leadership are the primary leadership styles that could effectively influence safety compliance and participation behaviors.

Research question #3*: What are the indicators of good safety leadership, and how to measure safety leadership efficacy of the current and future shipboard officers?*

By considering safety leadership behaviors (see Section 4.2) and influence tactics (see Section 4.3) as a basis for recognizing the indicators of good safety leadership, as well as additional inputs from theory and maritime researchers, this research question focused on designing a measurement tool that can be used to assess a shipboard leader's safety leadership performance and recognize room for improvement. The final SLSES included three sub-scales and 24 indicators/measurement items for good safety leadership, each of which directly or indirectly facilitates crew members' motivation for engaging in safety efforts.

The first subscale is used to measure shipboard leaders' efficacy in facilitating safety motivation. It included several indicators, such as the extent to which a leader could encourage their subordinates to report errors, near-misses or other safety-related information without fear of consequences, or items such as whether the leader can clearly articulate the desired safety behaviors and work practices, if they were aware of their influence and know what leadership strategies or tactics are needed to ensure safety in various situations. Another subscale measures leaders' efficacy in safety management, with indicators such as the extent to which the shipboard leaders could proactively manage risks, mobilize resources, implement measures to ensure safety compliance and improvise handling dynamic situations during ship operations, and whether they seriously consider subordinates' suggestions and initiatives for improving safety. The third subscale is used to measure leaders' efficacy in taking safety initiatives. Indicators used for measuring this factor included leaders' proficiency in setting goals, monitoring safety behaviors and exercising specific, discrete verbal and nonverbal leadership behaviors and initiations to encourage subordinates' involvement in safety activities. All three factors (i.e., safety management, safety initiative, safety motivation facilitation) and their measurement items remained in the final scale were appeared that good conceptual consistency and validity.

Research question #4*: What are the leadership implications of autonomous shipping?*

4.a. What is the applicability of current leadership competence requirements for MASS operations?

4.b. What are the future leadership competences that should be accrued by the personnel involved in MASS operations?

The study found that the adoption of a higher degree of autonomy in ships and reduced crew size did not imply that there would be a dramatic change to what leaders could provide, according to the consensus from the expert panel. Leadership behaviors and practices as required today will remain essential ingredients for future safe operations under both unmanned and manned MASS. However, there is a need to shift the expectations and change the competency framework for leadership. An increased degree of autonomy onboard ships implies that fewer operators will need to be present, which also implies that more dependencies will be placed on the expertise, mental resources and collaborations among the crews on board to deal with both normal and abnormal situations (Kim and Mallam, 2020). Crews onboard MASS must be able to work effectively within the new partnerships between human teams and automation technologies, while being systemic thinkers able to comprehend the mutual influence, relationships and dependencies (Kim and Mallam, 2020).

Answering subquestions 4.a and 4.b, the study has concluded that the STCW leadership KUPs as required today will remain basic leadership requirements for future shipboard leaders on manned MASS. Among these, the knowledge and ability to apply decision-making techniques and the knowledge and ability to acquire, handle and comprehend large amounts of system information were reported to have the highest level of importance for shipboard leaders on highly automated ships. In the remote-controlled and unmanned MASS scenario, two KUPs, the knowledge of shipboard personnel management and training and the knowledge and ability to apply effective resource management (except the ability to obtain and maintain situational awareness), were deemed no longer relevant and important for remote-control operators. Nevertheless, leaders' ability to obtain and maintain situational awareness will be increasingly critical, and their ability to acquire, handle and comprehend large amounts of system information—as a new KUP—will be important for safe and efficient operations in the future.

5.2 Contributions

This thesis has theoretical, practical and policy implications on maritime safety leadership, as summarized in Figure 10. First, although the pivotal role of leadership to safe operational performance and safety outcomes has been well studied in various high-risk industries, little research has been conducted to explore safety leadership phenomena in the maritime sector. This thesis addressed this fundamental gap in the maritime safety leadership literature by extending the understanding of how specific leaders' behaviors might affect maritime subordinates' safety-related activities and by providing clarification of the specific leadership behaviors likely to motivate and promote different aspects of maritime subordinates' safety behaviors. It further identified which of these leadership behaviors are likely to have the biggest impact on safety performance in ship operations. The results highlighted that leadership has an important impact on safety in ship operations. This issue therefore needs to receive attention alongside the technical and policy issues that have been the principal concern in the past. As stated in the preamble to the ISM Code, "In matters of safety and pollution prevention, it is the commitment, competence, attitudes and motivation of individuals at all levels that determines the end result" (IMO, 2014). Safety does not exist in written procedures or regulations but comes from the actions of the operators and the interaction among all control actors within the vessel system, in which leadership plays a fundamental role (Leveson, 2011).

Maritime leadership training programs should therefore tailor their focus to the leadership aspects more conducive to improving safety at sea. The findings generated through this thesis can be used as a reference guide for shipboard officers, maritime companies and MET institutes interested in improving leadership training or other non-technical skill-development programs. Shipboard leaders would benefit from developing a range of behaviors that encompass both transformational and transactional leadership, and their safety leadership potential could also be cultivated, activated and nurtured for effectiveness.

RQs	Articles	Main points	Contributions
RQ1	Leading for safety: A weighted safety leadership model in shipping	Synthesized the research findings in the field of safety leadership and seeked to extrapolate the findings to maritime context Described, evaluated and prioritized the key safety leadership behaviors at three main management levels with an expert panel Supported the importance of applying transformational and transactional leadership theory in the maritime context	Theoretical: • The results could contribute to knowledge in safety-specific transformational and transactional leadership theory Practical/policy: • The results may have reference value for professional seafarers, the leaders on shore and the ship-owners in establishing best leadership practices for safety • The prioritized model can be used as a basis for facilitating safety leadership training in shipping organizations
RQ2	Leaders' Influence Tactics for Shipboard Safety – An Exploratory Study	Studied shipboard leader's influence tactics for safety compliance and participation behaviors in maritime context in light of prior organizational influence research Maritime safety leadership is an influence relationship, it flows from exemplification, expert and personal sources of power Effective maritime safety leadership is pursued through using soft and rational influence tactics	Theoretical: • The results add knowledge to organizational influence research • The results add knowledge to safety-specific transformational and transactional leadership theory Practical/policy: • The results could provide practical implications for professional seafarers and MET institutes to establish best leadership practices and to build safety leadership influence for better safety on board ships
RQ3	Developing and Validating a Safety Leadership Self-Efficacy Scale (SLSES) in Maritime Context	Developed a scale to measure the extent to which shipboard leaders could exemplify and execute courses of action required to attain a good safety performance on-board ship The results have supported a higher order factor structure with three subscales – assessing leaders' efficacy in safety management, motivation facilitation and safety initiative	Theoretical: • The research formulated and tested a theoretical model for safety leadership efficacy • The results could contribute to maritime safety leadership research Practical/policy: • SLSES can provide maritime researchers, professional seafarers, MET institutes and shipping organizations with a tool to assess and enhance safety leadership potentials of current and future shipboard officers • The result could help training instructors to determine the best approach to increase safety leadership efficacy according to which area of safety leadership they are weakest in
RQ4	A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations	Evaluated the applicability of current STCW leadership requirements for Maritime Autonomous Surface Ship (MASS) operations The results have shown that the current STCW leadership competence requirements (e.g., knowledge, understanding and proficiency) are not fully relevant for MASS Discussed and prioritized the leadership competences that should be accrued by the personnel involved in future ship operations	Theoretical: • New research initiative to explore leadership implications of autonomous shipping • Highlighted several directions for future research on safety leadership Practical/policy: • The results could contribute to revision of STCW Table A-II/1, Table A-III/1, Table A-II/2 and Table A-III/2 • The results may have reference value for MET institutes to adapt their leadership training programs for MASS, and maintain relevancy of their training practices to effectively prepare current and future shipboard officers

Figure 10. Brief summary of research results and contributions

Further, as mentioned in Section 1.2, despite that leadership has been introduced as a mandatory competence requirement for global shipboard officers, as specified in STCW 1978, as amended (IMO, 2017), no theoretical models or scales are available to describe leadership performance and facilitate leadership measurement. If we do not measure to see what is getting better and what is not, it is hard to find a direction to improve, and we will not be able to recognize, anticipate or mitigate leadership problems. The mandatory training effort would consequently have no control on actual learning outcomes. In this thesis, a maritime safety leadership measurement scale was designed that can be used as an instrument to diagnose safety leadership efficacy and a basis for decisions regarding future training efforts by recognizing the area of leadership in which participants are weakest. Such an initiative is innovative in the current maritime safety leadership literature.

In addition, no research to date has explored the impact of autonomous shipping on leadership behaviors and STCW leadership competence requirements. The last stage of this thesis took the initiative to explore whether the disruptive changes with regard to MASS implementation will have an influence on leadership behaviors and STCW leadership requirements. New leadership competences that should be accrued by the personnel involved in the future configurations of ship operations were also discussed. The findings presented in Article 5 can also be used as an input for MET institutes to adapt training programs, assess the effects of training intervention and maintain the relevancy of the training practices to effectively prepare current and future leaders for successful ship operations in the future. Furthermore, this research could add value to the IMO instrument, STCW 1978, as amended. The leadership competence requirement derived from Article 5 could have policy implications for the future revision of STCW Table A-II/1, Table A-III/1, Table A-II/2 and Table A-III/2, as well as other STCW sections that detail the same leadership KUPs.

5.3 Concluding remarks

In conclusion, amid all the pressing priorities in today's shipping industry, the safety of the crews, passengers, cargos and ocean are the foremost moral and ethical obligations. It is one of the ultimate duties as well as challenges for today's leaders to effectively manage technology and lead people in safe and efficient ship operations.

Based on the identified knowledge gaps, the research problem is a lack of knowledge regarding safety leadership in the maritime context, despite its importance for ship operations. In light of this, the objective of this thesis was to explore and understand safety leadership phenomena in merchant shipping to broaden our theoretical understanding of maritime safety leadership and to guide practitioners in establishing best leadership practices. This thesis has contributed to achieving this objective by recognizing effective safety leadership behaviors, developing an assessment model for shipboard officers and analyzing future leadership competences in the age of autonomous ship operations. The results have implications to the literature, industry and policy authorities with increased knowledge regarding safety leadership in the maritime context. The thesis may also, hopefully, shed light on further thoughts and contributions toward improving the safety and efficiency of the maritime industry in the future.

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PART II

List of publications

Article 1

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Article 4

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Article 5

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A STAMP-based causal analysis of the Korean Sewol ferry accident

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ABSTRACT

The increased complexity of socio-technical systems has revealed the limited contributions of existing event-based accident analysis methods on sustainable safety improvements. Systems-Theoretic Accident Model and Processes (STAMP) – constructed upon Systems Theory – deploys a holistic approach to safety and provides broad insights into accident causality via the integration of the analysis from both direct and indirect factors involved. A dedicated STAMP-based analysis is conducted in this paper by taking the recent Sewol ferry tragedy as an example, to illustrate the utility of applying the STAMP-Model to the maritime transportation domain and to stimulate a broader view of accident mechanisms that expands casual analysis beyond immediate physical failures to a systemic view. Some recommendations are developed for continuous improvements and corrective actions to prevent such catastrophic accident from future occurrences.

1. Introduction

The implementation of numbers of safety-related regulations (IMO, 2015) and advances in technology and automation systems (*e.g.*, Hetherington et al., 2006) have steadily evolved the safety level of marine transportation (Allianz Global Corporate and Speciality, 2015). Yet despite the continuous improvement, the recent foundering of Costa Concordia (Schröder-Hinrichs et al., 2012), Norman Atlantic (Vairo et al., 2015) and Sewol – with the losses of innocent lives – have demonstrated unforeseen and sadly cataclysmic vulnerabilities, further underscored long-standing concerns over the safety of passenger ships.

Maritime transportation has been referred as an 'error-inducing system' (Perrow, 1999; Rijpma, 2003). It has been considered as a profit-oriented, authoritarian, poorly organized, and weakly unionized industry (Linstone et al., 1994; Burke et al., 2011), in which multiple errors might bring out unexpected interaction that can defeat a safety system (Perrow, 1999). In such a system, operator error is prominently given as an explanation for an accident as failures and consequences of actions appear immediately at the level of proximate personnel. This argument has put pressure on the identification and elimination of human errors, which has long been considered activities of critical importance for maritime accident investigation. This traditional view of safety has been criticized by many researchers (*e.g.*, Woods et al., 1994; Amalberti, 2001; Leveson, 2004; Dekker, 2006; Hollnagel, 2008), as it confuses safety with reliability (Besnard and Hollnagel, 2014). The growing complexity of socio-technical systems, in which humans and their habits are integrated parts of the technical system (Qureshi, 2007), indicates that safety analysis needs to consider not just individual reliability but also how the combination of system components as a whole interact with each other in such way to promote errors and accidents (Leveson, 2004; Salmon et al., 2015). Thus, focusing on eliminating individual errors and revealing so-called 'root causes' without improving the system design and constructing an effective safety control system to prevent those unsafe interactions, new accidents arising from other 'root causes' will continue to occur.

Several authors (*e.g.*, Reason, 1997; Rasmussen, 1997), in discussing the "safety space", have argued that socio-technical systems tend to drift toward states of higher risk. The performance of the actors within a socio-technical system is always constrained by the surroundings, *e.g.*, administrative, competitiveness, economic benefits and safety related constraints, which creates a small space of freedom for designers, operators, and managers to perform their work tasks with little considerations given to the feasibility and consequences (Rasmussen, 1997). Thus, accident analysis should incorporates the circumstances that induce variation in behaviors as well as the dysfunctional interactions among correctly operating components.

Several accident analysis models *e.g.*, Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012), AcciMap (Rasmussen, 1997), have been developed on the basis of systems approach (Underwood and Waterson, 2013). The current study uses Leveson's Systems-Theoretic Accident Model and Processes (STAMP) Model as (1) it encompasses both engineering development and operational

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aspect of the system, thus gives a broader representation of the factors influencing behavior and safety; (2) STAMP assists in understanding the entire accident process and further promotes generating complete recommendations for improving the overall system safety; (3) it provides formal basis and a more structured approach that can be suitably applied to maritime domain.

As of today, most studies in the field of Systems Theory together with STAMP have been applied to aerospace systems (Leveson, 2004), railway transportation (Ouyang et al., 2010; Underwood and Waterson, 2014), water contamination accident (Leveson et al., 2003), U.S. Army friendly fire shootings (Leveson et al., 2002), biodefense (Laracy, 2006) and aircraft accidents (Nelson, 2008). However, to the authors' knowledge no single study exists which covers in particular the marine transportation industry within the subject of passenger ship.

To fill this knowledge gap, a dedicated STAMP-based accident analysis is conducted by taking the case of the capsizing Sewol – the Korean Ro-Ro passenger ship – as an example to illustrate the appropriateness of STAMP application to the analysis of maritime accidents, with the aim to emphasize on why the accident occurred and how to prevent similar losses in the future.

2. STAMP methodology

The STAMP is, as an accident analysis model, constructed upon basic Systems Theory (Leveson, 2011) and focuses on inadequate control or enforcement of safety-related constraints on the system design, development and operation (Leveson, 2011). It provides a systemic view of causality, and examine non-linear, indirect, and feedback relationships between events (Ouyang et al., 2010). STAMP views systems as hierarchical structures with multiple control levels. Each level in the hierarchy imposes constraints on the activity of the level beneath it, the events leading to losses only occur when safety constraints were not successfully enforced or the constraints have been violated (Leveson, 2011). The potential for unsafe control may exist in the original design of the safety control structure and the controls may degrade over time, allowing the system to move to states of increasing risk.

In contrast, many traditional accident analysis techniques such as Event Tree Analysis (ETA), Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Cause-Consequence Analysis rely on a chain-of-event paradigm of causation (Qureshi, 2007), and deal with systems and the environment as a static design and unchanging structure (Leveson et al., 2003). Thus, arguably inappropriate for the study of modern engineering systems, especially complex software-intensive systems, complex human–machine interactions, and systems-of-systems with distributed decision-making that encompass both physical and organizational aspects (*e.g.*, Dulac, 2007; Leveson, 2011).

STAMP considers the dynamic nature of systems, identifying missing or inappropriate features (those which fail to maintain the constraints). It proceeds through analyzing feedback and control operations, which replaces the traditional chain-of-events model. Causal Analysis based on STAMP (CAST) (see Table 1) is one of the dedicated techniques and processes for accident analysis (Leveson, 2011) that was constructed by using STAMP as theoretical foundation.

CAST provides a framework to examine the entire accident process involved in the accident, identify the most important systemic causal factors involved (Leveson, 2011), with a focus on why the accident occurred and thereby succeeding in preventing future occurrences. The sequence of the analysis steps performed in this work has been slightly changed with the proximate event being presented before the start of the main analysis of the accident. Information about the Sewol accident and the control structure constructed in this work was obtained from the original investigation reports of Korean governmental agencies (*e.g.*, MOF, 2014; KMST, 2014) and available literature (*e.g.*, Cho and Yoon, 2015; Hwang, 2015; Zhang and Wang, 2015) detailing the events.

Table 1
Causal Analysis based on STAMP (CAST) process (adapted from Leveson (2011)).

Step No.	Description of steps
1	Identify the system(s) and hazard(s) involved in the accident
2	Identify the system safety constraints and system requirements associated with that hazard(s)
3	Document the safety control structure in place to control the hazard and enforce the safety constraints
4	Determine the proximate events leading to the accident
5	Analyze the accident at the physical system level
6	Moving up the levels of the safety control structure, determine how and why each successive higher level contributed to the inadequate control at the lower level
7	Analyze overall communications and coordination contributors to the accident
8	Determine if there were any changes to the system hierarchical safety control structure over time that migrated the system to a less safe position and contributed to the accident
9	Develop recommendations

3. CAST analysis of the capsize of Sewol accident

3.1. The proximate events

The following facts can be established as far as the official investigation reports stated:

On the 16th April 2014, the 20-year-old Korean flag Ro-Ro passenger vessel – Sewol (6825 tons) capsized during a frequent domestic voyage from Incheon to Jeju island leaving from port with more than 2 times overload condition (2142.7 tons of cargo loaded, compare with authorized limit 987 tons) (MOF, 2014). The capsizing led to the loss of 295 lives (excluding missing passengers), most of whom were high school students.

The ship traveled at about 18.9 knots under manual control by a third mate and helmsman. The Captain was absent from the steering room at the moment of the accident when the ferry entered the Maenggol Channel (KMST, 2014) – an area that was notorious for its strong and fast underwater currents. The third mate was monitoring the radar and gave two orders to the helmsman to turn starboard from 135 degrees to 145 degrees true course (KMST, 2014). According to the official report, these two 5-degree commands were inferred to be enacted with unnecessarily large rudder angle based on simulations. The changes in combination with the high speed resulted in a noticeable outward heel (15–20 degree) that caused it to lean sharply to port, which shifted the improperly stowed and secured cargo to the port side and further increased list. This allowed water to pour into the ship through the side door and the cargo access door located at the stern, and quickly developed a 60-degree list to port (MOF, 2014). Additionally, the ship did not carry sufficient amount of ballast (761.2 tons compare with required 1703 tons when fully loaded) although this was recommended by classification society at the time of approval (KMST, 2014). Progressive flooding within the superstructure exacerbated the situation, and in conjunction with the added effect of the fast underwater current, the vessel's list gradually increased until it capsized. A mayday call was transmitted via a working radio channel – Very High Frequency (VHF) 12 to contact the coastguard for rescue assistance. However, master and crew failed to provide timely evacuation instructions on board and the 44 available life rafts were not properly launched. Also, passengers were repeatedly told to stay where they were, thus prevented an early plausible evacuation and trapping the passengers inside the vessel.

3.2. Hazard identification, control structure

Leveson (2011) defines a hazard as "a system state or set of conditions that, together with a particular set of worst-case environmental conditions, will lead to an accident" (p.184). The system hazard related to the accident is the vulnerable stability of the vessel that causes fatalities, injuries or property damage during sailing. Accordingly, the hazard entails the following system safety constraint: (1) the vessel itself must have sufficient intact stability and steering ability for safe operation. The safety control structure must prescribe criteria for approving ship designs, accepting new buildings/conversions at the system development stage; (2) during operations, the safety control structure must ensure a satisfactory stability of the vessel to be allowed to sail out of port, and control any potential risks (*e.g.*, overloading, inappropriate cargo stowage and securing, improper maneuvering) that might allow the vessel to exceed the safety stability constraints; (3) moreover, appropriate emergency preparedness and response must be ensured, rapid rescue operations must be initiated after the loss of stability by the master and crew on board in coordination with other emergency responders (*e.g.*, coast guard, vessels in the vicinity).

Fig. 1 shows the hierarchical control structure that ensures safe development and operation of passenger ships in South Korea. The hierarchal control structure starts with the government who has the authority and responsibility for establishing guidelines and legislations to enforce regulations over vessels registered under its flag, while complying with the conventions from the International Maritime Organization (IMO) that are ratified by the state for domestic voyage.

As shown in Fig. 1, guidelines are provided to the Ministry of Oceans and Fisheries (MOF) who then give regulations, policies and certificates to the Korean coastal passenger transportation industry down to the captain and crew involved in the ship operation must comply with. MOF sub-delegated authority to a classification society – Korean Register of Shipping (KR) – for issues related to approvals of designs, surveys and classification matters, particularly in relation to ship design, structure, load lines, machinery and equipment requirements. The Korea Coast Guard (KCG), as an external branch of MOF, has primary responsibility for approving operation planning reporting provided by shipping companies, and further supervises and directs inspection practices conducted by the Korean Shipping Association (KSO) (MOF, 2014).

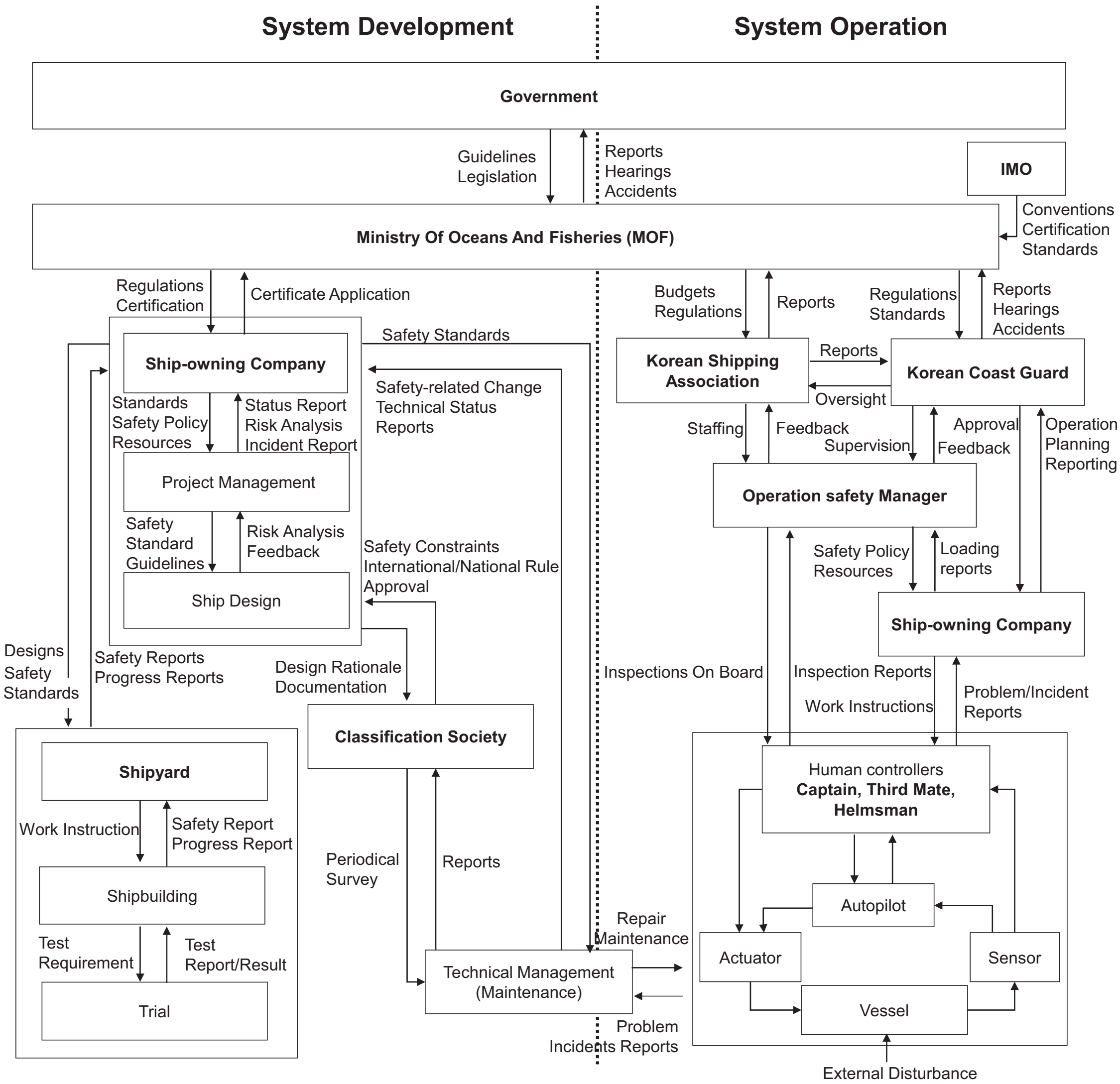

Fig. 1. The hierarchical control structure that ensures safe development and operation of passenger ships in Korea.

Ship-owning company has responsibility for enforcing policies and regulations that apply to the operation of the vessel, ensuring ships are operated in a sufficient condition that ensures safety of the crew and passengers. They further have the responsibility for continuing training requirements for crew to maintain competence as knowledge about safety, for appropriately maneuver the vessel, for correctly take out emergency actions and so on (KMST, 2014).

Together, the safety constraints enforced by all of these controllers must be adequate to enforce the overall safety constraints. It should be noted that the model of safety control structure shows in Fig. 1 incorporate the development stage of the vessel (on the left) and those involving the physical control in the operational part of the system (on the right), as safety during operation not only depends on the design and construction of the vessel, but also on effective control during operations. Each controller designed within the hierarchy of the passenger ship safety control system – has its own responsibilities for enforcing safety constraints appropriate for that component. These responsibilities and authorities taken together must enforce the safety constraints through the vessel design, operation, maintenance and management.

3.3. Constructing accident causation

The above mechanisms (see Fig. 1) would theoretically ensure ships and shipping activities are fully compliant with all applicable requirements throughout the ship's life. However, this is known not to be the case in reality as operators or organizations strive to deal with economic and efficiency pressures oblige to continue to jeopardize life, property and the environment. Following Sections 3.1 and 3.2, the causation of the capsizing of Sewol is constructed in this Section by gathering information about how the hazards could happen, and inspecting the control loop for each hazardous control action to specify its impact on the accident. The key components from the control structure were selected for further analysis – crew, ship-owning company, classification society, relevant government regulatory agencies and industry association. The violated safety constraints, mental model flaws, as well as inadequate enforcement of control actions or missing feedback were determined and analyzed.

