Pareto Analysis of ISM Code Deficiencies

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Abstract: The International Safety Management (ISM) Code concerns safety at sea and marine environment protection; primarily regarding SOLAS class vessels. The main purpose of this paper is to highlight the importance of reviewing the outcome of ISM external audits and port inspections as well as analyzing accident reports with a view to improve safety at sea and marine environment protection. The paper focuses on the outcomes of some 50000 Administration and Recognized Organizations (RO) noted non-conformities and over 100000 deficiencies observed by Port State Control Officers (PSCO) during their inspections. Included is a sample selected from some 300 accident reports to establish the root causes of non-conformities, deficiencies and accidents at sea.

In reviewing the root causes and contributing factors to the accidents, audit non-conformities and inspection deficiencies, the paper makes an attempt to find those with highest frequency of occurrence by applying Pareto analysis.

This paper concludes with a taxonomy model identifying the key factors contributing to accidents, non-conformities noted by Administration or ROs, as well as deficiencies observed by PSCOs when inspecting ships.

Keywords: Maritime Safety, Accidents at sea, ISM Code Audits, PSC Inspection.

1. Background

The International Maritime Organization (IMO) works very closely with national administrations e.g., governments, the Flag States. These administrations interact with their shipping companies.

One of the reasons contributing to maritime accidents is considered by the IMO to be the lack of effective implementation of the Conventions by Contracting Parties, especially Flag States, which are not discharging their responsibilities and obligations. Due to these concerns, for international organizations such as the IMO, it is fundamental that each Member State properly implement and enforce the legislative framework to which they are party. Therefore, to strengthen maritime safety and protection of the marine environment and assist Member States in terms of the implementation of IMO instruments, the IMO Assembly adopted the IMO instruments implementation Code (III Code) in December 2013 through Resolution A.1070(28)3. This entered into force on 1st January 2016. The IMO Instruments Implementation Code (IIIC) is the key instrument behind the IMO Member State Audit Scheme. It provides a Code that all Member States are audited against to assess their capabilities and resources to satisfy international obligations in terms of Port State, Coastal State and Flag State.

Furthermore, MEPC 56/17/1 report noted that an increasing number of Port State Control (PSC) inspections are recording deficiencies under ISM Code-related codes. It is evident that these deficiencies do exits and may be a consequence of an ineffective implementation of the ISM Code ashore or aboard, or raise question about the effectiveness of the ISM Code itself. The identification of multiple deficiencies during a Port State Control inspection could indicate to a systematic failure of either the Safety Management System (SMS) or its implementation, or both, with the result that the ship is detained. Table 1 shows the non-conformities found in ISM audits during 2017-2023.

At the same MSC meeting MAIB identified that the audit should take into account factors including:

- recent changes in ship ownership, Flag State and classification society;
- maritime experience of the Company;
- knowledge of the Company in operating the particular ship type;
- company familiarity with the implementation of safety management systems.

It is worth pointing out The OCIMF's SIRE program[1] facilitating the sharing of inspection data amongst Oil Tankers, Combination Carriers, Shuttle Tankers, Chemical Tankers and Gas Carriers should be considered a good practice. SIRE standardization of the inspection practice viz., the Uniform Vessel Inspection Procedure; and, the Vessel Particular Questionnaire (VPQ) could also be used as a model for the ISM audit practice.

A substantial number of shipping companies are family businesses and therefore the maritime experience of the companies and their knowledge of these companies in operating ship types varies. Furthermore, majority of these companies do not distinguish between management of the company and its governance. Yet, worldwide, each company has been allowed to establish their own safety policies, procedures and plans, often using another company's safety system without sufficient understanding of their responsibility for keeping the sea safe and the environment protected.

2. Introduction

The Centre for Factories of the Future (C4FF) has been actively involved in various marine safety and environmental protection projects. It recently carried out a major study on behalf of IMO on Effective Implementation of the ISM Code. As the Study is still confidential and IMO intends to present it to MSC 109, no direct references will be made to it in this paper. Information about C4FF marine and maritime projects can be found in the Centre's Education, Research and Innovation Platform, MariFuture (www.marifuture.org).

With the emergence of Maritime Autonomous Surface Ships (MASS) and the ongoing transformative changes in the shipping industry driven by advanced technologies and digitalization, the role of automation Ziarati et al. (2011) and Ziarati and Ziarati (2014) has become increasingly important. However, it is crucial to acknowledge that the human element continues to play a vital role both aboard and ashore and within the ISM Code as well as the STCW in the maritime sector.

