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The ISM Code: A critical view of the contemporary challenges and future prospects for maritime safety management systems (SMS) in the new digital Era

Gaizka Aitor Solagaistua Pineda[1,*], Lidia Paola Padilla Cruz[2]

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ABSTRACT

The International Safety Management Code (ISM Code) has been the international reference standard for safety management in global shipping for more than two decades. It was originally designed to reduce the number of maritime accidents through the implementation of standardized procedures and on-site audits. The ISM Code has proven to be effective in promoting a culture of prevention and reducing the number of accidents in the maritime sector. However, the accelerated pace of technological development, characterized by the increasing digitalization and automation of operational and administrative processes, is opening up new horizons and posing complex challenges.

This article takes a detailed and critical look at the current state of the ISM Code, identifying its main strengths while recognizing its limitations in the face of recent technological developments. Key challenges analyzed include the introduction of digital or remote audits, electronic documents, increasing technological dependence and emerging cybersecurity risks, which require specific and urgent regulatory adaptations.

It also examines how these changes directly affect ship crews, who must quickly adapt to new responsibilities and technical skills arising from the digitalized and automated environment. Technological change also poses a significant challenge to maritime professional training and qualifications, generating an urgent need to update existing maritime training programmes and certifications. In this sense, the potential impact of automation on crew reduction and the redefinition of the traditional role of the professional master and other officers on board is also addressed, aspects that generate additional uncertainty and concern within the sector.

The article also assesses the future implications of this technological change, considering how it could affect the operational and regulatory standards of international shipping in the coming years. In this context, it underlines the crucial importance of revising and modernizing the ISM Code to ensure its adaptation to these new technological realities, to preserve its operational effectiveness and to strengthen global maritime safety. The International Maritime Organization (IMO) has already set its sights on this issue for the year 2025.

Finally, this analysis seeks to provide practical and strategic recommendations for shipowners, maritime administrations, classification societies and international organizations, underlining the need to strike the right balance between the adoption of technology and the preservation of the human factor as a key and irreplaceable element in the comprehensive management of maritime safety in the future.

[1]Universidad de La Laguna. Spain.
[*]Corresponding author: Gaizka Aitor Solagaistua Pineda. E-mail Address: gsolagai@ull.edu.es.

1. Introduction.

Rapid technological development and digitalization are profoundly changing all sectors, including shipping. The ISM Code, which has traditionally provided a robust and stable framework for safety management on board ships, now faces an unprecedented challenge: to adapt effectively to this digitized and highly automated environment. On the one hand, digitalization offers an extraordinary opportunity to strengthen and improve safety management by facilitating real-time monitoring, streamlining audits and enabling continuous and efficient remote monitoring. This could lead to a significant improvement in the prevention and management of maritime incidents, thereby enhancing compliance with the basic principles of the ISM Code.

However, the reader will agree with me that this technological change also creates significant uncertainties, particularly for crews. Crew members are now required to rapidly acquire new technical skills, broadening their profile from traditional seafarers to experts in complex digital systems, critical information management and cyber security. This can lead to stress, anxiety and a natural resistance to change, testing the practical effectiveness of Safety Management System (SMS) on board.

In addition, we must consider that the increasing reliance on automated systems and digital and other advanced technologies, such as process automation, real-time remote monitoring, artificial intelligence applied to navigation and predictive maintenance through IoT sensors, brings additional risks that the current ISM Code does not yet fully cover.

The real possibility of cyber-attacks, technological failures or loss of communication raises questions about the current ability of the Code to deal with these emerging digital scenarios. The analysis of digitalization in the maritime domain is therefore not only technological, but also profoundly human and legal. A new era is opening up, full of learning opportunities and professional development for crews, but also of legitimate uncertainty about the future and their role in this new digitized reality. For crews, this technological change will significantly alter their traditional roles and responsibilities, as they will have to familiarize themselves with increasingly complex and highly specialized systems. The reliance on advanced technologies implies an urgent need for continuous training, especially in critical areas such as cyber security and automated systems management. Many experienced seafarers are now expressing concern about this rapid transition, highlighting the potential gradual loss of essential and traditional navigation, manual handling and emergency response skills that have characterized life on board for decades.