3.3.1. Analysis of the physical system

The physical process of the vessel system is shown in Fig. 2. The physical process being controlled is the operation of the Ro-Ro passenger vessel to ensure a safe and efficient navigation through

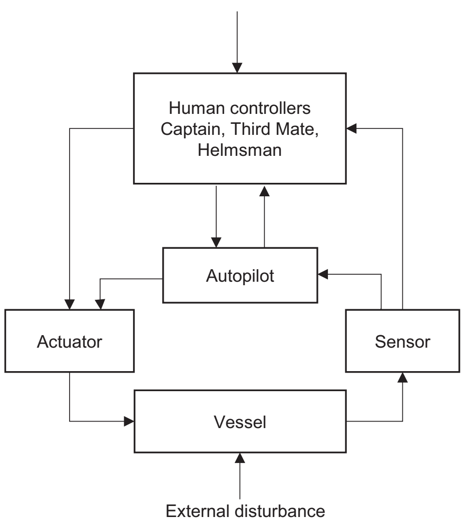

Fig. 2. Vessel Operating Process.

coastal waters. The Sewol is controlled in two main modes: either manually where navigators manipulate actuators (*e.g.*, rudder, propellers), or automatically where the vessel is controlled by the autopilot that manipulates the actuators to follow a pre-programmed route. Despite the Sewol being under automatic control, crew still need to monitor the autopilot and the vesseĺs course and speed, and they must regain manual control if the need to do so arises.

Before entering the Maenggol Channel the third mate turned off the autopilot. This was the first time the third mate steered toward Jeju Island (KMST, 2014). As the crew of Sewol was the real controller prior to and during the accident, the contextual and behavior-shaping mechanisms will be analyzed and discussed in detail to reveal how they contributed toward accident causality (see next Section 3.3.2).

The limitation of the physical system design is that ships of this type (RO-RO passenger) have un-subdivided deck, and a very large superstructure compared with other types. Such vessels often suffer from extremely high lever arm alterations, shorter rolling periods, and consequently are critically endangered by high transverse acceleration forces (IMO, 2006). Given the large free surfaces in the ship, sudden movements of the vessel can cause the cargo on the vehicle deck to break loose from their lashings and pile up on the low side of a listing deck that can result in insufficient upright metacentric height (GM) force.

Sewol was originally constructed and operated in Japan from 1994 and it was bought by Chonghaejin at 2012 and modified in a Korean yard to boost capacity. Modifications included adding extra passenger cabins and raising the cargo capacity that would have compromised her intact stability and evacuation performance to some extent (Hwang, 2015; KMST, 2014).

At the time Sewol departed from Incheon port, the ship was overloaded significantly (2142.7 tons of cargo loaded, compare with authorized limit of 987 tons) with improperly secured cargos and insufficient ballast. The partially filled ballast tanks had potential to create a large free surface effect and which, combined with cargo shifting and overloading, resulted in a negative GM and caused the vessel to capsize, as described in the investigation report. All risk factors of the system and the environmental context bring the vessel into an unacceptable high-risk state for the proximate operators, *i.e.*, master and crew, to trigger the undesirable interactions and defeat the system.

3.3.2. Crew level analysis

The CAST framework is a bottom up approach, starting at the lowest level. The personnel with the closest proximity to the actual process controlled, *e.g.*, the crew onboard the ship, that was involved in the loss at the physical system level, will be addressed first.

Fig. 3 shows the results of a STAMP-based causal analysis of the Sewol ferry operators. The crew is responsible operating in compliance with ship-owner and flag state's rules and instructions to perform safe and efficient ship operation. Master and crew are required to know the (physical) limitations of vessel, being aware of the ship loading condition, ballast condition and potential hazards. Navigation, transmission of information, cargo securing and stowage, and other activities must be ensured that are conducted within the safety constraints in accordance with Korean Seaman's Acts (Kim, 2011). The seafarers employed on passenger ship are required to provide proper evacuation plans and instructions in case of emergency situations, as per their instruction manuals (Kim, 2011).

Evidence from the accident investigation report (KMST, 2014) ascertained that master and crew of Sewol failed to conduct adequate inspection to prevent cargo movement through proper securing and stowage, and failed to perform cautious maneuvering

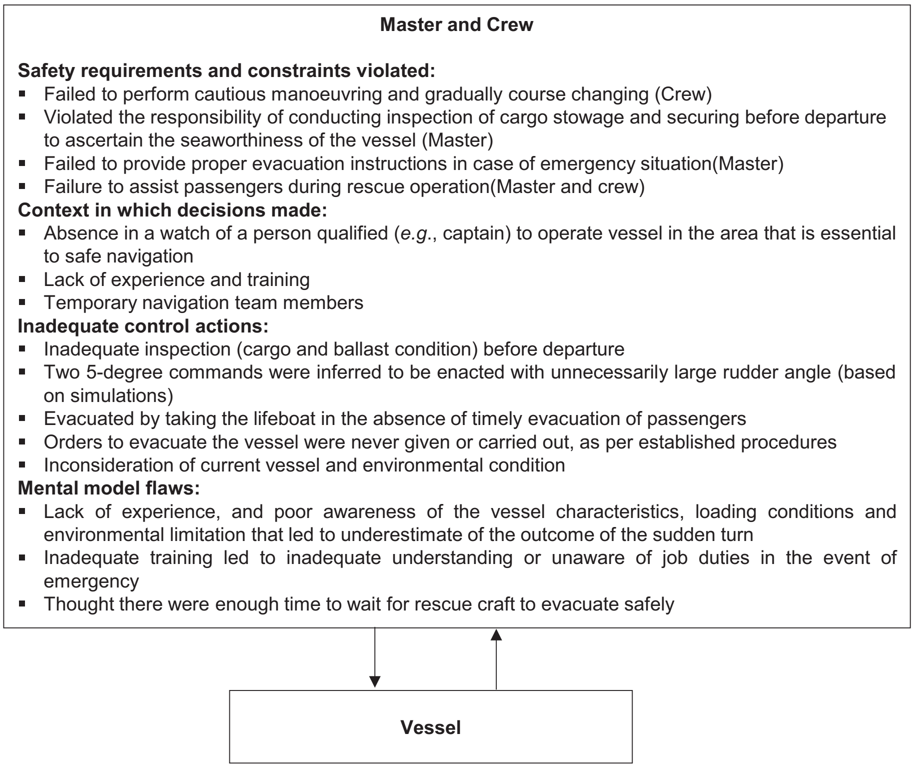

Fig. 3. The analysis at the ship master and crew level.

and gradually course changing. The context in which the third mate continuous course changing order was made affected her performance, namely the absence of the captain or first mate whose presence on the bridge when the ship was operating in the challenging area could be considered essential to safe navigation. Following the two continuous commands issued by the third mate, the rudder angle carried out by the helmsman was inferred to be unnecessarily large that cannot be accepted under current state of the vessel. However, the analysis of the explanation of the actual rudder angle is complicated by the fact that it might be a technical flaw of the rudder which resulted in the rudder performance not being consistent with the order, or it may has been an oversteering made by the helmsman or could be caused by other unidentified facts.

In either case, the large rudder angle – regardless of originating from a human control flaw or from a technical error, when combined with the significant overload condition, cargo shifts and the insufficient amount of ballast water, give a plausible technical explanation to the sudden heeling motion of the ship. Strong underwater current where the capsizing occurred may have interacted with the unfortunate physical conditions described of cargo, rudders and ballast to increase the magnitude of the heeling motion. Flaws in both of the navigators (*i.e.*, third mate and helmsman) mental models include their inaccurate assessment of risk with poor awareness of the overloading conditions, vessel characteristics and limitation imposed by the external environment. The inconsistency between their mental maps and state of the system led to an underestimation of the effect of issuing and executing the control commands.

As the Sewol sank, the life rafts that had not been launched by the crew did not automatically deploy, nor were they required to do so (KMST, 2014). The captain executed inappropriate decisions and actions by giving repeated orders to passengers to stay in their cabins, rather than issue and provide appropriate evacuation instructions on how to proceed over the public address system. He thought the cold and fast ocean waters were unsafe without rescue boats present and assumed there were enough time to wait for rescue craft to evacuate safely. Another factor that might have influenced behavior, according to the investigation, was that among the 15 crew members in charge of navigation, most were temporary contract seafarers. A relatively low degree of engagement and cooperativeness may be inferred that contributed to the poor performance under emergency situation, which can also be observed from the improper actions taken by captain, first mate and chief engineer who abandoned the ship leaving no evacuation instructions to the passengers. Inadequate emergency response during the chaotic moments reveals the incompetency of the crew to enforce established safety constraints, due to an apparent poor state of preparedness, improper training, and inadequate understanding or lack of awareness of their duties as defined by their roles.

Accordingly, inappropriate issue and execution of vessel command, poor awareness of hazards, failure to provide evacuation instructions on time, and failure to assist passengers by master and crew during rescue operation are considered the flawed control actions identified in CAST that trigger the accident to take place at the sharp-end level.

3.3.3. Ship-owning company level analysis

Fig. 4 summarizes the role of the ship-owning company in the accident. Many of the flawed decisions and control actions taken by the master and crew onboard of Sewol can be explained and understood by examining this level. The ship-owning company of Sewol ferry, performed all forms of ship management services: technical, crew, and commercial management that involve vessel operation, maintenance, fleet management, crew recruiting and training, etc. For the operational aspect (see Fig. 1), the owning company violated the safety constraints that stipulate that it is responsible for ensuring all seafarers in its employ are suitably

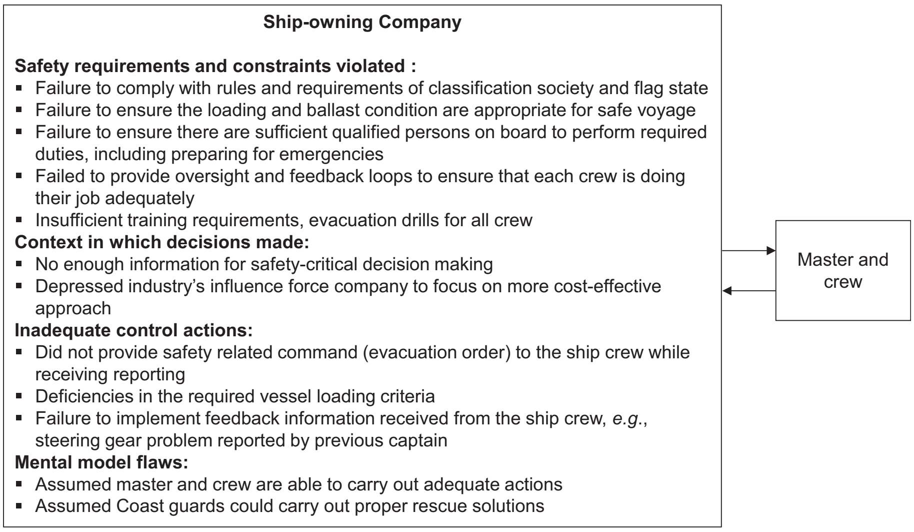

Fig. 4. Ship-owning company level analysis.

instructed in the hazards connected with their work and the shipboard environment to avoid accidents and injuries (KMST, 2014).

The conversion of the Sewol ferry was verified by classification society and given the class, nevertheless, several operational recommendations that were laid down on the ballast and loaded cargo condition of the ship. The main stipulation was that it should operate with an additional 1333 tons of ballast with less cargo than the limits before modification (KMST, 2014). The ship-owning company violated the constraints placed by the classification society illegally overloading the vessel with cargos, and release certain amount of ballast in order to prevent the displacement of the vessel exceeding required load line that can be observed by the supervisory authorities at port. Furthermore, the plan of stowage and securing of cargo units and vehicles approved by classification was not enforced explicitly by the person in charge within the owning company. The use of ISO standard 8 feet containers results in inefficiency in lashing, as the container loading area of Sewol imported from Japan are designed for standard 10 feet containers (Korea Maritime Institute, 2014; KMST, 2014). The safe operation was compromised with a vessel that had inadequate stability characteristics allowed to be in service.

In this occurrence, the owner failed to provide sufficiently qualified personnel on board to perform required duties or provide enhanced awareness of their safe practices during normal and emergency operations. The negligent training results in crew that are unaware of the stability characteristics of their vessel and the general principles involved that may unknowingly place themselves and their vessel at undue risk. At the time of accident, the ship-owning company received the reporting from the captain but did not provide adequate orders regarding to evacuation and assumed that the crew would take care of the problems. Owner also neglected the feedback information received from the ship, *e.g.*, a steering gear problem was reported by a previous captain (KMST, 2014), which reflects the ineffectiveness of the problem-reporting channel. At this point, it appears that its communication channels and safety management system had not been adequately established by the ship-owning company for operators to express the concerns when a hazardous condition is detected onboard, several recommendations can be generated from this part of analysis (see Section 3.4).

3.3.4. Classification society

The flag state's responsibilities of technical inspection and survey are delegated to a classification society – Korean Register of Shipping (KR) (MOF, 2014), the interaction among the primary high level controllers involves in operation and development of the vessel are showed in Fig. 5. Thus, KR verifies the ship, the construction and condition of which that satisfy the applicable rules and requirements, and register it with the corresponding class and class notations.

The most significant role of KR in relation to this accident is the relative inspections and calculations regarding the issuance of modification design of Sewol. KR approved the modifications (as all safety margin calculations meet with the required standards) only as long as certain operational conditions were met, involving the loading and ballast condition of the ship as previously mentioned. The actions of KR were consistent with their process model of normal vessel inspection and survey. However, for some reasons, information feedback between the classification society and the flag state authorities is missing (see Fig. 5) – the certain loading limits of vessel that have been recommended by classification society were only given to the company but not recognized by other authorities, resulting in the instructions becoming ineffective.

Inadequately communicated feedback about the safety constraints enforcements implied by the Classification indicates weaknesses of the safety control structure that need to be revised or redesigned to ensure the effectiveness of measuring channels.

3.3.5. Government regulatory authorities and industry association

The flag state authority should provide appropriate inspection services to enforce or administer the application of the provisions of national laws and regulations. Where the safety of the ship, crew and passengers are endangered, the authority should, in accordance with national laws and regulations, take effective measures to ensure that the ship is prohibited from leaving port until such deficiencies have been remedied and compliance with the relevant laws and regulations assured (KMST, 2014).

In this case, the mission of technical inspection and survey is delegated to classification society – KR as previously mentioned, the operational capability inspection is delegated to Korean Coast Guard (KCG) and further to the Korea Shipping Association (KSA) (MOF, 2014). KSA – as a private industry association that represents the interests of shipping companies engaged in coastal shipping, undertake the responsibility of monitoring and inspecting the departing condition of the ship at port on behalf of KCG. Thus, this reallocation of regulatory responsibility has moved the passenger ship safety control to a decentralized industry self-regulation process, but whether such industry self-regulation raise the problem

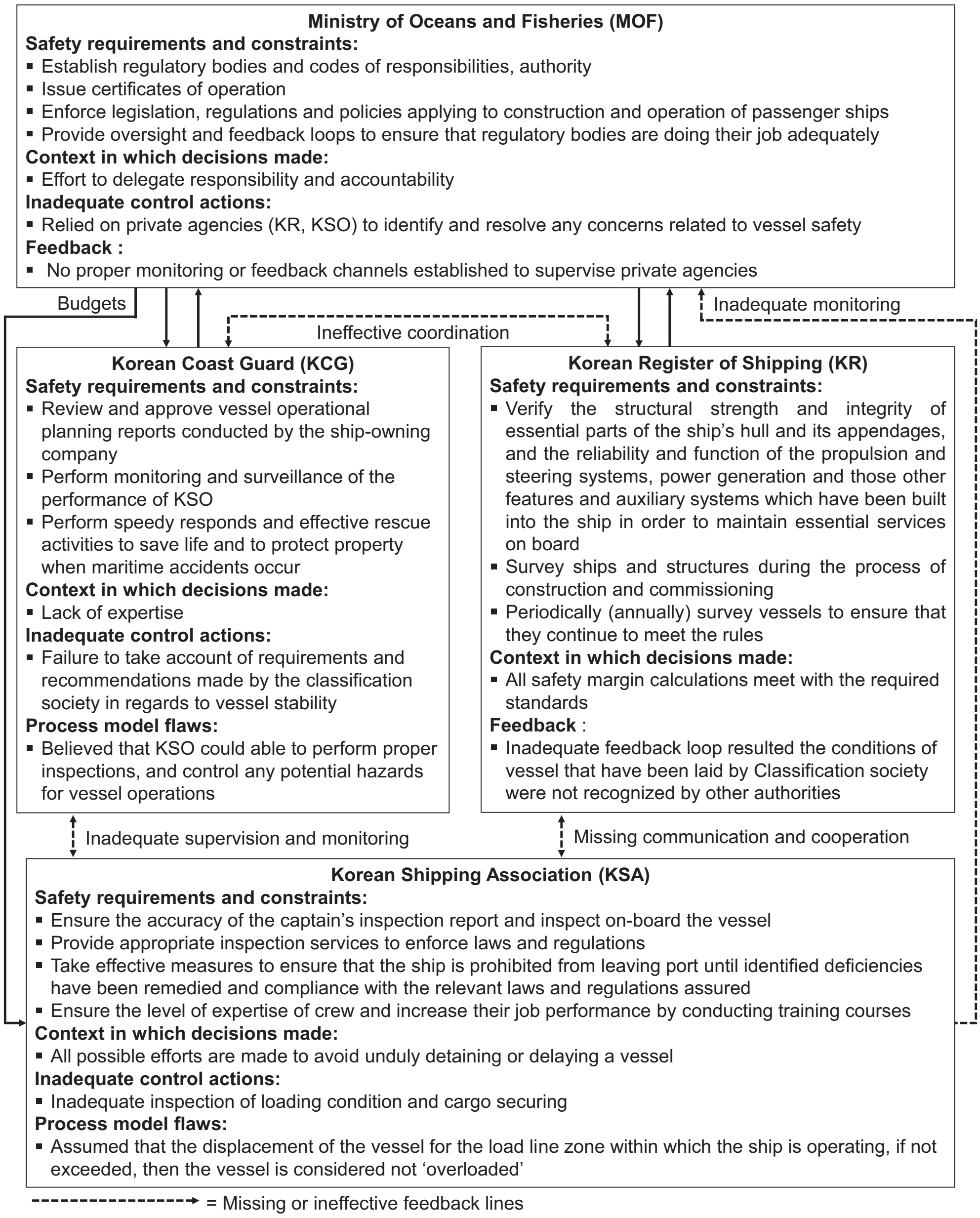

Fig. 5. Analysis of classification society, industry association and government regulatory authorities.

of opportunistic behavior among members, however, did not mention in the official report, thus will not be considered further in this analysis.

KSA simply observed the displacement of the vessel for the load line zone within which the ship is operating. If not exceeded, then the vessel is considered not 'overloaded'. KSA obviously violates the formal procedures (KMST, 2014) to ensure the accuracy of the captain's inspection report regarding the loading condition of the vessel, or inspect the safety equipment on-board, or take any effective measures to ensure that the ship is prohibited from leaving port until identified deficiencies have been remedied in compliance with the relevant laws and regulations assured.

The negligent inspection practice may have resulted from inadequate routines or possible efforts that were made to avoid unduly detaining or delaying the vessel further as Sewol had already been delayed due to fog. The context within which their decisions and control actions take place was that KSA were unaware of the loading limits that were recommended by the classification, necessary information thus being incomplete for KSA decision makers. Failure to exchange such essential information and poor cooperation among governmental agencies and the industry association have vital influence on the attainment of an accurate and acceptable level of vessel safety control.

3.4. Recommendations

To prevent reoccurrence of similar accidents in the future and as a result of the analysis of the accident involving the Sewol Ro-Ro passenger ship, an effective safety assurance and control structure should be redesigned and constructed from the integration of all layers, rather than simply attempt to fix the apparent 'symptoms' (*e.g.*, either the crew failings, the KCG or the KSA in isolation).

The problem detected during the CAST analysis of this study generates the following safety recommendations for preventing similar losses in the future:

(1) Thorough improvement should be carried out on the entire safety control structure, proper measuring channel, such as feedback that reflects the effectiveness of safety constraints need to be designed for continuous improvements and corrective actions.
(2) Establish integrated and corporate safety information system to maintain accurate process (mental) models of all system controllers to assist in their decision making.
(3) The safety limits of the vessel should be based on the shipyard's original design and the level of upgrading with respect to increased requirements or limits. A thorough risk assessment should routinely be carried out to ensure safe working practices. Continuous monitoring of risk and identifying potential areas of concern before they develop into hazards should be given priority. Constrain hazards before they lead to accidents.
(4) The ship's command should desist from taking risks and give absolute priority to the safety of the vessel and passenger, which also includes the securing of cargo and provision of a sufficiently intact lashing system in accordance with requirements to maintain ship stability.
(5) Crew of Ro-Ro passenger ships should be properly trained for accurate and immediate actions during emergency, and should have clear instructions on maximizing their vessels' chances of survival in cases of water ingress to the car deck. The training should address day-to-day shipboard operations, risk assessment procedures as well as contingency planning and emergency preparedness.

4. Discussion

The analysis of the tragic capsizing of the Sewol Ro-Ro passenger ship was approached from a systemic perspective by examining weaknesses in the safety control structure. The model of STAMP-based casual analysis has served the two main aims of the paper:

- Posed questions on systemic issues of Sewol accident and uncovered the rationale behind the decisions that were made leading up to this huge death toll.
- Illustrate the utility of applying the STAMP-Model to the maritime transportation domain to stimulate a broader view of accident mechanisms that expands the analysis beyond immediate physical failures to a systemic view. This insight in turn ensures that a systems approach can be taken to the design of robust safety systems.

As Leveson (2011) pointed out, if the purpose of accident analyses is to find the "root cause" or someone to blame, we might lose the sight to seek potential opportunities to maximize what can be learned from the accident.

The rudder command – regardless of whether it was a flawed human decision or a technical error, should not be addressed as a primary explanation for Sewol accident. The financial incentives and cost-cutting efforts to ship-owners moved the vessel to an unacceptable high risk state in which accidents are inevitable. Government regulatory agencies and industry associations failing to enforce proper constraints or establish effective feedback channel to ensure safety–critical information and activities are being carried out correctly and that adaptions at lower levels have not moved operations beyond safe limits. Thus, the improperly designed vessel safety control structure with unbalanced responsibility created an unacceptable hazardous condition. Those making decisions regarding vessel conversion design, approvals, cargo arrangement, crew management, vessel operation and inspections were ignored or unaware the negative impact of their decisions on other parts in the safety systems.

Some of the components were indeed operated 'reliably' in terms of making decisions (*e.g.*, KR) based on their context and information they had, however, poor coordination and communication, dysfunctional interactions among the components of the total safety system played a critical role in leading to the hazards involved and escalating to an accident. Obviously, many of these systemic casual factors are only indirectly related to the immediate events and conditions. The STAMP-based analysis of Sewol tragedy conducted in this work has demonstrated both of the direct and indirect casual factors associated with the accident that were not identified by those conducted under traditional analysis methods (*i.e.*, Zhang and Wang, 2015).

Whilst no burden can be lifted from those whose lives have been so radically changed, the Sewol tragedy provides an important lesson for the passenger transport industry. It highlights the needs for taking a systems approach to the detection and prevention of breaches of safety constraints and calls for corrective actions at both national and international level. Only then can we supersede the quick fixes of symptoms provided by individual components of the system and get to the true cure.

5. Conclusion

Despite the endeavor of international organizations, flag and port administrations and classification societies in terms of promulgating regulations and requirements that make the maritime industry safer overall, the responsibility for ensuring the safety of ships, crew and passengers must initiate from the owners themselves. The reality calls for a cost-effective safety management approach that balance safety with economic, efficiency, performance constraints, which do not cause the degradation in safety efforts over time.

The STAMP-based casual analysis method has assisted in exploring and constructing accident causation via a holistic and systematic approach, and uncovered the rationale behind the decisions that were made leading up to this huge death toll. Nevertheless, limitations associated with the application of STAMP on maritime domain are also recognized: (1) a thorough and in-depth CAST analysis requires extensive data associated with the overall system that may difficult to be fully obtained from available resources; (2) the recommendations generated in the analysis may also face difficulties to be substantially and timely carried out.

The case of the capsizing of the Sewol ferry surely still has a lot of unsolved questions, and whilst this study provided some new insights to encourage further discussion and research into the establishment of effective measures for national and international maritime safety control and management.

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Leading for safety: A weighted safety leadership model in shipping

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ABSTRACT

Recent years have witnessed a growing concern for safety and highlighted the importance of leadership in safety practice within high-risk organizations. By following up and integrating the state-of-art research trends, this study aims at (1) bridging a gap in safety leadership research – i.e., the lack of a holistic understanding of safety leadership contribution at all managerial levels within high-risk organizations; (2) developing and validating a weighted safety leadership model in the context of shipping which incorporates key safety leadership behaviors that may enable researchers and practitioners to better understand and exercise safety leadership in shipping organizations. To systematically fulfill the research aims, this study integrates both numerical and descriptive data by sequentially applying three interdependent research techniques – namely inductive analysis of literature, modified Delphi method and Analytical Hierarchy Process (AHP). The study results in a holistic weighted model with concrete safety leadership behaviors at each managerial level, which contributes to the building of theoretical foundations in the domain of safety leadership research and serves as practical standards for accelerating safety leadership development in shipping organizations.

1. Introduction

The credibility of the safety leadership development with regard to the operation of hazardous systems has been notably heightened, with many studies identifying the significant correlates of leadership and organizational safety performance (i.e., [4,15,43]). Initiating or contributory factors to near misses or accidents – such as inaccurate safety management, insufficient training, etc. – can often be traced to the failure of leadership to establish *systemic solutions* to ensure safety [24].

The recent theoretical development of safety approaches (e.g., [28,39]) – inspired by Systems Theory – has stimulated a broader view that expands the safety focus beyond the proximate level to the system as a whole. The decisions and actions across all levels within a sociotechnical system interact with each other and have vital influence on the attainment of the overall safety performance [29]. Leadership for safety must therefore be instilled throughout the organization at all levels, to ensure that all parts are highly committed to safety. Safety leadership development and assessment are consequently required to expand sufficiently to accommodate a wider systemic perspective in order to guide the effort of organizations in pursuit of overall positive safety outcome [11].

Safety leadership studies based upon generic leadership theories – e.g., Transformational Leadership, Transactional Leadership, Leader-Member Exchange (LMX), Empowering Leadership, etc. – have flourished with a vast and considerable literature, supporting the positive effects of managers' leadership intervention on safety compliance, safety participation, reduced injury rate and near-misses in various high-risk industrial contexts, e.g., oil and gas, process, container shipping, construction, etc. Nevertheless, essential leadership behaviors influencing safety have merely been assessed and identified at one particular managerial level, which reveals the incomplete understanding of safety leadership within the organization as a whole. Additionally, few safety leadership studies have been conducted within the context of shipping. The shortcoming in itself is an indicator of the need for further investigations, with the aim of fully recognizing the key safety leadership behaviors at all management levels. Moreover, to facilitate the empirical training and developing of safety leaders in the shipping industry, a systemic picture of safety leadership addressing concrete behaviors, instead of broad leadership styles, is of considerable value.

