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Integration of Human, Technology, Organization, and Innovation Elements in Safety Management to Meet Challenges of Advanced Maritime Technology including MASS

Deepak Raj Sharma[1,*]

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ABSTRACT

The advancements in maritime technology and its use both onboard and ashore have impacted safety management practices over the years. However, recent developments, especially in areas related to Maritime Autonomous Surface Ships (MASS) have presented greater challenges for contemporary safety management approach. The systemic approach for improvement of safety, inherent in the maritime safety management, could also be used in providing solutions to the new challenges due to technological developments in the sector in recent times. This paper discusses integration of the four major themes – Human Element, Technology, Organization, and Innovation, in holistic manner, to meet the challenges of safety management and provides an insight into futuristic challenges and solutions relevant in the context of the common theme of MASS.

1. Introduction.

The International Maritime Organization (IMO) implemented the International Safety Management (ISM) Code in 1998 to ensure safe management and operation of ships and for pollution prevention (IMO, 2018b). The purpose of the Code is to provide an international standard for the safe management & operation of ships and for pollution prevention. Maritime safety management was introduced as a concept and tool for improving the effective implementation of regulations and practices related to maritime safety and environment protection.

To verify the compliance of the ISM Code, the respective country's Maritime Administration conducts audits of the shipping companies and their ships, often with the aid of private classification companies. These audits also verify that safety systems are in place and are rigorously being followed.

The compliance of the ISM code and other rules and regulations is primarily the responsibility of the Flag State of the Ship (IMO, 2018a). However, Port States may also inspect foreign ships within established regimes of Port State Control (PSC). Thus, the quality and effectiveness of the auditing systems is of vital importance for maritime safety management.

The advancements in maritime technology and its use both onboard and ashore have impacted safety management practices over the years. However, recent developments, especially in areas related to Maritime Autonomous Surface Ships (MASS) have presented greater challenges for contemporary safety management approach. Thus, the role of all elements impacting the imbibing of these new challenges through a proactive approach becomes more significant.

The importance of humans in safety management cannot be discounted even in a MASS environment. Further, the technology itself can also contribute to improving the safety management practices, through the organizations involved as stakeholders and their innovation in business models.

The paper discusses integration of the four major themes – Human Element, Technology, Organization, and Innovation, in holistic manner, to meet the challenges of safety management and provides an insight into futuristic challenges and solutions relevant in the context of the common theme of MASS.

[1]Western Norway University of Applied Sciences, Haugesund, Norway.
[*]Corresponding author: Deepak Raj Sharma. E-mail Address: ders@hvl.no.

2. Significance of Human Factors in Maritime Safety Management.

While safety is the freedom from unacceptable consequences, safety management is the process to realize certain safety functions and the aim of safety management is safety, protecting human beings, the environment, equipment and property from unacceptable risk (Li & Guldenmund, 2018). Risk management is a critical component of safety management which is further controlled by using management control systems. Further, audits, both internal and external, are used to assess and improve the safety management systems.

A recent study analyzing the causal factors of maritime incidents and accidents attempted to understand the contribution of the entire safety control system – regulators, insurers, manufactures and supplies, shipping companies, ships, equipment, etc., (Puisa et al., 2018). The study highlighted their importance for prevention of accidents, incidents, and other unwanted events, going beyond proximate failures & flawed interactions at the ship and shipping company levels, as well as unhelpful assumptions that unfortunate events are mainly random and caused by human erroneous actions. However, human, and organizational factors still constitute the main stakes in maritime safety.

Human factors comprise operative human errors – derived from personnel own qualifications, or from their physical, mental and personal conditions- and situational errors– derived from work environment design, management problems, or human-machine interface, amongst others (Berg, 2013). Thus, the involvement of humans in a system will inherently bring forth the limitations or weaknesses in individual and social/group behavioral actions. The role of human factors in maritime accidents could consist of three types – cognitive factors at individual level, social or interpersonal factors at group level and systemic or organizational factors at an overall system level (Chauvin, 2011).

Incidentally, International Civil Aviation Organization (ICAO) has recognized the influence of human factors not only in aviation safety in general but also in affecting the performance of the Safety Auditors and has therefore published Human Factors Guidelines for Safety Audits Manual (ICAO, 2002). It mentions challenges about different types of auditor's bias – frequency, selectivity, familiarity, conformity, framing and overconfidence, along with cultural perceptions – temporal precision, interruptions and management styles, language, and emotions, especially in a multicultural audit team, which may affect the audit findings. Though the significance of human factors in maritime safety has been accepted quite well for a long time, such detailed focus about human factors in maritime auditing per se, as in aviation, is yet to be acknowledged.