On the other hand, digitalization promotes increased transparency in terms of operational oversight, which is generally beneficial from a safety and Safety Management System (SMS) perspective, but can also raise concerns among crews, who may feel that they are under constant surveillance or subject to constant remote assessment by auditors or inspectors on the ground.

This context calls for an urgent regulatory update of both the ISM Code and ships' SMSs, balancing technological innovation with clear procedures, specialized training and a strong safety culture that always puts the human factor first. This is the only way to ensure that this digital transformation does not compromise but enhances the fundamental objective of the ISM Code: the protection of human life, ships and the marine environment. This digital transformation is changing the way ships operate and manage their operational safety.

Finally, the future outlook presents additional uncertainties related to the gradual introduction of autonomous ships. This raises questions for crews about job stability, the gradual reduction in the number of crew required on board and the radical transformation of the traditional role of the seafarer. In this context, it is crucial that the maritime industry and international administrations proactively address these concerns through clear digital transition policies, ensuring that technology serves to enhance rather than undermine the essential and ever-needed role of the human factor in maritime safety. We are sailing into a new era of maritime professionals.

2. The impact of digitalization and cybersecurity on safety management.

The integration of digital technologies and new cybersecurity paradigms has significantly reshaped the requirements and implementation of the International Safety Management Code (ISM Code). This framework, designed to ensure operational safety and pollution prevention, faces unprecedented challenges and opportunities arising from the digital transformation of the maritime sector.

Initially focused on traditional operational and environmental risks, the ISM Code has incorporated cyber risk management as an essential component. IMO Resolution MSC.428(98), adopted in 2017, states that safety management systems should include regular information technology (IT) and operational technology (OT) vulnerability assessments. This means that companies must document specific policies for controlling access to external networks and devices, updating firmware and navigation systems, and segregating critical networks to prevent intrusions. A BIMCO survey found that 68% of ships are operating with outdated systems, requiring enhanced internal audits to verify compliance with these new guidelines.

Therefore, the roles and responsibilities of crew members, such as the reformulated Cyber Security Officer (CSO), which has emerged as a complement to the traditional ISM Code Designated Person (DPA). While the DPA oversees the overall system, the CSO focuses on the implementation of controls such as firewalls, SGS authentication and data encryption. This change reflects the need for technical specialization, supported by certifications such as ISO/IEC 27001 for Information Security Management Systems. This requirement leads to updated training and auditing procedures. Training programmes under ISM now include mandatory modules on operational cybersecurity. An example is Bureau Veritas' ISM Code internal auditor courses, which include simulated attacks, ransomware and data recovery techniques. This is in addition to knowledge of contingency plans for cyber incidents or the implementation of security patches in ECDIS and propulsion systems. The integration of new technologies, such as artificial intelligence, with predictive algorithms for engine maintenance must be validated under

ISM Chapter 12, which requires all critical equipment to have documented operating and emergency procedures.

However, there are now regulatory harmonization challenges as the overlap between regulations such as the ISPS Code and ISM creates complexity. While ISPS focuses on physical protection against external threats, ISM extends its focus to digital resilience. However, there is overlap: both require inventories of OT systems and remote access policies. Code Resolution MSC.428(98) has reduced this fragmentation by stating that cyber risks should be managed through the existing SMS (ISM Code) to avoid duplication. However, leading companies such as Maersk have adopted additional standards (e.g. NIST Cybersecurity Framework) to go beyond the minimum requirements.

The evolution of the ISM Code reflects the synergy between operational and digital security. Digitalization has not only introduced new risks, but also the tools to proactively manage them. The success of this transition depends on public-private collaboration to standardize protocols, investment in R&D to update these outdated systems, and a holistic approach that integrates technical, maritime and digital skills in crews.