In this light, the fuel behind this study is the need to clarify and formulate normative ideas of safety leadership practice, and bridge a gap in safety leadership research – i.e., the lack of a holistic approach to the understanding of safety leadership at various managerial levels within high-risk organizations.

In this regard, this study aims at 1) Identifying key safety leadership behaviors at all managerial levels in high-risk industries; 2) Verifying the applicability of the identified key safety leadership behaviors at all managerial levels in the context of shipping; 3) Developing a *weighted safety leadership model* which enables researchers and practitioners to better understand and exercise safety leadership behaviors in shipping organizations. Drawing upon the state-of-the-art literature reviews,

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inductive analysis (coding), modified Delphi method and Analytical Hierarchy Process (AHP) constitute the research methods of the present study, formulating a blueprint for the authors to systematically integrate theoretical and empirical data to accomplish the research aims.

2. Literature review of safety leadership in high-risk industries

The theoretical development of safety leadership in various high-risk industries has undergone many refinements. However, few studies have focused on identifying safety leadership behaviors in the context of shipping, which indicates the need to extrapolate from the studies that have been conducted in other high-risk industries and use it as a point of departure for developing a model for the shipping industry. Safety leadership studies in high-risk industries are reviewed and classified according to the level of management involved – lower, middle or top management. The review culminates in three tables showing the identified important safety leadership behaviors at each managerial level in various high-risk industries.

2.1. Lower-level management

Lower-level managers – such as operational, supervisory and first-line managers – are in direct contact with the frontline workers and operators, and most closely related with the supervision and control of actual operations. Many studies have hypothesized the transactional and the transformational leadership as the antecedents for manager's safety-specific leadership behaviors [1,14,56]. Transformational and transactional leadership have contributed to the identification of effective safety leadership behaviors. Transactional leaders monitor and control the work that must be done by subordinates, and reward them for successfully completing stated objectives. Whereas transformational leaders demonstrate *idealized influence, inspirational motivation, intellectual stimulation and individualized consideration*, which are recognized as required qualities of leaders that can enhance subordinate's safety performance and concerns [21]. As shown in Table 1, specific transformational leadership behaviors, such as encouraging subordinates to work safely and discussing safety openly, maintaining and initiating a safe working environment, listening to safety concerns, etc., were found to affect the subordinates' attitudes and behaviors towards safety-critical work tasks, as well as to positively correlate with safety compliance and participation [23]. The effect of supervisors' transactional leadership is varying across different high-risk industries. In manufacturing, Clarke and Ward [5] claim that transactional leadership-related tactics – i.e., rational persuasion (for instance using logical arguments and factual evidence to ensure compliance) and coalition (e.g., using co-workers to create pressure for the subordinates to comply) – are directly effective in exerting influence over subordinates' safety participation. In addition, front-line supervisors can effectively encourage subordinates to adopt safety behaviors by exercising transformational leadership behaviors such as promoting involvement in decision making and generating enthusiasm for safety through inspirational appeals [5]. Cohen [6] and Simard and Marchand [47] identified a significant association between the involvement of first-line supervisors in safety work and lower injury rates. In the observational study conducted by Parker, Yule, Flin, and McKinley [37] in healthcare, surgeons' intraoperative leadership behaviors such as guiding and supporting, communicating and coordinating, as well as task management behaviors, were frequently associated with safe team performance. The effect of supervisors' transactional leadership on the subordinates' safety performance is, however, not identified as statistically significant in manufacturing, construction and services industry [13].

Based on the leadership theory that focus on the relational aspects, Hofmann and Morgeson [18] found that high-quality LMX relationship can foster more open and frequent upward communication pertaining to safety issues, which in turn contributes to the reduced injury rate and accidents in manufacturing. Likewise, in other high-risk industries, such as the nuclear industry, Kivimaki, Kalimo, and Salminen [25] observed that participative management with more communication and feedback was associated with better safety performance. Moreover, as shown in Table 1, a study on Empowering Leadership within the nuclear industry identified six essential safety leadership behaviors [33]. Several studies have also recognized the importance of trust and distrust in subordinates' engagement in safety behaviors. For instance, Conchie, Taylor, and Charlton [8] argue that to reduce distrust between leaders and subordinates the leaders should focus on reducing subordinates' perceptions that a leader lacks care or concern for others' safety. Cooper [9] indicated that *caring* is the crucial factor to effective leadership for high-risk industries. Frontline leaders should demonstrate caring behavior concerned with the welfare of the subordinates, which can promote a good rapport and mutual trust relationships [8,9,56]. These results are consistent with the findings obtained in the container shipping context regarding perceived supervisor's leadership practice, e.g., caring about crew's safety, encouraging safe behaviors, and keeping crew informed of the safety rules [30].

In general, as synthesized in Table 1, transformational and transactional leadership, LMX and empowering leadership-based behaviors, appears to be the means by which managers can exert positive influence over their subordinates pertaining to the safety-related activities.

2.2. Middle-level management

Recent studies have highlighted the pivotal influence of middle managerial positions – a vital link between frontline supervisors and top managers – on organizational safety performance. Middle managers, such as head of department, operational-, line-, site- and fleet managers, execute and implement the policies framed by the top-level to their subordinates. It is of crucial importance that the top-level managers' vision of safety be effectively communicated to the first line supervisors and workers [16]. However, the desired leadership factors performed by the middle management have not been thoroughly examined for organizational safety, only a limited amount of research has been conducted at this level of management.

Cooper [9] suggested that middle managers should be fully involved in establishing safe work systems and safety standards, as well as assisting in risk assessment to demonstrate their commitment to safety as well as their care and concern for subordinates. Flin and Yule [16] note that middle managers are key to transferring corporate safety vision from top managers to lower-level managers. The safety issues and concerns from frontline operations must also be accurately communicated when passing the middle-level on the way up to the top-level management. Accurate and consistent reporting provides a true lens on organizational safety performance and enhances the top management's ability in appropriate safety-related decision-making. In a study conducted in the oil and gas industry, O'Dea and Flin [36] observed that participative management is considered as the best practice in safety leadership for site managers. As when leaders facilitate a 'consulting' and 'joining' relationship with their subordinates, more time is spent in communicating safety issues. Frontline workers seemed to conduct more safety initiative behaviors when the middle managers adopted a transformational leadership style, while a transactional leadership style did not show any significant effects at offshore platforms [16]. Nevertheless, middle-management's involvement in safety initiatives and reinforcement of supervisors' safety activities is identified as critical leadership behavior for safety. By synthesizing the literature, Flin and Yule [16] argue that middle managers' transactional leadership behaviors (such as becoming involved in safety initiatives) and transformational leadership behaviors (e.g., emphasizing safety over productivity, adopting a decentralized style, relaying the corporate vision for safety to supervisors), are possibly applicable to healthcare as desired leadership for safety. Leaders' empowering behaviors have also been deemed important in influencing safety performance: Empowering subordinates to be flexible in times of uncertainty and change increases their ownership and willingness to shoulder the responsibilities and share the information

Table 1
Summary of the identified leadership behaviors affecting safety performance at lower-level management.

Author(s)	High-risk Industry context	Related Leadership theory	Type of managers	Identified leadership behaviors affecting safety performance
Clarke and Ward [5]	Manufacturing	Transformational	Immediate supervisor	• Promote involvement in decision making
		Transactional		• Generating enthusiasm for safety • Using logical arguments and factual evidence • Using co-workers to create pressure for the subordinates to comply
Hofmann and Morgeson [18]	Manufacturing	Leader-Member exchange	Group leaders	• Engage in communication pertaining to safety issues • Promote more open and frequent communication and feedback
Parker et al. [37]	Healthcare	Not specified	Surgeon	• Guiding and supporting • Communicating and coordinating • Task management behaviors
Flin and Yule [16]	Healthcare	Transactional	Supervisor	• "Monitoring and reinforcing workers' safe behaviors" • "Participating in frontline workers' safety activities" p. 46
		Transformational		• "Being supportive of safety initiatives" • "Encouraging subordinate involvement in safety initiatives" p. 46
Lu and Tsai [30]	Container shipping	Not specified	Supervisor	• Caring about crew safety • Encouraging safe behaviors • Keeping crew informed of the safety rules and providing necessary safety information
Martínez-Córcoles et al. [33]	Nuclear industry	Empowering leadership	Immediate supervisor	• "Showing what should be achieved and why; explaining not only what should be done, but also the reasons, contributing to giving more sense to the task" • "Promoting subordinates' self-effectiveness and increasing the feeling that they can accomplish the task" • "Offering examples of good practices that subordinates can imitate" • "Developing subordinates' abilities, which will allow them to steadily increase their contributions" • "Providing positive emotional support by recognizing good work and taking care of the members' welfare" • "Organizing work to enable subordinates to achieve success and derive personal satisfaction from the work, increasing subordinates' perception of auto-efficacy, and inspiring them to achieve increasingly higher goals" p. 1126
Conchie et al. [8]	Construction	Not specified	Supervisor	• Demonstrating benevolence by caring and concerning for subordinates' safety and welfare
Hoffmeister et al. [17]	Construction	Transformational	Supervisor	• Instilling pride in subordinates • Expressing safety values to subordinates
Hofmann and Stetzer [19]	Large utility organization	Not specified	Supervisor	• Facilitating open communication on safety
Wu et al. [52, 53]	Petrochemical	Not specified	Supervisor	• (Safety caring) To respect and trust subordinates, to care about subordinates' needs and empathize with their problems • (Safety coaching) To stimulate subordinates' abilities, to share opinions, and allow subordinates to participate in decision making • (Safety controlling) To set the rules by which the organization runs, to use their power to give a reward or a punishment and to review subordinates' behaviors

regarding critical problems [28]. Role autonomy – the extent to which the management allows a supervisor to schedule work and make decisions regarding safety issues – is found to facilitate the supervisors' engagement in active safety leadership in the construction industry [7]. This, in turn, affects their behaviors in encouraging subordinates' safety compliance and voluntary participation in safety. Safety informing by middle-level managers is recognized as a significant predictive factor for promoting safety culture that drives safe behaviors in the telecommunications industry [51]. Safety informing refers to the dissemination of information regarding safety, which means that middle managers need to acquire safety-related information through a monitoring system, and continuously circulate information so that subordinates can receive important updates regarding safety issues [51]. Furthermore, middle managers need to frequently attend safety committee meetings and offer suggestions on safety policies and practice [51]. It is also argued that middle managers should ensure effective coordination and team performance, and engage in actions that demonstrate the importance of safety [38]. A summary of the identified safety leadership behaviors at middle-level management is presented in Table 2.

2.3. Top-level management

The higher an individual is within an organizational hierarchy, the greater is their potential to influence organizational safety outcomes [16, 40]. The top management – such as ship-owners, business directors and board members – is directly influencing and controlling

Table. 2
Summary of the identified leadership behaviors affecting safety performance at middle-level management.

Author(s)	High-risk Industry context	Related Leadership theory	Type of managers	Identified leadership behaviors affecting safety performance
Flin and Yule [16]	Healthcare	Transactional	Managers-frontline	• "Becoming involved in safety initiatives" p. 46
		Transformational		• "Emphasizing safety over productivity" • "Adopting a decentralized style" • "Relaying the corporate vision for safety to supervisors" p. 46
Conchie and Moon [7]	Construction	Not specified	Manager-supervisor	• Promoting role autonomy
O'Dea and Flin [36]	Oil and gas	Not specified	Site managers	• Facilitating open and participative relationship with subordinates through "consulting" and "joining" behaviors
T.-C. Wu et al. [51]	Tele-communications	Not specified	Operations manager	• Acquiring safety information through a monitoring system (Safety monitoring) • Continuously circulating information so that subordinates receive important updates (Safety disseminating) • Frequently attending safety committee meetings (Safety representing)
Petersen [38]	No targeted industry	Not specified	Middle managers	• Ensuring the quality of subordinate, supervisor or team performance in respect to safety matters • Engaging in visible actions that demonstrate the importance of safety

the organization from the highest hierarchical level.

The safety concern from the top management is identified as the most important factor in discriminating between safe and unsafe companies, as observed by Kjellén [26]. By affecting the priorities, attitudes, behaviors of managers and subordinates, as well as by formulating and imposing safety culture for the organizations, it has been shown that the attitude, interests and decisions made at top-level have a major impact on the reception given to safety critical activities [9,42]. Top managers can demonstrate their commitment to safety by establishing the safety control system and policy [28], by enabling the subordinates to enhance their capacities to do things safely [10]. A comprehensive safety approach ultimately requires clear and consistent support from the top managers to allocate appropriate resources, to demonstrate concern over safety issues and to exhibit and encourage a participatory leadership style in middle managers and supervisors [16]. As the lower-level managers and their subordinates must work according to production requirements, directives, rules, procedures and instructions which they have little or no say in elaborating, top managers' prioritization of safety against other business drivers (e.g., productivity) thus emerges as clearly important [10]. In companies with high safety performance, safety is not viewed as incompatible goals but rather as an integral part of productivity, efficiency and profitability [28].

Previous research has found that top managers who were rated higher on transformational leadership – intellectual stimulation and individualized consideration – led industrial departments with lower injury rates [16]. Transformational leadership style – e.g., safety motivation and safety concern – is also proved to be positively related to safety behavior in container terminal operations [31]. According to Lu and Yang [31], safety motivation relates to the extent to which a top manager creates a motivation, or an incentive system to motivate safe behaviors, encourage reporting potential incidents and safety suggestions, and facilitate workers' participation. Safety concern refers to the extent to which a top manager comes across as a role model to subordinates while emphasizing their interest in safety, the importance of safety equipment, etc. [31].

Several studies within the healthcare industry also focused on the importance of the top management level. The CEO's leadership style is found to correspond with positive improvements and safety outcome [34]; top managers should make safety a top priority and devote necessary resources to safety initiatives in order to realize maximal safety outcome [34]. Yang, Wang, Chang, Guo, and Huang [54] concluded that consideration leadership – i.e. the extent to which the leader exhibits concern for the welfare of subordinates – significantly affected safety audit assessment. Audit assessment is related to the initiating structure of leadership – the extent to which the top management defines the role of leader and the group members, which significantly affects accident investigation management [54].

These findings are consistent with the observations from the coal mine industry [12]. Based on a summary of the literature and on interviews with the senior managers in the oil and gas industry, Roger, Flin, and Mearns [41] extracted six behavior categories (see Table 3) that represent the key functions of senior managers' safety leadership. Consistently with previous studies, they also point out the importance of emphasizing safety as an organizational priority. Moreover, they argue that top managers must establish clear communication for safety, participate in safety activities, set and enforce safety standards while maintaining risk awareness as well as motivating and supporting the subordinates [41]. Perceived organizational support is shown to provide a foundation for a more open and free communication flow for raising safety-related concerns [18]. Furthermore, Conchie et al. [8] have identified a significant direct path of influence between trust in top management and employees on the reporting of unsafe behaviors, and further on the organizational safety performance.

In the shipping industry, the physical distance between shore managers and crews reduces the frequency of face-to-face communication and possibly hinders the development of trusting relationship among them. Bhattacharya [2] observed that the low level of interpersonal trust leads to insufficient interaction and communication, which in turn leads to under-reporting of incidents and accidents, and brings undesired safety performance. Thus, fostering a high level of trust among the leaders and subordinates has considerable value for creating safety in the high-risk organizations.

A summary of the identified safety leadership behaviors at top management level – which are extracted from the above literature review – is presented in Table 3.

In spite of the different approaches, certain leadership behaviors for safety repeatedly emerge in the course of this review at each of the managerial levels, emphasizing the strong connections with good safety performance and positive safety outcome. The outcome of the literature review is further analyzed in the following section by using an inductive coding approach to articulate the key safety leadership behavior categories.

3. Research methods

To address the research aims, this study is endowed with three

Table 3
Summary of the identified leadership behaviors affecting safety performance at top-level management.

Author(s)	High-risk Industry context	Related Leadership theory	Type of managers	Identified leadership behaviors affecting safety performance
Yang et al. [54]	Healthcare	Consideration leadership	Top management	• Exhibiting concern for the safety of the subordinates
		Initiating structure leadership		• Establishing an organization system for safety activities, audits and communication
McFadden et al. [34]	Healthcare	Transformational	Top management	• Making safety a primary priority • Devoting necessary resources to safety initiatives
Lu and Yang [31]	Container terminal operations	Transactional	Senior management	• "Creating a clear mission, responsibility and goal to set standards of behavior for subordinates" • "Setting up a safety system to correct workers' safety behaviors" p. 124
		Transformational		• Role modelling • Stressing the importance of safety equipment • Emphasizing interests in acting on safety policies • Praising employees' safety behaviors • Encouraging employees' participation in safety decision
Roger et al. [41]	Energy industry	Not specified	Senior managers/ Health and safety professionals	• "Emphasizing safety as an organizational priority" • "Establishing clear communication for safety" • "Participating in safety activities" • "Setting and maintaining safety standards" • "Maintaining risk awareness" • "Motivating and supporting the workforce" p. 1145
Du and Sun [12]	Coalmines	Transactional	Senior managers	• (Safety monitor) Setting up clear goals and safety systems in order to ensure the safe behaviors of subordinates
		Transformational		• (Safety motivation) Creating a motivation system to encourage employees' safety behaviors
Yule, Flin, and Murdy [55]	Power-generating	Not specified	Senior managers	• Provide resources for training of the workforce • Encourage supervisors' involvement in safety activities
Bhattacharya [2]	Shipping	Not specified	Top management	• Promoting high level of trust between employers and seafarers
C. Wu, Fang, and Li [50]	High speed railway construction	Transformational and transactional	Owner	• (Safety influence and role modelling) Establishing employees' trust and loyalty to leaders by exhibiting idealized influence and role modelling in safety • (Safety motivation and coaching) Providing meaning and challenge to their work, encouraging the subordinates to envision future state • (Safety caring and individual respect) Paying attention to the safety of the subordinates, providing help when needed. Establishing harmonious relationship with subordinates while maintaining effective communication channels. • (Safety controlling and performance management) Allocating safety responsibility and establishing standards and expectations for safety performance.

methodological phases – inductive coding, modified Delphi and Analytic Hierarchy Process. A clear visual representation of the research design is presented in Fig. 1, which provides a detailed overview of the model development processes.

3.1. Inductive analysis of theoretical data

By using an inductive analysis approach [35,48], two researchers performed the coding process of the theoretical data with the aim of: 1) condensing varied safety leadership findings derived from the extensive literature into concrete, summarized categories; 2) using the emerging categories as the input to the safety leadership theoretical model for further analysis. The first author performed inductive coding of all identified leadership behaviors affecting safety performance at the three managerial levels; the result was then presented to the second author, who also coded the safety leadership behaviors inductively. The two researchers reached an extent of 88% similarities regarding the codes; at this stage, finally the first author decided on the codes. Thus, drawing upon the extensive safety leadership literature conducted in high-risk industries – which has contributed to identify a wide range of important leadership behaviors for safety – a novel set of key safety leadership behavior categories, which capture all essentials, has emerged.

3.2. Modified delphi method

A modified Delphi method (i.e., [3]) is utilized to verify the applicability and validity of the identified safety leadership behavior categories in the context of *shipping*. Delphi is a structured communication method used to assess experts opinions, as well as to determine the extent of agreement on a specific topic [20]. A single round Delphi questionnaire is designed and utilized to obtain a collective view on safety leadership from a panel of shipping experts. The questionnaire starts with open-ended questions, and asks the panel to rate and confirm the relevance and importance of the identified safety leadership behaviors as part of a confirmatory validation process. Questions such as "What is the importance and relevance of the following safety leadership behaviors for Lower-level management (shipboard leader, captain, officers on-board)?" or "Would you

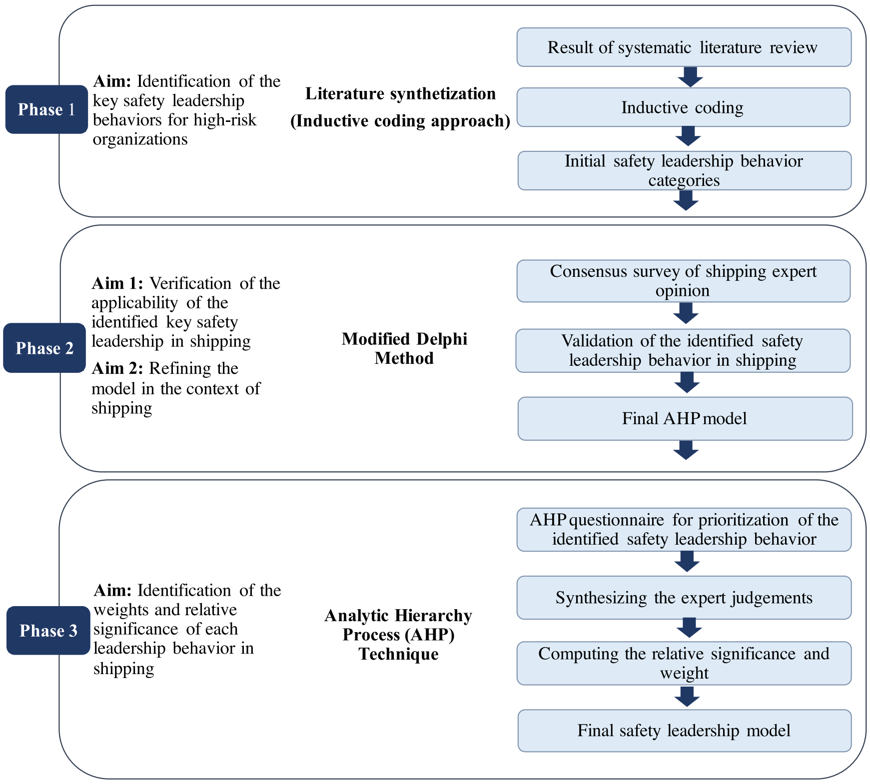

Fig. 1. Research design and model development process.

say the following behaviors can be considered as the key safety leadership behaviors of shipboard leader, captain, officers on-board?" are used to help and facilitate the experts to generate ideas. Each leadership behavior is then rated, first on a Yes or No scale, then at a five-point scale of appropriateness for inclusion as an essential behavior of safety leadership in shipping.

In order to quantify the consensus level of expert opinions on each of the identified safety leadership behaviors, the Content Validity Ratio (CVR) was calculated based on the following equation [27]:

$$CVR=\frac{n_e - N/2}{N/2} \tag{1}$$

n_e refers to the number of experts indicating a specific factor as "extremely important" or "very important", N denotes the total number of experts who participated. As a key to the interpretation, if more than half the number of the experts indicate that the identified safety leadership behavior is "extremely important" or "very important", the CVR will be positive (CVR > 0). If fewer than half, it will turn to negative. As recommended by Lawshe [27], the minimum value of CVR for 25 experts should exceed 0.37. To ensure high quality of the study, all safety leadership behavior to be included in the final model will need to meet this minimum value. By applying the Delphi method where the shipping experts evaluate the appropriateness and significance of each safety leadership behavior, a pre-validated safety leadership model, which consists of key safety leadership behaviors in shipping, can be suitably constructed.

3.3. Analytical hierarchy process (AHP)

To identify the relative significance of each safety leadership behavior category and also those that are playing the leading and decisive role, a dedicated mathematical approach – Analytical Hierarchy Process (AHP) – is utilized as the subsequent stage of modified Delphi method. AHP – a multi-criteria decision-making approach – has attracted the interest of many researchers due to the practical mathematical properties [22,45,46,49]. AHP converts the expert evaluation into numerical values so that it can be utilized to rank the relative importance of various alternatives, and its pairwise comparison algorithm can be seen as the standard eigenvalue problem. Saaty [44] proposed to utilize Consistency Index (CI) and Consistency Ratio (CR) to verify the consistency of the comparison matrix. CI is defined as follow:

$$CI=(\lambda - n)/(n - 1) \tag{2}$$

This CI can be compared with Random Matrix (RI), which is represented as:

$$CR=CI/RI \tag{3}$$

Saaty [44] suggests that the value of CR should be less than 10% for it to be considered as acceptable judgements.

3.4. Sampling

To identify and verify the appropriateness, applicability and relative importance of the identified safety leadership behavior categories in the context of shipping, a collective view of shipping experts pertaining to this issue has been obtained. The potential participants must hold a position of authority in a shipping organization in order to be considered as "leaders" to participate in this study. As a result, the number of individuals in this population is limited and the opportunity to gain access to the population is also constrained by various circumstances (e.g., available time of participants, contacting issues, limited internet connection at sea etc.). The majority of the studies which adopted the same methods (i.e., Delphi and AHP) suggested that 15 to 20 experts is a sufficient quantity to obtain a representative pooling of judgments [20,32].

In total, 25 out of the 105 invited experts participated in this study, with an effective response rate of 24.04%. The key statistics regarding the participating experts in Delphi and AHP are presented in Table 4.

Approximately 61% of the experts have over 10-year work experience from the shipping industry, 35% have more than 20 years' experience while holding leadership positions such as CEO, deputy

Table 4
Key statistics of the shipping expert panel participating in Delphi and AHP.

Criteria of classification	Statistics
Managerial level	Top-level manager: 8.70% Middle-level manager. 34.78% Lower-level manager: 56.52%
Years of Experience in shipping	≥ 20: 34.78% 10–20: 26.09% 5–10: 4.35% ≤5: 34.78%
No. of experts invited	105
No. of experts involved in Delphi panel and AHP	25 (Total 24 in use, 1 response is excluded)
Total response rate (%)	24.04%

managing director, vessel executive, fleet manager, technical superintendent, captain or chief engineer in their shipping organizations. Approximately 56.5% of the experts are classified as lower-level managers, 34.8% as middle managers and 8.7% as top managers.

The experts are involved in various high-hazard shipping sectors, e.g., dry bulk, Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), Floating Storage Regasification Unit (FSRU), tanker and roll-on/roll-off passenger (Ro-Pax), constituting a strong expert panel for the present study to generate representative findings.

4. Results and discussion

In the light of the research design presented in Fig. 1, this section integrates the findings derived from the three interdependent analytical phases in order to establish and validate a safety leadership model in the context of shipping.

4.1. Phase 1 – identification of the key leadership behaviors in high-risk industries

The desired managerial leadership behavior categories at all three managerial levels – lower, middle and top management – are synthesized through the inductive analysis of the studies within various high-risk industries that have yielded equivalent or similar findings. The final inductive analysis of the key leadership behaviors influencing safety derived 12 essential behavior categories, four on each managerial level.

Based on the results, a two-layer hierarchy structure of safety leadership on the lower-, middle- and top-managerial level has been constructed, as shown in Table 5.

Table 5
A two-layer hierarchy structure of safety leadership behavior in high-risk industries.