2.1. Human Factors in Autonomy.

In the context of MASS, a new dimension is emerging with automated systems which are primarily aimed at reducing human error. However, it also brings forth the complexities of socio-technical systems in which humans and Robotic, Intelligent, Autonomous (RIA) technology coexist and form dynamic relationships (Hynnekleiv, Lutzhoft, & Earthy, 2019). As future MASS ships are being considered to be manned, at least partially and to some degree controlled by humans, the design of such a system requires extensive reflection of human factors issues since in some cases, the roles of humans and RIA may overlap, and thus result in incomplete or interrupted interactions. Therefore, the human role even in high levels of maritime automation cannot be discounted which in turn still leaves scope for human error influencing maritime safety.

Bainbridge (1983) in a pioneering paper on automation had brought out the irony that the more advanced a control system is, the more crucial may be the contribution of the human operator. Further, automation of simpler tasks leaving more complex ones for human operator along with degradation of human skills and knowledge, presents greater challenges while responding to emergency situations due to failure of automatic systems (Bainbridge, 1983).

Subsequently, newer ironies of human-automation are being recognized where automation can enhance system performance through its reliability and accuracy, but can also disguise operator performance shortcomings (Strauch, 2018). Further, accidents also illustrate an additional irony of automation that even relatively minor anomalies in complex sociotechnical systems can increase the severity of potential consequences through operator interaction with automation.

Interestingly, repeated exposure to human–automation interaction errors does not necessarily resolve the cause of the errors and this irony has, if anything, increased in scope with additional exposure to and experience in automation operations.

Thus, it is evident that human reliability also influences the overall system reliability in automatic systems. This influence can both be negative (e.g., human working error) or positive (e.g., controlling system breakdowns or system problems (Berg, 2013).

Another intriguing aspect of the human element is the legal and liability discussions related to MASS. The legal questions and challenges linked to autonomous shipping, as well as the solutions needed to resolve them, will differ depending on what choices are made in relation to manning, crew location, and autonomy level (Ringbom, 2019). Legal issues will start to surface, either when the level of autonomy is increased to the extent that navigational decisions are made autonomously or when the level of manning is altered as a consequence of automation.

It is expected that even after development of specific legal or regulatory instrument for MASS, the challenges in addressing issues related to automating situational awareness & decision making and overlapping operational responsibility in case of relocated remote operations will nevertheless bring in human element in a different form.

Humans will be important also in systems with increased autonomy and with the human involvement on strategic, tactical and operational levels, the importance of defining the concepts of responsibility, authority and control from the perspective of humans, rather than that of the vessel is apparent (Relling et al., 2018). Further, use of technical advancements not only in automation of vessels or shipping but also in risk analysis/management, accident investigation & prediction and other core maritime safety functions will also improve the overall maritime safety management.

Using an innovative machine learning approach to calculate a leading maritime risk indicator by combining the shipboard safety related data and algorithm based risk management methods enable a forward-looking identification and assessment of existing risks for ship and crew, which in turn allows the implementation of mitigating measures before adverse events occur (Kretschmann, 2020).

Heij & Knapp (2018) in their study presented a quantitative link between past Port State Control (PSC) inspection outcomes, in particular past deficiencies related to human factor aspects, and the probability of future shipping accidents. Thus, the deficiencies detected during PSC inspections have predictive power for future accident risk, in addition to other vessel-specific risk factors like ship type, age, size, flag, and owner. The empirical analysis links accidents to past inspection outcomes and is based on data from all around the globe of PSC regimes using harmonized deficiency codes aggregated into eight groups related to human factor aspects like crew qualifications, working and living conditions, and fatigue and safety management (Heij & Knapp, 2018).

Thus, the significance of the human element in maritime safety management in general and MASS in particular continues to be valid and needs to be factored in terms of the effect of the human factors, though in a new context.