To prevent accidents and incidents at sea and in ports, it is crucial to establish a safety system that focuses on prevention of contributing factors. This approach aims to ensure that safety measures are implemented correctly the first time (Right First Time) and focuses on eliminating the underlying causes through practices like Poka Yoke[2]. Establishing key performance indicators at international, national, and company levels can help reduce the risk of accidents by highlighting the main causes and enabling stakeholders to learn from past incidents. The existing databases maintained by the International Maritime Organization (IMO) can serve as a valuable resource for this purpose. It is essential to recognize that commercial considerations and pressures, such as adhering to schedules and key performance indicators, may sometimes work against the system, leading to under-reporting of incidents and non-conformities. The comparisons of PSC inspections deficiencies with ISM Code external audit non-conformities, as well as accident reviews clearly indicate that there is a great deal to learn about the implementation of the ISM Code and/or its effectiveness. However, one thing that is clear is that top management commitment is essential for effective implementation of the ISM Code. This in turn has a positive impact on companies' competitiveness (Pantouvakis and Karakasnaki, 2018).

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[1] OCIMF established a Ship Inspection Report (SIRE) Program enabled OCIMF members to submit their ship inspection reports to OCIMF for distribution to OCIMF members and certain qualifying non OCIMF members. This helped in sharing the data after ship inspection which should be considered a good practice.

[2] Poka Yoke is a mechanism for that is put in place to prevent human error. The purpose of a poka-yoke is to inhibit, correct or highlight an error as it occurs. Poka-yoke roughly means "avoid unexpected surprises" or "avoid blunders" in Japanese. In English, a poka-yoke is sometimes referred to as "mistake-proof" or "fool-proof." See - Bayers, P. C. (1994), Using Poka Yoke (mistake proofing devices) to ensure quality, Proceedings of 1994 IEEE Applied Power Electronics Conference and Exposition - ASPEC'94

It should be recognized that the companies, due to pressures from the clients, have introduced a host of ISO systems in addition to ISO 9000 such as ISO 14000, ISO 45000 and several have also opted for ISO 50000 and ISO 25000. Each of these systems demand top management commitment, involvement of all personnel in implementation of the ISM Code; and continuous development of quality assurance and control which includes development of the crew, ship and means to protect the marine environment. ISO systems are often the core of Total Quality Management. This promotes good management practices such as formation of a quality circle in an organization embracing personal and organization factors as well as employees' well-being. The quality circle ensures all employees are involved in planning, monitoring and implementation of procedures as well as action plans. Therefore, employees/crews able freely to provide feedback and suggest ideas for improvements.

The Quality Specialists are aware that quality has grades, for instance, hotels start with 1-star to 7-star or in the Olympic games there are gold, silver and bronze medals. These represent given and well-defined standards of products, or services, or achievements. As companies are allowed to develop their safety management system, therefore, there are as many grades of quality as they are shipping companies. Quality means fitness-for-purpose and compliance with specification. The crews' and ships' fitness/seaworthiness are a measure of ISM effectiveness. Compliance with rules and regulations as well as the companies' own policies, procedures, processes/operations and plans are measures of effective implementation. Fitness/seaworthiness and compliance are the sides of the same quality coin.

It is recognised that a system is as strong as its weakest link. A review of corrective actions taken after audits or inspection as well as after accidents and incidents clearly suggests serious issues with ISM and its implementation.

Over 100,000 deficiencies including 5,000 ISM non-conformities were reported by PSC Paris MoU during 2019-2021 [3] and during 2018-2022 over 45,000 ISM non-conformities were reported by Recognised Organizations (IACS/LR) clearly suggesting that the shipping industry has to see the wood from the trees and address the ISM Code weaknesses.

A review of deficiencies by PSC Paris MoU shows that the ISM non-conformities have shown, by far, to be the highest category, responsible for some 25% of the deficiencies in the top 10 categories. This is also evidenced by a recent paper by Biocic et al. (2023).

It is a requirement of SMS to amend inadequate or inappropriate documented procedures and to identify where actual practices do not meet those that are documented and to propose corrective action(s).

It would helpful if a system could be in place that distinguished between root cause of non-conformities either as human-element related (often referred by insurance companies as human negligence or crew-related Mistake) or ship quality assurance system/ISM (often referred to as Company-related Error). In this paper an analysis is carried out and a system has been developed to distinguish between deficiencies relating to quality assurance and those relating to the human element and the machinery system. It is important to realize that the quality assurance includes all the requirements of ISM Code which embraces the company's own policies, procedures, processes and plans; and distinguish between crew-related mistakes and company-related errors. Figure 1, adopted from Baines[4] analysis of investigation results, shows one way of doing this.