In this scenario, the ISM is no longer a static framework but a dynamic ecosystem, where continuous improvement (PDCA cycle) is applied to both diesel engines marine and machine algorithms learning. The crews of the future, equipped with devices IoT and trained in virtual reality, will incorporate this fusion of maritime tradition and cutting-edge technology.

3. The Impact of digitalization on Ships' Crews: Operational transformation and emerging challenges.

We would agree that we are facing a huge challenge in the digitalization of shipping, and therefore of ships, and that the impact on crews is an issue major. Digitalization is transforming working conditions at sea, with both positive and negative effects. Thus, the positive effects on crews go hand in hand with increased safety and reduced human error. In terms of navigational safety and bridge guards and engine, we now have modern warning systems and monitoring real-time of equipment and systems on board, which minimize the risks of maritime accidents, reducing the manual workload and improving decision-making.

Digitalization in the maritime sector represents a transformative duality for crews. On the one hand, it frees professionals from repetitive tasks, improves operational safety and opens up opportunities for more specialized technical skills. On the other hand, it requires continuous adaptation to new tools, cybersecurity protocols and human-machine collaboration models. Today's crews must prepare for an increasingly near future in which they will have to balance traditional maritime skills with advanced digital skills, while retaining the ability to make critical judgements and decisions in the face of automated systems. In this new ecosystem, the human factor remains irreplaceable, but its value is being redefined in line with the smart technologies that are reshaping the global maritime industry. The success of this transition depends on comprehensive strategies that combine technological investments with tailored training programmes and customized human resources.

Maritime operations on ships are being radically redefined by the age of digitalization, with profound implications for ship crews. From the automation of administrative tasks to the integration of artificial intelligence (AI) systems and augmented reality. Professionals in the industry have always faced a constantly evolving landscape, but not on this scale. These technologies are transforming the day-to-day tasks of crews, improving operational efficiency and safety, but also posing new challenges in terms of workforce adaptation, cyber risk management and redefining technical skills, ushering in a new era of maritime professionals.

4. The challenge is to ensure that digitalization improves safety without compromising operability and without displacing crews.

Operational safety and Safety Management Systems (SMS) in maritime transport are evolving to adapt to the new realities of the 21st century, especially in the face of increasing digitalization and automation. But here are the big questions as to what the ideal strategy should be. On the one hand, we could move towards total digitalization with crew reduction or, on the other hand, towards hybrid digitalization with adapted crews. On the one hand, we might think that technological advances will make the presence of large crews unnecessary on some ships. With process automation, artificial intelligence and remote navigation, autonomous or minimally manned vessels could become the norm. There would be a greater impact on operational safety, such as with MASS (Maritime Autonomous Surface Ships), with more precise navigation, less human error thanks to high-precision sensor systems combined with AI, minimizing fatigue accidents, as current crew members work in harsh conditions, which, according to statistics, are behind 75-96% of maritime accidents due to human error, and automation could reduce all of this, together with better emergency management with continuous monitoring systems that can anticipate failures or emergency situations before they become critical. On the other hand, there are other challenges, such as vulnerability to cyber-attacks, as an autonomous ship could be digitally hijacked, or the lack of human decision-making in crises, as AI cannot always foresee unforeseen situations such as rescues at sea, evacuations on board, and finally, there would be massive maritime unemployment of thousands of crew members if the world fleet is finally automated.

On the other hand, we could pursue a hybrid digitalization strategy with an adapted crew. Instead of minimizing crews, a hybrid digitalization could be implemented, where digital systems complement the work of seafarers without completely replacing them. The result in terms of operational safety would be better decision-making, as officers would use AI systems to anticipate risks, but with a 'plan B' in case of technological failure, with a better resilience or process to adapt to the threat of cyber-attacks, as digital attacks have less impact with humans overseeing the systems. And, of course, there would be a better transition of jobs, encouraging seafarers to specialize in digital maintenance, cybersecurity and data analysis management and

this is something that the IMO regulation on maritime cybersecurity (MSC- FAL.1/Circ.3) has shown how digital technology can be used to reduce risks without eliminating the human asset. However, it should also be noted that, on the other hand, there will be high costs in training plans to train crews in new technologies, as well as resistance to change, as a large number of traditional seafarers currently reject this change towards digitization, in addition to the increase in digital responsibilities on board, as crew members will have to ensure both physical security and cybersecurity.