3. Impact of Technology in Maritime Safety Management.

The role of technology in maritime safety has been acknowledged with improvements in almost all areas of shipping. However, technological advancements have also resulted in creating new challenges. In a major analysis of maritime safety over the past decade, Lloyd's List Intelligence and DNV show a marked decline in casualties, losses, and detentions, recognizing significant improvement in safety over the past decade due to higher standards of ship construction and operation. However, it also cautions about the major challenge and safety gap from emerging risks from new fuels and digital technologies including cyber threats (Lloyd's List Intelligence, 2021). Thus, additional risks likely to be introduced due to the new technological dimension cannot be discounted in maritime safety management.

The common opinion that modern technology has reduced seafarer's workload and improved safety of ships ignores that human error induced by technology also contributes significantly to risk of shipping (Mišković, Bielić, & Čulin, 2018). The study on impact of technology on safety revealed that the non-standardization of equipment, i.e., the differences in the settings and display interfaces between different manufacturers and poor design, prolong time needed for familiarization, and in combination with short period of handover, can contribute to the occurrence of human error.

3.1. Safety Advancements for Autonomous Vessels.

In the context of MASS, some scholars have a simplistic view that the advent of autonomous ships that are unmanned or low-manned will reduce the number of people at risk at sea and even when autonomous navigation does not reduce the number of accidents, this means that safety at sea will increase (De Vos, Hekkenberg, & Valdez Banda, 2021). They claim that the number of shipping accidents at sea may also be decreased through autonomous navigation thereby improving safety at sea.

Taking a cue not only from the automation in land transportation systems e.g., cars, but also in other maritime sectors, the benefits in operational efficiency and improved safety are being touted in maritime domain too. Precision Fish Farming (PFF) concept whose aim is to apply control-engineering principles to fish production, thereby improving farmer's the ability to monitor, control and document biological processes in fish farms through increased use of emerging technologies and automated systems solving specific challenges related to biomass monitoring, control of feed delivery, parasite monitoring and management of crowding operations demonstrates such benefits in aquaculture (Føre et al., 2018).

However, few others offer more realistic arguments recognizing technical challenges still existing in designing systems for automatic navigation control and collision avoidance in dynamic sea conditions and traffic situations (Kim & schroder-Hinrichs, 2021). Interestingly, they also bring out that Independent from the goal of MASS, steady technological development in this area would certainly be a good aid to navigation even for ordinary ships, especially during poor visibility due to darkness and fog. This approach seems to support the claim about improved maritime safety due to technological advancements in automation irrespective of the degree of automation. However, challenges in communication and developing an integrated system to realize the potential for MASS need to be overcome. Further, we have to also consider that due to changes in operational concept and unique human-machine roles/interactions, new hazards and risks will emerge in terms of security and safety considerations.

A host of technological research has been ongoing in a variety of fields related to MASS, which could be distinctively observed to be addressing safety challenges thereby strengthening the argument of technology enabling improvement in overall maritime safety.

Facilitating decision support for remote operators proposes keeping a copy of the AI expert-system controlling the ship, updated and running in parallel in the control center to keep the operator's situation awareness during short communication glitches along with designing a "quickly-getting-into-the-loop-display" which automatically will appear in an alarm situation, allowing the operator just-in-time and simple-to-understand information (Porathe, 2021).

Deep learning technology to capture helmsman behavior supported by decision support layer for solutions in distinct navigation situations, thus cloning human response through ship intelligence systems developed using neural networks, is likely to address autonomous ship navigation and possible COLREGs failures (Perera, 2020).

Developments in the field of simulation-based test system for Situation Awareness Systems and Automatic Navigation Systems (ANS) creating a virtual world to simulate environment conditions, geographical information, and interaction with other maritime traffic to ensure that ANS algorithms are safe and do not cause accidents are also being undertaken to complement real life testing and validation (Pedersen et al., 2020).

Another interesting aspect is to focus also on conventional vessels for improving safety of interactions between such vessels & MASS and not only burden the latter, especially in terms of situational assessment and prediction making of other ship's actions. Apart from regulatory interventions, technical solutions for use of land-based sensors by all ships, installation of suitable equipment and communication system on both ships to inform about the autonomy status, etc. are being considered (Rødseth, Wennersberg, & Nordahl, 2021).