[3] Paris MoU Annual Report 2022 - https://parismou.org/system/files/20236/Paris%20MOU%20Annual%20Report%202022.pdf

[4] https://www.raes-hfg.com/reports/21may09-Potential/21may09-baines.pdf

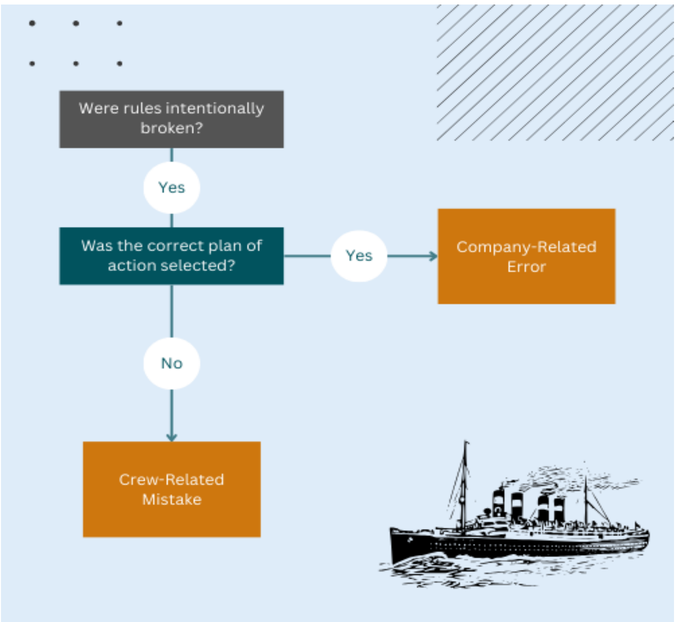

Figure 1. Adaptation from Baines- Company-related Error vs. Crew-related Mistake

3. Data from Industry

There are several sets of data presented in the paper viz., data from the IACS about the ISM Code non-conformities, PSC inspection deficiencies and accident reviews.

The data concerning non-conformities during 2017-2023 is presented in Table 1. To analysis this data and to ascertain the top non-conformities noted Pareto analysis[5] was applied. In this paper, the Ziarati's adaption of Pareto analysis applied in several safety papers[6] is used. It should be noted that other analysis methods were used in the IMO ISM Study such as Event Tree Analysis but due to confidentiality issues the outcome of these analyses are not reported here.

The application of the Pareto analysis, as shown in Tables 1a and 1b, has identified Ship Maintenance (Element 10), Shipboard Operation (Elements 7) and Resources and Personnel (Element 6) to be the top most frequent non-conformities.

Table 1a. ISM Non-Conformities Observed 2017-23 – Part 1 (Source: IACS, the final column is from LR)

[5] Pareto analysis is a formal statistical technique used in decision making. It is useful in selection of a number of tasks that produce maximum impact. In this paper, it is used where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action, then selects a number of the most effective actions that deliver a total benefit reasonably close to the maximal possible one. Alternatively, it can seek to find the contributing factors to a failure and identify the most frequent recuring cause or factor.

[6] https://www.marifuture.org/Publications/Papers/safety_at_sea_applying_pareto_analysis.pdf (published by IMechE) and https://www.marifuture.org/Publications/Papers/Avoiding_Collisions_At_Sea.pdf (presented at and published by IAMU Aga 2017).

Non Conformities Observed/Noted								
Row Labels	**1 Jan - 31 Dec 2018**	**2 Jan - 31 Dec 2019**	**3 Jan - 31 Dec 2020**	**4 Jan - 31 Dec 2021**	**5 Jan - 31 Dec 2022**	**Grand Total**	**Average**	
1. General	1401	1203	1207	1824	1765	7400	1480	1.2.2.1 - Safe Working Practices, 1.2.2.2 - Safeguards against identified risks, 1.2.2.3 - Safety Management skills & preparing for emergencies, 1.2.3.1 - Compliance with rules & regulations; 1.2.3.2 - Taking into account of codes, guidelines & standards; 1.4 - Functional Requirements
2. SAFETY AND ENVIROMENTAL PROTECTION POLICY	112	72	90	112	135	521	104.2	2.1 - Establishing a safety & environmental policy; 2.2 - Implementing the SMS Policy
3. COMPANY RESPONSIBILITY AND AUTHORITY	230	184	183	205	186	988	197.6	3.1 - Ship owner assigning ISM responsibility; 3.2 - Defining & documenting responsibilities and 3.3 - Adequate resources for the DPA
4. DESIGNATED PERSON(S)	95	76	83	79	107	440	88	4 - Role of the DPA
5. MASTER'S RESPONSIBILITY AND AUTHORITY	322	328	286	309	380	1625	325	5.1.1 - Master implementing the SMS Policy; 5.1.2 - Master motivating the crew; 5.1.4 - Master verifying SMS related activities; 5.1.5 - Master periodically reviewing the SMS and 5.2 - Use and knowledge of the overriding authority
6. RESOURCES AND PERSONNEL	1642	1625	1425	1732	1877	8301	1660.2	6.1.1 - Master properly qualified for command; 6.1.2 - Master fully conversant with SMS; 6.1.3 - Master given necessary support; 6.2.1 - Ship manned with qualified and medically fit personnel; 6.2.2 - Ship appropriately manned to safely cover all operations; 6.3 - Crews familiarisation on board; 6.4 - Adequate knowledge of rules and regulations; 6.5 - Identification of training needs; 6.6 - Working language used and 6.7 - Effective communication used.

