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RESEARCH ARTICLE

A validation study of ISM Code's continual effectiveness through a multilateral comparative analysis of maritime accidents in Korean waters

Ick-soo Mok,[1] Enrico D'agostini,[2,3]* and Dong-keun Ryoo[4]

[1] Division of Shipping Management, Korea Maritime and Ocean University, Busan, Republic of Korea
[2] Department of International Logistics, Tongmyong University, Busan, Republic of Korea
[3] Department of Business & Enterprise Management, Faculty of Economics, Management and Accountancy, University of Malta, Malta
[4] Division of Shipping Management, Korea Maritime and Ocean University, Busan, Republic of Korea.
*Corresponding author. E-mails: enrico@tu.ac.kr, enrico.dagostini@um.edu.mt

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Abstract

This study investigates whether the International Safety Management (ISM) Code remains an effective regulatory tool for the shipping industry by analysing maritime accident statistics published for the last 32 years by the Korea Maritime Safety Tribunal, 24 years by the International Maritime Organization (IMO) and seven years by the European Maritime Safety Agency. For this purpose, the data were divided into four groups: pre-ISM Code, in-transit, post-1 and post-2 periods, and tested by multilateral comparative analysis. The results show that the Korean merchant fleet has no improvement over the periods, whereas the world merchant fleet has a continual decrease in serious casualties. This study confirmed a trend of maritime accidents in recent years: fewer in number but heavier in damage. Conclusively, the results suggest that IMO and decision-makers in the maritime industry must review the ISM Code again and seek solutions to achieve the goal of continual improvement, as specified in the code.

1. Introduction

Intergovernmental organisations, including the International Maritime Organization (IMO) and shipping stakeholders, have put forth multilateral efforts to prevent maritime accidents for several decades. Consequently, several imperative international Conventions were adopted and implemented during the 1970s and 1980s. Of these, the International Safety Management (ISM) Code, annexed to the Safety of Life at Sea (SOLAS) Chapter IX in 1994 and entered into force on 1 July 1, 1998, is one of the most recognised and comprehensive maritime safety norms amongst all (IMO Our Work, 2022a).

Despite numerous improvements and updates brought into the SOLAS Convention, the maritime industry is still subject to accidents directly related to the ISM Code failure. Arguably, a contributing factor is the pace and the magnitude at which the shipping industry is changing and evolving. For instance, in the last few decades, maritime conditions in ship design, naval technologies and autonomous shipping, crew composition, shipboard working conditions, and seafarers' education and training have noticeably changed and are a current and potential future challenge to maritime safety and operations (Horck, 2006; Astratinei, 2016; Hamad, 2016; D'agostini et al., 2017; Jo and D'agostini, 2020; Jo et al., 2020; Merakeras, 2020; Lloyd's List Intelligence, 2021).

However, arguing that maritime accidents are purely caused by the pace of change in the industry cannot justify recent ship accidents that, in different ways, highlighted the relationship with the ISM

Code. Amongst the most notable and recent ones, the accidents involving the *Bow Mariner*, *Cougar Ace*, *Bourbon Dolphin* and *Cosco Busan* are worth mentioning due to the causal link with the ISM Code. In the case of the *Bow Mariner*, in 2004 a fire explosion was caused by the operator and senior officer's failure to properly implement the company and vessel's Safety, Quality and Environmental Protection Management System (SQEMS). The *Cougar Ace* was involved in a severe listing during ballast water exchange operations in 2006. The findings showed a failure to clearly define and document the assignment of duties and responsibilities in the vessel's Safety Management System (SMS). The *Bourbon Dolphin* capsized in 2007 due to the anchor chain sliding, and the shipowner had not followed the ISM requirements in relation to the crew's qualification for demanding operations. Another example is provided by the *Cosco Busan*, which was involved in a collision and oil spill in 2007, and the investigation revealed that the key officers on board were not familiar with SMS (Safety4Sea, 2019).

Therefore, due to the numbers and the consequences of such accidents for the maritime community as a whole and for its stakeholders, the question of whether the ISM Code is still effective in enhancing maritime safety and preventing maritime casualties is worth researching. Under this perspective, while the ISM Code's effectiveness concerning the issue of maritime safety overall suggests a certain degree of positive effects since its implementation, most of the past studies examined only the topic considering the early implementation stage of the code for a specific region (Lee, 2002; Anderson, 2003; Ventilos et al., 2003; Noh and Kim, 2006; Lappalainen, 2008; Tzannatos and Kokotos, 2009; Tzannatos, 2010) or considering a relatively shorter-term period (Bhattacharya, 2012; Lappalainen et al., 2012; Butt et al., 2013; Kokotos, 2013; Batalden and Sydnes, 2014; Lee, 2016; Storkersen et al., 2017; EMSA, 2021; Lloyd's List Intelligence, 2021). In contrast to previous studies, this research utilises a relatively longer-term period (32 years) and compares the Korean data with other regions (i.e. international and European waters), hence proving a significantly extended time period and a more global perspective of the issue. Moreover, we selected repeated-measures ANOVA as an analysis tool to compare the pre-ISM period with the in-transit, post-1 and post-2 periods to identify the persistence of the code's effect. With the application of these methodologies, we can conduct an in-depth analysis of the differences over time using additional post hoc tests.