Thus, the advancement of technology is surely a significant enabler for enhanced maritime safety, however, it is also presenting challenges in evolving newer practices in safety management in terms of identification of new hazards & risks, documentation & verification of compliance, monitoring, and responsibility. Evaluating of MASS by any auditor for issue of a Safety Management Certificate (SMC) as per the ISM Code or even under a new regulatory instrument, will create unique difficulties if auditing per se does not imbibe technological innovations and improvements. Remote or hybrid auditing solutions for the vessels using technological tools witnessed during COVID pandemic, when the shipping industry and the regulators faced accessibility and mobility issues for auditors, indicate prospective areas of innovation in this field.

4. Increased Relevance of Organization in Maritime Safety Management.

The origins and the necessity of the ISM Code have been well documented in terms of the need for accountability of the Shipping Companies in management and safe operations of ships. It was recognized that the role of the shipping company in safe management and operations of ships was vital as it ensures that all safety issues are given priority and that appropriate safety system, procedures, training, documentation, and records are in place. Thus, the importance of organizational factors apart from human factors was recognized in preventing maritime accidents or incidents and the ISM Code became the prime enabler for ensuring compliance of the safety responsibilities by the shipping companies.

4.1. Organization Leading Safety Management in Maritime Domain.

The management commitment to the safety goals is the most important factor distinguishing safe from unsafe systems & companies, and top management concern about safety is the most important factor in discriminating between safe and unsafe companies matched on other variables (Leverson, 2011). Companies play an important role in risk assessment and management. Apart from the traditional hazard analysis methods, such as Fault Tree Analysis (FTA), Failure Modes and Effects Criticality Analysis (FMECA), Event Tree Analysis (ETA), and Hazard and Operability Analysis (HAZOP), new methods like System-Theoretic Process Analysis (STPA) are used to identify many more, often software-related and non-failure, scenarios that the traditional methods did not find (Leveson & Thomas, 2018).

Further, interesting areas are also being explored to approach safety management differently. The Functional Resonance Analysis Method (FRAM) which describes that sometimes things happen without clearly recognized causes provides a framework for bringing new nuances to safety management (Hollnagel, 2017). Maritime domain represents a safety-critical system that has complex and temporary human collaborations and a framework under FRAM can be used under the safety-II perspective applied to maritime accidents analysis & safety strategy derivation (Lee, Yoon, & Chung, 2020). An innovative approach to integrate Human and Organizational Factors into risk analysis in the maritime industry using a Bayesian Belief Network (BBN) has been proposed to model the Maritime Transport System (MTS), by taking into account its different actors (i.e., ship-owner, shipyard, port and regulator) and their mutual influences (Trucco et al., 2008).

The discussions about the concepts of High Reliability Organizations and resilience engineering highlight the significance of organization response in risk handling, departing from traditional risk assessment and control measures (Rosnes et al., 2010). Due to the complexity in maritime systems with increased autonomy, systemic safety models to amplify positive human performance variability rather than the traditional reductionist safety models need to be explored as humans will be also important in such systems with involvement on strategic, tactical and operational levels and therefore it is important to define the concepts responsibility, authority and control from the perspective of humans, rather than that of the vessel (Relling et al., 2018).

4.2. Impact of Other Organizations and Stakeholders.

Let us now enlarge the scope from a narrow focus on only shipping companies in our discussions on organizations and examine how other organizations are addressing the new challenges in MASS. Though the primacy of the shipping company in steering safety management is indisputable, it is prudent to discuss the collaborative structure impacting overall safety framework in a pioneer field of MASS.

The organizations involved in the maritime framework have been actively working to facilitate safe implementation of novel technologies related to autonomous and remotely controlled vessels. Recognizing a prominent enabler role of the classification societies, DNV has formulated Class guidelines on the subject to assist development of MASS and lay a framework to support solutions about regulatory compliance through exemptions, within the existing IMO and domestic regulations (DNV, 2018).

International, regional, and national organizations have also supported research institutions and maritime companies to explore improved maritime safety in conventional shipping and MASS apart from development of regulatory and legal framework in this field. International Maritime Organization (IMO) undertook a regulatory scoping exercise to analyze relevant ship safety treaties, in order to assess how MASS could be regulated, which has been completed (IMO, 2021). The completion of the scoping exercise represents an all important first step, paving the way to focused discussions to ensure that regulation will keep pace with technological developments.

European Union (EU) MUNIN project (Maritime Unmanned Navigation through Intelligence in Networks) aiming to develop a concept for an unmanned dry bulk carrier on deep-sea voyages not only addressed challenges of unmanned bridge but also contributed in identifying e-Navigation gaps which ironically has strong focus on human element (Burmeister et al., 2014). Thus, the technological advancements related to MASS are also resulting in safety improvement spin-offs to conventional ships in terms of better decision support systems for navigational safety and collision avoidance.