Table 1b. ISM Non-Conformities Observed 2017-23 – Part 2 (Source: IACS – the final column is from LR)

7. SHIPBOARD OPERATIONS	2038	1897	1848	2027	2424	10234	2046.8	7 - Shipboard Operations
8. EMERGENCY PREPARDNESS	1201	1195	1033	1202	1470	6101	1220.2	8.1 - Identification of contingency plans; 8.2 - Drills & exercise planning for emergencies and 8.3 - Companys ability to respond to emergencies.
9. REPORTS AND ANALYSIS OF NON-CONFORMITIES, ACCIDENTS NAD HAZARDOUS OCCURRENCES	1127	1088	1028	967	1107	5317	1063.4	9.1 - Reporting, investigating, analysing accidents, NCs, etc. and 9.2 - Implementation of corrective actions.
10. MAINTENANCE OF THE SHIP AND EQUIPMENT	3968	3689	3296	3778	4419	19150	3830	10.1 - Establish procedures to maintain the ship; 10.2.1 - Inspections held at the proper interval; 10.2.2 - Deficiencies reported; 10.2.3 - Appropriate action on deficiencies taken; 10.2.4 - records of activities maintained; 10.3 - Identification & Measures for critical equipment and 10.4 - Inspection routines & follow up incorporated in the maintenance routines.
11. DOCUMENTATION	1152	965	912	968	1086	5083	1016.6	11.1 - Establishing document & data control; 11.2.1 - Valid documents available on relevant locations; 11.2.2 - Review & approval of (changes to) documentation; 11.2.3 - Obsolete documents promptly removed and 11.3 - Suitable & effective SMS maintained.
12. COMPANY VERIFICATION, RECIEW AND EVALUATION	692	713	679	719	728	3531	706.2	12.1 - Internal audits at 12 month intervals12.2 - Personnel undertaking tasks in conformity with Companys responsibilities; 12.3 - Management review; 12.4 - Audits and corrective actions in accordance with procedures; 12.5 - Independence of internal auditors; 12.6 - Reporting results of internal audits and reviews and 12.7 - Timely corrective action on findings noted.
Grand Total	13980	13035	12070	13922	15684			

The data from IACS was complemented by the data obtained from LR. The LR data represents 15% of the IACS data. The difference between the data provided by the IACS and LR is significant. The IACS data only concerns the 12 elements of the ISM Code but the LR data goes deeper and provide non-conformities at sub-element levels. The reason why the LR data is significant is that whilst IACS data is able to for instance identify Ship Maintenance as the top most frequent non-conformity, the LR data shows that the top most frequent non-conformity to be Non-Compliance with rules & regulations (Sub-element 1.2.3.1). The following shows the top ten most frequent non-conformities from LR data:

- 1.2.3.1 Non-Compliance with rules & regulations.
- 10.2.1 - Inspections not held at the proper interval; 10.1 - Establish procedures not in place to maintain the ship; 10.3 - Identification & Measures not in place for critical equipment; 10.4 - Inspection routines & follow up not incorporated in the maintenance routines.
- 12.1 - Internal audits not held at 12-month intervals; 12.3 - Management review not conducted 12.4 - Audits and corrective actions not in accordance with procedures; 12.7 - Timely corrective action not taken on findings noted.
- 5.1.5 - Master not periodically reviewing the SMS.
- 7. Shipboard operations
- 1.2.2.2 Inadequate safeguards against identified risk
- 9.1 – Lack or inadequate reporting, investigating, analyzing accidents, NCs, etc.
- 8.2 – Inadequate drills & exercise planning for emergencies
- 11.2.1 - Valid documents not available on relevant locations
- 9.2 – Non-implementation of corrective actions.

Data from Port Inspections

Table 2 displays the recorded number of ISM deficiencies across several PSC MoUs, with a notable portion being detainable. Typically, shipping companies must undertake corrective actions to ensure their vessels are fit for sailing. This emphasizes the importance of addressing these deficiencies promptly to maintain compliance and safety standards within the maritime industry. Table 4 shows the similar data for Paris MoU.