This study primarily investigates the continual validity of the ISM Code in the shipping industry and seeks to suggest timely countermeasures according to the results obtained. The Korean merchant (KM) fleet is set as a test group applicable to the SOLAS Convention, particularly to the ISM Code. The Korea Maritime Safety Tribunal (KMST) provides maritime accidents data that occurred in Korean coastal waters. This study also includes two comparison groups: the Korean fishing (KF) fleet as a non-Convention group and the world merchant (WM) fleet as a Convention group. The data set of the comparison groups was obtained from KMST and the Global Integrated Shipping Information System (GISIS). To the authors' knowledge, no validation study of the code in Korean waters has been previously conducted through comparative methods before and after the code's entry into force. Hence, the study contributes to the advancement of theoretical and managerial knowledge by offering a unique approach to test the ISM Code's validation using more than two decades of accumulated data produced by both Korean and international authorities.

2. Theoretical backgrounds and formulation of research hypotheses

2.1. The development of international maritime safety instruments

According to Kopacz et al. (2001), the maritime safety system comprises law-making institutions, legal instruments, and operational institutions. They have been rapidly developing, particularly thanks to the advancement of terrestrial and space radio-communication technology, such as the Global Maritime Distress and Safety System (GMDSS). Meanwhile, the maritime industry has experienced disasters repeatedly. Butt et al. (2013) summarised the development of international safety regulations; they pointed out that major maritime accidents are critical drivers of new legislation. The most famous disaster of all, the sinking of the *Titanic* in 1912, provoked a genuine international cooperation on safety regulations, eventually codified as SOLAS 1974. The oil spill from Torrey Canyon in 1967 and

Amoco Cadiz in 1978 led to enacting the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) and the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW 1978). Nevertheless, many severe accidents occurred repeatedly during the late 1980s, and they were manifestly caused by human errors, with management faults also identified as contributing factors. On the occasion of the *Herald of Free Enterprise* capsizing in 1987, the IMO seriously addressed human elements involved in maritime safety.

In 1989, the IMO adopted resolution A.647(16), the Guidelines on Management for ships' safe operation and pollution prevention, which is the forerunner of the ISM Code. In 1993, the IMO adopted resolution A.741(18), the current form of the ISM Code, which was annexed to Chapter IX of SOLAS on 24 May 1994 and became mandatory after 1 July 1998. After a recent revision in 2013, it now consists of a preamble and 16 chapters with a Supplementary Appendix.

The ISM Code explicitly states that the code's objectives are to ensure safety at sea, prevention of human injury, loss of life and avoidance of damage to the environment, in particular to the marine environment and property. Additionally, it defines the company's safety management objectives as continuously improving the safety management skills of personnel ashore and aboard ships, including preparing for emergencies related to safety and environmental protection. The code is mandatorily applicable to all vessels engaged in international trade. Without effective management of the Document of Compliance (DOC) and Ship Safety Management Certificate (SMC), a shipping company or its agent may not operate a ship. IMO member states' information and UN Treaties (2022) prove that the vessels of the 178 countries which signed the Convention account for nearly 99% of international trade engagement. Korea incorporated the ISM Code into domestic law through the Maritime Safety Act on 8 February 1999, which applied to domestic merchant ships from 1 July 2002 to 1 July 2004, according to the cargo type and vessel size.

2.2. Correlation between the ISM code and maritime accident

The code in its preamble is expressed in broad terms to have widespread applications. Whether shore-based or at sea, different management levels require varying levels of knowledge and awareness of the items outlined. In this regard, Batalden and Sydnes (2014) investigated the correlations between the causal factors of maritime accidents and sections stipulated in the code. By analysing the 94 cases investigated by the Maritime Accident Investigation Branch (MAIB) in the UK, they focused on the code, particularly on the various sections dealing with different aspects of casualties and incidents, providing a holistic and integrated approach to safety management. They found that 42 · 4% of the total causal factors are pertinent to chapters 5 and 6 of the code regarding human factors and the responsibility and authority of the captain. Of the total, 14 · 4% belongs to chapter 7 regarding the development of plans for shipboard operations; and 16 · 9% of the total stems from chapter 12 concerning company verification, review, and evaluation.

IMO recognised the human elements as a primary element of the safety of life on board ships and a contributing factor to most of the casualties in the shipping sector. Several studies support the interpretation melted in the code. Ventilos et al. (2003) analysed questionnaires of crewmembers from 100 ships, of which owners or operators were based in Europe. The questionnaires focused on depicting the current practice of human factors, mainly through implementing the code. They conducted two surveys. The first one utilised data produced by the Transportation Safety Board (TSB) from 1981 to 1992, revealing that human elements caused 74% of marine accidents. The second survey showed that 84% of the accidents were connected to human-related causes. They concluded the code is one of the most important IMO instruments focusing on the human element and maritime safety. Tzannatos (2010) analysed Greek-flagged ships during the 1993–2006 period and their worldwide operations and found that 57 · 1% of all accidents were attributed to the human element. Due to onboard human causes, the ship's Master was involved in 80 · 4% of the accidents related to chapters 5, 6 and 7 of the Code.

Accordingly, it supports the feasibility of the study methods that the ISM Code adopted as the key influencer of maritime safety and the grouping of the term divided by pre-and post-implementation.

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Nevertheless, Lappalainen (2008) indicated that despite a common consensus about the positive contribution of the ISM Code to maritime safety, the direct effects and influences of the code could not be entirely isolated from other explanatory factors, such as maritime training and environmental issues as established by the STCW and MARPOL Conventions. In line with this, EMSA (2021) suggested that whilst the human element is a major contributing factor to maritime casualties, other elements, such as environment, rules, procedures and training and tools and equipment, are also very important in explaining shipping incidents.