Managerial level	Notation	Safety leadership behaviors
Lower-level management (LM)	LM1	Communicating
	LM2	Caring and supporting
	LM3	Controlling and enforcing
	LM4	Participative involvement
Middle-level management (MM)	MM1	Empowering
	MM2	Monitoring
	MM3	Informing
	MM4	Coordinating
Top-level management (TM)	TM1	Enabling
	TM2	Safety concern
	TM3	Establishing and structuring
	TM4	Inspiring and facilitating

4.2. Phase 2 – verification of the identified key leadership behaviors in shipping industry

Delphi method questionnaires were distributed to the shipping experts to verify whether these behaviors are sufficient, appropriate and important for the development of safety leadership in shipping. To ensure the high degree of consensus among all shipping experts, Content Validity Ratios (CVR)s are calculated for comparison with the predetermined criteria, i.e., CVR > 0.37. Eleven out of the twelve safety leadership behaviors identified in high-risk industries obtained high CVR values ranging from 0.67 to 1.00. However, *controlling and enforcing* – which was identified as an essential safety leadership behavior for lower-level management – did not obtain a significant level of consensus (CVR < 0.37) among the participants. Considering the highly regulated nature of shipping industry and the managerial position of the shipboard leaders, the decisions regarding daily vessel operations and safety management are well specified by the shipping organizations, the flag states as well as by the international regulatory associations, which may not allow them to set the rules and provide reward or punishment to the crew members. Consequently, in the present study - which examines the effective safety leadership for normal vessel operations - *Controlling and enforcing* through setting the rules and providing reward or punishment will be excluded in phase 3. One expert also argued that "*When demonstrating their safety commitment, the shipboard leaders should base their decisions on guidelines/rules issued by the company*". However, when the situation requires the vessel operation to deviate from the standards or normal operations (i.e., collision, grounding), the shipboard leaders should demonstrate firm controlling and enforcing behavior in order to ensure the safety of the ship and her crew.

Lower-level managers' *participative involvement*, i.e., the extent to which the shipboard leaders promote crew's involvement in decision making and participating in safety activities, obtained a considerable level of agreement among shipping experts. In the Delphi open question section where the experts were invited to express their ideas, they argued that "*being flexible where he can take the crew's opinion into considerations over certain issues*" is considered as one effective way a shipboard leader can demonstrate his/her commitment to safety. "*Leading by example*" is a keyword highlighted by eleven experts, indicating that "*leading by example is one of the most powerful means of establishing a safety culture onboard*". Managers are required to instill the shared safety values through demonstration of actions and behaviors, not merely through words. *Communicating, caring and supporting* leadership behaviors also received significant level of agreement. As mentioned by the shipping experts, safety precautions and issues need to be discussed and communicated clearly with all crew members through regular safety meetings and discussions in order to ensure the awareness of risk involved in each job. The shipboard leaders need to encourage safety-related ideas and innovativeness, as well as "*explain the related past incidents and various precautions to avoid and prevent all major concerns related to safety*".

Middle-level management's *monitoring* behavior is considered as a key safety leadership behavior for shore-based leaders (e.g., fleet manager, head of department). Several responses further confirmed that middle managers should monitor safety performance records of fleets in the light of the Key Performance Indicators (KPI) to govern and to support the vessels. *Informing* and *coordinating* behaviors have frequently appeared in the open question sections. The experts argued that shored-based leaders should "*communicate effectively with the top management and the ship staff with regards to safety measures and philosophy", "ensure to update the master with all the latest safety information available in his arsenal by being ashore*", and may additionally "*share incidents, good practices, Protection and Indemnity insurance (P&I) news, classification societies circulars from industries with vessel staff for creating awareness*". Middle managers' *empowering* behavior has also received sufficient attention among experts as a very effective means to "*not only facilitate individual to perform better, but also encourage to take responsibility as a whole with loyalty and trust".*

Top-level managers' *safety concern* reached the highest level of consensus, with 79% of the experts agreeing that it is "extremely important", and 21% agreeing that it is "very important". One of the CEOs' indicated that:

"*Top managers should make safety the top priority for the company, provide full commitment and support for the safety issues, encourage mid-level management and ship staff to embrace safety as a culture rather than a checklist thing to do. In addition, top managers should provide the budgetary support for safety measures including training or supply of necessary equipment, fund and attend crew seminars to demonstrate commitment to safety.*"

The value of safety should also be reflected in the structure and policies that set safety as a top priority. Top managers should be "*constantly reviewing and enhancing the current system that they are practicing*", they should enable and enhance the managers and the operators' capacities to do things safely, demonstrate their commitment through prioritizing safety and promulgate their sincere safety-related concern to vessel managers, who in turn would convey the same to the masters.

4.3. Phase 3 – assigning relative significance for each leadership behavior verified

The shipping experts were invited to prioritize the safety leadership categories by conducting a set of pairwise comparisons for all safety leadership behavior categories derived from the previous phase. The experts' judgements are synthetized through calculating the Geometric Mean. The final weighted safety leadership model, which is the result of this final ranking, is presented in Table 6.

The result suggests that in general, top-level management's leadership behavior has slightly higher perceived significance than lower-, and middle management. The pairwise comparisons among the 11 identified safety leadership behavior showed that the lower-level managers' *participative involvement* is considered as the most critical leadership behavior with the highest relative importance (15.76%) and a significant contribution to the safety performance of vessel operations. *Establishing and structuring* behavior demonstrated by the top management (12.21%) has also reached a high level of consensus, as it is important to establish the overall standards pertaining to safety issues and enforce constraints on behaviors for safe operation.

Middle managers' *informing* behavior (11.88%) also displays a high level of adherence; indeed, this behavior – e.g., ensure to update the master with all the latest safety information available – is identified as the best way in which a shore-based leader (e.g., fleet manager, head of department) can demonstrate his/her commitment to safety. The priority identified through AHP is aligned with the expert panels' judgements and opinions in the previous Delphi phase.

An overwhelming amount of research points towards effective leadership as the key factor to drive and sustain safety performance in high-risk organizations. Passionate, effective leadership is required throughout the organization, to ensure that all management levels are committed to safety. Safety leadership assessment and development, thus, must expand sufficiently to accommodate a wider systemic perspective to guide the effort of organizations in pursuit of overall desired safety outcome.

By sequentially applying three interdependent research methods, this study delineated a weighted safety leadership model through the lens of System Thinking, whilst contributing to the building of theoretical foundations in the domain of safety leadership research.

Table 6
The final weighted safety leadership model in the shipping industry.

Managerial level	Safety leadership behavior	Calculated relative significance	Rank
	Communicating	0.113	4
Lower-level management (LM)	Caring and supporting	0.090	6
	Participative involvement	0.158	1
	Empowering	0.036	11
Middle-level management (MM)	Monitoring	0.059	9
	Informing	0.119	3
	Coordinating	0.054	10
	Enabling	0.101	5
Top-level management (TM)	Safety concern	0.068	8
	Establishing and structuring	0.122	2
	Inspiring and facilitating	0.079	7

4.4. Limitations and future research

Some limitations with the present study deserve note. Firstly, the sensitivity of safety-related data in shipping organizations hinders the authors in adopting a strict experimental design and delving deeper into the context to determine the extent of the cause-and-effect relationship between each leadership behavior and safety performance in the shipping organization. Secondly, the initial hierarchy model is derived from multiple interpretations of the theoretical data by the researchers who performed the coding process. Inevitably, the findings are shaped by the assumptions of the researchers who conducted the literature review and carried out the data analysis. Thirdly, the sampling size of the experts who participated in the present study may limit the generalizability of the findings obtained through Phase 2 and 3.

Further research can also contribute to validate the proposed hierarchy model with larger number of samples at each managerial level while considering the influence of nationality on perceived importance of safety leadership behaviors. Moreover, it is also interesting to verify whether the behaviors on one managerial level are significant at other managerial levels.

In the context of the dynamic operational shipping environment, it can be inferred that the relative importance of each leadership behavior for safety is also context-dependent. The current study suggests that the organizations should consistently monitor and prioritize the determinants to ensure the effectiveness of their safety leadership development, as well as the long-term sustainability of safety performance.

5. Conclusion

In response to the call for further investigation of a holistic leadership approach to safety, this study meets the aforementioned research aims with three main contributions:

(1) By condensing the safety leadership literature from various high-risk industries, a hierarchy model is constructed constituting 12 key safety leadership behaviors at all three organizational levels – lower, middle and top-level management. This contributes to bridge a gap in safety leadership research – i.e. the lack of a holistic approach to the understanding of safety leadership behavior in high-risk organizations;

(2) Through integrating representative experts' opinions with the support of Delphi, a safety leadership model in the context of shipping is constructed, incorporating 11 verified key safety leadership behaviors – these being lower-level managers' *communicating, caring and supporting, participative involvement*, middle-level managers' *empowering, monitoring, informing and coordinating*, and top managers' *enabling, safety concern, establishing and structuring, inspiring and facilitating* behaviors. The model can be used as a basis for accelerating safety leadership development and help align the leadership behaviors for all managerial levels in shipping organizations; more importantly, it could provide a benchmark for developing the competence of new or less experienced managers in required leadership competence to safety;

(3) In an effort to facilitate the organization to make appropriate training or investment decisions according to the significant effects, all safety leadership behaviors are prioritized on the basis of their relative significance evaluated by the shipping experts.

Future studies may apply the model to other industrial contexts, and the differences in priority sets can then provide a basis for identifying the situational effects.

Generating a more holistic and systemic picture of leadership's approach to safety, with the surplus of the thought which we now can muster, may hopefully encourage more contributions of safety measures for shipping and other high-risk industries.

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Leaders' Influence Tactics for Safety: An Exploratory Study in the Maritime Context

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Abstract: A growing body of research has pointed out effective leadership as an important influencing factor for safety performance in various high-risk industrial contexts. However, limited systematic knowledge is available about how leaders can effectively persuade rule compliance, and stimulate actions and participation. Recognizing effective means of influence is of value for safety leadership development and evaluation. This study seeks to empirically investigate leaders' influence tactics for safety in a maritime context. Qualitative exploration is performed with data being collected through focus group discussions and individual interviews with 41 experienced shipboard leaders from various shipping sectors. Five core influence tactics—coaching, role modeling, pressure, consultation and exchange tactics—appeared to be the shipboard leaders' effective tactics to influence subordinates' safety compliance and participation behaviors in ship operations. Safety leadership influences flow from exemplification, expert and personal sources of power, and being pursued through soft and rational influence tactics rather than coercion or constructive inducements. The results indicate that the more relationship-oriented the leaders are, the more effective their safety leadership would be in influencing safety behaviors. The implication of the results for maritime safety leadership research, maritime education and training are discussed.

Keywords: safety leadership; influence tactics; safety behaviors; maritime industry

1. Introduction

Despite continual improvements to safety records at sea, the scope and severity of maritime accidents persist [1,2]. Human failures—errors or violations—are still the main issues when it comes to maritime safety, which accounted for 75 percent of marine liability claims, with over USD 1.6 billion of losses for the industry in the period 2011–2016 [3]. Among many contributing factors to safety, the pivotal role of leadership influence has been continually highlighted as a crucial determinant for safety culture, effective safety management and organisational safety performance [4–8]. Shipboard leaders, e.g., deck (bridge) and engine officers, are the ones who closely related to supervision and operations, with an essential role in influencing safety culture, crew members' safety perception, and safe work practices [2,9]. Their leadership competence has also been considered as an important position-based expectation, as stated in the 2010-amended International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) [10].

To effectively influence others so that they accomplish organisational objectives is the essence of leadership [11]. A growing body of research has broadened our perspective on various general leadership styles and their effectiveness in driving organisational safety performance. However, there has been little crossover of this body of research into the maritime sector, with only a few studies examining safety leadership behaviours (e.g., [12]). Investigations into leaders' influence tactics, i.e., the method of exerting influence [13] for safety purposes, remain scarce. The ways in which leaders can effectively stimulate and persuade subordinates' safety compliance (i.e., adhering to safety rules and procedures) and safety participation (i.e., engaging in safety activities, raising safety concerns), have received scant attention in the maritime context.

The influx of new technologies on ships today—together with increasing administrative requirements, economic pressure, as well as the dynamic situations occurring at sea—applies constant pressures and increased demand on shipboard personnel [14,15]. The shipboard leaders play an increasingly important role in leading their crews to deal with complex demands and promote safe working behaviour while they themselves must cultivate a portfolio of leadership styles and tactics that address different situations. To our knowledge, limited studies to date have been conducted to explore the influence process of leaders on safety behaviour and to categorize the ways in which they can effectively stimulate actions, persuade compliance and participation in safety. Following up on our previous research [12], the intent of the present study is to address the research gap by inductively exploring the following research question: What are the shipboard leaders' effective tactics to influence subordinates' safety compliance and participation behaviours in ship operations? The paper begins with Section 2 describing the theoretical background of safety in ship operations. To understand the extent to which influence tactics have been studied in relation to safety, a review of relevant studies is also presented. In accordance with the chosen methodological approach, as described in Section 3, results of the collated data are presented in Section 4. The emerged influence tactics dimensions are discussed in light of previous research in Section 5, in which safety leadership practices and different influence tactics used by shipboard leaders are elucidated, and followed by the concluding remarks.

2. Theoretical Background

2.1. Safety in Ship Operations

The pursuit of safety in ship operations is a long-standing goal of industrial practice and academic research, due to the possible human, financial, legal and reputational consequences subsequent to an accident [16]. Safe, reliable operational performance relies on the systemic safety management strategies [17], collective commitment [12], and the frontline teams' expertise in adapting to and addressing the dynamic situations [18]. As stated by Wahl and Kongsvik [19], "safety needs to be considered as a social and collective accomplishment".

The hazardous working conditions, international character, hostile and dynamic nature of ship operations [20] have evolved the maritime industry into a highly regulated domain [21]. An increasing amount of safety rules and requirements has been set by the International Maritime Organization (IMO), flag and port state control, as well as the ship-owning companies. Complying with the established safety rules and requirements in ship operations is part of the formal responsibilities of all seafarers [10]. Individual unsafe acts and breach of safety procedures and regulations are often considered as important accident causations [22]. Adhering to safety rules, operating procedures, checklists, using personal protective measures are generally referred to as safety compliance [23,24]. Compliance with established safety rules to avoid unsafe work processes and reduce the occurrence of errors is essential in pursuit of highly reliable operational performance.

However, actual operational environment may differ from what was anticipated: pre-defined safety rules and procedures have a finite limit to their applicability and effectiveness [25], as it may not be possible to account for the fluid, dynamic nature of operations that involve many unpredictable and unusual situations [26]. Thus, it is paramount to learn from near misses, non-conformities and improvised actions in order to develop new risk-control measures and solutions [27]. Frontline operators' voluntary and active safety participation—through providing safety suggestion, honest reporting, commitment to developing novel safety solutions—can facilitate early detection of rule inconsistencies and early signs of dysfunctionalities in systems that are not yet being anticipated or built into the procedures. Facilitating safety participation opens the way for collecting input from frontline operators for improving the rules, systems design and the capability to eliminate potential errors from future occurrences [28]. To produce dynamic non-events, both safety behaviours, i.e., safety compliance and participation from frontline operators, should be encouraged not only to achieve performance reliability but also to increase the system capability to absorb more situations and unexpected disruptions to deliver sustainable safety performance.

2.2. Influence Research

Recognizing the effective means of persuasion for safety is valuable for practitioners in developing and enhancing their safety leadership capacity and potential [12]. However, the initial literature review using the databases of Scopus, Google Scholar, Web of Science, ScienceDirect with the search words, e.g., "safety behaviours" and "influence tactics", revealed few peer-reviewed studies specifically focused on examining leaders' influence tactics for safety (e.g., [29,30]). None of them concentrated on the identification aspect of leaders' influence tactics for safety purposes in the context of hazardous systems operation in high-risk industries. Nevertheless, in general organizational settings, Kipnis, Schmidt [13] have spearheaded an empirical and inductive study aimed at identifying upward, downward and lateral tactics according to their influence towards superiors, subordinates or peers. The result has been widely used as a landmark in influence research. Investigating downward influence is customarily referred to as the study of leadership [13], which has received most research attention. A review of the most relevant and notable peer-reviewed articles on influence tactic identification and validation is summarized in Table 1.

Table 1. Prior research on influence tactic identification and validation (in chronological order).

Author	Type of Study	Sample and Data Collected	Data Analysis Method	Key Findings
Kipnis, Schmidt [13]	Exploratory study/tactic identification	n = 293, collected critical incidents that describe successful and unsuccessful influence attempts	Content analysis and factor analysis	1. Identification of 8 influence tactic categories: • Assertiveness: Instructing, demanding and setting deadlines for task completion • Rationality: Using logical arguments and factual information to convince a target • Sanctions: Using administrative sanctions such as "prevented salary increases" and "threatened job security" to induce compliance from subordinates • Blocking: "Engaging in a work slowdown" and "threatening to stop working with the target person" • Upward appeals: Bringing additional pressure for conformity by invoking the influence of higher levels authorities in the organization such as making a formal appeal to higher levels or obtaining the informal support • Coalitions: Using co-workers to create steady pressure for compliance • Exchange: Exchanging of positive benefit, e.g., "offering an exchange" and "offering to make personal sacrifices" • Ingratiation: Making the other person feels appreciated and important 2. Description of the directional difference in using tactics (upward, downward, and lateral)
Yukl and Falbe [31]	Study 1: Replication of the Kipnis, Schmidt [13] research Study 2: Verification from the	Study 1: n = 197, using agent version of influence questionnaire Study 2: n = 237, using target version of	Duncan multiple range test	1. Exclusion of "blocking" and "sanctions" due to conceptual problems and infrequent use 2. Re-conceptualization of six of Kipnis et al.'s dimensions, e.g., rational persuasion was substituted for rationality, pressure was substituted for assertiveness

	target point of view	influence questionnaire		3. Claim that consultation and inspirational appeals are important additions to Kipnis et al.'s list of influence tactics: • Consultation: Seeking participation in planning stage or decision making regarding a suggested change or policy • Inspirational appeals: Making an emotional request or proposal that motivates enthusiasm by appealing to target values and ideals 4. No significant directional differences were found for rational persuasion
Schriesheim and Hinkin [32]	Validating Kipnis, Schmidt [13]'s research	Study 1: 34 judges Study 2: n = 251 Study 3: n = 281 Study3: n = 181	Factor analysis	1. Validation of the influence tactic typology proposed by Kipnis, Schmidt [13] 2. Exclusion of two tactics: sanction and blocking, due to their inappropriateness for upward influence
Yukl and Tracey [11]	Hypothesis testing	526 subordinates, 543 peers, and 128 superiors from five large Companies using Influence Behaviour Questionnaire (IBQ)-1990 version	Factor analysis	1. Found that some tactics were more effective than others in influencing target commitment 2. Effective tactics were rational persuasion, inspirational appeal, and consultation; the least effective were pressure, coalition, and legitimating 3. Ingratiation and exchange were moderately effective for influencing subordinates and peers but were not effective for influencing superiors
Yukl, Falbe [33]	Exploratory study	n = 145 (≥ 3 incidents/stories each)	Qualitative analysis of collected influence incidents	1. Confirmation of most of the findings from Yukl and Tracey [11] 2. Ingratiation and personal appeals were used more in initial influence attempts. Exchange and legitimating were used more in immediate follow-up influence attempts. Coalitions and pressure tactics were used more in delayed follow-up 3. Inspirational appeals are seldom used as single tactics, but rational persuasion is used most often both alone and in combinations
Yukl, Guinan [34]	Hypothesis testing	Study 1: n = 215, Collection of influence incidents Study 2: Questionnaire study	Chi-square test	1. Most of the tactics can be used for any of the objectives 2. Tactics used most frequently for a particular objective may not be the most effective one 3. Most managers would benefit from formal training in how to diagnose their power relationship and how to use each type of influence tactics effectively
Kennedy, Fu [35]	Identification and validation study	Collection of influence incidents across twelve countries	Discriminant analysis	1. Rational persuasion, consultation, collaboration and apprising were identified as effective tactics in all the countries 2. Patterns of perceived effectiveness for the influence tactics can distinguish countries in a manner consistent with their known cultural values
Yukl, Chavez [36]	Tactic identification and verification	Study 1: 259 subordinates and 229 peers, field survey using IBQ Study 2: n = 29, collection of influence incidents Study 3: n = 318, experiment	Confirmatory factor analysis, inductive analysis, analysis of variance	1. Validatation of two new influence tactics • Collaboration: Offering to provide relevant resources or assistance if the target will carry out a request • Apprising: Explaining how the target person will benefit by complying with the request 2. Collaboration is more effective than exchange, and rational persuasion was more effective than apprising
Clarke and	Hypothesis testing	n = 105	Structural Equation	1. The result indicated a strong effect of Kipnis's leader influence tactics on individual employee behaviours in relation to safety

Ward [29]			Modelling (SEM)	2. Suggest that leadership development would be an effective intervention for enhancing employee safety participation
Yukl, Seifert [37]	Validation study	Sample 1: 259 subordinates, and 229 peers; Sample 2: n = 70; Sample 3: 71 subordinates, 75 peers of 26 middle managers; Sample 4: 45 subordinates, 65 peers of 9 middle managers	Confirmatory factor analysis	The results provide support for the reliability and validity of the 11 tactic scales in the newest version of the IBQ including • Legitimating: Make appeals to the rules, policies, norms, or authorities • Pressure: Using demands, threats, or harassment to induce compliance from the target

As presented in Figure 1, a total of eleven influence tactics has been identified hitherto. Among these, inspiration appeals, ingratiation, pressure, apprising, exchange, collaboration, and consultation were found being frequently employed in downward influence attempts [11,36]. Since downward influence tactics are clearly related to leadership, those are the most relevant for this study.

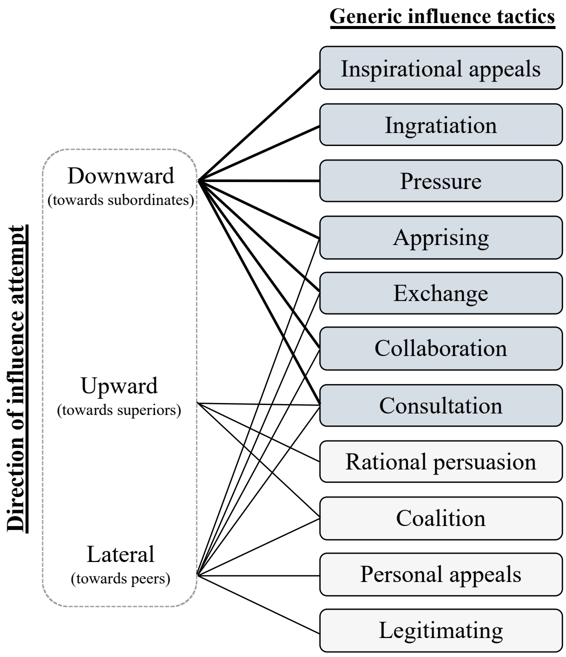

Figure 1. Summary of downward, upward and lateral influence tactics.

Downward influence tactics (i.e., the type of tactics used to influence subordinates) have been further grouped into hard, soft and rational tactics, differentiated by the degree to which the agent takes control over the situation or threaten the target's autonomy. Hard influence tactics (e.g., pressure, apprising) draw on positional power to force compliance in an impersonal way [38]. Conversely, soft influence tactics—such as inspirational appeals, consultation, ingratiation—are associated with employee commitment through the transformation of employees' value systems to be aligned with organizational goals—which also reflected a transformational leadership style [39]. Rational influence tactics—e.g., exchange, persuasion on the basis of logic or self-interest rather than transforming values—were closely aligned with transactional leadership [29]. Among these, soft and rational influence tactics have been proven to be most effective in engaging employee commitment, and are being more frequently used by leaders comparing to hard influence tactics [40,41]. In testing the effect of general leaders' influence tactics on employees' safety participation in manufacturing, a prior study [29] has observed that the use of rational persuasion and coalition was directly effective in enhancing subordinates' safety participation and involvement.

3. Method

An exploratory study with abductive reasoning [42] was used as the methodological approach as it offered the opportunity to develop new theoretical insights through the process of revisiting and enriching the existing theoretical frameworks. Establishing the credibility of qualitative studies depends on the quality of the data as well as how condensation, abstractions and interpretation are carried out [43]. This study was compiled with a sequence of procedures in order to draw valid inferences and explanations from the valuable responses provided by the informants, as illustrated in Figure 2.

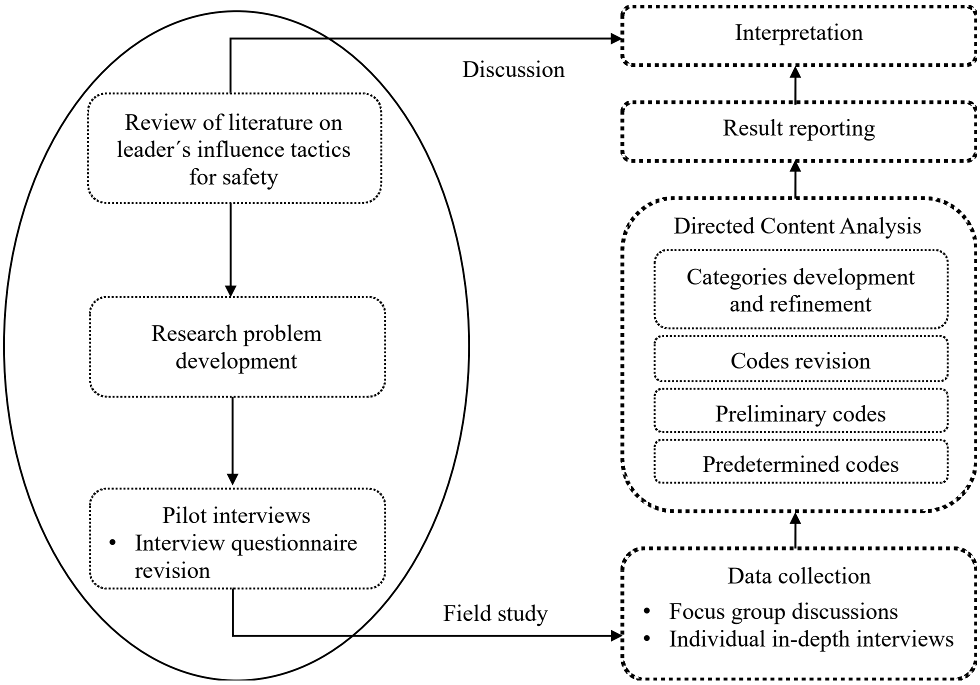

Figure 2. Methodological approach.

An interview guide, consisting of two sections, was developed for both focus groups and interviews. Section 1 involved four research questions to elicit views and experiences, e.g., "In which way do you influence your crew in order to strengthen their compliance on safety rules, policies and procedures? Can you give an example/story of when you have successfully improved the safety compliance of a crew/team?"; "Have you tried to encourage voluntary participation in safety activities and motivate them to report near misses/deficiencies, suggest safe action plans, etc.? Can you describe the initiatives you've led and the outcome?". The questions enabled the shipboard leaders to describe the method used to influence their crews on safety compliance and participation. Additional questions were also asked during the focus group discussions and the individual interviews, in order to obtain information regarding the specific situation, target attitude, followed responses or resistance. Section 2 involved the demographics, including current position, year of experience, nationality, maritime sectors. Two field tests were conducted; first, a pilot interview with one ship captain (year of experience ≥ 20). The questions were then evaluated and revised before the second pilot interview with another captain (year of experience ≥ 20) to check if the answers were in line with the theoretical focus of the study.