The national maritime administrations have also been looking to facilitate development of autonomous shipping addressing safety issues in a prompt manner while allowing technical innovation. A study by World Maritime University (WMU) on technology and transformation towards autonomous shipping focused on Norway where a unique combination of factors has enabled the emergence of autonomous ships (World Maritime University, 2019).

Norwegian Maritime Authority's positive approach towards facilitating autonomous shipping is evident in the special Circular issued for guidance in connection with the construction or installation of automated functionality aimed at performing unmanned or partially unmanned operations (Sjøfartsdirektoratet, 2020). It not only aims to ensure that autonomous or remotely operated ships have the same safety levels as conventional ships & that risks which may arise due to remote operation or autonomy are also identified, but also mandates a certified safety management system. Interestingly, the Authority also wishes to participate in all such projects as an observer, which demonstrates a collaborative approach with all stakeholders rather than acting as a pure regulator or administrator. Thus, the role of national agencies acting as maritime administration is crucial in prioritizing safety management while facilitating introduction of autonomous shipping.

Further, as a pioneer in the field, Massterly has been established as the world's first autonomous shipping company as a joint venture between Wilhelmsen and Kongsberg, offering a complete value chain for autonomous ships, from design and development, to control systems, logistics services and vessel operations (Wilhelmsen Holding ASA, 2018). Land-based control centres will be established by the company to monitor and operate autonomous ships in Norway and internationally. This development appropriately recognizes the complexities and challenges in operating MASS by not incorporating it into the traditional ship management company dealing with a variety of conventional vessels and also integrating a technology company in the new ship management roles, highlighting greater significance of technical expertise in management of such vessels.

Thus, maritime safety and safety management has been accorded high priority in organizational perspective, both by shipping companies and all other stakeholders in maritime framework, in conventional shipping as well as MASS.

5. Influence of Innovation in Maritime Domain on Safety Management.

The business model has a central role in value creation and value capture and therefore influences the overall business approach and outcome of a particular company. Though technology development can facilitate new business models and there may be a relationship between technology innovation and business model innovation, yet the business model construct is essentially separable from technology (Baden-Fuller & Haefliger, 2013).

The economic value of a technology remains latent until it is commercialized in some way via a business model and unless a suitable model can be found, these technologies will yield less value to the firm than they otherwise might (Chesbrough, 2010).

Though the shipping industry is often termed conservative, this does not mean that there is no innovation and in a recent study about new business models for shipping intended for innovation in Netherlands, three core focus areas – zero emission, digital & autonomous shipping and safety in shipping were highlighted (Veenstra, 2021). Though all three areas were oriented towards the ship needs to become more cleaner, smarter, and safer rather than the real business of shipping, the study brings out that it does lead to innovation in business model also.

Chesbrough & Rosenbloom (2002) highlighted realizing the true potential of technological spin-offs through evolving business models substantially different from existing ones. However, they also brought out the inherent constraints in business model innovation and identified it to be sometimes more challenging than technical innovation (Chesbrough & Rosenbloom, 2002).

5.1. Technical and Business Model innovations in MASS.

MASS is providing an opportunity for a chain of innovations attempting to integrate a host of new technical developments and creating a new approach to maritime transportation. The business model of the first autonomous container vessel in Norway, Yara Birkeland, is not that of a conventional shipping company which transports cargo from A to B on demand, but of providing a total captive transport solution to a land based company (not a shipping company) primarily aiming to reduce emissions due to road transportation of their products and also be efficient & cost effective (World Maritime University, 2019).

In other autonomous projects in Norway, the business models are also vastly different than just integrating autonomous vessels as another mode of transportation in the inventory of vessels of existing shipping companies. Therefore, it is evident that the true potential of technical innovation is being harnessed through innovation in business model.