2.3. Literature review

Most recent reports (AGCS, 2021; AoN, 2021; EMSA, 2021; Lloyd's List Intelligence, 2021) have generally agreed that shipping accidents are decreasing in numbers. Nevertheless, there are various arguments about the effectiveness of the code yielded through qualitative and quantitative research, as follows.

The first group evaluated the code's effectiveness by its perceptions. At the early stage of its enforcement, most studies focused on the implementation and employment of SMS and perceptions of the application for operations ashore and onboard. Lee (2002) indicated that 82% of the survey respondents were seafarers from 102 Korean shipping companies certified with SMS experienced mental stress, and 97% of them observed an increase in workload from SMS activities. They agreed on the necessity of the code, but only 24% had considerable knowledge about it and claimed that it improves the relevancy of the documents. Ventilos et al. (2003) showed 60% negative versus 40% positive towards the generic view concerning the acceptance of crewmembers for the ISM Code and other novel safety-oriented initiatives. Anderson (2003) noted the excessive paperwork due to voluminous documentation and many irrelevant procedures and checklists involved in the system. Lappalainen (2008) pointed out that there have been both positive and negative arguments for the benefits of the code. His METKU research project quoted several studies (Anderson, 2003; Paris MoU 2008; ReportISM 2008 as cited in Lappalainen, 2008) and showed a two-sided perception of the impact of the code. The first one recognised its significant contribution to maritime safety and how shipping companies and crewmembers are more environmentally friendly and safety oriented than 12 years ago. The other perception contended that, as no appropriate statistics and safety performance measures are available, it is impossible to draw specific conclusions about the benefits of implementing the code. At the same time, it suggested renewing the first version of the code in 1993, citing the findings of the British Maritime and Coastguard Agency (MCA) and the problems and difficulties with the implementation of SMS listed by Anderson (2003). Lappalainen (2008) quoted the MCA found a lack of standardisation in interpreting the requirements of the code in practice.

Approximately 10 years after the enforcement of the code, many have attempted to verify how effectively it has functioned. Bhattacharya (2012), questioning the actual effectiveness of the code, outlined a wide disparity in the performance of the code between the perceptions of managers and seafarers. Accordingly, he asserted the need for the true nature of seafarers' participation. Lappalainen et al. (2012) cited ConsultISM Ltd (2008) and agreed on the positive role of the ISM Code for maritime safety. Nevertheless, they claimed that a prerequisite to developing a continuous improvement tool and its application in practice and enhancing uniformity in the interpretation and implementation of the code was necessary because of its excessive rules and bureaucracy.

The second group tested the effectiveness by analysis of statistical data. Ventilos et al. (2003) showed quantitative trends of accidents as a result of the code's implementation; 50% were maintained, 15% increased, and 35% reduced. Noh and Kim (2006) compared the rate of maritime accidents in Korean coastal waters between code-applicable vessels and non-applicable vessels. They found a $12 \cdot 1\%$ decrease in maritime casualties for code-applicable vessels considering a seven-year period since1998. However, the study has limitations owing to the short-term data utilised. Similarly, Tzannatos and Kokotos (2009) reported the effectiveness of the code for shipping safety by analysing accident data of Greek-flagged ships during the period 1993–2006. Still, they added possible variances depending on

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vessel type and whether the navigation area was open or restricted. Tzannatos (2010) indicated a 12 · 2% reduction of post-ISM from pre-ISM in human-caused accidents in his study of 268 Greek-flagged ships operated between the period 1993–2006 worldwide. Kokotos (2013) focused on the effectiveness of the code by crosstab analysis for three-period groups of maritime accidents that occurred on the Greek coast for 17 years from 1995 to 2011. He concluded that the code has not satisfactorily worked, even though it led to a significant reduction in human-induced accidents. However, it was limited to short-term data within Greek-flagged ships in restricted waters, and mainly focusing on human errors.

The third group investigated the effectiveness of the code with the association of PSC and ISO. Lee (2016) examined the ISM Code's effectiveness by analysing the correlation between ISM audit and PSC inspection. It utilised a five years' data set of Korean vessels and found that the code has required a systematic approach for its continuous improvement while PSC is robust in addressing immediate problems through its police function. According to Storkersen et al. (2017), maritime casualties and accidents have little relevance in decreasing PSC deficiencies and personnel injuries on board. They proposed simplifying the procedure and minimising navigation disturbances to prevent ship accidents. Bastug et al. (2021) cited two contrasting views. The European Maritime Safety Agency (EMSA), in their 2016 annual report, indicated a dramatic increase in maritime accidents, with ISM-related defects the most frequent, while the Paris MoU statistics of 2018 showed declining deficiencies within Europe. These scholars pointed out that most studies consider the SMS a static system, even though its flexibility with the generic nature of self-regulation may not lead stakeholders to develop innovations themselves. They proposed a holistic conceptual safety management system to identify the steps in the Seven C's management model and the hidden criteria to improve the conceptual framework. On the other hand, Lloyd's List Intelligence (2021) published 'Maritime Safety 2012–2021: A decade of progress'. It reviewed 866,000 inspections, 26,000 detentions, 22,000 casualty incidents, and 1,000 losses from its own databases. According to the report, the incident rate obtained through the total number of casualties divided by the total fleet number showed no considerable changes from 2012 to 2020. Nevertheless, the report underlined a remarkable reduction in ship losses by 56%, from 132 in 2012 to 58 in 2020. The detention rate by PSC decreased from 3 · 7% in 2012 to 2 · 4% in 2019. The report demonstrated that this positive trend was attributed to measures such as digitised systems, modern class rules, higher standards of ship construction, tighter regulatory supervision, and especially an improved safety culture. On the other hand, it indicated that the major challenges are mainly related to the safety gap emerging from cyber threats, new technologies, new fuels and crewmember working conditions during pandemics. Meanwhile, Pantouvakis and Karakasnaki (2016) suggested that the code may synergise its effectiveness when it goes together with the International Standard Organization (ISO).