The question then arises as to what is the ideal balance in the maritime sector today, and more specifically on board ships. Should ships operate with minimal manning and a high degree of automation, or does maritime safety require a hybrid model where manning still plays a key role? My position is that digitalization should complement manning, not replace it completely. But the reality is that the global trend is to reduce the number of crew on board, and it will be up to each shipping company to adapt to a different strategy, possibly influenced by the maritime business and national and international regulations and commercial requirements.

The idea of turning seafarers into digital technicians is a major cultural and professional change, and although it seems to be the trend, there are still many regulatory and operational gaps to be filled, especially with regard to operational safety and safety management systems (ISM Code).

5. Digital Integration in Safety Management Systems, the "ISM 4.0" and "ISM 5.0".

The concept of Industry 4.0, also known as the Fourth Industrial Revolution, is defined as the comprehensive transformation of the industrial environment through the integration of advanced digital technologies. This transformation aims to create smart factories, more efficient, flexible and adaptive production processes, and a highly interconnected business environment.

The evolution of the ISM Code towards a 4.0 model represents a strategic response to the convergence between traditional operational security and the emerging challenges of the digital age. The technological advances described in Maritime Industry 4.0, such as the Internet of Things (IoT), artificial intelligence (AI) and real-time data management, are redefining the compliance parameters of the ISM, requiring an adaptation Code comprehensive that integrates cybersecurity, technological and advanced human capabilities.

The term "ISM 4.0" is not an official concept recognized by the International Maritime Organization (IMO) in relation to the International Safety Management Code (ISM Code). However, in various forums and discussions within the maritime industry, "ISM 4.0" is used to describe the evolution and adaptation of the ISM Code in response to technological developments associated with Industry 4.0.

The IMO Resolution MSC.428(98) has been a key catalyst in establishing that cyber risks must be managed within the Security Management System (existing). This approach SMS comprehensive means that companies must not only ensure the physical integrity of ships, but also protect their OT (operational technologies) and IT (information technology) networks through protocols such as IEC 62443 and standards such as ISO/IEC 27001712. For example, the implementation of firewalls in ECDIS systems and the segregation of critical networks are now implicit requirements in audits ISM Code .

The ISM 4.0 is characterized by its ability to operate under a continuous improvement cycle, where automated data collection concept , using sensors IoT and digital twins, allows for the identification of operational and environmental risks in real time. Platforms such as "SafePort", used in Spanish ports, illustrate how predictive simulation and analysis big data optimize decision-making, reducing emergency response times by 30%. However, this model requires updating the ISM certification criteria to include periodic evaluations of technological resilience, beyond physical inspections or audits conventional . In short, ISM 4.0 is not a mere regulatory update, but a paradigm that redefines the relationship between technology, safety and the human factor in the maritime domain. Its success will depend on the ability of crews to balance reliance on automated systems with expert critical judgement, ensuring that digital innovation always serves as a complementary tool to, not a substitute for, traditional nautical expertise.

The differences between the ISM 4.0 Code and the Safety Management Systems (SMS) that are implemented and certified under these new digital parameters with respect to the existing traditional ones, are based on a qualitative transformation, integrating the principles of Industry 4.0 and the current cybersecurity demands within the framework of the International Safety Management Code (ISM) Code. This "new and unofficial" Code concept ISM 4.0 is not a mere update, but a paradigm shift that merges traditional operational security with digital resilience, and unlike its predecessors, it integrates cyber security as a central focus, not as an annex. It relies on 4.0 technologies (IoT, AI, blockchain) for predictive risk management, requiring global collaboration, harmonizing IMO standards, IACS and national regulations. It also redefines professional competences, prioritizing digital skills alongside nautical technology. This approach positions the maritime sector to face future challenges, from autonomous shipping to the circular economy, where safety is built on data, not just procedures and manuals.