Table 2. PSC MoU Observed deficiencies

PSC MoU	US Coast Guard MoU	Mediterranean MoU	Black Sea MoU	Tokyo MoU	Riyadh MoU	Indian Ocean MoU Secretariat
PSC Inspections with ISM deficiencies	929	944	1743	5630	891	1666
ISM and ISM-related deficiencies	1152	5657	11756	6187	994	1751
Detainable ISM and ISM related deficiencies	313	1213	1799	1230	42	332

It is important to point out that different MoU regions have their own categories of the ISM deficiencies. As an example, Table 3 shows the categories of considered by Black Sea MoU.

Table 3. PSC MoU observed deficiencies by Black Sea MoU

Categories of the ISM Deficiencies Identified by Black Sea MoU
Safety and environment policy
Company responsibility and authority
Designated person(s)
Master's responsibility and authority
Resources and personnel
Shipboard operations
Emergency preparedness
Reports of non-conformities, accidents & hazardous occur
Maintenance of the ship and equipment
Documentation
Company verification, review and evaluation

Table 4. PSC Paris MoU Observed deficiencies – Review of Inspections 2019 - 2021

Year	2019	2020	2021
Number of inspections	17,916	13,168	15,387
Number of individual ships inspected	15,447	12,092	13,797
Number of deficiencies	39,821	28,372	36,113
Number of detainable deficiencies	3,015	2,182	3,274
Detentions in % of the total number of inspections	2.98	2.92	3.43
Number of refusals of access to ports	25	8	11

The Figure 2 shows the ISM to be the highest category of deficiencies, responsible for some 25% of the deficiencies in the top 10 categories as observed by Paris MoU.

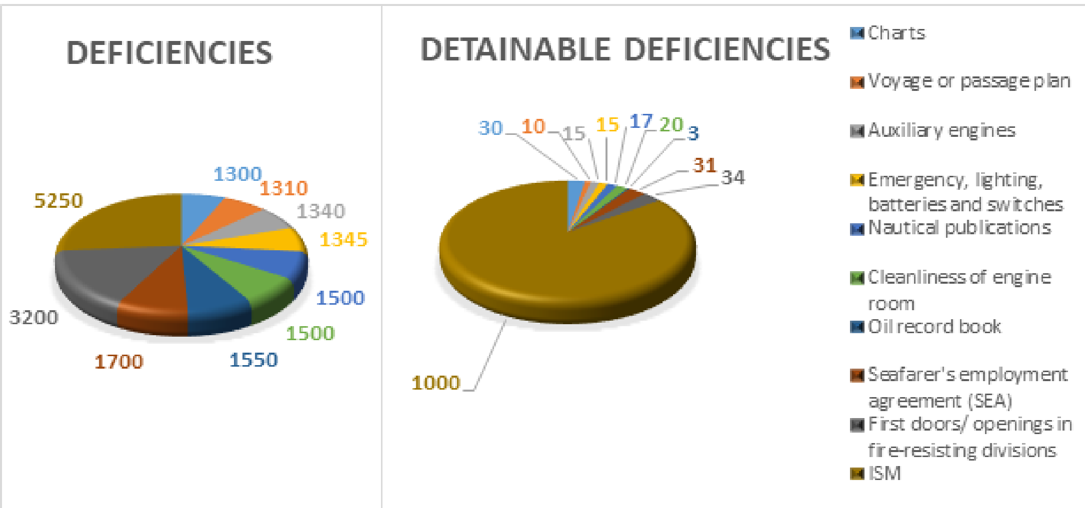

Figure 2. The ten most frequent deficiencies detected on ships during by Paris MoU 2019-2021 (Source: Paris MoU Annual Report 2022)[7]

[7] https://parismou.org/system/files/20236/Paris%20MOU%20Annual%20Report%202022.pdf

4. Learning from Audits, Inspections and Accidents

C4FF through some 30 funded projects and having reviewed the results of external audits, port inspection and over 1000 accidents, has identified some 25 top root causes of accidents and non-conformities and deficiencies as shown in Table 5.

As it can be seen from Table 6 each group category has its top root-causes within each category group the key root causes/contributing factors are also identified. As can be seen the Leadership item, viz., "Inadequate risk assessment, inadequate team composition, inappropriate pressure to perform a task and a directed task with inadequate qualification, experience or equipment", was found to be the top cause of accidents.