2.4. Research model

This study aims to determine if the code remains influential on the KM fleet through multilateral comparison analysis. To achieve this goal, we designed a research model shown in Figure 1. We collected

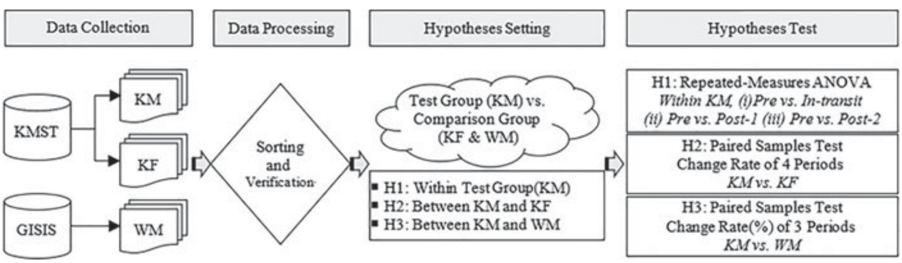

Figure 1. *Research model.* [1]*KM: Korean merchant fleet, KF: Korean fishing fleet, WM: world merchant fleet.* [2]*Convention group where SOLAS applicable: KM & WMS, Non-Convention group: KF.* [3]*Pre-ISM period: 1989–1996, In-transit: 1997–2004, Post-1: 2005–2012, Post-2: 2013–2020.*

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data from reliable sources for the test group and two comparison groups; KF fleet as non-Convention Korean vessels and WM fleet as Convention worldwide operating vessels. The data was sorted and verified thoroughly. According to the pre-interpretation of the data and literature review, we have set hypotheses and tested them by multilateral comparison analysis. Two types of tests were conducted. One was a trends analysis conducted within four period groups of the KM fleet by comparing the first group with the rest. The other analysis was the mean difference test between the Conventions (KM and WM fleet) and the non-Convention (KF fleet). We utilised the testing instruments of repeated-measures ANOVA and paired samples t-tests.

2.5. Hypotheses setting

Based on the literature review, it is often considered that the code has positively contributed to building a safety culture and reducing maritime accidents. Nevertheless, there are doubts concerning whether the code is still effective in continuously improving maritime safety. Lappalainen (2008) underlined that the fundamental idea of the code is that companies should continuously improve safety. After 30 years of adopting the code, it is vital to check its progress. Accordingly, as shown in Table 1, we established research hypotheses to investigate the code's continual effectiveness.

We formulated the hypotheses to test the code's validation by multiple comparisons. Hypothesis 1 (H1) represents the comparison with different period groups within the Korean merchant fleet, which is compulsory to abide by the code. It may prove that the code is continuously sustainable. Hypothesis

Table 1. *Hypotheses setting.*

H1. The frequency of maritime accidents in the Korean merchant fleet has been continuously decreasing due to the implementation of the ISM Code since 1998.		
$H1._1$	The frequency of maritime accidents for the Korean merchant fleet in p2 is lower than p1	KMp2 < KMp1
$H1._2$	The frequency of maritime accidents for the Korean merchant fleet in p3 is lower than p1	KMp3 < KMp1
$H1._3$	The frequency of maritime accidents for the Korean merchant fleet in p4 is lower than p1	KMp4 < KMp1
H2. The decreasing rate of maritime accidents for the Korean merchant fleet is higher than that of the Korean fishing fleets due to the implementation of the ISM Code since 1998.		
$H2._1$	The decreasing rate of maritime accidents in p2 compared to p1 for the Korean merchant fleet is higher than that of the Korean fishing fleet.	$\frac{KMp2}{KMp1} < \frac{KFp2}{KFp1}$
$H2._2$	The decreasing rate of maritime accidents in p3 compared to p1 for the Korean merchant fleet is higher than that of the Korean fishing fleet.	$\frac{KMp3}{KMp1} < \frac{KFp3}{KFp1}$
$H2._3$	The decreasing rate of maritime accidents in p4 compared to p1 for the Korean merchant fleet is higher than that of the Korean fishing fleet.	$\frac{KMp4}{KMp1} < \frac{KFp4}{KFp1}$
H3. The decreasing rate of maritime accidents between the Korean and the world merchant fleet will show no significant differences since 1998, when the ISM Code was simultaneously applied.		
$H3._1$:	The decreasing rate of maritime accidents in p3 compared to p2 between Korean and world merchant fleets will show no significant differences.	$\frac{KMp3}{KMp2} \cong \frac{WMp3}{WMp2}$
$H3._2$	The decreasing rate of maritime accidents in p4 compared to p2 between Korean and world merchant fleets will show no significant differences.	$\frac{KMp4}{KMp2} \cong \frac{WMp4}{WMp2}$

[1]Period: p1(Pre-ISM) 1989–1996, p2(In-transit) 1997–2004, p3(Post-1) 2005–2012, p4(Post-2) 2013–2020.
[2]Ship Type: KM = Korean merchant fleet, KF = Korean fishing fleet, WM = world merchant fleet.