But progress is so meteoric that Industry 5.0 has emerged as the future of digitalization with a Human and approach sustainable. If Industry 4.0 has marked the digital transformation through automation, the Internet of Things (IoT), Artificial Intelligence (AI) and robotization, Industry 5.0 goes one step further, putting the human factor, personalization and sustainability at the center of technological innovation. Industry 5.0 does not seek to completely replace humans with autonomous machines, but to integrate artificial intelligence with human intelligence to improve safety, efficiency and real-time decision-making. It also introduces a greener approach, prioritizing technologies that reduce environmental impact.

In contrast to Industry 4.0, which emphasized full automation, Industry 5.0 seeks to have humans working in synergy

Table 1: Measurement Model Results.

Aspect	Industry 4.0 in SMS and the ISM Code	Industry 5.0 in SMS and the ISM Code
Safety management approach	Digitalization and automation of safety processes, reducing manual intervention.	Balanced integration between technology and human factors to enhance safety decision-making.
Operational safety supervision	Remote monitoring of safety through IoT sensors and Big Data.	Hybrid supervision with AI collaboration to detect risk patterns and assist human decision-making.
Incident investigation and risk analysis	Analysis of historical data and electronic records to improve accident prevention.	Predictive modeling and digital twins to simulate and anticipate risks in safety management.
ISM compliance audits	Digital and remote audits with Blockchain-record verification, minimizing the need for physical inspections.	Smart audits with AI that perform real-time safety trend analysis and adapt verification protocols.
Emergency management and crisis response	Digital emergency response protocols, integration of virtual drills.	AI-based emergency management systems providing real-time automated responses and assistance to the crew.
Cybersecurity in SMS	Implementation of basic digital protection strategies and access control for ISM systems.	Advanced cybersecurity with proactive threat detection, automated responses, and digital resilience in SMS.
Maintenance and reliability of safety equipment	Predictive maintenance using data to reduce failures of critical safety equipment.	Adaptive maintenance with AI and collaborative robotics that automatically adjust inspection intervals and enhance reliability.
ISM Code documentation management	Digitization of Safety Management System (SMS) Manuals, facilitating remote access.	Interactive and adaptable documentation, with real-time updates based on regulatory changes or new risk detection.
Crew training and competency in SMS	Virtual reality (VR) simulations to train crew in safety scenarios and emergencies.	Training in AI applied to safety, interaction with autonomous systems, and hybrid decision-making in safety management.
Safety culture and incident reporting	Digital platforms for incident reporting, facilitating communication with the company's administration.	Implementation of human behavior analysis and digital ergonomics to enhance safety culture and reduce human errors.
Energy efficiency and sustainability in SMS	Optimization of energy consumption and emission reduction through digital efficiency monitoring.	Integration of ISM standards with MARPOL and environmental regulations, applying AI for real-time emission reduction.
Improvements in interaction with maritime authorities	Real-time ISM compliance communication with maritime administrations through digital records.	Interoperability between vessels, companies, and administrations with integrated safety management systems and automated reporting.

Source: Authors.

with machines. Human-machine collaboration. AI does not replace the operator, but assists him and enhances his analytical and decision-making capabilities. In the maritime sector, this means that Safety Management Systems (SMS) will be able to dynamically adjust according to ship type, cargo, operating conditions and crew. But in addition, sustainability and reduction of environmental impact and energy efficiency are key, with stricter regulations to minimize carbon footprint. Industry 5.0 is already driving alternative fuel technologies, eco-efficient autonomous vessels and reduced CO2 and Sulphur oxides (SOx) emissions. Cybersecurity and digital resilience will also be vital. With the enormous connectivity of the maritime sector, the risks of cyber-attacks on critical systems are increasing. Industry 5.0 reinforces digital security with advanced cybersecurity protocols, blockchain and quantum technologies to protect data and operations.