Incidentally, the underlying idea of the Transforming Shipping through Ecosystem Business model Innovation (TSEBI) project funded by the Research Council of Norway is to innovate at the level of entire industrial ecosystems (and not just the firm level) through new digitally enabled sustainable business models (Forskningsrådet, 2019). It involves working towards reliable and sustainable future transport system by commercializing a fully electrical and autonomous vessel, expanding the digital shipping solutions like Kognifai platform of Kongsberg and also incorporates specific autonomous vessel projects Yara Birkeland and Asko. TSEBI intends to develop and implement a step-by-step method for sustainable business model innovation that aligns interests and incentives across ecosystem actors to jointly agree on value creation, value delivery and value capturing arrangement. Risk and safety management is an important part of the project and by bringing together all the actors in the niche field of autonomous shipping, it creates a platform to also look at innovative approaches to safety management to address newer challenges in this field.

The risk and safety management of autonomous vessels also demands innovative approaches as a fully autonomous vessel must be able to handle everyday navigation and propulsion in addition to an extensive list of other tasks such as cargo handling, emergency manoeuvering, ship-ship and ship-shore communications, situational awareness, and much more (Manzur Tirado, Brown, & Valdez Banda, 2019). As such systems are being implemented for the sake of increased safety, their operational risk and safety must be managed & assured and existing safety management practices need to be suitably modified or new systems evolved to meet these challenges.

The Internet of Things (IoT) is recognized as one of the most important areas of future technology and few sub-technologies essential for deployment of IoT products & services which are relevant for MASS could be Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), middleware, cloud computing, and IoT application software (Lee & Lee, 2015). This will facilitate in more effective and safe land-based monitoring and control, improved decision support for human intervention through big data analytics and information sharing & collaboration between human & machines for enhanced situational awareness. Therefore, companies with new business models suited to these innovations in maritime automation could benefit from this opportunity. The rapid adoption of IoT technologies in the maritime industry in general will also facilitate effective management of primary services, including vessel tracking, emissions control, predictive maintenance, welfare of crew and overall maritime safety (Plaza-Hernández et al., 2021).

Another important area relates to the business model dilemma of technology shifts where radical technological changes are met with business model inertia (Tongur & Engwall, 2014). The maritime industry may be on the cusp of such a change in the next decade or so, which may not drastically alter the conventional shipping but is surely likely to make maritime transportation highly digitally enabled and interconnected with use of innovative technologies. Though, it is particularly expected to enhance maritime safety in general.

Thus, the maritime safety management is likely to witness complexities due to technological innovations, especially concerning autonomous shipping, however, with business model innovation approach by the companies, solutions will emerge to meet the new challenges to harness the full potential and benefits of these technical advancements. We can also expect the auditing organizations - the maritime administrations, Recognized Organizations, and third-party auditors, to also imbibe the new technical and business model innovations to offer improved solutions for maritime safety management.

Conclusions.

The developments and perspectives in maritime safety related to human element, especially the complexities of socio-technical systems in which humans and Robotic, Intelligent, Autonomous technology coexist, demonstrates that the human role even in high levels of maritime automation cannot be discounted which in turn still leaves scope for human error influencing maritime safety. The complexities in incorporating MASS in the regulatory framework evident during the scoping exercise of IMO will also challenge the maritime safety management practices. Further, the effect of MASS is not likely to be limited to technical advancements designed for such vessels but also impact conventional shipping as spin-offs in improved navigation safety, situational awareness, and collision avoidance. Therefore, the regulatory framework and operational practices in safety management in terms of identification of new hazards & risks, documentation & verification of compliance, monitoring, and responsibility is expected with the advancement of technology.

Maritime safety management is a collaborative effort by all the stakeholders involved, though the shipping company operating the ship plays a leading role. The involvement of classification society, international & regional organizations, research institutions and national maritime administrations in development and safe implementation of novel technologies related to autonomous and remotely controlled vessels is an effective way forward. Further, the new ship management concept for MASS with integration of a technology company as a partner also recognizes distinct challenges in managing such vessels and is likely to also influence new approaches to maritime safety management.

The current practices of auditing for maritime safety management will also be impacted with the new approach to the business model innovation as land-based companies with no maritime background or focus get involved in maritime transportation. The use of technical solutions like remote auditing, predictive algorithms for deficiencies expected based on past ISM & PSC inspections and IoT applications will also improve the auditing function of verification and compliance of ISM objectives. Influence of human factors not only in maritime safety in general but also in affecting the performance of the Safety Auditors, in line with the practices in aviation, is likely to address auditor's bias that affect the audit findings.

Thus, the integration of all elements – human, technology, organization, and innovation, in maritime safety management, is essential to meet the challenges of advanced maritime technology in future in MASS as well as conventional ships.

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