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2 (H2) represents the comparison between the KM fleet and the KF fleet, of which the latter does not apply to the code. It may prove the differentiation between the Convention and non-Convention vessels. Hypothesis 3 (H3) represents the comparison between different regions. It may prove that the code has the same effect regardless of the navigation area.

3. Datasets

3.1. Data collection and sorting

This study collected datasets mainly from the KMST and GISIS of the IMO. KMST, a Korean government body responsible for the investigation and judgment of maritime accidents, was founded in January 1963 as the Maritime Accident Inquiry Committee and was subsequently renamed. The KMST has produced statistics on maritime accidents annually with detailed breakdowns and analytic reviews since 1983. Additionally, the IMO has furnished details of casualties and incidents through GISIS of IMO Web Accounts since 1973 (KMST, 2022; IMO Web Accounts, 2022).

Relevant data spanning 32 years (1989 to 2020) were obtained from KMST to compare the KM fleet as a Convention group and the KF fleet as a non-Convention group. According to the definition of KMST, the merchant fleet includes three types of ships: cargo ships including container ships, passenger ships, and oil tankers, and are classified as a test group. The fishing fleet, excluding leisure boats, is classified as a comparison group.

Simultaneously, as detailed in Table 2, the data sets were divided into four categories, considering an eight-years period for each. When segregating the data, we took two main elements into account: the history of the code's enactment and the even spread of each category as much as possible. As a first step, we assumed the second category as 'in-transit' to be placed sometime between the adoption of the code in 1993, the adoption of Casualty Investigation in 1997, the first year of effect in 1998, and the full implementation in 2002. We counted the second category from 1997 to 2004, considering the required time for full enforcement and even spread among the periods. As a result, the first category as 'pre-ISM' is eight years between 1989 and 1996. The third category as 'post-1' is placed between 2005 and 2012 when STCW was revised to a large extent and became effective. The remaining eight years between 2013 and 2020 were defined as 'post-2' category, by which we may construe the most recent trends of maritime accidents.

Table 2. *Four period categories of datasets from KMST.*

Categories	Length	Period
p1 (pre-ISM)	8 years	1989–1996
p2 (in-transit)	8 years	1997–2004
p3 (post-1)	8 years	2005–2012
p4 (post-2)	8 years	2013–2020

Meanwhile, this study imported maritime accident data from IMO's GISIS to compare Korean and global merchant fleets. As the GISIS data is valid with comparable information only since 1997, we collected 24 years of data from GISIS from that year on. Next, we divided them into three groups that were eight years long each: 1997–2004, 2005–2012 and 2013–2020. Due to the time lag between data reception and input after confirmation from flag states or coastal states, the data for 2020 appears incomplete (IMO Our Work, 2022b).

3.2. Data classification and verification

First, this study identified the procedures of data generation and grounds for data collection to confirm the reliability and validity of the data. Figure 2 illustrates the process of collecting and producing

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data. Article 43 of the Korea Maritime Safety Act stipulated compulsory reporting for any maritime accident.

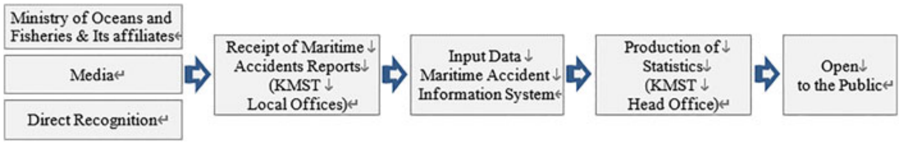

Figure 2. *The process of data production by the KMST. Source: KMST. (Authors' free translation.).*

The IMO receives maritime accident reports from the administrations of flag states according to the United Nations Convention on the Law of the Sea (UNCLOS) Article 94, SOLAS regulation I/21, MARPOL Articles 8 and 12, and Load Line Conventions Article 23. The reports became more formal, containing more specific information, such as severity types and SOLAS status, from 1997 when all previous resolutions were amalgamated and expanded by adopting the IMO resolution A.849(20). As each administration was mandatorily required to report accidents from 2010 when the Code for the Investigation of Marine Casualties and Incidents was incorporated into SOLAS, it is estimated that missing data will be scarce from then onwards (IMO Our Work, 2022c). Nevertheless, recognising the usual lack of adequacy and excellence of maritime transport data (Ventilos et al., 2003), we have thoroughly screened the GISIS data, excluded missing or incomplete values, and sorted out non-merchant ships from the relevant data. Also, we excluded 'less serious cases', which are not mandatorily required and only considered 'serious' and 'very serious' ones. Moreover, as it usually takes more than one year from the date of the occurrence until its availability in the GISIS, we acknowledged the data for 2020 will not be fully covered.

When comparing variables, it is imperative to make them commensurable to accomplish a reliable comparison. This study made necessary adjustments or equalisation processes by thoroughly examining the data. It excluded non-motorised ships, the type of casualty classified as 'others', and other inconsistent data throughout the period considered. In addition, the number of engine failures was counted out because merchant ships and fishing boats had different criteria for defining such incidents.