Data were obtained through focus group discussions and individual interviews with 41 experienced shipboard leaders working in various shipping sectors. As illustrated in Table 2, four focus group discussions with 30 experienced shipboard leaders were performed. In addition, 11 individual semi-structured in-depth interviews were conducted to obtain more detailed information with new informants working in various sectors of the global maritime industry. Due to physical restrictions such as duty period at sea and limited internet connection, a written form of the individual interview, with the pre-determined questions, was preferred by three informants. All subjects gave their informed consent for inclusion before they participated in the study. The research was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Norwegian Data Protection Services (NSD).

Table 2. Data collection.

Method	Instrument	Informant	Documentation
Focus group discussions	Individual and group reflection and discussions based on given questions	Four focus groups with 30 informants	Individual notes Researcher notes Group presentations
Individual in-depth interviews	Interview guide	11 informants	Transcripts and written interview responses

The focus group discussions employed the Individual, Group and Plenary discussion (IGP) method [44], which consists of four phases: material reading (e.g., informed consent and research questions), individual reflection, group reflection/presentations and plenary discussions. Each focus group comprised of seven or eight informants and occupied a private meeting room. An information sheet outlining the discussion topic was distributed to all participants at the outset. The notes generated throughout the process of focus group discussions, consisting of both individual notes and group presentations as well as the researchers' own reflection notes, were collected.

All informants were officers with managerial or operational responsibilities in the safety operation of the ship and its machinery, having leadership roles in supervising and coordinating their crew members [10]. Their demographic characteristics are summarised in Table 3.

Table 3. Demographic characteristics of informants.

Characteristics	Range	Frequency	Percent (%)
Year of experience in the industry	Less than 5	6	14,63
	5–10	4	9.76
	10–20	9	21.95
	More than 20	20	48.78
	Unspecified	2	4.88
Sectors	Gas carriers (LNG, LPG)	13	31.71
	Passenger ships	3	7.32
	Seismic	17	41.46
	Navy	6	14.63
	Container	2	4.88
Age	Under 29	6	14.63
	30–39	6	14.63
	40–49	7	17.07
	50–59	18	43.90
	60+	2	4.88
	Missing	2	4.88
Leadership positions	Ship masters	9	21.95
	Deck department senior officers	14	34.15
	Deck department junior officers	7	17.07
	Engine department senior officers	7	17.07
	Engine department junior officers	4	9.76

Directed content analysis [45–47] and coding [48] were used to derive sets of similar influence behavioural categories that appear frequently and consistently in the data responses. Previous research (as synthesised in Table 1) was used as a reference during directed content analysis to draw inference and persuasive evidence to provide analytical conclusions. Data which related to the purpose but did not fit into a suitable predetermined category were coded inductively to form new categories. The influence practices that repeatedly emerged in interviews and discussions pertaining to the same phenomenon were grouped into themes. This combined use of deductive and inductive reasoning led to the abductive approach of the study. This approach allowed the researchers to go back and forth between the theories and the data sources, which could not be performed by solely using inductive or deductive approach [42]. Two maritime researchers were engaged in the process of data analysis to consolidate the data received. Individual coding processes were performed prior to discussion and merging. The datasets were analysed line by line and grouped into abstract categories to enable the authors to identify emerging patterns and similarities.

4. Results

As described by the informants, the context of ship operations demands reliability and efficiency with less room for misconduct; the shipboard leaders and the teams generally committed to producing results and act efficiently towards pre-defined priorities and goals. When taking initiatives for safety, many of the shipboard leaders prefer to look for ways that can codify their safety value and expectations into procedures and policies, and introduce it at the macro level to request changes, rather than having too frequent interpersonal interaction with their crew members. Proceduralization of safety is, therefore, a preferred response to safety enhancement for the majority of shipboard leaders. The reason for this is not only to govern or guide behaviours, but also potentially associated with the ease of management. The tactics that improve safety behaviours over the long haul were not prioritised if immediate behavioural changes were more desired and significant for the safety of the operations. Leaders' expected future interaction and the desire to sustain a comfortable relationship were found to be the salient factors affecting the choice of influence tactics. Although obtaining the desired behavioural outcome (i.e., safety compliance and participation) from the targets was by no doubt a significant priority, the potential relational outcome of the influence attempt was an equally important consideration in tactic selection.

To be more specific, the result revealed that leaders employ a variety of tactics to exercise influence on their subordinates' safety behaviours rather than reinforcement through the use of positional power. Offering support and experience through coaching-related behaviours appeared frequently across the responses in the attempt to reduce subordinates' non-compliance behaviours (e.g., taking shortcuts, non-compliance with precautions). One informant mentioned:

> "Understanding of the reasoning behind the safety regulations and instructions, the associated risk, or the financial implications of non-compliance are the prerequisites for the crews' compliance."

Safety compliance is understood to be strongly associated with crew members' level of risk awareness, perceived efficiency and manageability of the checklists. The informants described that they seek behavioural change from their subordinates through facilitating them to overcome ability, knowledge or motivational barriers for safety compliance. Coaching is manifested through (1) leaders offering experience-based knowledge, explaining the past events or incidents to increase awareness of risk factors, (2) providing frequent reminder of safety rules and performance feedback, or (3) clarifying risk understanding through questions, and facilitating subordinates to do the risk analysis to envision the outcome before a job. Differing from the "collaboration" tactic in prior influence research (see Table 1), coaching is didactic, focusing on skill or knowledge transmission, and directly concerned with the immediate improvement of the performance through a form of support and instructions to enhance the target self-efficacy.

Facilitating targets to overcome ability, motivation or knowledge barriers to obtain the desired outcome is one of the objectives that can generate sustained and consistent behaviours rather than short-term, one-off changes. Nevertheless, it is the leader's credibility, competence and trustworthiness, as perceived by the subordinates, that determine the persuasiveness and effectiveness of a coaching intervention. Apart from the use of experience and factual knowledge to influence compliance through coaching, several intentional exemplification behaviours also emerged from the data.

Role modelling, appeared as a new influence tactic and was coded as a key category including several types of influence behaviours such as (1) purposely carrying out the work in compliance with the requirements as set out in SMS procedures, (2) frequently citing the company's safety rules in meetings, or (3) participating actively in safety activities (e.g., drills, tool box meetings). Leaders aim to convey their safety values, attitudes and priorities to encourage their followers/observers to act as they do. Unlike coaching, role modelling is a gradual influence process, communicating through behaviours rather than through verbal sharing of information. The tactics of intentional role modelling and coaching are often combined to impart values and generate behavioural changes. As explained by several informants, full compliance to checklists also entails cumbersome paperwork, which sometimes takes the focus away from high-risk areas that need more attention and creative thinking. Leading by example is one way of softening the resistance of followers towards the overwhelming amount of procedures so that they will be more likely to pay attention to adhering to safe practices.

The data also revealed types of influence processes such as monitoring, supervising and frequent checking which were associated with pressure tactics by leaders to influence the subordinate's safety compliance. Pressure tactics are used in an attempt to influence a target to carry out a request through demands, threats, frequent checking, or persistent reminders. The influence behaviours coded into this category are more aligned with a covert form of pressure rather than overt. Despite the strict subordination relationship and the shipboard leaders' legitimate power to draw on when making a request for safety compliance, some informants deemed it negative and inappropriate to pull rank rather than show respect in the daily operations. Overt forms of pressure tactics such as impersonal or direct ordering and demanding did not emerge from the descriptions in the context of daily operations. The influence behaviours displayed by the shipboard leaders are consistent with soft and rational ways of leading, relying less on traditional command-and-control models. The context of ship operation is characterised by intensive use of checklists and procedures to avoid hazardous work processes. The dynamic situations occurring at sea often intensify the extent and complexity of the demands placed on the crew members. As several informants pointed out, although compliance to safety rules, standards and checklists are formally required, non-conformities and improvised actions are sometimes inevitable due to the dynamic situations at sea. Predetermined safety procedures were perceived to have a finite limit to their applicability and effectiveness. Despite that the Safety Management System (SMS) itself often invites all crew members to contribute to safety with formal procedures to report non-conformities, incidents or near-misses, leaders still play an important role in motivating and generating voluntary participation. In the attempt to influence subordinates' contribution to safety, frequent use of consultation and exchange was identified.

Tool-box meetings or suggestion boxes appeared to be the means and the arenas which shipboard leaders use to enable communication on safety issues between shipboard leaders and crew members. One informant argued:

> "Beyond the formal ways to facilitate participation, generating openness through welcoming and encouraging all the crew members to report near misses and discuss possible risks without fearing criticism are clearly important."

Continual learning through non-conformities and near-misses reporting was seen as an important way of identifying vulnerability in existing operational processes, especially those processes that are particularly challenging to execute reliably or often causing problems. So that measures can be developed proactively, which can be a crucial input for safety improvement and complementary to formal safety procedures. Although the system itself often encourages safety participation through rewarding, consultation—i.e., encouraging individuals to speak out their safety concerns, observations and near-misses—is often employed by shipboard leaders as an additional means to generate commitment and contribution. Influence behaviours such as inviting the crew members to participate and help in decision-making related to planning and organisation, asking them to speak out their concerns, were also coded into this category.

Consultation tactics were also frequently used to facilitate a social and participative process for learning from past events, and a fair environment is an important condition as it provides psychological safety for crews to openly discussing errors. It is often an extra step used by senior shipboard leaders to encourage subordinates to perform to their potential during toolbox meetings and drills, which was perceived to be more effective than the organizational safety promotion programs. The data also revealed types of influence behaviours associated with the use of exchange tactics to offer recognition, incentives or awards in return for frequent safety participations, e.g., submitting safety cards and providing safety suggestions.

Soft and rational tactics were often selected and preferred in usage over impersonal tactics in pursuit of a positive relationship, without placing strain on the relationship. Achieving positive relational outcomes (such as good relationship, respect, trust) for future collaborations was perceived to be of great enduring value. The means through which to achieve the influence objective is contingent and adaptive. The targets' maturity, experience and relationship with the agent were also perceived as significant factors for the reaction towards influence attempts. Coaching, consultation and pressure tactics were found to be more appropriate and effective towards relatively new or inexperienced followers and appeared less appropriate when the desired behaviours have become the norm in daily operations.

Furthermore, whether to establish a leadership event was seen in connection with the leaders' commitment with safety and criticality of the problem. Leaders' learning orientation from errors, adverse events and incidents also determine the use or non-use of tactics in influencing for safety participation. Regarding differences in the use of influence tactics with respect to different nationalities, the observations in our study differ from previous studies, e.g., Kennedy, Fu [35], by showing a tendency not to differentiate the leader's approach towards different nationalities. No specific patterns were observed regarding culture-based differences in tactic selection and usage.

5. Discussion

The goal of this study was to investigate effective influence tactics employed by shipboard leaders that influence their subordinates' safety compliance and participation behaviours in the maritime context. While the shipboard leaders have the formal authority available to request the subordinates to adhere to safety, the findings have revealed that leaders utilize a variety of tactics to exercise influence on their subordinates' safety behaviours rather than reinforcing through positional power. As shown in Figure 3, several generic downward influence tactics, e.g., exchange, pressure, consultation, remain effective in influencing safety behaviours in the maritime context, in which exchange and consultation were found to be frequently used when leaders seek to initiate behavioural changes on their subordinates' safety participation.

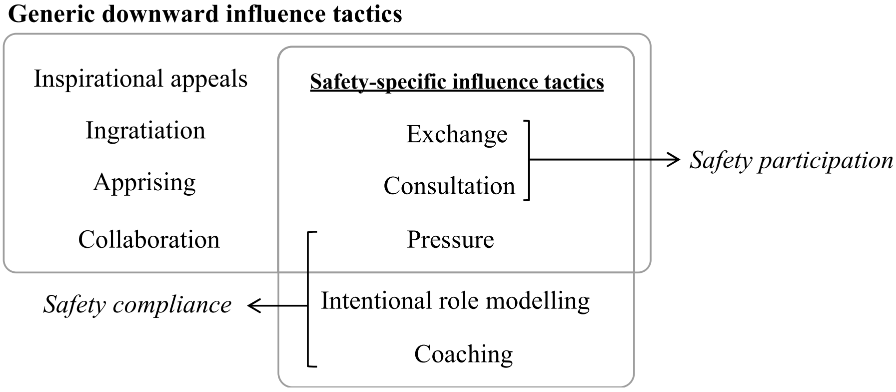

Figure 3. Identified influence tactics for safety behaviours in the maritime context.

Exchange and consultation tactics are interaction-oriented, and involve implementing a two-way communication in which the subordinates are enabled to engage in the process of exploring, exchanging information and understanding the need for changes. These ways of influence align with the relation- and task-oriented leadership mode as described by Bass and Stogdill [49]. It implies that leadership with both orientations are likely to encourage safety participation (e.g., report near-misses, submit safety cards and provide safety suggestions) from their subordinates. When looking into how leaders can effectively persuade rule compliance and reduce non-compliance behaviours (e.g., taking shortcuts, non-compliance with precautions), frequent use of pressure, coaching and intentional role modelling behaviours were observed, as described in the findings section. The use of intentional exemplification and coaching-related behaviours in the attempt to reduce subordinates' non-compliance behaviours, is distinct from other downward tactics identified in earlier research, according to their definitions (see Table 1). While requesting subordinates to adhere to safety rules may be more amendable to be enforced through use of authority [29], hard tactics such as coalitions and legitimating were not found to be prevalent means of influence for safety, neither were blocking and sanctions observed in the results, corroborating the findings of Yukl and Falbe [31]. Effective leadership influence flows from the exemplification, expert and personal sources of power, and being pursued through soft and rational influence tactics rather than coercion or constructive inducements.

Leaders' safety compliance-gaining tactics were also integrated in both relationship and task orientations. As relationship- and task-oriented leadership behaviours have been recognised as linked to transformational and transactional leadership styles, where transactional is defined as task-oriented while transformational is defined as a relationship-oriented leadership style [50], it can therefore be concluded that transactional and transformational leadership styles are directly effective in influencing safety compliance and participation behaviours in a ship operational context. This point is inconsistent with previous research which suggested that transformational leadership is positively and directly related to employee safety participation [29,51], but indirectly [29] or not significantly related to safety compliance behaviours as it did not affect whether the subordinates followed safety rules [52]. Through looking into the effective means by which leaders exert influence over subordinates' safety behaviours, our exploratory study reveals the existence of both leadership styles in the maritime setting.

However, as the majority of the reported influence tactics are in favour of a relationship orientation, the result indicated that the more relationship-oriented the leaders are, the more effective their safety leadership would be in improving safety behaviours. This result corroborates the findings of [53] and also supports another study conducted in a functionally similar field (i.e., air traffic control), which concluded that the most frequent leadership style for safety has a high relationship-oriented and low task-oriented behavioural pattern [54].

Previous studies argue that leaders may select their influence tactics depending on various factors peculiar to the organization, situation and followership [55]. As described in Section 5, our data has also revealed several factors influencing the selection of tactics. One of those is the expectation of future interaction. The transitory nature of ships' crew structure does not foster the development of unfriendly or coercive interaction patterns, the expectancy of harmonious interaction diminishes the use of hard tactics. This point echoed the findings from Van Knippenberg and Steensma [41], who claimed that the expectation of future interaction is an important determinant for the use of hard and soft influence tactics. Another factor that evidently influenced the choice of influence tactics was the competence level of the subordinates. This aligned the underlying assumptions in situational leadership that subordinate maturity determines the leader's choice in the use of task- and relationship-oriented behaviours [49].

Safety leadership in ship operations has clearly shifted from long-recognised authoritative approach to a more structural, resourceful and supportive way of leading. As discussed in many safety studies, e.g., Dekker [26], Wachter and Yorio [56], effective safety management goes beyond the general goal to be compliant with safety rules and procedures. The revealed influence tactics also suggest that ensuring safety in operations cannot be achieved through only constraint or control of people to be compliant with regulatory demands for checklists and paperwork. The importance of making subordinates behave in a participative way with regard to safety, and empowering them to generate ideas for safety improvement, is clearly important for good safety performance.

To our knowledge, this is the first qualitative study that explores the influence process of leaders on safety behaviours and categorizes the ways in which the leaders can effectively stimulate actions, persuade compliance and participation in safety. However, several limitations need to be mentioned. Firstly, due to the vast amount of data collected, the emphasis was placed on the investigation of the most relevant and core influence tactics. The categories presented here is not a complete representation of all the available influence behaviours but a representative and legitimate set of tactics that can be used by leaders in a high-risk and highly regulated work context. Due to scarcity and difficulties in recruiting female shipboard leaders, the informants were primarily males. Secondly, the analysis relied on the incidents provided from the supply perspective. Future research can explore how the tactics can be perceived on the other side of the dyads.

6. Conclusions

To facilitate good levels of procedural compliance and safety participation is a persistent leadership challenge for shipboard leaders. Building on the analysis of the literature and the diversified influence attempts described by 41 shipboard leaders, five core influence tactics—coaching, role modelling, pressure, consultation and exchange tactics—appeared to be the shipboard leaders' effective tactics to influence subordinates' safety compliance and participation behaviours in ship operations. The results indicated that the more relationship-oriented the leaders are, the more effective their safety leadership would be in influencing safety behaviours.

This study has both theoretical and practical implications. Theoretically, it brings together prior influence and safety research to empirically investigate leaders' influence tactics on safety in the maritime context and provides systematic information about how leaders can effectively persuade rule compliance, stimulate actions and participation for safety. The important role of leaders in influencing and shaping safety behaviours should not be overlooked. The study extends the argument that more research is needed to explore and understand the complexity and particularities of shipboard officers' leadership behaviours and practices. Furthermore, the results should prove of value to enable analytical generalisation to other industrial contexts and as a starting point for further explorations using different methodological approaches spanning different sectors. Practically, the influence tactics revealed in this study provide practical implications for mariners, maritime education and training institutes to establish best practices and to build needed safety leadership skills to pursue better safety performance.

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Development and validation of a safety leadership Self-Efficacy Scale (SLSES) in maritime context

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SLSES

ABSTRACT

Extensive studies have highlighted the importance of leadership on safety in the maritime industry. However, current research lacks empirically tested theoretical models with valid and reliable scales for describing and measuring safety leadership in ship operations. This study reports the development and validation process of the first *Safety Leadership Self-Efficacy Scale* (SLSES) for assessing shipboard officer's efficacy in exercising leadership for safety in merchant shipping. The research has been divided into three stages, including a content validation study (20 subject matter experts), an Exploratory Factor Analysis (EFA) ($n = 150$) and a Confirmatory Factor Analysis (CFA) ($n = 396$). The results have supported a higher order factor structure with three subscales – motivation facilitation, safety management and safety initiative – contributing to the measurement of safety leadership self-efficacy. The resulting scale has revealed adequate measurement properties with good explanatory power, construct validity and high internal reliability (Cronbach's $\alpha = 0.971$). SLSES can provide maritime researchers, practitioners and shipping organizations with a tool to assess and enhance safety leadership potentials of current and future shipboard officers. The theoretical, methodological and practical implications of SLSES were discussed.

1. Introduction

Although the maritime industry has gone to great lengths to enhance safety by promulgating safety rules, regulations and standards, unanticipated – and sometimes catastrophic – accidents still occur (Schröder-Hinrichs et al., 2012; Batalden and Sydnes, 2014; Kim et al., 2016). Lessons learned from accidents (e.g., Costa Concordia, Sanchi, Sewol ferry, Bow Mariner) have consistently observed the important role of human element, especially leadership and management practice for safety (Grech et al., 2008; Kim et al., 2016). A well-functioning Safety Management System (SMS), good accident prevention activities and active safety communications cannot be envisioned without the existence of strong leadership and management support (O'Dea and Flin, 2001; Kim and Gausdal, 2017). As Leveson (2011) put it, "Safety starts with management leadership and commitment. Without these, the efforts of others in the organization are almost doomed to failure" (p. 177).

Across various high-risk industrial contexts, extensive research has shown the important impact of leadership on safety culture (Yang et al., 2009; Ross, 2011), on safety climate, subordinates' safety compliance and participation behaviours (Clarke, 2013; Pilbeam et al., 2016; Kim and Gausdal, 2020) as well as safety outcomes (e.g., accidents and injury rate) (Mullen and Kelloway, 2009). It has been considered as an important differentiating factor between high and low accident companies (Kjellen, 1982; Bentley and Haslam, 2001; Mattson et al., 2019) and an even more important predictor for safety performance compare to hazard reduction systems (de Koster et al., 2011).

By acknowledging the importance of leadership issues for safety in ship operations, the International Maritime Organization (IMO) has raised the minimum standards of competence for seafarers by including leadership training as a mandatory competence requirement for shipboard officers at both management and operational level (IMO, 2017; Wahl and Kongsvik, 2018; Kim and Mallam, 2020), as specified under the International Convention on Standards of Training, Certification and Watchkeeping (STCW 1978 as amended) (IMO, 2017). However, research into maritime safety leadership (e.g., its determinants, behaviours and process) is very scarce, and it also lacks empirically tested theoretical models – with a validated and reliable scale – for describing and assessing safety leadership in ship operations (Kim and Gausdal, 2017; Besikçi, 2019). This knowledge gap has consequently undermined

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our theoretical understanding and training practice of safety leadership in the maritime context. Current leadership training objectives and materials were largely based on generic leadership knowledge and the Crew Recourse Management (CRM) training adapted from the aviation industry with little sector-specific adjustments and scientific adaptation to the maritime context (Barnett et al., 2003; Oltedal and Lützhöft, 2018). The unique nature of shipping, such as the remote working condition, closed social milieu, exposure to hazardous substances, dynamic situation at sea, as well as the transient and multinational crew composition, has made the ship operational context differ from any other industries (Håvold, 2005; Slišković and Penezić, 2015; Besikçi, 2019). These inherent sector specific characteristics render the effectiveness of transferring leadership knowledge from other industries to the maritime setting (O'Connor, 2011; Oltedal and Lützhöft, 2018; Besikçi, 2019).

In this light, the purpose of this research is to give particular focus to maritime safety leadership, and to design a Safety Leadership Self-Efficacy Scale (SLSES) for describing and assessing shipboard officer's safety leadership self-efficacy in the context of merchant shipping. The research drew upon the insights of safety leadership literature and Bandura's self-efficacy theory, while engaged in a three-stage process to systematically explore and examine the validity and reliability of the measurement scale.

2. Theoretical background

2.1. Safety leadership

Safety leadership has been defined as a process of interaction between leaders and followers to achieve organizational safety goals (Wu, 2005). Leaders' behaviours and the way they interact with their subordinates have been consistently recognized that have significant effect on safety performance (Clarke, 2013) and are important predictors of safety records in many hazardous industrial contexts (Hofmann and Morgeson, 1999; Zohar, 2002). Majority of safety leadership studies have predominantly concerned with investigating and identifying the form of leadership style for safety in formal roles, with reference to a well-established leadership theory (e.g., transformational and transactional leadership theory (Bass, 1985), Leader-Member Exchange (LMX) theory (Graen and Uhl-Bien, 1995), authentic leadership theory (Cooper et al., 2005), situational leadership theory (Graeff, 1983)). Each of these theories view the complex and continuing leadership phenomenon from different angles and emphasize different means for influencing followers. Among which transformational and transactional leadership theory have received the most attention (Clarke, 2013).

Transformational leadership is relationship-oriented, whereas transactional leadership has a stronger task-orientation (Bass and Avolio, 1997). Research based on transformational leadership views leadership as leaders' ability to exert influence to their followers through inspiration, engagement and empathy to achieve "performance beyond expectations" (Zohar, 2003). Transactional leaders focus on maintaining routines, minimizing variations, increasing reliability and predictability from their followers to ensure "expected performance" are in place (Zohar, 2003). A series of studies have shown that a combined use of both transformational and transactional leadership are most beneficial for safety (Clarke, 2013; Kim and Gausdal, 2020). These leadership research are in line with safety theories arguing that to effectively manage safety of today's complex socio-technical systems, it is important to not only avoid that things would go wrong to achieve performance reliability, but also need to increase the system capability to adapt to and succeed under varying conditions and unexpected disruptions to deliver sustainable safety performance (Hollnagel, 2014).

Among limited empirical studies which focused specifically on the study of safety leadership in the shipping industry, an attempt were made by Kim and Gausdal (2017) to synthesize the behaviours and actions manifested by effective leaders in shipping organizations. The study argued that achieving, maintaining and sustaining safety performance in ship operations demands effective safety leadership to be instilled at all organizational levels. Kim and Gausdal (2017) identified eleven key behaviours enabling good safety performance in ship operations, which includes lower-level managers' communicating, caring and supporting, participative involvement; middle-level managers' empowering, monitoring, informing and coordinating; and top managers' enabling, safety concern, inspiring and facilitating behaviours. Organizational leadership for safety significantly influence the learning outcomes from the minor, moderate and major near-misses, which are valuable inputs for the organization to update the safety management practices and generate corrective/preventive actions (Ginsburg et al., 2010). A positive association between the participant's perception of their manager's leadership skills and frequency of incident reporting is also noted by Oltedal and McArthur (2011) in merchant shipping.

Existing literature investigating leadership impact on safety outcomes have provided several important implications: Firstly, it indicated that the variations in individuals and teams' safety practices are causally related to managerial leadership styles and behaviours, and susceptible to influence. Secondly, leaders should excel both task and relationship-oriented leadership in order to effectively influence safety behaviours and outcomes. Thirdly and most importantly, it highlighted the tremendous need for safety leadership assessment and development in order to recognize the current level of performance and identify room for improvement.

2.2. Leadership self-efficacy

Self-efficacy is a critical construct within Bandura's social cognitive theory (Bandura and Walters, 1977), he defined it as: "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performance" (Bandura, 1986, p. 391). It influences on "what challenges to undertake, how much effort to expend in the endeavour, and how long to persevere in the face of difficulties" (Bandura, 1986, p. 29).

Wood and Bandura (1989) has first linked self-efficacy construct to management. Leadership self-efficacy is a key variable regulating leader's functioning in a dynamic environment (McCormick, 2001). It determines not only initiation, intensity and persistence of leadership behaviours (Paglis, 2010), but also fosters the level of motivation, organizational commitment and efficient analytic thinking ability (Wood and Bandura, 1989), with meta-analysis reported a significant correlation G(r_+ = 0.38) between self-efficacy and performance (Stajkovic and Luthans, 1998). Credible evidence supports the statement that possessing strong leadership self-efficacy could impact not only on leadership effectiveness (Anderson et al., 2008; Hannah et al., 2008) but also the work-related performance (Stajkovic and Luthans, 1998; McCormick, 2001). Anderson et al. (2008) identified 18 dimensions as key components of leadership self-efficacy i.e., change, drive, solve, build, act, involve, self-control, relate, oversee, project credibility, challenge, guide, communicate, mentor, motivate, serve, convince, and know. Leaders with higher self-efficacy are more likely to initiate and engage in leadership attempts (Paglis and Green, 2002), use leadership skills and have better effectiveness compare to those with lower self-efficacy (Anderson et al., 2008). Research also observed that frontline leaders' self-efficacy have direct and positive effects on safety behaviours (Chen and Chen, 2014). Furthermore, self-efficacy, work engagement and human error are significantly correlated, in which self-efficacy significantly predicts probability of human errors in aviation (Li et al., 2018).