Table 5a. The top 25 categories of the root cause of non-conformities, deficiencies and contributing factors to accidents and incidents at sea - Source: M'aider 2010, ACTs 2015 and ACTS Plus 2017 & OPTIMISM 2024[8]

A- Work Environment	1	Lack of visibility, excessive noise or vibration, hot/cold working environment, bad weather, sudden movements.
	2	Inappropriate work environment/ergonomics, poor human–machine interface, automation issues, maintenance and equipment misfunctions.
	3	Inadequate system design
	4	Issues with procurement/purchasing
B- Personal	5	Inadequate personal fitness
	6	Inadequate mental fitness
	7	Inadequate Knowledge
	8	Inadequate competence/skills
	9	lack of motivation or complacency
	10	Ineffective communication, language differences, non-standard (Non SMCP) or complex communication and the impact of differences in rank.
	11	Poor team operation, working towards different goals, no cross-checking, no means of reporting or speaking up, no quality circles.
	12	Incorrect perception, motion illusion, visual pretention/illusion and the misperception of changing environments or instruments.
	13	Lack of focus/incorrect awareness leading to misinterpretation of the operation by a crew member – lack of attention, confusion, distraction, discoordination, stress/poor mental perception.
	14	Forgetfulness, inaccurate recall or using outdated information.

Table 5b. The top 25 categories of the root cause of non-conformities, deficiencies and contributing factors to accidents and incidents at sea – Source: M'aider 2010, ACTs 2015 and ACTS Plus 2017 and OPTIMISM 2024[9]

C- Leadership	15	Inadequate leadership and personnel management, including no personnel measures against regular risky behavior, a lack of feedback on safety reporting, no role model and personality conflicts.
	16	Inadequate risk assessment, inadequate team composition, inappropriate pressure to perform a task and a directed task with inadequate qualification, experience or equipment.
	17	Inadequate leadership of operational tasks, including a lack of correction of unsafe practices, no enforcement of existing rules, allowing unwritten policies to become standards and directed deviations from procedures
	18	Inadequate manning (intentional or unintentional disregard for the guidelines).
D - Organizational	19	Inappropriate policy manual
	20	Inappropriate/inadquate procedure
	21	Inadquate supervision
	22	Problems with safety culture, lack of culture of reporting, learning or just culture, social and status barriers causing misunderstandings.
	23	Unsuitable documented policy or procedures, limitations of proactive risk management, reactive safety assurance, lack of safety promotion and training
	24	Insufficient resources for safe operations, including personnel, budgets, equipment, training programs, operational information and lack of operational manual of ship installations.
	25	Commercial Pressures, business and competition affecting safety, including relations with contractors, trade pressure to keep the plans and costs.

[8] Safety at Sea and Maritime Environment Protection with Special References to Human Factors, MT'24. 10th International Conference on Maritime Transport, Barcelona, June 5-7, 2024 - See also Stroeve, S., et al. (2023) Shield Human Factors Taxonomy and Database for Learning from Aviation and Maritime Safety Occurrences, Safety, MDPI 2023.

Table 6. Frequency occurrence of the top 25 root cause of non-conformities, deficiencies and contributing factors to accidents and incidence for some 50 accidents selected from over 300 accidents.

Legend: • = Applies

NO	Vessel	Accident type	Working Environment				Personal										Leadership				Organisation						
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		Loss of Stability								•	•	•	•		•		•	•	•	•		•	•	•	•		•
2		Human Factor			•	•									•		•	•	•				•			•	
3		Collision			•						•						•	•	•		•	•	•	•	•	•	•
4		Operational Accident		•	•					•			•				•	•	•		•	•	•		•	•	
5		Operational Accident		•	•									•				•	•		•	•	•			•	
6		Collision		•			•											•			•	•	•				•
7		Grounding		•									•				•	•			•	•	•	•		•	•
8		Collision		•						•			•		•			•			•	•	•			•	
9		Grounding								•			•	•				•	•		•	•		•			
10		Capsize		•			•	•	•	•	•		•	•	•		•	•	•	•	•	•		•			•
11		Capsize and Grounding							•	•	•						•	•	•		•	•	•	•	•		
12		Fall from 18m height	•		•					•			•	•			•	•									
13		Overflow and Pollution		•	•					•	•				•			•	•	•			•				
14		Collision		•	•					•			•					•	•				•				
15		Ent. Into enclosed space							•	•	•		•	•	•		•	•	•		•	•	•	•			
16		Ent. Into enclosed space							•	•				•			•	•	•			•	•				
17		Operational Accident		•						•			•		•		•	•	•		•	•	•	•			
18		Operational Accident		•			•			•			•	•	•		•	•	•	•	•	•	•	•	•	•	
19		Operational Accident		•						•				•				•						•			
20		Grounding					•	•	•	•	•			•			•	•	•	•	•	•	•	•			•
21		Fire in Engine Room		•					•			•						•			•	•	•	•			
22		Collision			•							•	•														
23		Sinking while Towage	•	•	•				•	•	•										•	•	•				
24		Container over board	•	•								•	•	•							•	•	•	•			
25		Collision		•								•	•	•			•										
26		Accident in Drills							•	•								•	•			•	•				
27		Lifeboat Failed			•																						
28		Lifeboat Failed			•																						
29		Engine Room Accident						•	•		•																
30		Overboard Accident	•	•					•	•							•	•			•	•	•	•	•	•	
31		Collision										•	•	•	•												
32		Crew Member Died	•									•	•									•		•			
33		Man fell overboard																									
34		Man fell from height																									
35		Operational Accident		•					•									•	•								
36		Operational Accident	•							•			•					•							•		
37		Operational Accident	•	•					•	•		•							•								
38		Operational Accident		•					•	•			•				•	•	•			•	•				
39		Death of Passenger			•																		•			•	
40		Operational Accident							•				•		•			•	•		•	•	•	•			
TOTAL			7	19	12	1	4	3	14	21	9	8	19	12	10	0	16	27	20	5	18	23	24	16	7	9	6