4. Hypotheses tests, results, and discussions

4.1. Hypotheses tests and results

4.1.1. Hypothesis H1: The frequency of maritime accidents in the Korean merchant fleet has been continuously decreasing due to the implementation of the ISM Code since 1998

To test H1, we used the maritime accident data of the KM fleet from KMST after splitting them into four groups. The test group was set by the eight-year weighted numbers until 1996, when the code had not yet been implemented. The comparison groups were set by the weighted numbers of the 24-year data with three period groups. The first group was the in-transit period between 1997 and 2004. The next two eight-year groups were between 2005 and 2020. A repeated-measures ANOVA was performed to compare the effectiveness of the pre-ISM period with the following three period groups. The test results showed no significant differences between the groups (F (2, 18) = 0.813, $p = .459$). Post-hoc pairwise comparisons confirmed that none of the two groups was indifferent. There were no statistically significant differences among the four groups. It indicated that no significant reductions in maritime accidents had been made since the code's implementation. Accordingly, all research hypotheses $H1._1$, $H1._2$, and $H1._3$ were rejected. This indicates the KM fleet showed no continual improvement in the in-transit period of the ISM Code and in the following two eight-year groups. However, the tendency of maritime accidents did not indicate upward but nearly stable paths, that is, p1(M = 143 · 1, SD = 2 · 7), p2(M = 132 · 5, SD = 22 · 7), p3(M = 123 · 8, SD = 19 · 05), and p4(M = 126 · 9, SD = 10 · 36).

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4.1.2. Hypothesis H2: The decreasing rate of maritime accidents for the Korean merchant fleet is higher than that of the Korean fishing fleet due to the implementation of the ISM Code since 1998

To test H2, we used the maritime accident data of the KM and KF fleet from KMST after splitting them into four period groups. We calculated the experimental and control groups' increase rates by year-on-year comparison after sorting the data in descending order within a period group. We performed a paired sample t-test to compare the accident increase or decrease rates between period groups crossly with each other. There were significant differences in the rate for all three corresponding comparisons, that is, case I (p2-on-p1) with $t(7) = -7 \cdot 85$, $p < .000$, case II (p3-on-p1) with $t(7) = -5 \cdot 28$, $p = 0 \cdot 001$, and case III (p3-on-p2) with $t(7) = -10 \cdot 90$, $p < .000$. Accordingly, all the research hypotheses (H2.$_1$, H2.$_2$, and H2.$_3$) were accepted. We may deduce from the results that the trends of maritime accidents in the KM fleet are distinctively opposite to those of the KF fleet. These results support that the ISM Code has a relatively more positive effect on the former (Convention group) than the latter (non-Convention group).

4.1.3. Hypothesis H3: The decreasing rate of maritime accidents between the Korean and the world merchant fleet will show no significant differences since 1998, when the ISM Code was simultaneously applied

To test H3, we used twenty-four years of maritime accident data of KMST and IMO by splitting them into three period groups, that is, p2 from 1998 to 2004, p3 from 2005 to 2012 and p4 from 2013 to 2020. We obtained the change rate (%) of p3 and p4 compared to p2, respectively, by year-on-year comparison after sorting the data in descending order within a period group. We analysed them using a paired samples t-test. As a result of the first comparison between p3 and p2, there was a significant difference in the change rate for the KM fleet (M = 8 · 34, SD = 9 · 35) and the WM fleet (M = −10 · 74, SD = 18 · 69); $t(7) = 2 \cdot 580$, $p = 0 \cdot 036$. The second comparison between p4 and p2 also indicated a significant difference between the KM fleet (M = 57 · 41, SD = 24 · 83), and the WM fleet (M = −33 · 69, SD = 2 · 88); $t(7) = 9 \cdot 581$, $p < .000$. Therefore, the research hypothesis both H3.$_1$ ($(KMp3/KMp2) \cong (WMp3/WMp2)$ and H3.$_2$ ($(KMp4/KMp2) \cong (WMp4/WMp2)$) were rejected. From the results of the H3 test, we can observe significant different trends between the KM fleet and WM fleet, although both are Convention vessels applicable by the code. We may deduce it is because the former has no significant reduction in maritime accidents, while the latter shows a continual decrease over the periods.

4.2. Discussions

The overall test results showed that the KM fleet had no significant improvement over the periods, but is comparatively positive trends towards the KF fleet, and negative towards the WM fleet. However, we attempted to conduct post-hoc analysis for the WM fleet by recognising the limitations of the GISIS data. The number of WM fleets has grown by 63% during the past two decades, according to the Electronic Quality Shipping Information System (EQUASIS, 2021) statistics. As the GISIS data on the accidents of the WM fleet have different sources and reporting standards and criteria, it is difficult to prove the relevant coefficients of correlation between vessel numbers and casualty frequencies. Moreover, the GISIS statistics mainly focus on 'very serious' and 'serious' marine casualties, and they are unlikely to represent the whole fleet's evolving tendency. Henceforth, we did not count that factor into the adjustment of maritime accident numbers for testing H3. Considering those conditions, we attempted to confirm the decreasing trends of accidents in the WM fleet by reflecting only 'very serious' and 'serious' cases and adjusting the numbers by weight factors of the fleet size evolution. A one-way repeated-measures ANOVA was performed to compare the tendency of maritime accidents for the three period groups. The test indicated that there were statistically significant differences between at least two periods ($F(2, 14) = 23 \cdot 770$, $p \leq .000$). Bonferroni tests revealed all comparison groups are significantly different, i.e. between p3 and p2 (MD = −188 · 88, SD = 50 · 41); $p = 0 \cdot 022$, between p4 and p2 (MD = −268 · 50, SD = 40 · 53); $p = 0 \cdot 001$, and between p4 and p3 (MD = −79 · 63, SD = 24 · 83; $p = 0 \cdot 045$). The results supported continual improvement in the number of accidents in the WM fleet.