In this study, we define *safety leadership self-efficacy* as the extent to which leaders perceive their capabilities to exemplify and execute courses of action required to attain a good safety performance on-board ship. It refers to, for instance, the extent to which shipboard officers perceive their self-efficacy in relation to the development, implementation, and oversight of standard operating procedures (STCW code

Table A-II/2, KUP 6), how they perceive their knowledge and ability to apply decision-making techniques (STCW code Table A-II/2, KUP 5), how they facilitate effective communication (STCW code Table A-II/2, KUP 4), etc (IMO, 2017; Kim and Mallam, 2020). We reason that leadership self-efficacy is particularly important in this safety-critical working environment, where a greater level of confidence and self-belief is needed in order to manage and lead a high-risk activity that has massive risk and uncertainty built-in. Wherein proficient technical competence, a greater level of decisiveness, assertiveness and adaptive skills need to be orchestrated in order to lead effectively, make critical decisions and achieve good performance under the dynamic situations. Thus, measuring leadership self-efficacy is of importance to indicate the current level and recognize room for improvement.

3. Methodology

To reliably and accurately assess a theoretical construct, the measurement tool should be developed following a systematic and rigorous process of development and validation (DeVellis, 2016; Farooq, 2016). The scale development process, as discussed by Carpenter (2018), is both theoretically and methodologically demanding. In this study, the scale development process was divided into three stages, including a content validity study with Subject Matter Experts (SMEs) who are familiar with this topic, an Exploratory Factor Analysis and a Confirmatory Factor Analysis using Structural Equation Modelling, with the goal to examine the content validity through SMEs, and to explore and confirm the underlying factor structure of the scale with shipboard officers. The overall flow of the research is illustrated in Fig. 1, which consists of several key steps taken in this research on the development and estimation of the measurement properties of the safety leadership self-efficacy scale.

3.1. *Item generation*

One cannot adequately measure self-efficacy without taking into account the specific domain and the actual tasks and responsibilities (Bandura, 2006). The initial item pool was developed by the authors based on the findings from safety-specific leadership research, general leadership self-efficacy research, STCW leadership requirement as well as the inputs of three maritime researchers to adapt general items to maritime context.

Firstly, as described in the theory Section 2.1, several studies have investigated or summarized what constitute effective leadership and highlighted the behaviours or styles that associated with improved safety culture, safety compliance and participation behaviours and other safety-related outcomes in maritime context. In addition to this, we have also considered the general Leadership Self-Efficacy (LSE) taxonomy developed by Anderson et al. (2008), which included 18 dimensions as key components of leadership self-efficacy. These dimensions also have causal relationships with leadership effectiveness, which can be used as a reasonable inventory for understanding different leadership self-efficacy dimensions. Thus, by taking into account these two groups of research, STCW leadership requirements, as well as the knowledge and maritime experience of the investigators, initial 65 items were generated for measuring safety leadership (see Section 4, Table 3). These items are linked not only with leader's personal accountability such as safety commitment, knowledge, confidence and consciousness, but also his/her behaviours and actions that promote safety. Each of these items can be considered as an important behaviour that leaders should exhibit at the frontline level of ship operations, and it is also associated with one dimension of LSE taxonomy (Anderson et al., 2008). For the dimensions that was included in LSE taxonomy, but the causal relationship to safety was not specifically studied in the field of safety leadership research (e.g., self-control), we have still included them in the item pool. An expert panel will be established to review, judge and determine the extent to

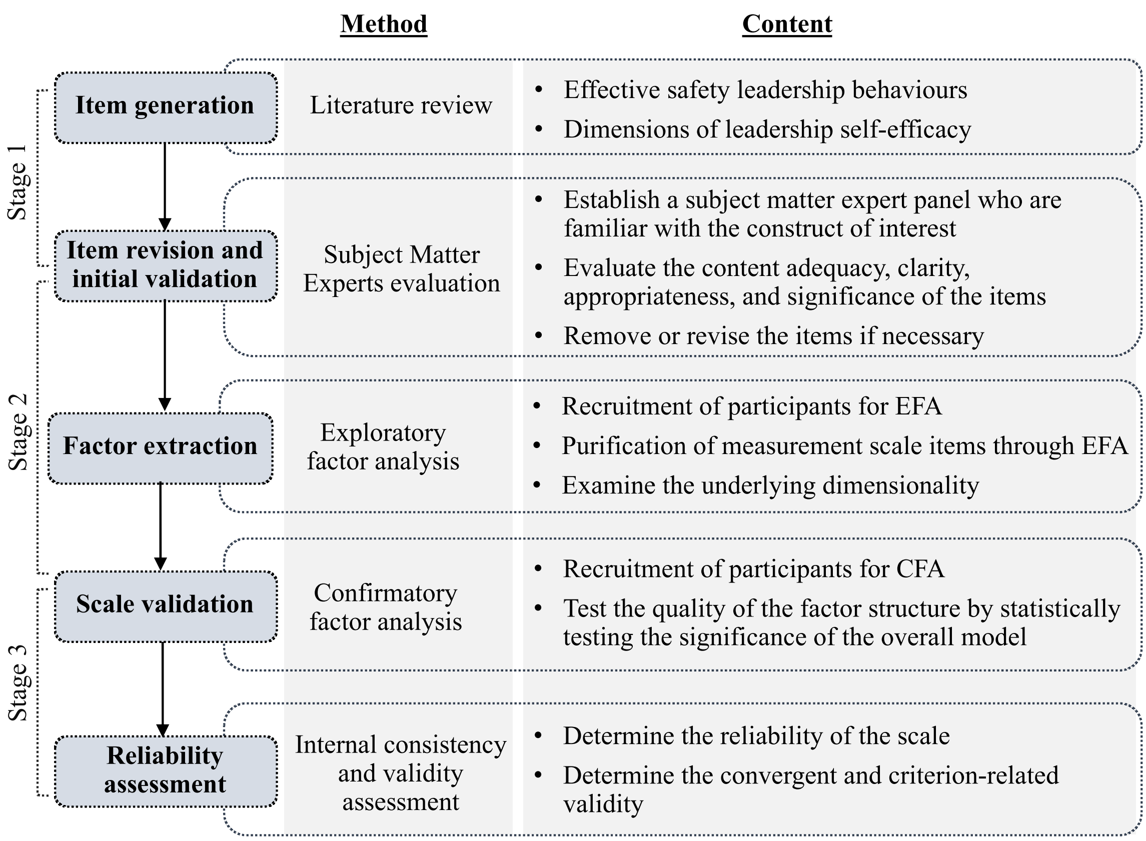

Fig. 1. Safety Leadership Self-Efficacy Scale (SLSES) development process.

which the item could be considered as an important variable to measure.

3.2. Overall scale development process

Stage 1: Content validity assessment process

The first stage has fundamental importance to the instrument development process, as it enables the researchers to validate the representativeness, content validity and clarity of the items through synthesizing the evaluations from subject matter experts. The established item pool was reviewed and evaluated by a team of experts (N = 20) to examine the content validity, clarity, appropriateness of each item for measuring safety leadership self-efficacy of shipboard officers. These experts are invited to review the items and rate their viewpoints on the appropriateness of each item on a 9-point Likert scale questionnaire. The experts were also asked to offer their suggestions for adding new items. Demographic profiles of the expert participated in item validation is summarized in the following Table 1.

Total 20 SMEs participated, among which 40% of them work within merchant shipping industry, 60% are university professors, lecturers, researchers in maritime subjects, constituting a strong expert panel to provide reasonable judgement of the items. Based on the SMEs' evaluation, content validity is examined to reflect the degree to which this measurement scale and its items are appropriate for the construct being measured. Content Validity Index (CVI) is the most widely reported approach in scale development studies (Shi et al., 2012; Zamanzadeh et al., 2015). It includes obtaining the validity index for both individual item (I-CVI) and the scale itself (S-CVI). I-CVI can be computed by taking the number of experts who gave a high rating on each item and divided by total number of experts (Zamanzadeh et al., 2015). In addition to CVI, statisticians (e.g., Wynd et al., 2003) have recommended to include a consensus index – Cohen's coefficient kappa (K) – in content validity studies to supplement the CVI, as the CVI does not consider the possibility of inflated values due to chance agreement. Kappa statistics was calculated using the equations below:

$$P_C = [N!/A!(N\text{-}A)!]^* .5^N$$

In which P_c refers to the chance agreement, and A refers to the number of panellists indicating a specific item can appropriately measure the safety leadership self-efficacy of shipboard leaders. N denotes the total number of experts who participated in the panel. After obtaining the results of CVI, Kappa (K) was calculated with the following equation:

$$K = (\text{I-CVI} - P_C)/(1 - P_C)$$

The K value above 0.74 is considered excellent, between 0.60 and 0.74 is good, between 0.40 and 0.59 is fair, below 0.40 is poor (Cicchetti and Sparrow, 1981). The probability of chance agreement will reduce with increasing number of experts and the value of I-CVI and kappa should converge (Zamanzadeh et al., 2015).

Table 1
Demographic characteristics of Subject Matter Experts (SME).

Criteria of classification	Statistics
Sectors	Merchant shipping: 40%
	Maritime research and education: 60%
Years of Experience in shipping	≥ 20: 15%
	16–20: 25%
	10–15: 10%
	6–10: 35%
	≤5: 15%
Experienced maritime accidents	Yes: 75%
	No: 25%
Level of education	High school or equivalent: 15%
	Bachelor's degree: 20%
	Master's degree (including MBA): 35%
	PhD: 30%
Total No. of experts participated	20

Stage 2: Exploratory Factor Analysis (EFA)

Evaluating the performance of the items through factor analysis to assess whether they adequately constitute the scale are considered to be one of the most critical steps in determining the viability of the developed scale. Both EFA and CFA were used in this study to examine the underlying dimensionality of the items, and to test the quality of the factor structure by statistically testing the significance of the overall model.

In stage 2, EFA is performed to determine the number of latent variables based on commonalities within the data and to examine the loading of individual items. Several methods exist for factor extraction in the EFA process, in this study we used Maximum likelihood for extraction as it offers more reliable estimation for scale development research (Worthington and Whittaker, 2006a, 2006b). Oblique rotation (i.e., Promax) method was selected instead of commonly used orthogonal rotation, as it is unreasonable to assume the items to be completely uncorrelated to each other (Fabrigar et al., 1999). Sampling adequacy for EFA was assessed using Kaiser-Meyer-Olkin (KMO) Test, with the criteria to be greater than 0.70 and p-value to be less than 0.01. To ensure rigor of this process, items with factor loading lower than 0.5 and high cross loading (>0.4) (Hatcher, 1994) will be removed at this stage. The Cronbach's alpha of the extracted factors should be >0.70 (Nunnally, 1994).

Stage 3: Confirmatory Factor Analysis (CFA)

After the EFA, we used Structural Equation Modelling (SEM) to examine the relationship between the factors and measured variables, and to test and confirm the factor structure by using a new data set. SEM is a term for a large set of techniques based on the general linear model (Ullman, 2006), in which CFA technique is one type of SEM (Ullman, 2006). The factor structure derived from stage 2 was then incorporated as the measurement model in CFA. This process plays an important role in validating the hypothesized model and finding the reliability of the measurement. Subject samples for factor analyses have included ship masters and officers etc. working on the global merchant shipping industry. The demographical distribution was summarized in Table 2.

In total the data used in stage 2 and 3 was collected from 396 participants from global merchant shipping industry. The diversity of the participants has also been heightened as the questionnaire was distributed in both Europe and Asia to allow for better generalizability. Majority of participants were from the main shipping sectors i.e., tankers, roll-on/roll-off vessels or bulker carriers, who hold leadership positions such as ship captains, chief engineers, deck and engineering department officers. The questionnaires were developed and administered using Qualtrics™ with anonynous link, in which the participants were asked to put their answers on a 9-point Likert-type scale under each

Table 2
Demographic profiles of 396 participants.

Criteria of classification	Range	*N*	Percent (%)
Year of experience as a shipboard leader	More than 20 years	56	14.1
	10–20 years	81	20.4
	Less than 10 years	259	65.4
Leadership positions	Ship masters	64	16.2
	Deck department officers	130	32.9
	Chief Engineer	27	6.8
	Engine department officers	84	21.2
	Bosun and other position	91	23
Shipping sectors	Passenger ships	33	8.3
	Tankers	117	29.5
	Container ships	20	5.1
	RoRo (Roll on Roll Off)	83	21.0
	Seismic vessels	11	2.8
	Fishing Vessels	13	3.3
	Oil industry vessels	39	9.8
	Other ship types (e.g., bulk carriers)	80	20.2

item. The questionnaires were designed with “forced responses” function, questions need to be answered before proceeding further, therefore no missing values was recorded in the dataset. Data analysis were performed using Excel, SPSS v25 and RStudio. Following Kline (2015) and Crawford and Kelder (2019)’s suggestions regarding the reporting of fit indices, we reported the χ2, RMSEA, Bentler’s comparative fit index (CFI), Tucker–Lewis’s goodness-of-fit index (TLI), and the Standardized Root Mean Square Residual (SRMR) to indicate the model-data fit. Cronbach’s alpha, AVE, Construct Reliability (C.R.) were also be assessed. The overall research methodology aligns with both Carpenter (2018) and DeVellis (2016)’ guidelines on scale development and reporting.

4. Results

4.1. Results of Stage 1: Content adequacy assessment with subject matter experts

Based on the rationale and criteria described in Section 3, the following Table 3 summarizes the results of S-CVI, I-CVI and kappa (K) – the measures that quantify the consensus level of expert opinions on each of the 65 safety leadership self-efficacy measurement items. As shown in the table, the value of the Kappa statistics (K) of all items has all reached above 0.74, which indicates good agreement among SMEs. The CVI of the overall scale has also produced a result of S-CVI/Ave = 0.96, which reflected that the individual items as well as the scale in total has a high level of content validity.

The items contained in the scale have fulfilled the criteria and appeared to be reasonably measure safety leadership self-efficacy of shipboard officers as perceived by the 20 SMEs. Although item 36, 43, 61 have a slightly lower rating compare to the rest (I-CVI = 0.79), they are still within the criteria for inclusion. Accordingly, it can be said that each item is suitable for the given purpose, all items have been kept for next stage of analysis.

4.2. Results of Stage 2: Scale purification

In stage 2, an iterative approach was taken to conduct EFA with the first available 150 samples to purify the measurement items and to explore the latent constructs that cause covariance among items. Factorability of the items was firstly examined, the KMO has yielded an overall measure of sampling adequacy of 0.962, Bartlett’s test of sphericity was also significant ($\chi2$ (325) = 4175.945, $p < .000$), which indicates the existence of a strong relationship between the variables.

The initial result of the analysis was a pattern matrix initially consisting of 7 factors with eigenvalues >1 that account for 76.917% of the variance. Thirty-nine items were dropped during the EFA process due to insignificant loading (<0.5) or high cross-loading (≥0.4). The iterative analysis process has yielded extraction of three factors with 26 items to be considered for inclusion in a hypothesized factor structure for the safety leadership self-efficacy scale, which accounts for 74.821% of the variance but enhances the overview of the matrix considerably. As shown in Table 4, 26 items comprising three factors with loadings vary between 0.523 and 0.859. Each item had a unique contribution to one of these three factors.

Results of the analysis have revealed that safety leadership self-efficacy is a multidimensional construct, which consists of three dimensions (factors) reflecting leader’s confidence in their ability to enact safety leadership activities as of now. The items clustered on factor 1 were given the label as leaders’ efficacy in *safety motivation facilitation*, it refers to the extent to which shipboard leaders could simulate follower’s safety motivation. The items in general related to how leaders use social skills to influence, motivate, and build relationships with crew members to succeed with regards to safety. Items that loaded on the second factor were associated with shipboard leaders’ competence for safety management, which includes identifying, managing, controlling and

Table 3
Results of I-CVI, S-CVI and kappa for all items.

Notation	Item description	Importance		I-CVI	*Pc*	*K*
		Rating 3,4,5	Rating 1 or 2			
I1	Have the ability to foresee risks	18	2	0,9474	0,0002	0,95
I2	Able to make changes in personnel and task assignments to ensure safe and efficient operations	18	2	0,9474	0,0002	0,95
I3	Have the ability to change the operation to improve safety	20	0	1,0526	0,0000	1,05
I4	Have the ability to establish new rules and work procedures to improve safety	19	1	1,0000	0,0000	1,00
I5	Capable of gathering safety information to make necessary changes	19	1	1,0000	0,0000	1,00
I6	Encourage learning as a basis for improving safety	19	1	1,0000	0,0000	1,00
I7	Able to identify hazards proactively	19	1	1,0000	0,0000	1,00
I8	Able to proactively manage safety risks	19	1	1,0000	0,0000	1,00
I9	Able to use formal authority to ensure crew members adhere to the safety procedures and policies	19	1	1,0000	0,0000	1,00
I10	Ensure achievable safety goals are set	19	1	1,0000	0,0000	1,00
I11	Prioritize safety over other business targets and activities	19	1	1,0000	0,0000	1,00
I12	Follow up crew members to ensure that tasks are completed in a timely and efficient manner	16	4	0,8421	0,0046	0,84
I13	Make concrete plans and programs for the safety activities	18	2	0,9474	0,0002	0,95
I14	Have sufficient knowledge of the technical performance of the vessel	20	0	1,0526	0,0000	1,05
I15	Provide expert knowledge to crew members	18	2	0,9474	0,0002	0,95
I16	Have the capacity to manage the technical skills of the crew members	19	1	1,0000	0,0000	1,00
I17	When undesirable incidents occur, be able to follow the established	20	0	1,0526	0,0000	1,05

(*continued on next page*)

Table 3 (*continued*)

Notation	Item description	Importance		I-CVI	*Pc*	*K*
		Rating 3,4,5	Rating 1 or 2			
	procedures to deal with the situation					
I18	When undesirable incidents occur, be able to improvise to handle the situation effectively	18	2	0,9474	0,0002	0,95
I19	Able to develop effective teams to operate safely	20	0	1,0526	0,0000	1,05
I20	Allocate resources adequately to ensure safe and efficient operation	20	0	1,0526	0,0000	1,05
I21	Able to ensure necessary safety precautions are being carried out by conducting regular supervision	17	3	0,8947	0,0011	0,89
I22	Participate actively in workforce safety activities and initiatives	18	2	0,9474	0,0002	0,95
I23	Able to make sound decisions and the right choices	19	1	1,0000	0,0000	1,00
I24	Able to mobilize the resources to make effective decisions in a timely manner	18	2	0,9474	0,0002	0,95
I25	Confident that crew members will follow up leaders' decisions	18	2	0,9474	0,0002	0,95
I26	Able to initiate and engage in toolbox sessions during safety meetings on board	18	2	0,9474	0,0002	0,95
I27	Involve crew members actively in recommending revisions to established procedures	19	1	1,0000	0,0000	1,00
I28	Able to delegate work tasks effectively and encourage crew members to accept responsibility for safety	18	2	0,9474	0,0002	0,95
I29	Actively listen to the crew members, and promote their involvement in decision making	19	1	1,0000	0,0000	1,00
I30	Seriously consider the subordinates' suggestions and initiatives for improving safety	19	1	1,0000	0,0000	1,00
I31	Able to successfully foster effective collaboration among crew members	18	2	0,9474	0,0002	0,95
I32	Able to foster positive attitudes and mutual respect among crew members	18	2	0,9474	0,0002	0,95
I33	Monitor performance and ensure that safety procedures are followed by crew members	18	2	0,9474	0,0002	0,95
I34	Use appropriate sanctions to respond to unsafe actions	16	4	0,8421	0,0046	0,84
I35	Able to closely observe crew performance during safety drills on board, and highlight shortcomings and good work	18	2	0,9474	0,0002	0,95
I36	Encourage crew members to create peer pressures to avoid safety complacency	15	5	0,7895	0,0148	0,79
I37	Treat all crew members with dignity and respect	20	0	1,0526	0,0000	1,05
I38	Willing to deal with resistance from crew members in an open and constructive manner	20	0	1,0526	0,0000	1,05
I39	Concerned with how crew members perceive justice and seek to lead in a fair manner	18	2	0,9474	0,0002	0,95
I40	Appear honest and credible to others	19	1	1,0000	0,0000	1,00
I41	Challenge their own and the team's performance against safety objectives to avoid complacency	16	4	0,8421	0,0046	0,84
I42	Set high safety standards for vessel operations	18	2	0,9474	0,0002	0,95
I43	Pioneer in achieving high safety standards	15	5	0,7895	0,0148	0,79
I44	Use logical arguments and factual evidence to ensure crew members' compliance with safety rules/procedures	17	3	0,8947	0,0011	0,89
I45	Use good seamanship in	19	1	1,0000	0,0000	1,00

(*continued on next page*)

Table 3 (*continued*)

Notation	Item description	Importance		I-CVI	*Pc*	*K*
		Rating 3,4,5	Rating 1 or 2			
	leading and training the crew					
I46	Have the necessary competence to provide proper directions to the crew	20	0	1,0526	0,0000	1,05
I47	Provide feedback on task performance frequently	16	4	0,8421	0,0046	0,84
I48	Foster open and frequent communication among crew members on safety issues	19	1	1,0000	0,0000	1,00
I49	Able to clearly articulate the desired safety behaviours and work practices	18	2	0,9474	0,0002	0,95
I50	Have the cultural awareness to communicate effectively with all crew members	19	1	1,0000	0,0000	1,00
I51	Circulate important safety information among crew members	19	1	1,0000	0,0000	1,00
I52	Able to lead by example, and communicate the importance of safety through both words and actions	20	0	1,0526	0,0000	1,05
I53	Care about crew member' safety, express compassion and empathy where appropriate	20	0	1,0526	0,0000	1,05
I54	Provide recognition and incentives to crew members for promoting positive safety on board ship	18	2	0,9474	0,0002	0,95
I55	Provide positive emotional support and take care of the crew's welfare	17	3	0,8947	0,0011	0,89
I56	Make the crew more confident to accomplish their tasks	17	3	0,8947	0,0011	0,89
I57	Encourage people to report errors, near-misses or other safety-related information without fear of the consequences	20	0	1,0526	0,0000	1,05
I58	Confident in ensuring the motivation of crews to follow Safety Management Systems (SMS)	18	2	0,9474	0,0002	0,95
I59	Will not bend safety rules to achieve performance targets	18	2	0,9474	0,0002	0,95
I60	Willing to reflect on, and revise leader's decisions based on feedback from the crew	18	2	0,9474	0,0002	0,95
I61	Explain and justify the activities to be performed to give more purpose to the task	15	5	0,7895	0,0148	0,79
I62	Able to galvanize the crews' support to achieve safety standards and goals	17	3	0,8947	0,0011	0,89
I63	Aware of their influence and know what leadership strategies or tactics are needed to ensure safety in various situations	17	3	0,8947	0,0011	0,89
I64	Capable of sourcing the pertinent information for decision making	18	2	0,9474	0,0002	0,95
I65	Capable of keeping safety information updated	19	1	1,0000	0,0000	1,00

Note: I-CVI refers to content validity index for each item, Pc is the probability of a chance occurrence. Kappa statistics (K): <. 40 is poor, 0.40-0.59 Fair, 0.60-0.74 is Good, 0.75–1.00 is Excellent (Cicchetti and Sparrow, 1981).

handling risk and hazardous situations during ship operations. Accordingly, factor 2 was labelled as *safety management* efficacy. The third group of items included specific, discrete verbal and nonverbal leadership behaviours and initiations that encourage subordinates to be involved in safety activities, which in general reflected leaders' efficacy on taking *safety initiative*.

The EFA process has reduced the 65 items measurement scale to a more manageable number. As shown in Table 5, the factor correlations ranged from 0.730 to 0.763, suggesting a higher order factor that should be tested during next CFA stage.

In this stage, the overall Cronbach's α of the scale with 26 items was 0.979. The three subscales have also obtained excellent internal consistency: Cronbach's α has reached 0.971 for efficacy in safety motivation facilitation, 0.933 for efficacy in safety management and 0.923 for efficacy in taking safety initiatives. The Corrected Item-Total Correlation was ranged from 0.619 to 0.874. The Alpha If Item Deleted also showed that the α value would not be improved if any of the items being eliminated, thus all 26 items derived from EFA were worthy of retention for next scale validation stage.

4.3. Results of Stage 3: Scale validation and reliability assessment

In Stage 3, a CFA analysis was conducted using 396 samples with maximum likelihood robust estimation to validate the model derived

Table 4
Results from Exploratory Factor Analysis ($n = 150$).

Factor label	Items	Loading	Communalities	
			Initial	Extracted
Factor 1: Efficacy in Safety Motivation Cronbach's α = 0.971	I57	0.859	0.779	0.720
	I58	0.834	0.770	0.752
	I56	0.811	0.800	0.756
	I40	0.782	0.703	0.614
	I63	0.742	0.724	0.652
	I49	0.673	0.841	0.816
	I48	0.673	0.865	0.833
	I39	0.671	0.774	0.709
	I53	0.617	0.772	0.737
	I37	0.578	0.757	0.660
	I46	0.560	0.807	0.739
	I44	0.546	0.798	0.726
	I50	0.544	0.766	0.723
	I60	0.534	0.721	0.674
Factor 2: Efficacy in Safety Management Cronbach's α = 0.933	I30	0.729	0.834	0.846
	I29	0.725	0.838	0.808
	I18	0.718	0.722	0.695
	I2	0.675	0.610	0.486
	I24	0.531	0.797	0.743
	I8	0.523	0.748	0.662
Factor 3: Efficacy in Safety Initiative Cronbach's α = 0.923	I26	0.846	0.794	0.798
	I47	0.730	0.719	0.671
	I43	0.653	0.716	0.684
	I27	0.651	0.798	0.769
	I35	0.602	0.774	0.672
	I10	0.587	0.681	0.581

Table 5
Factor correlation matrix.

Factor	1	2	3
1	1.000		
2	0.750	1.000	
3	0.763	0.730	1.000

through Stage 2 (EFA). Two items (I37 and I43) were dropped due to low r-square value during the initial CFA. The final model, as illustrated in the following Fig. 2, was tested and it revealed that the model fits the data well, the goodness-of-fit indices are adequate with $\chi^2 MLR$ (249, N = 396) = 493.904 ($p < .001$), R-CFI = 0.947, R-TLI = 0.941, CFI = 0.944, TLI = 0.938, RMSEA = 0.050 (90% CI, [0.045,0.055]), Standardized RMR = 0.034.

The result confirms a second-order model in which safety leadership self-efficacy (second-order factor) is comprised of three first-order factors including efficacy in safety management, efficacy in safety motivation facilitation and efficacy in taking safety initiatives. The final CFA estimation is presented in the following Table 6.