During a further review of accidents, as depicted in appendixes 1 and 2, it was found that the key contribution factors in accident are human vulnerability, poor decision making and/or person-to-person communication. In this further review an attempt was made to also identify whether the accident was Crew-related Mistake or Company-related Error.

Conclusions

The Pareto Analysis of ISM Non-conformities, PSC Inspections and accidents clearly suggests that focusing on ship maintenance, shipboard operations and non-compliance with rules and regulations to be the top most frequent key factors in audit non-conformities, inspection deficiencies and accidents. The Pareto analysis of findings from accidents showed that the highest frequency occurrences are the ISM Code Elements 1, 7 and 10. This was also true for the IACS/LR data and PSC inspection. In Element 1 'Compliance with rules and regulations', 'Taking into account codes, guidelines and standards’, 'Safeguard against identified risks' and 'Safe working practices' were the main problem areas. Element 7 'Shipboard Operations' was the second most occurring problem area. In Element 10 'Establishing procedures to maintain the ship' was the next top occurring problem area. If these problem areas are targeted and resolved, they are expected to make the most impact on effectiveness and the effective implementation of the ISM Code. Review of accidents also showed that 'Ineffective communication/language issues'. 'Inadequate supervisions', Crew familiarization on board', 'Human Vulnerabilities' ands 'lack of knowledge' to be main root causes of, or a contributing factor in many accidents. The review of accidents tallied well with the outcome of the ISM audits by IACS/LR, on like for like basis.

It is equally important to identify other specific aspects of rules and regulations that have led to accident at sea such as COLREGs. In appendix 2, it is shown that Pareto analysis identified one of the key issues regarding accidents at sea to be collisions primarily due to complexities of the Rules, particularly Rule 19.

The results presented here clearly shows that the focus of improving the effectiveness and effective implementation of ISM Code should be on ISM Audit non-conformities, PSC Inspections and accidents and a further analysis is required to ascertain what are the key issues with specific rules for instance with COLREGs or ship maintenance or shipboard operations. Safety improvements are only possible if ISM and STCW are reviewed together since ISM and STCW are sides of the same coin. Furthermore, the studies that have led to this paper clearly suggest human vulnerability, decision-making and person-to-person communications to be key factors for consideration. Safety is not an absolute phenomenon and a system such as ISM is as strong as its weakest point. Risk assessment plays a major rule in ISM. To this end, whilst this paper promotes the idea of Pareto analysis to focus on areas that bear maximum impact, it should be noted that each non-conformity or deficiency or root cause of a near miss is an accident waiting to happen.

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Appendixes

Tables 1 and 2 is a set of micro analysis of accident reports. Mistake indicates that the main cause of the accident or a contribution factor to it is due to crew-related action or inaction and Error indicates a company-related issue primarily related to quality assurance and/or control. There are cases were the cause or the contributing factor of the accidents could be crew-related as well as company-related. Three clear causes or contributing factors to accidents reviewed were found to be human vulnerability, decision-making and/or person-to-person communication.