However, we noted that the accident numbers in 2020 populated by IMO GISIS may be incomplete or irregular. In general, marine casualty reports from the flag or coastal states are unlikely to arrive at GISIS

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within a year (IMO Our Work, 2022d). Despite a relatively high share of casualties by passenger vessels, these numbers noticeably dropped as their operations were stopped due to the impact of the pandemic in 2020. In addition, we presume the possible variances of individual reporters' or coastal states' standards or criteria for the GISIS data. Accordingly, it will be too early to draw conclusions from recent statistics of GISIS. We compared the KM fleet to other regions to compensate for and supplement the incomplete and irregular situations in the WM fleet. Accordingly, we investigated the EMSA data harmonised by fleet size evolution from 2014 to 2020. EMSA created OccIDs (Occurrence Indicators), ratios between the number of reported accidents for a given ship type and the corresponding fleet size. The formula is

$$\mathrm{OccID}(i,\ t) = \frac{\mathrm{Nr.\ \ Accidents}\ (i,\ t)}{\mathrm{Fleet\ \ size}\ (i,\ t)} \times 1000$$

We calculated OccIDs of KM and WM fleets with the same formula applied to EMSA and visualised them, as shown in Figure 3. These data also support that the KM fleet offers upwards trends, while the other groups show downwards trends. Moreover, we explored the accident data of the KM and WM fleets according to their severity and analysed the trends, as shown in Figure 4. It illustrates that the WM fleet's 'very serious' group and the KM fleet's 'less serious' group tended upwards. The rest of the severity group had a steady or downwards tendency.

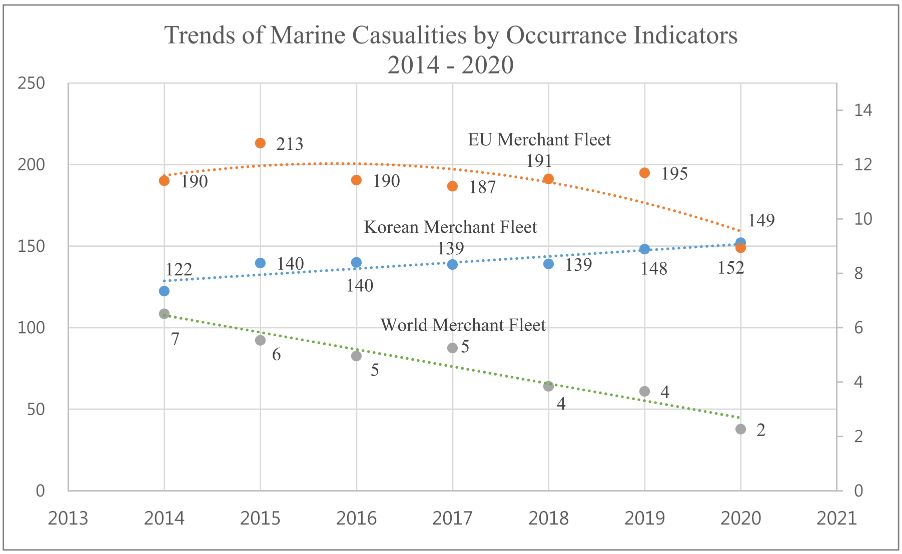

Figure 3. *Trends of maritime accidents by occurrence indicators, 2014–2020.* [1]*Indicators: KM & EU fleet at the left axis, WM fleet at the right axis.* [2]*Occurrence indicator (OccID) formula:*

$$\mathrm{OccID}(i,\ t) = \frac{\mathrm{Nr.\ Accidents}\ (i,\ t)}{\mathrm{Fleet\ size}\ (i,\ t)} \times 1000.$$

This study showed no clear indication of the trends of maritime accidents. Recent reports from the insurance industry represent all of these phenomena. Hammer (as quoted in Lloyd's List Intelligence, 2021), managing director of the Nordic Association of Marine Insurers, interpreted recent developments in maritime safety as follows:

> While total losses may be down, the individual risks are increasing due to the growing size of vessels and the number of vessels in the global fleet, environmental concerns, and requirements from coastal states. This means that the potential implications of a single incident represent a higher exposure and risk to seafarers and marine life.

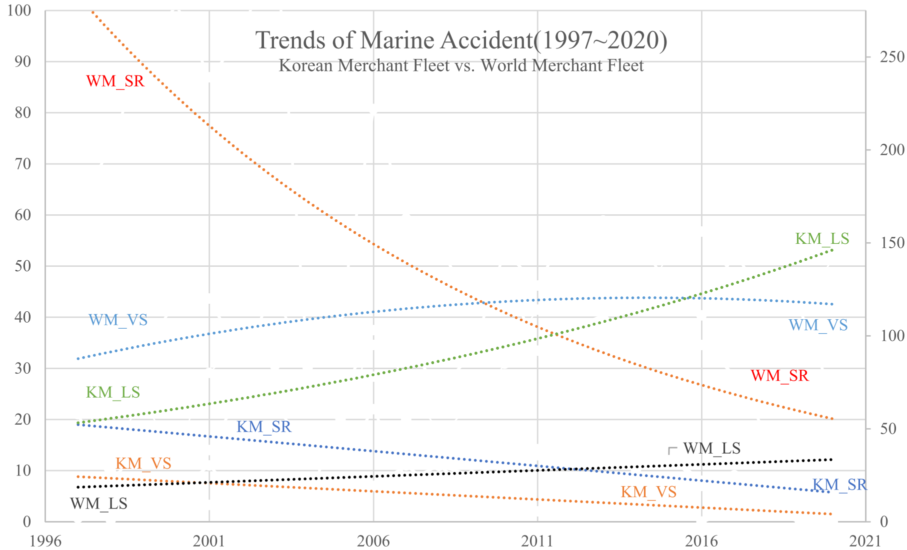

Figure 4. *Trends of maritime accidents by Severity, 1997–2000. [1]Frequency: KMST at the left axis, IMO at the right axis [2]KM: Korean merchant fleet, WM: world merchant fleet, VS: very serious, SR: serious, LS: less serious.*