All standardized coefficient beta (β) are above 0.7, R-squared are above 0.5 indicating superb explanatory power. The standard structural coefficients of the first order factor on safety leadership self-efficacy construct are the estimates of the validity of the factors, thus the larger the factor loadings are, the stronger the evidence that the factors represent the underlying construct. The loadings are high (i.e., 0.946, 0.961 and 0.963), which indicates that the safety leadership self-efficacy can be well explained by these three first-order factors and reflected the contribution of safety leadership efficacy on its three sub-constructs is good. Parameter estimates for the confirmatory factor model are significant at the 0.001 level. The overall internal reliability of SLSES is 0.971. Cronbach's α of the subscales and Composite Reliability (C.R.) were calculated as shown in Table 7.

As shown in Table 6 and 7, the factor loadings of the observed variables (standardized λ) are significant between 0.707 and 0.861, which indicates good convergent validity. Cronbach's alpha of the subscales were ranged from 0.887 to 0.954, AVEs are above 0.6, and the composite reliabilities of each dimension have also exceeded the recommended upper level of 0.70, indicating reasonable reliability of the model. Content validity index of the scale was recalculated based on the result of stage 3, S-CVI/Ave is 0.914, indicating excellent content validity of the scale. Based on the three stages presented above, the final Safety Leadership Self-Efficacy Scale (SLSES) was constructed. All factors and their items remained in the final scale appeared to have good conceptual consistency, adequately explained safety leadership of shipboard officers, and successfully covered what we have tried to identify as the core functions of a safety leader.

5. Discussion

This study presented the development and validation process of a Safety Leadership Self-Efficacy Scale (SLSES) to prepare an instrument to aid in understanding and predicting safety leadership of shipboard officers. The resulting scale has demonstrated adequate measurement properties with good validity and reliability.

SLSES consists of three subscales (factors) to reflect leader's efficacy in their ability to facilitate motivations, manage safety and take safety initiatives. The first factor, efficacy in motivation facilitation, reflected an important leadership function which is to inspire motivation of their

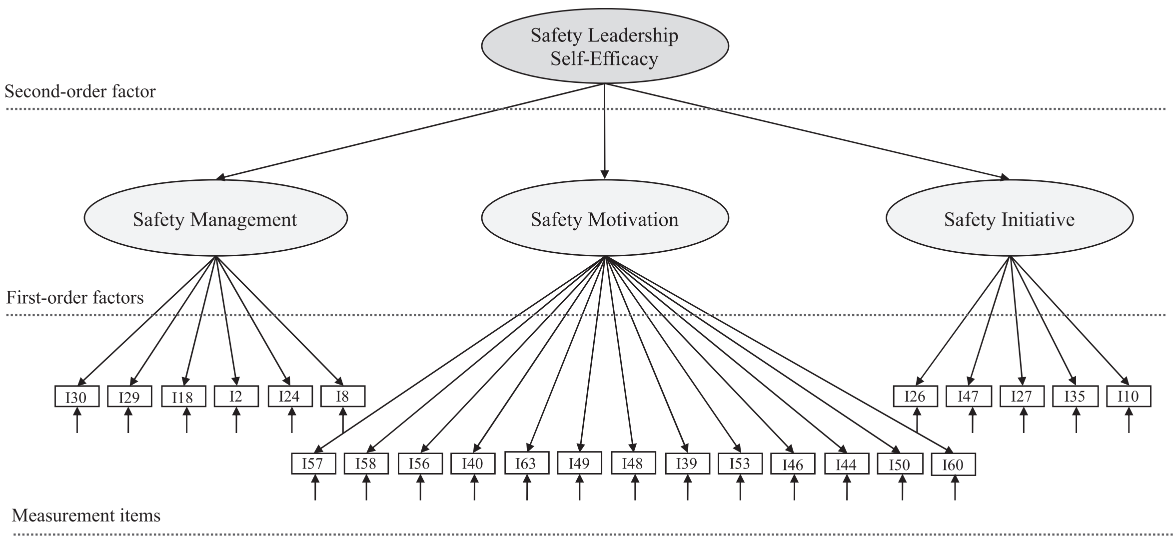

Fig. 2. Measurement model.

Table 6
Final result from Confirmatory Factor Analysis ($n = 396$).

Notation	Item	Estimate		R^2	S.E.	z-value	P(>|z|)	Cronbach Alpha
		B	β					
Efficacy in safety motivation facilitation			*0.946					0.954
I57	Encourage people to report errors, near-misses or other safety-related information without fear of the consequences	1.000	0.767	0.588			1.116	
I58	Confident in ensuring the motivation of crews to follow Safety Management Systems (SMS)	1.096	0.794	0.631	0.065	16.925	0.000	
I56	Make the crew more confident to accomplish their tasks	1.020	0.804	0.646	0.053	19.186	0.000	
I40	Appear honest and credible to others	0.978	0.739	0.546	0.053	18.547	0.000	
I63	Aware of their influence and know what leadership strategies or tactics are needed to ensure safety in various situations	0.994	0.799	0.639	0.074	13.384	0.000	
I49	Able to clearly articulate the desired safety behaviours and work practices	1.085	0.849	0.721	0.069	15.628	0.000	
I48	Foster open and frequent communication among crew members on safety issues	1.083	0.826	0.683	0.069	15.650	0.000	
I39	Concerned with how crew members perceive justice and seek to lead in a fair manner	0.988	0.762	0.580	0.062	15.860	0.000	
I53	Care about crew member' safety, express compassion and empathy where appropriate	0.952	0.771	0.594	0.056	17.033	0.000	
I46	Have the necessary competence to provide proper directions to the crew	1.154	0.807	0.651	0.076	15.095	0.000	
I44	Use logical arguments and factual evidence to ensure crew members' compliance with safety rules/procedures	0.990	0.804	0.646	0.056	17.597	0.000	
I50	Have the cultural awareness to communicate effectively with all crew members	1.063	0.722	0.521	0.083	12.761	0.000	
I60	Willing to reflect on, and revise leader's decisions based on feedback from the crew	0.916	0.760	0.578	0.074	12.457	0.000	
Efficacy in safety management			*0.961					0.906
I30	Seriously consider the subordinates' suggestions and initiatives for improving safety	1.000	0.806	0.650			1.076	
I29	Actively listen to the crew members, and promote their involvement in decision making	1.078	0.814	0.662	0.074	14.596	0.000	
I18	When undesirable incidents occur, be able to improvise to handle the situation effectively	1.092	0.791	0.625	0.093	11.704	0.000	
I2	Able to use formal authority to ensure crew members adhere to the safety procedures and policies	1.047	0.707	0.500	0.096	10.918	0.000	
I24	Able to mobilize the resources to make effective decisions in a timely manner	1.098	0.861	0.741	0.083	13.213	0.000	
I8	Able to proactively manage safety risks	0.977	0.745	0.555	0.069	14.096	0.000	
Efficacy in safety initiative			*0.963					0.887
I26	Able to initiate and engage in toolbox sessions during safety meetings on board	1.000	0.801	0.641			1.279	
I47	Provide feedback on task performance frequently	0.953	0.769	0.591	0.063	15.040	0.000	
I27	Involve crew members actively in recommending revisions to established procedures	0.963	0.807	0.651	0.038	25.197	0.000	
I35	Able to closely observe crew performance during safety drills on board, and highlight shortcomings and good work	0.931	0.814	0.662	0.050	18.646	0.000	
I10	Ensure achievable safety goals are set	0.760	0.723	0.523	0.054	14.156	0.000	
	SLSES TOTAL							**0.971**

Table 7
Cronbach's α, composite reliability and average variance extracted.

Factor	Cronbach's α	Composite Reliability (C.R.)	Average Variance Extracted (AVE)
Efficacy in safety motivation facilitation	0.954	0.954	0.617
Efficacy in safety management	0.906	0.908	0.622
Efficacy in safety initiative	0.887	0.888	0.614

crew members to actively participate, freely report and pay attention to the procedures in order to succeed with regards to safety. The items listed under this subscale incorporated various leadership behaviours that directly or indirectly facilitate crew members motivation for safety, such as encouraging people to report errors, near-misses or other safety-related information without fear of the consequences, using logical arguments and factual evidence to ensure crew members' compliance with safety rules and procedures, etc. The extent to which leaders create a motivation system to encourage their followers' safety behaviours, namely safety motivation, is closely linked to the transformational leadership (Du and Sun, 2012). Transformational leaders inspire confidence, articulate goals, motivate subordinates to take extra efforts and so that it can improve the performance beyond expectation (Zohar, 2002). The items grouped into this factor are largely in line with transformational leadership theory which implies that the exercise of good transformational leadership behaviours would reflect safety leadership potentials to motivate subordinates in engaging in safety efforts.

Items loaded on the second factor were associated with shipboard leaders' competence for safety management, which is another core feature of safety leadership. Items used to assess this factor included several key management practices related to the needed for standardization, reliability, as well as the required improvising skills. Measurement items included the extent to which the shipboard leaders could proactively managing risks, mobilizing resource, implementing measures to ensure safety compliance, improvising to handle dynamic situations during ship operations, etc. These items are mainly associated with the transactional leaders' behaviours that aimed to ensure the expected performance standards are met (Martínez-Córcoles and Stephanou, 2017), though they also include items that reflect on the inclusion of subordinates and improvisation, more characteristic of transformational leadership behaviours (Bass and Avolio, 1997). Lately, there has been some discussions regarding the distinction between the "safety management" and "safety leadership", as these two terms have been used interchangeably in maritime context. Our research finding has shown that safety management is one dimention of safety leadership. Good shipboard leaders need to exercise both formal and informal leadership functions to not only enforce the safety rules to ensure people behave in a safe manner, but also to use good seamanship, influence practices and social skills to increase subordinate's risk awareness, motivation and willingness to act safely.

The third subscale is used to measure shipboard leaders' efficacy in taking safety initiative, which has made the highest contribution to the overall safety leadership self-efficacy ($\lambda = 0.963$). Leaders proficiency in exercising specific, discrete verbal and nonverbal leadership behaviours and initiations to encourage subordinates to be involved in safety activities, reflect leaders' efficacy on taking safety initiatives. They include setting goals, monitoring behaviour, providing feedback, and such. The items under the subscale on safety initiative also predominantly reflects a transactional leadership style (Stogdill and Bass, 1981).

The findings of this study reflect previous research that concludes that a combined approach of transformational and transactional leadership behaviours are most benefitial for safety leadership (Clarke, 2013). The SLSES demonstrates that there is no dichotomy between transactional and transformational leadership styles, but rather that safety leadership incorporates both. Meanwhile, it is also provides the important insight that the transactional and transformational leadership styles vary in importance in terms of leaders abilities to motivate, manage safety and take safety initiatives. This provides direction to future studies of leadership studies in the maritime industry. Finally, the proposed SLSES highlights the need for adaptive safety leadership, to handle complexity and uncertainty while achieving sustainable safety performance (Hollnagel, 2014).

Studies have recognized that effective leadership requires leaders to be skilled in use of influence (Yukl and Falbe, 1990), have good level of motivation and confidence towards their own leadership capabilities (Allen et al., 2014), and have psychological and behavioral resources to deal with the emerging demands during times of change and stress (Fredrickson, 2001; Hannah et al., 2008). SLSES incorporated the items that could help in assessing these aspects. It has also several important benefits for the shipowners, crew management companies and maritime training providers, as it forms a valuable source of information regarding the shipboard officer's leadership potential for safety and can serve as a means or a basis for decisions regarding future training and other personal development efforts. The scale can be used before and after the mandatory STCW leadership training to identify the area of safety leadership they are weakest in to guide the training effort. Subordinates would not want to follow a leader who appears to lack in confidence. Vice versa, when a leader does not exhibit confidence in their own decisions and actions, they do not engender confidence in their subordinates. It is expected SLSES could lead to diverse approach in practice to acknowledge and augment one's safety leadership capacity.

Despite the contribution of the proposed SLSES, future research should be conducted. In this study, by following up on an expert consensus survey, we used 150 samples for EFA, 396 samples for CFA, which is in accordance with the sampling recommendations (Worthington and Whittaker, 2006a, 2006b). Since the communalities for all items in the initial EFA were high, sample size have relatively little impact on the quality of the factor analysis solution, which means that "accurate recovery of population solutions may be obtained using a fairly small sample" (MacCallum et al., 1999, p. 90). However, follow-up studies should use a larger sample size to validate the developed scale, to conduct correlational analysis and to assess the predictability of SLSES for safety culture, near-misses reporting rate, or other indicators of actual safety performance. In addition, there are many sociodemographic factors (e.g., nationality, education, seniority, gender) and shipping sector-specific characteristics could affect leadership styles and safety behaviors. It is worthwhile to expand research in this area to obtain a fuller picture of maritime safety leadership phenomenon.

As organizations evolve in an increasingly complex environment – characterized by new technological, regulatory, social and economic challenges, the dynamic situations occurring at sea and shore, the amount of administration procedures and papers often intensify the pressure and demands placed on the leaders. When evaluating the safety leadership self-efficacy, personal factors as well as the context and situations encountered by the leaders might need to be considered. The evaluation of leaders' self-efficacy for safety should involve an appraisal of the interaction of the perceived capabilities with the situational demands and obstacles.

6. Conclusion

While regulatory bodies make substantial efforts in promulgating safety rules and conventions to enhance safety standards, the effect and consequently the safety performance ultimately depends upon how organizations and their leaders value safety and approach its implementation. Safety leadership is a key driver to a mature safety management system and this study can add to this area. Given that this is the first safety leadership self-efficacy measurement scale in a maritime context, it may provide a distinct contribution to theory-building and practice of leadership training in maritime education and training institutions. SLSES can be used as an instrument to diagnose shipboard leader's self-efficacy level and allows the shipping companies to examine the belief, attitude and behavioural patterns prior to the promotion and selection of leaders. By providing an understanding of the current level of safety leadership self-efficacy, it can help training instructors to determine the best approach to increase trainees' self-efficacy based on the relative scores in each safety leadership dimension.

In conclusion, we expect that the SLSES could lead to diverse approach in maritime research and training practice to augment individual safety leadership capacities and to create a high safety leadership efficacy climate.

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ARTICLE

A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations

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Abstract

Accelerating technological advancement in the maritime industry is gradually increasing the range of functions once performed by humans to become automated. In the era of autonomous shipping, where the autonomous operating system takes the lead and data flows define decision-making, how the ship and its leaders can successfully navigate these new ways of working have important implications for safety, efficiency and reliability of future ship operations. It is critical that the non-technical skills requirements, in particular the leadership competencies, be re-evaluated as new operational paradigms of shipping systems emerge and evolve. This study extends the current research of Maritime Autonomous Surface Ships (MASS) by using a Delphi consensus survey and Analytic Hierarchy Process (AHP) with a panel of 36 experts to (1) bridge a knowledge gap, i.e., the lack of an understanding regarding the leadership implication of autonomous shipping; (2) evaluate the applicability of current STCW leadership requirements for MASS operations; (3) identify and prioritize the leadership competences that should be accrued by the personnel involved in future ship operations. The results have shown that the current STCW framework is not fully relevant for MASS. The redefined leadership competence and the constructed hierarchy of criticality generated from this study can be valuable input for revision of the STCW and maritime education and training practices, contributing to successful ship operations of the future.

Keywords MASS · MET · Leadership · Human element · IMO

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1 Introduction

The maritime industry is undergoing a wave of increased automation and digitalization, while interest and development of unmanned, remotely controlled and autonomous vessels are flourishing (Porathe et al. 2018; Ringbom 2019; WMU and ITF 2019).

Remotely controlled and autonomous shipping solutions have the potential of addressing many concerns the industry currently faces—such as seafarer shortages, welfare of seagoing personnel, safety and reliability of ship operations, improved fuel consumption and operational efficiency—through reducing or reorganizing the workload of human operators, manning requirements and the risks associated with human failures (i.e., errors or violations) (Komianos 2018; Porathe et al. 2018; Pribyl and Vessels 2018). Pioneered by several exploratory Maritime Autonomous Surface Ships (MASS) projects (e.g., "Iris Leader," "Yara Birkeland," "MUNIN"), the area of autonomous and remote operation for surface ships is evolving around the globe (Pribyl and Weigel 2018; WMU and ITF 2019). Besides the numerous anticipated advantages, research has revealed scepticism toward proposed benefits. Challenges, including safety and cyber security issues (Montewka et al. 2018; Kavallieratos et al. 2019), economic feasibility (Santos and Guedes Soares 2018), operational challenges (Kooij et al. 2018) and regulatory acceptance (Ringbom 2019) as well as other non-technical hurdles are yet to be solved (Bertram 2016; Mallam et al. 2019b).

As global shipping sails into a more autonomous future, the potential impact of MASS on the competence requirement of global seafarers should not be overlooked. Moving towards highly automated, remotely controlled or autonomous solutions implies that the routines of ship operations and the roles, duties and responsibilities as well as the leadership displayed by the shipboard leaders (e.g., masters, chief officers, chief engineers and second engineers) will be radically different compared with conventional shipboard organization (Kitada et al. 2018). The existence of these positions may also be in jeopardy (Sharma et al. 2019). How the ship and its leaders navigate these new ways of working has important implications for the safety and reliability of ship operations. The leadership knowledge, understanding and proficiencies (KUP) as required in the International Convention on Standards of Training, Certification and Watchkeeping 1978, as amended (STCW 1978), that have yielded safe and effective operations in the past may no longer be as relevant or effective when automation is implemented to higher degrees (Sharma et al. 2019). Therefore, it is critical that the STCW leadership strategies be re-evaluated in this new context to adequately take advantage of autonomous shipping potentials.

As of present, there has been little discussion on the potential impact of autonomous shipping on leadership and organization of shipboard personnel (Kitada et al. 2018). No research to date has evaluated the applicability and relevance of current STCW leadership requirements under different MASS operational situations. Bolden and O'Regan (2016) state that digital technology has "significant implications for leadership theory, practice, and development that, as yet, remain largely unexplored in mainstream academic literature" (p. 438). By following up on the research trend on MASS, this paper aims to address this gap by investigating the leadership implication of autonomous shipping, evaluating the STCW leadership requirements to cope with increased autonomy and exploring the future leadership competences that should be accrued by the personnel involved in the ship operations.

2 Research scope and background

2.1 Manned, unmanned and remotely controlled MASS

The International Maritime Organization (IMO) defines a MASS as "a ship which, to a varying degree, can operate independent of human interaction" (IMO 2018). For the purpose of the regulatory scoping exercise on MASS, four degrees of autonomy have been established by IMO (IMO 2018), as illustrated in Fig. 1.

According to this scale (IMO 2018), degree 1 level of autonomy involves seafarers onboard to operate and control the shipboard systems and functions. Under degrees 2 and 3, the ship is controlled and operated by remote control operators from another location. Seafarers are available onboard to take control in degree 2, whereas the ship is unmanned and remotely controlled in degree 3. In degree 4, the ship is fully autonomous as the operating system will be able to make decisions and determine actions by itself and operate independently of direct human interaction (IMO 2018). With the involvement of operators remotely operating the MASS, it can be expected that those operators will also need to be trained and certificated in accordance with mandatory minimum requirements set out in future versions of STCW (Ringbom 2019; Sharma et al. 2019). It is noted that the degree of autonomy is not necessarily intended to be linear or hierarchical; MASS can operate at one or more degrees of autonomy during a single voyage.

	Level of autonomy	*Human presence*	*Operational control*	*Human role*
Degree 1	Ship with automated processes and decision support	Yes	Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control	Supervision and operation
Degree 2	Remotely-controlled with seafarers on board	Yes	The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions	Backup to manoeuvre, supervise the systems
Degree 3	Remotely-controlled without seafarers on board	No	The ship is controlled and operated from another location. There are no seafarers on board	Monitoring and remote control
Degree 4	Fully autonomous	No	The operating system of the ship is able to make decisions and determines actions by itself	Monitoring and emergency management

Fig. 1 MASS's level of automation (adapted from IMO 2018, Kim et al. 2019)

To limit the scope of our research and frame our discussions, this research considered two MASS areas as the main focus of this study: *manned MASS* and *unmanned and remotely controlled MASS*, corresponding to degree 1 and degree 3 automation in according to IMO's definition (IMO 2018).

2.2 Shipboard organization and leadership requirement

Ship operations conventionally depend on a high degree of human involvement. Many of the functions and tasks onboard ships, such as navigation, propulsion, cargo security, mooring and anchoring, have traditionally required the attendance of one or several people for carrying out the tasks for successful and safe operations. The masters and crews who operate ships today are the on-scene operators, problem solvers, decision makers, repairmen and physical security providers, who make shipping a safe, secure, efficient and economical transport solution.

Throughout history, the advent of new technologies, increased reliability and efficacy of automated systems have gradually reduced the manning level onboard ships required to carry out functions. A historical example of this is the migration from the coal-fired steam engine propulsion to diesel-powered engines during the twentieth century. This new technology and propulsion solution enabled the size of the engine-room crews to reduce due to the change in work tasks and requirements for operation. Advances in propulsion technology and automation have allowed a typical engineering crew of several hundred (e.g., 211 onboard the Titanic in 1912) (Titanicfacts 2020) to in many cases less than 10 in attendance today for carrying out ship functions and maintenance. In general, most merchant vessels today typically require a crew team of 15 to 26 personnel (Cambanis 2011), which consists of officers (e.g., master, chief mate, second mate, chief engineer, second engineer), specialist technicians (e.g., electricians, mechanics) and ratings (e.g., bosun, able seaman, ordinary seaman, wiper, cooks and oilers).

The conventional organizational structure of a merchant ship emphasizes a strong hierarchy and a clear path of accountability to govern performance. When a ship is at sea, the master has the highest responsibility for the safe and efficient execution of the voyage and all operations, whose authority at sea is supreme and overriding (Cartner et al. 2009). Masters carry the ultimate responsibility for the safety of all cargo and crew onboard. Furthermore, there are many other obligations and rights vested in the master under current national legislation and international conventions (e.g., Danish Maritime Authority 2017; IMO 2017). The master and other shipboard managers' decision making, judgment and leadership styles have vital influence towards the crews and the way the ship is managed and operated in daily and abnormal situations.

The STCW 1978 as amended have included leadership training as a mandatory competence requirement for officers at both management and operational level (e.g., masters, chief officers, chief engineers and second engineers) (STCW 1978). The specific leadership knowledge, understanding and proficiency (KUP) as set out in Table A-II/2 (for masters and chief mates), Table A-III/2 (for chief engineer officers and second engineer officers), Table A-II/1 (for officers in charge of a navigational watch) and Table A-III/1 (officers in charge of an engineering watch) (STCW 1978) are summarized in Table 1.

Table 1 Required leadership competence for management and operational level onboard conventional merchant ships set out in STCW code Table A-II/2, Table A-III/2, Table A-II/1 and Table A-III/1 (STCW 1978)

Target	Knowledge, understanding and proficiency (KUP)
STCW required leadership competence for both management and operational level onboard conventional merchant ships	KUP 1: Knowledge of shipboard personnel management and training KUP 2: Knowledge of related international maritime conventions and recommendations and national legislation KUP 3: Ability to apply task and workload management, including: .1 planning and coordination .2 personnel assignment .3 time and resource constraints .4 prioritization KUP 4: Knowledge and ability to apply effective resource management: .1 allocation, assignment, and prioritization of resources .2 effective communication on board and ashore .3 decisions reflect consideration of team experience .4 assertiveness and leadership, including motivation .5 obtaining and maintaining situation awareness KUP 5: Knowledge and ability to apply decision-making techniques: .1 situation and risk assessment .2 identify and generate options .3 select course of action .4 evaluation of outcome effectiveness KUP 6: Development, implementation and oversight of standard operating procedures (*only for management level)

In addition to these leadership requirements as outlined in STCW 1978 as amended (STCW 1978), research has also examined other elements of leadership competence, such as actual shipboard leaders' practices and behaviours and their impact for safety and efficiency. Studies have revealed that many of the contributing factors to maritime accidents (e.g., poor safety culture, dysfunctional teamwork, poor communication, ineffective implementation of the safety management system) can be traced to the failure of leadership for safety (Kim et al. 2016). The likelihood of subordinates' safety compliance and safety participation are determined by the safety culture and the leaders' behaviours they are modelling (Griffin and Neal 2000; Kim et al. 2016; Mallam et al. 2019a; Kim and Gausdal 2020), their safety commitment and engagement are highly influenced by perceived organizational support and the quality of interpersonal relationships (Eid et al. 2012). By synthesizing the literature, Kim and Gausdal (2017) derived four leadership behavioural categories that are essential for safety at the shipboard level, which are communicating (i.e., facilitate effective communication on board and ashore, foster open and frequent feedback pertaining safety issues); caring and supporting (i.e., respect and trust the crew members, care about their needs and empathize with their problems); controlling and enforcing (i.e., set the rules by which the organization runs, use their power to give a reward or a punishment); Participative involvement (i.e., promote crew members' involvement in decision making and their participation in safety activities) (Kim and Gausdal 2017).

Among these, participative involvement from the shipboard management has been perceived as having the highest importance and contribution to safety performance in ship operations (Kim and Gausdal 2017). Participative involvement opens the way for collecting feedback and input from the crew members to improve work procedures and systems design to prevent future recurrences of error (Kim and Gausdal 2017). As communication category overlaps with KUP 4.2 (see Table 1), there are total 6 KUPs and 3 additional leadership behavioural categories that should be evaluated.

Introducing novel technologies for autonomous and remote control of ship functions is, in theory, making it possible to reduce or even eliminate onboard crews in both deck and engine departments and re-organize the work tasks, demands and structure for those reduced crews. If unmanned and autonomous shipping continues to develop and proliferate, the function allocation and shipboard management, as we know today, could be radically different in the future. As shown in Fig. 2, contrasting the manned MASS leadership model (left), the ship automated operating system can act as a middle manager and conduct the ship operation in accordance to the goals and standards defined by the human leaders at the upper level (e.g., ship owners, fleet manager) (right).

Moreover, within this scenario, it can be presumed that many of the obligations and leadership functions resting with the masters today in conventional ships will be distributed between the autonomous operating system and shore-based human operators. This, in turn, is linked to the question of whether traditional leadership knowledge, styles and practices that are defined in human relationships will still be applicable and important under autonomous ship operations. Furthermore, in the case that a ship is remotely controlled, can the leadership role be taken over by remote control operators? If yes, then what kind of leadership practices are needed for remote control operators in autonomous ship operations? These questions guide the direction and objective of this research.