Appendix 1 Table 1. The First Set of Micro Analysis of Accident Reviews

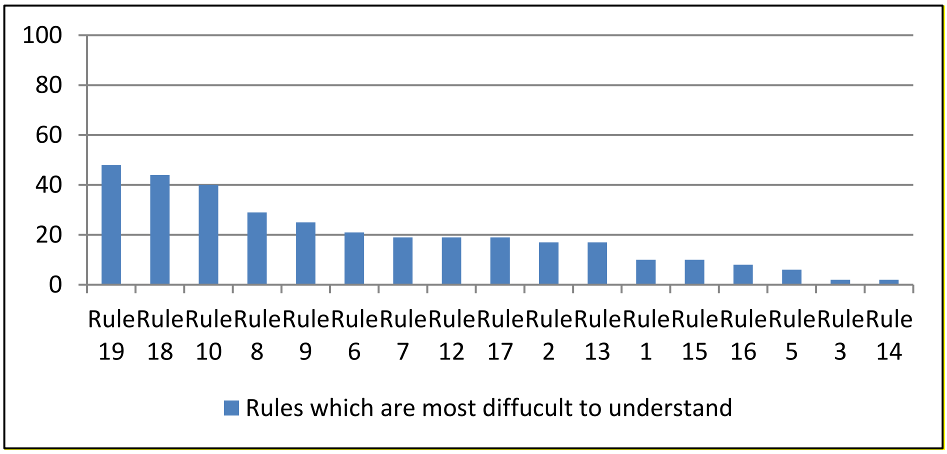
Type	Accident	Mistake	Error	Human vulnerability	Decision making	Communication
Ro-Ro Ferry	Grounding	x		x	x	x
Ro-Ro Ferry	Fire in the ER		x	x	x	x
Bulk Carrier	Collision		x	x	x	x
Offshore Supply ship	Sinking		x	x	x	x
Container	Containers overboard		x	x	x	x
Car Carrier	Collision	x	x	x	x	x
Bulk Carrier	Lifeboat falling		x	x	x	x
Life Boat safety latch	Lifeboat falling		x			x
Ro-Ro Passenger	Lifeboat falling		x	x	x	x
Oil Tanker	Engine room fire	x		x	x	x
General Cargo	Drowning of 3/O	x	x	x	x	x
Container/Cargo ship	Collision	x	x	x	x	x
General Cargo	Fall and death		x	x	x	x
Bulk Carrier	Fall and death		x	x	x	x
Reefer	Fall and death		x	x	x	x
Bulk Carrier	Mooring rope death		x	x	x	x
Bulk Carrier	Drowning of bosun		x	x	x	x
Bulk Carrier	Oiler died		x	x	x	x
Cruiser	OS drowned			x	x	x
Ro-Ro Passenger	Passenger died	x	x	x	x	x

Appendix 1 Table 2. The Second Set of Micro Analysis of Accident Reviews

Type	Accident	Mistake	Error	Human vulnerability	Decision making	Communication
Container	Collision	x		x	x	x
Gas Carrier	Collision	x		x	x	x
Ro-Ro Ferry	Grounding	x		x		x
Cement Carrier	Capsize/Sinking		x	x	x	
Bulk Carrier	Grounding	x	x		x	
RoRo Passenger	Fire	x				
Ro-Ro Ferry	Grounding		x		x	x
Chemical tanker	Explosion		x		x	
ULCC	Grounding		x		x	x
Ro-Ro Ferry	Collision	x		x		x
Cruise Ship	Grounding	x		x		x
Oil Tanker	Fatal accident		x	x		
Bulk Carrier	Fatal accident	x	x		x	x
Bulk Carrier	Fatal accident		x	x		x
Gas Carrier	Fatal accident		x	x		
Bulk Carrier	Fatal accident	x	x		x	x
General Cargo	Collision	x	x		x	x
General Cargo	Collision	x	x		x	X
Chemical Tanker	Grounding		x	x		
General Cargo	Fatal accident		x	x		
Bulk Carrier	Fatal accident		x		x	

Appendix 2. Sample of problem areas – Collision Rules which are most difficult for students to understand

The application of the Pareto analysis when reviewing the ISM audits and port inspection data clearly showed that non-compliance with rules and regulations was a major non-compliance or deficiency. The analysis in this respect showed, for instance, that the understanding of the collision rules (COLREGs) and their correct application is unsatisfactory, hence a weak link in the safety chain. Therefore, any research in this field can be fully justified if it increases knowledge and understanding of safety issues. The scenarios which have been developed in the ACTS+ project[10] present even more complex cases of encountering ships when the correct application of the Rules is even more demanding. One of the very good principles for solving such complex cases is the principle of "Divida et Impera". It is important to emphasize that this principle can be applied to any complex case of encountering ships, and the result (possible collision avoidance actions) obtained in this way is in compliance with the Rules. Complex cases, which cannot be solved in this way, belong to the category of "special cases" and will require further research in this field. In ACTS project, the most significant finding was to identify the rules that were found to be most difficult by the students as reported by the instructors such as Rule 19 (Figure 1 below). It is not just COLREGs which require attention but ISPS specifically cyber security necessitates additional efforts in ensuring safer seas and better marine environment protection.



Appendix 2. Figure 1. Rules which are most difficult for students to understand – answered by lecturers

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