The International Group of Protection and Indemnity (IG P&I, 2021) has announced that the reinsurance rate for 2022 is finalised with an 18%–55% increase from 2021, depending on vessel type, noting a combination of hardening market conditions. In this regard, Hughes (as quoted in Informa, 2021) has pointed out that the trajectory of marine losses has continued to move relentlessly upwards over the recent past. In addition, AoN (2021), pointing out deteriorating loss records over the last decade, remarked:

> Looking at the figures, it is hard to argue with the P&I club's conclusion regarding the trend of the number of major incidents not increasing while the value of those incidents jumps significantly.

5. Conclusion

The results of this study reveal that the KM fleet has shown no decline in maritime accidents since the ISM Code's implementation in 1998. However, when we exclude the cases of 'less serious' casualties of the KM fleet, the trends are in the same stable or downwards direction as the world and EU merchant fleet. Besides, we can notice that despite declining signs in the recent couple of years, the events of 'serious' casualties of the WM fleet remained at a similar level or slightly moved upwards through the post periods.

This study suggests the following implications for authorities which establish maritime policies, stakeholders involved in vessel operations and scholars who intend to investigate the maritime safety sector further.

First, the KM fleet (Convention vessels), compared to the KF fleet (non-Convention vessels), has a positive effect on preventing maritime accidents indisputably. Nevertheless, the accident trends of the KM fleet do not indicate continuous improvement throughout the periods, which is significantly different from that of the WM fleet. The KM fleet has 703 cases of 'less serious' in p1 (1989–1996), 548 in p2 (1997–2004), and 665 in p3(2005–2012), but in p4 (2013–2020), 1051 cases increased by 58% from p3. As the cases of 'very serious' and 'serious' casualties decrease, it needs to identify the leading cause of 'less serious' events and establish a response plan accordingly.

Second, this study confirmed that the consistent trend of maritime accidents in recent years is fewer in number but heavier in damage. Despite the positive trend in frequency, there is no room for complacency

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when considering disastrous accidents, such as the *Golden Ray* in 2019, *Wakasio* in 2020, and *Ever Given* in 2020, which resulted in a sharp increase in insurance premiums. These results confirm the trends of larger vessels' larger exposures. Over the last two decades, the vessel size has grown by 75% in terms of deadweight (UNCTAD, 2021). In addition, we are encountering many new challenges that may cause an increase in risk exposure. As the pandemic continues, crew fatigue is growing. Intensified cyber securities are required for complex and sophisticated digital systems. Furthermore, new fuel may imply machinery failure or damage. In this regard, seafarers' continual competence development in developing areas is critical for managing the transition safely.

Third, we noted that the latest revision of the ISM Code was made in 2010. Many scholars pointed out from the literature review that seafarers are reluctant to acclimate themselves to new SMS requirements established by the ISM Code because of impracticalities and inherent bureaucracy. In addition, as seafarers' safety behaviour is seriously affected by commercial pressure from shore managers, relevant practices and policies need to be established (Etman and Halawa, 2007; Vinagre-Rios and Iglesias-Baniela, 2013). Consequently, the IMO and industry stakeholders need to review the Code and other safety conventions, such as the STCW, and develop human-centric solutions based on safety-first culture.

However, some limitations of the study should be clarified. First, when considering period groups in four to test hypothesis H1, we were challenged on how to separate the different periods. Considering the ISM Code development timeline, we set p2 as the transition period for eight years from 1997. The Code was adopted in 1993 and entered into force in 1998 for the ocean-going KM fleet and in 2004 for the rest of Korean domestic sailing vessels. Under no clear-cut baseline for dividing period groups, we considered the time of entry into force and adjustment until full implementation to KM fleet evenly spread 32 years of KMST data for fair comparisons with other period groups. Accordingly, we decided considering p2 from 1997 to 2004. Second, because IMO does not require mandatory reports about 'less serious' and 'marine incident' cases, inconsistent and insufficient information is available in GISIS. Thus, we cannot compare these categories with the KM fleet. Other challenges pertain to the homogeneity of the comparative data. There are some uncertainties and limitations related to the low quality and diversity of methodology in GISIS, and the complex socioeconomic changes involved in KF data through the period. Meantime, the EMSA has calculated OccIDs to provide objective information harmonised according to vessel number evolutions, of which indicators are reasonably relevant to the comparison analysis, although the data are available for only seven years from 2014. Nevertheless, there are some avenues for future research on the topic. Researchers may explore the causal relationship between PSC inspection data and maritime accident trends to gain more insight on the contributing factors to maritime casualties. Another potential extension of the topic may be to investigate statistics of other maritime countries and regions and compare the findings under a geographical perspective.

Supplementary material. The supplementary material for this paper can be found at https://doi.org/10.1017/S0373463322000571.

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