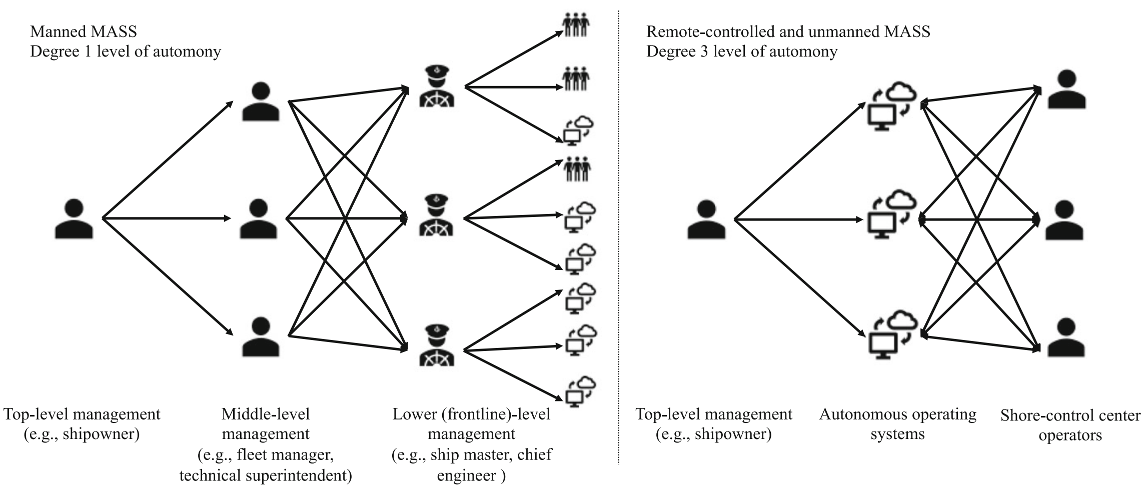

Fig. 2 Hierarchical leadership relation in comparison

3 Methodology and research process

To address the research questions, this study was endowed with two methodological phases integrating the Delphi technique (Murry Jr and Hammons 1995) and Analytic Hierarchy Process (AHP) (Saaty 2003) with two sequential surveys seeking to collect empirical data from the experts. The surveys do not collect any personal identifiable information. Delphi is a structured consensus building method used to derive experts' opinion and to determine the extent of agreement on a specific topic through structuring a communication process, which typically involves two or three "rounds" in which selected experts respond to questions until reaching a good level of consensus (Hsu and Sandford 2007). In this study, by building on the results derived from Delphi, a mathematically grounded technique for multiple-criteria decision making—AHP (Saaty 2003)—was applied to rank the leadership competence requirements based on their relative importance under different MASS operational situations and to identify the critical leadership competence that plays the principal role. AHP incorporates expert's judgments, uses pair-wise comparison method and generates ratio data, which could tell the relative importance of an item in comparison with another and determine an overall ranking of the alternatives (Podvezko 2009; Chelst and Canbolat 2011). As a mature and well-accepted decision-making method, AHP has been widely applied to a diverse array of research problems in various domain (Saaty 2002; Vaidya and Kumar 2006). The overall research process is presented in Fig. 3.

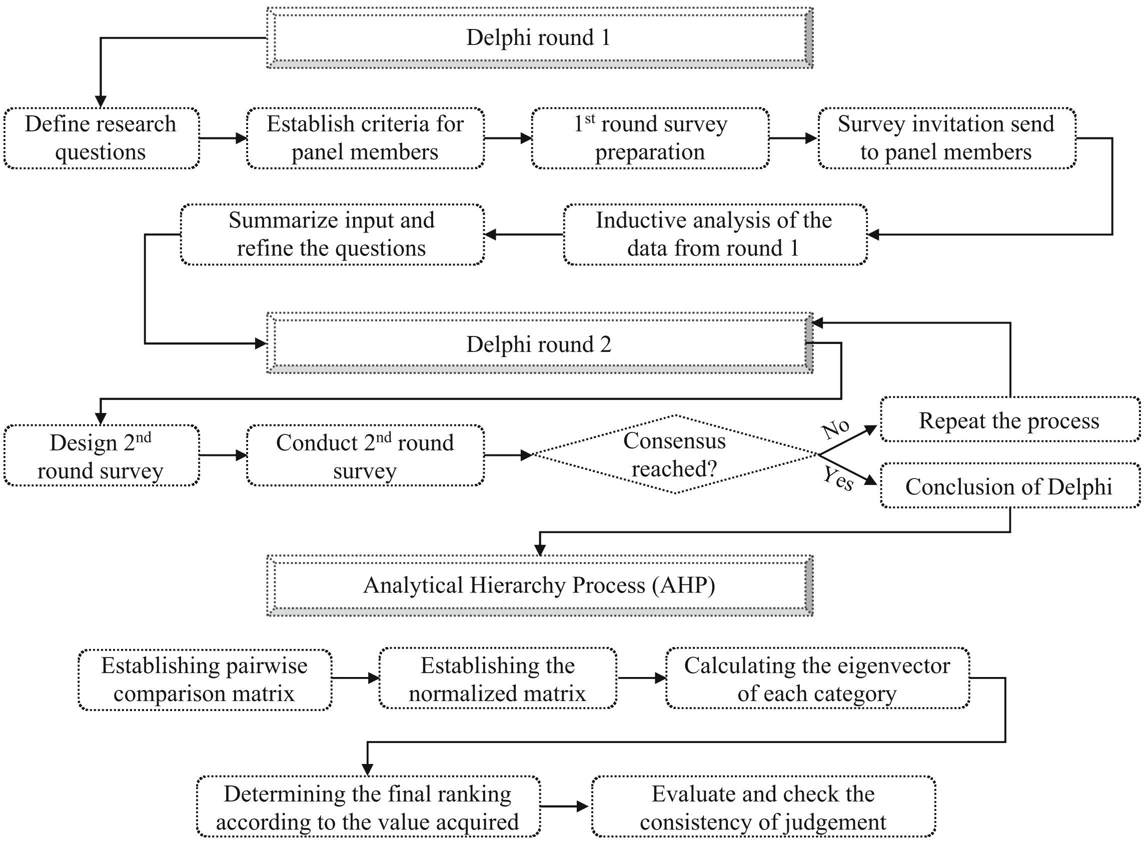

Fig. 3 Flowchart of research process

3.1 Panel selection

The panellists to be selected were required to have relevant experience and expertise in the field of maritime leadership training, maritime research or professional seafarers (see Table 2). We picked the first six experts and asked them to refer to other experts they know who could fit the description of samples needed, which correspond to a snowball sampling process (Biernacki and Waldorf 1981). In total, thirty-six panellists participated in this study, in which 24 panellists completed the first round of Delphi survey. A heterogeneous panel with 12 experts was established for the second round to verify the first round output and to add new perspective and insight.

As shown in Table 2, there are over 36% of the panellists who have more than 15 years' experience in the maritime industry while holding positions such as ship owners, non-technical skills training providers, masters, chief officers, chief engineers or port operators. Further, majority of the panellists have experience as a professional seafarer or maritime researcher in the field of leadership training and/or MASS research, constituting a reasonable expert panel for the study to generate appropriate and representative findings.

3.2 Delphi and AHP procedure

In the first round of the Delphi survey, a questionnaire consisting of two sections was used to elicit opinions from the panellists on the contemporary development of autonomous maritime operations and the perceived impact on shipboard leadership arrangement and STCW leadership requirements. The first section included five core open-ended questions, e.g., "as the automation technologies advance, the range of automatable tasks onboard ships are also increasing. On a highly automated ship, systems will perform most of the functions with few crews needed onboard to monitor the system's functioning and intervene if considered necessary. What are the essential leadership competencies you think the remaining onboard crews should have in order to ensure safety and efficiency?"; "If the ship is remotely controlled with no

Table 2 Key statistics regarding the panellists participated in Delphi and AHP

Criteria of classification	Statistics	Frequency	Percentage (%)
Area of expertise	Ship owning/operating company	2	5.6
	Maritime training institute/provider	5	13.9
	Maritime research	6	16.7
	Professional seafarer (e.g., master, chief mate, chief engineer)	22	61.1
	Other area (e.g., port operator)	1	2.8
Years of experience in shipping	> 15	13	36.1
	11–15	1	2.8
	6–10	8	22.2
	≤ 5	14	38.9

seafarer presence onboard, what leadership competencies do you think the people involved (e.g., remote control operators) should have?"

The second part of the questionnaire asked the panellists to evaluate the relevance and importance of 6 STCW KUPs and 3 leadership behavioural categories under both manned and unmanned MASS scenarios, on a 5-point Likert scale from totally disagree (1) to totally agree (5). The consensus in favour of a topic in this study was set to reach above 80% amongst panellists, as a rigorous standard, for it to be considered as an important leadership competence. To calculate the overall percentage of agreement, the number of times the expert agreed in a particular leadership competence was divided by the total number of ratings performed (Miles et al. 1994). The questionnaire was distributed to the panellists, and the results were then analysed through an abductive coding process in light of STCW leadership requirements (as shown in Table 1), as well as prior research to identify commonalities that represent future leadership competence. In the second round, respondents were required to confirm the results derived from the previous questionnaire. An AHP questionnaire was designed for prioritizing and ranking the leadership competence, identifying the leadership competence that, according to the informants, play principal and decisive roles in future autonomous shipping.

In order to calculate the relative importance of each leadership competence category, a matrix of pairwise comparisons were established for AHP: i.e., Criterion A versus Criterion B. For example, when considering a question such as: "If the ship is remotely controlled with no seafarer presence onboard, which competence do you think is more important than the other for the remote control operators? how much more important?" The judgement/evaluation will then be given on a scale with the values 1, 3, 5, 7 and 9 (Saaty 1980; Podvezko 2009). The higher the value, the more important the corresponding criterion. Experts' judgement will result a set of n objects/criteria with their weights (w_1, w_2, . . . , w_n), which formulate a matrix of comparison:

$$A=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \quad (1)$$

The normalized eigenvector of the matrix can be obtained:

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} \mathrm{n}w_1 \\ nw_2 \\ \vdots \\ nw_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (2)$$

The corresponding normalized eigenvector of the comparison matrix gives the relative importance of each criteria (i.e., leadership KUP) being compared. The above equation can be represented as:

$$Av = \lambda v \quad (3)$$

Accordingly, the AHP pairwise comparison algorithm can be seen as the standard eigenvalue problem. Satty (1979) proposed to utilize Consistency Index (CI) and

Consistency Ratio (CR) to check the consistency of the comparison matrix. CI is defined as follows:

$$CI = (\lambda - n)/(n - 1) \quad (4)$$

This value can be compared with Random Matrix (RI) (Saaty 1979), which is represented as:

$$CR = CI/RI \quad (5)$$

The inconsistency, the value of CR, should be less than 10% in order to be considered as acceptable judgement (Saaty 1979).

4 Results

4.1 Results from round 1: Delphi consensus survey

The adoption of higher automation in ships does not imply that there is no longer a need for what leaders provide. On the contrary, the consensus from the panellists has shown that leadership remains an essential ingredient for future ship operations under both unmanned and manned MASS. The result generated through Delphi consensus survey, as shown in Table 3, indicates that automation technology for autonomous and unmanned operations will have significant impact on many of the required leadership competences for both management and operational level as set out in STCW 1978 as amended. The 6 leadership KUPs and behavioural categories (B1, B2, B3) will remain as basic leadership shipboard requirements for future shipboard leaders on manned MASS. However, in the remote-controlled and unmanned MASS scenario, 2 out of 6 leadership KUPs, i.e., knowledge of shipboard personnel management and training and knowledge and ability to apply effective resource management (except a subpoint under this KUP: Ability to obtain and maintain situation awareness), were deem no longer relevant and important for remote control operators.

However, the results indicate that there is a need to shift the expectations and change the competency framework for leadership. As mentioned by the panellists in the open-ended question section, increased automation implies that fewer operators are needed to be present onboard and also implies more dependencies on the expertise, mental resources and collaborations amongst the crews onboard for dealing with all normal and abnormal situations. Crews onboard MASS need to seek for a way to work effectively within the new partnerships between human teams and machines, while being externally connected and agile. As explained by a panellist:

"Since there will be only few crew members onboard, the ability to facilitate effective horizontal collaborations to acquire contributions from each (human) member is perhaps more important compare to top down leadership."

The words commonly associated with future leadership for both shipboard leaders and remote control operators include "remote collaboration," "horizontal management," "delegation skills," "emergency leadership," "technological understanding," "information processing" etc. Inductive analysis of all qualitative responses have

Table 3 Degree of agreement regarding the relevance of each leadership KUP for MASS

Notation	Common knowledge, understanding and proficiency (KUP) of leadership for both management and operational level onboard merchant ships	Relevant under manned MASS (degree 1)?	Relevant under remotely controlled MASS (degree 3)?	Comparison (%)
KUP 1	Knowledge of shipboard personnel management and training	Yes (92%)	No (63%)	− 29
KUP 2	Knowledge of related international maritime conventions and recommendations, and national legislation	Yes (100%)	Yes (88%)	− 12
KUP 3	Ability to apply task and workload management including planning and coordination, personnel assignment, time and resource constraints, prioritization	Yes (100%)	Yes (100%)	0
KUP 4	Knowledge and ability to apply effective resource management	Yes (92%)	No (79%)	13
	.1 Ability to allocate, assign, and prioritize resources	Yes (96%)	No (79%)	17
	.2 Ability to initiate and maintain effective communication on board and ashore	Yes (100%)	No (79%)	21
	.3 Ability to make decisions reflect consideration of team experience	Yes (100%)	No (79%)	21
	.4 Assertiveness and leadership, including motivation	Yes (96%)	No (67%)	29
	.5 Ability to obtain and maintain situation awareness	Yes (100%)	Yes (88%)	12
KUP 5	Knowledge and ability to apply decision-making techniques	Yes (100%)	Yes (92%)	8
	.1 Knowledge and ability to conduct situation and risk assessment	Yes (100%)	Yes (88%)	12
	.2 Knowledge and ability to identify and generate options	Yes (100%)	Yes (83%)	17
	.3 Knowledge and ability to select course of action	Yes (92%)	Yes (92%)	0
	.4 Knowledge and ability to evaluation of outcome effectiveness	Yes (88%)	Yes (88%)	0
KUP 6	Development, implementation, and oversight of standard operating procedures	Yes (92%)	Yes (92%)	0
B1	Caring and supporting (i.e., respect and trust employees, and care about crew's needs and empathize with their problems)	Yes (92%)	No (71%)	21
B2	Controlling and enforcing (i.e., set the rules by which the teams/organization runs, use their power to give a reward or a punishment)	Yes (100%)	No (71%)	29
B3	Participative involvement (i.e., promote crew's involvement in decision making and participating in safety activities)	Yes (100%)	No (71%)	29

Percentage of agreement: number of agreements/total number of agreements + disagreements × 100%

highlighted the importance and relevance of an additional leadership competence requirement in relation to the ability to understand and interpret large amounts of information generated through the systems, we coded this as a new competence requirement: "Knowledge and ability to acquire, handle and comprehend large amount of system information." Crews onboard will be required to be systemic thinkers to comprehend the information from various system components and to look for interconnectedness of the issues, address the root cause instead of the obvious symptoms (e.g., alarms, visual signals).

4.2 Results from round 2: Delphi verification and AHP results

Based on the results derived from the first round Delphi study, the panellists were invited to confirm the first round results and also to prioritize leadership competences by conducting a set of pairwise comparisons for remote control operators as well as shipboard officers on highly automated ships. The final weighted leadership competence lists and the results of the final ranking are presented in Tables 4 and 5. Data inconsistency was checked (as described in Sect. 3), the resulting ratio is 2.3% and 2.0% (less than 10%), which indicate that judgements made by the panellists were consistent.

The result indicates, for remote control operators on unmanned ships, the ability to obtain and maintain situation awareness is perceived as the most critical leadership competence requirement, with the highest reported importance weight (30.9%), for safe and efficient operation. Another competence requirement that has received high level of significance is the knowledge and ability to acquire, handle and comprehend large amount of system information (23.9%). As the information given by the ship through its various sensor systems will influence and guide the decisions of the remote control operators, the ability to accurately interpret and comprehend the system information is of importance for leaders' decision making. In contrast, knowledge of related international maritime conventions and recommendations and national legislation (KUP 2), as well as the ability to apply task and workload management (KUP 3), were perceived to be less important for remote control operators.

Table 4 Required leadership competence and importance weights for remote control operators of unmanned MASS under degree 3 level of automation

Notation	Leadership requirement for remote control operators of unmanned MASS	Weight	Importance ranking
KUP 4.5	Ability to obtain and maintain situation awareness	0.3088	1
New KUP	Knowledge and ability to acquire, handle and comprehend large amount of system information	0.2385	2
KUP 5	Knowledge and ability to apply decision-making techniques	0.1904	3
KUP 6	Development, implementation, and oversight of standard operating procedures	0.1027	4
KUP 3	Ability to apply task and workload management	0.0830	5
KUP 2	Knowledge of international maritime conventions and recommendations, and related national legislation	0.0766	6

Table 5 Required leadership competence for shipboard officers on manned MASS under degree 1 automation

Notation	Leadership requirement for shipboard leaders on manned MASS	Weight	Importance ranking
KUP 5	Knowledge and ability to apply decision-making techniques	0.1554	1
New KUP	Knowledge and ability to acquire, handle and comprehend large amount of system information	0.1454	2
B3	Participative involvement (i.e., promote crew's involvement in decision making and participating in safety activities)	0.1105	3
B1	Caring and supporting (i.e., respect and trust employees, and care about crew's needs and empathize with their problems)	0.1029	4
KUP 4	Knowledge and ability to apply effective resource management	0.1007	5
KUP 6	Development, implementation, and oversight of standard operating procedures	0.0913	6
KUP 3	Ability to apply task and workload management	0.0912	7
B2	Controlling and enforcing (i.e., set the rules by which the teams/organization runs, use their power to give a reward or a punishment)	0.0795	8
KUP 2	Knowledge of related international maritime conventions and recommendations, and national legislation	0.0622	9
KUP 1	Knowledge of shipboard personnel management and training	0.0608	10

Under manned MASS scenario, the autonomous operating system takes main role for ship operations, but humans will still play an important role in monitoring, planning and optimizing the logistics, where more leadership roles and tasks be potentially placed on obtaining and maintaining situation awareness through systems thinking and predications. The ability to take a holistic approach to analysis that focuses not only on an individual system (e.g., ECDIS, autopilot) but also on how different systems would influence one another within the whole system would be an important competence to improve situational awareness and enable more effective problem solving and decision making. By looking at the priority weights in Table 5, knowledge and ability to apply decision-making techniques (15.54%), knowledge and ability to acquire, handle and comprehend large amount of system information (14.54%) were reported to have a high level of importance for shipboard leaders on highly automated ships. The reduced crew size onboard implies that the knowledge of shipboard personnel management and training would become the least relevant and important from the shipboard leaders' perspective.

5 Discussion

5.1 Implication of unmanned, remotely controlled MASS scenario on leadership

As acknowledged in recent research (Samani et al. 2012; Wesche and Sonderegger 2019), humans are not necessarily a mandatory component for leadership to occur. Computer agents could take the lead to "guide, structure and facilitate activities and relationship in a group and organization" (Wesche and Sonderegger 2019). In the case of unmanned, remotely controlled MASS scenarios where the ship is autonomous with no human operators to intervene unless the system requests so, the leadership functions onboard would be replaced by automated decision-making, but not necessarily all of the manual functions required to successfully operate the ship autonomously (i.e., system monitoring, route planning etc.). The information given by the ship through its various sensor systems will influence and direct the decisions made by the remote control operators. The remote control operators will need to trust, completely reliant and blindly accept the information sent by the systems. Accordingly, the hierarchical leadership relations in autonomous ship operations under degree 3 level of autonomy would differ in comparison with degree 1 mode of operation, as illustrated in Fig. 2. However, delegating shipboard leadership decisions to the system also has moral ramifications, as human leaders are in no way able to (or allowed to, or have competence to) participate in, or contribute to, the decision-making process onboard of ship.

Several researchers have discussed the opportunities and also challenges of implementing remote and unmanned control solutions for safety and efficiency of ship operations. Man et al. (2016) analysed shore-based unmanned ships and found that by monitoring a ship remotely, the operators may have reduced senses of the ship. It is difficult, or impossible, to develop the same level of "feeling" and bodily understanding regarding the ships' status, including smells, vibrations, variation or movement of the ship and how it is reacting to the external environment (e.g., waves, currents, winds etc.) (Mallam and Lundh 2016; WMU and ITF 2019). This implies that the operators in the control centre will have limited ship senses. The tactic knowledge that is developed by the navigators onboard, which aid in successful ship manoeuvring, is needed to be transferred to shore. Many knowledge and skills are not relevant that once were extremely important, as illustrated in our findings.

A parallel can be drawn between concepts of unmanned ships and military unmanned aerial vehicles (popularly known as "drones"). Upon initial introduction of drones, the US Air Force implemented conventional aircraft pilots in their land-based control centres. However, due to the difference in skills required between conventional flying and land-based drone flying, the competence requirements, operator profiles and training programs were redefined (Hoagland 2013; FAA 2020). The introduction of drone technology and the ability to fly aircraft from land-based locations are changing our traditional concepts of what it is to be an "aircraft pilot," similar to what the maritime domain now faces as new technologies redefine the concept, skills and work profile of what future "seafarers" will be.

Given the impact of automation, the need to retrain or reskill the future operators would represent as a challenge for the industry. Furthermore, due to the large amount of information displayed in the shore-based remote control centre, information overloading could also be a potential problem that influence the accuracy of situation awareness and decision making, especially if the operator is overseeing several ships at one time. The systems will be more complex, which indicates increased ambiguity and uncertainty to comprehend and make sound decisions. These challenges threaten the reliability of remotely controlled MASS and also increase the complexity to operate safely and efficiently from the shore-side.

5.2 Implication of manned MASS Scenario on leadership

In the manned MASS configuration, operational decisions are delegated to the system, and it performs the tasks under direct supervision by the crews onboard. The autonomous operating system serves as substitute for deck officers in handling routine navigational tasks, as routine operational processes are more likely to be automated as they occur repetitive enough to enable strategic preparation and the decision rules and algorithms to be developed. It can be expected that the decision points that will be faced by ship crews are more likely to involve exceptions, unusual problems or emergency situations that could not be sufficiently dealt by an autonomous operating system. These scenarios will challenge the leaders to deal with more complex technical problems that may not have been faced frequently, or at all, in conventional ship operations. This will require the ship crews to be able to demonstrate a higher system understanding so that adequate emergency leadership can be exercised in case of abnormal situations. Further, they should also be able to rapidly bring together the information required for the problems, making instantaneous decisions through interactions with the crew and the technological systems.

Although the crew composition of manned MASS scenarios are currently unknown and unproven, it can be projected that the increased automation implementation implies that fewer operators will be needed to be present onboard. This also implies more dependencies on the expertise, mental resources and collaborations among the few crew onboard to carry out the tasks and deal with all possible situations. Fewer crew onboard will also imply that the system will take over more parts of the human leaders' interaction with their subordinates, more functions and power will be given to the autonomous operating system. The crew onboard and the ships' automation systems will be no longer in a master/slave relationship but gradually on a more equal level of hierarchy. The shipboard officers will need to consider not only how to interact and collaborate with other human teammates but also how to work with the machines that have non-negligible cognitive capacity and high intelligence. This situation implies that leadership competence should be developed beyond the classical leadership knowledge recognized in human-human interaction scenarios, but to consider and construct leadership skills that can help leaders to build good partnership with autonomous systems for operational efficiency in human-robot navigation scenarios (Samani et al. 2012; Wesche and Sonderegger 2019). A new host of leadership and teamwork questions is likely to be emerged in the future, which need to be further explored and addressed to ensure human-robot teams to be effective (Gombolay et al. 2015a; Gombolay et al. 2015b).

5.3 Limitations

Several limitations of this study deserve to be mentioned. The area of autonomous and remote operation of vessels is still an immature field. The result presented here can form an impartial basis for further discussion regarding MASS and its policy consideration. The present study employed AHP to obtain the importance ranking of leadership competence, as it is one of the most frequently used multi-criteria decision making methods (Velasquez and Hester 2013). A limitation is that AHP model assumes independences among all alternatives. To validate the results presented in this paper, future research should be conducted to verify the independencies through statistical analysis using larger sample sizes. Further, future studies could also use other approaches, e.g., Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), to estimate the relative weights of each leadership competence under different autonomous operation situations. The results of such future studies can then be compared with those presented in this study. In addition, nationality, cultural background could have an influence on the selection and utilization of different leadership strategies. Future research may also consider the cultural background of the experts; the difference in the ranking could also provide interesting information for future seafarers.

5.4 Future research directions

Future research on leadership for safety-critical systems must address the role of humans and effective human leadership within fast-changing and increasingly automated organizations. The present study generates several directions for future research exploration:

First, as O'Heigeartaigh (2013) remarked that "When a machine is 'wrong', it can be wrong in a far more dramatic way, with more unpredictable outcomes, than a human could" (para. 12). The ethical, legal and other threshold issues have continued relevancy within the discussion of autonomous operating systems. How should the accountability of systems for Degree 3 and 4 level of autonomy be established, and should the machine always take the lead? How will humans come to accept and follow a computer leader is an area which needs to be further evaluated. Future research should also look into the accountability and ethical issues in the development of autonomous operating systems to suggest legal and ethical standards and laws in parallel of technological development.

Second, the significantly enhanced level of digital dependence and automation in the maritime industry has already, and will further reduce onboard manning levels. This has also shifted the role from direct interaction and control to more supervisory activities. This will continue to pose new attentional and cognitive demands for seafarers (Lützhöft and Dekker 2002). Reskilling and retraining are of importance for seafarers to keep updated with the new risk portfolio related to the new technologies and to create needed skills and awareness for ensuring safety and reliability in ship operations. This also has implication on the infrastructure and Maritime Education and Training (MET) industry.

Third, as autonomous and unmanned ships will further alter the nature of ship operations and team composition, it cannot be assumed that such vessels will still be safe based exclusively on the knowledge that we developed through learning from earlier systems (Komianos 2018). Future research can delve deeper into the leadership and management issues for all organizational levels and explore the applicable leadership models for effective management of autonomous ship operations.

Furthermore, reducing or eliminating the onboard crews should be based on the provision of technical solutions that could perform equally good or even better performance in comparison with crew in attendance with regards to safety, reliability and efficiency. Future research should be conducted to compare and further explore the competitive advantage among different operational scenarios and also to identify the most optimal alternative for all stakeholders in the maritime domain and within specific industrial sectors.

6 Conclusion

Technology exists inside the context of human society. To understand and advance a technology requires adequate and sufficient understanding not only of its mechanisms but also the cultural, social and environmental milieu in which it operates. The move to autonomous shipping is a natural progression in the evolution of maritime operations and the direction of societal functioning in general. However, utilizing intelligent algorithms and their burgeoning decision-making potential indicates the need for changes and reorganization of people/levels in the system. Automation technology is gradually taking centre stage and changing the principles and practice of leadership onboard ships. It is important to consider how to better prepare the current and future leaders to meet the challenges presented by technological disruption.

In this paper, we have explored if the disruptive changes with regards to the implementation of autonomous technologies will have an influence on leadership practices and STCW competence requirements. We have also discussed the new leadership competences that should be accrued by the personnel involved in the future configurations of ship operations. The results revealed that the (i) knowledge and ability to apply decision-making techniques, (ii) knowledge and ability to acquire, handle and comprehend large amount of system information, and (iii) the ability to obtain and maintain situation awareness could be the main determinants for safe and efficient operation of MASS. These research findings could add value to the ongoing policy discussion regarding the impact of MASS on IMO instruments and, in particular, the STCW 1978 as amended. The leadership competence requirement derived in this study could contribute to the revision of STCW Table A-II/1, Table A-III/1, Table A-II/2 and Table A-III/2. This research can also be used as an input for Maritime Education and Training (MET) institutes in order to adapt their MET programs and maintain relevancy of their training practices to effectively prepare current and future leaders for successful ship operations of the future.

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