The maritime sector is evolving rapidly and the ISM Code will have to adapt to the new trends of Industry 5.0, where there are several areas to consider:

- Management Safety in Smart Ships. The new digital and autonomous ships will require tailored safety procedures, adapted to their level of automation and interaction with the crew. Intelligent procedures will need to be implemented within the SMS, adjustable in real time according to weather conditions, cargo or sea traffic. Hybrid safety systems will be used, where AI and crew work together to make decisions.
- Crew training, education and skills. Industry 5.0 will not eliminate manning, but will require a new generation of seafarers with skills in digitalization, AI and cybersecurity. Professional bridge and engine officers will be re-

quired to operate advanced predictive maintenance systems. Virtual reality and simulation training will be enhanced to prepare crews to operate in fully digital environments.

- Digitized audits and certifications. ISM audits and integrated management systems (ISO 9001, 14001, 45001 and 50000) will be 100% digital with a blockchain of records. Real-time audits will be introduced, allowing inspectors to automatically verify the safety status of the ship without the need for a physical visit.

- Alternative fuels and emission reduction. Industry 5.0 promotes the use of hydrogen, biofuels and green ammonia to reduce dependence on fossil fuels in shipping. The ISM Code should include specific safety measures for the handling of new fuels, optimizing the current procedures of the ISM Code and the IGF Code.

Ultimately this new ISM 5.0 will not replace maritime safety , but it will radically transform it. The key will be how to integrate new technologies without losing human oversight management and undoubtedly the evolution of the ISM Code will have to contemplate personalized and AI-based safety management, the new model of digital audits and real-time remote, advanced training for crews in cybersecurity and automation, and procedures within the SMS of each shipping company and ship, adjusted to the new fuels and hybrid propulsion systems.

The following comparative table shows the improvements that Industry 4.0 and Industry 5.0 can bring to Safety Management Systems (SMS) implemented in shipping companies and vessels according to the ISM Code.

The need to work in this way should be seriously considered by the IMO, not as a simple update of the current code, but as a comprehensive restructuring that reflects the reality of maritime safety in the age of automation and advanced digitalization. The evolution of shipping requires a modern regulatory framework, where artificial intelligence, cybersecurity, adaptive training, digital auditing and sustainability are key pillars of safety management.

The SOLAS Convention, as the most important regulation for the safety of ships and human life at sea, needs to be reviewed and updated:

- Chapter II-1: Construction - Structure, Watertightness and Machinery. It is necessary to include requirements for autonomous and digital machinery management systems, ensuring the reliability of IoT sensors, predictive maintenance and manual redundancies in critical systems.

- Chapter III: Life safety equipment and measures. Requirements for emergency drills, automated evacuation and abandonment equipment, training in virtual reality (VR) and augmented reality (AR) environments should be modernized to improve crew preparedness and training.

- Chapter V: Safety of navigation. Navigation is evolving with AI and autonomous systems. SOLAS should include provisions for the safe operation of remotely operated and autonomous vessels, regulating the interaction between humans and AI-based control systems.

- Chapter IX: Management of the safe operation of ships. This chapter already introduces the ISM Code, but should be revised to include the digitalization of ISM audits, operational cyber security, artificial intelligence in safety decision-making and hybrid models of compliance verification and real-time certification.

- Chapter XI-2: Measures to enhance maritime security. With the increasing threat of cyber-attacks on navigation and cargo systems, it is imperative that SOLAS includes cyber-security guidelines in operational security.

The MARPOL Convention, which regulates ship-source pollution, needs to be revised to address the challenges of digitalization, energy efficiency and alternative fuels. Aspects of MARPOL that need revision:

- Annex VI: Prevention of air pollution from ships. Specific safety protocols should be established within the ISM Code for the management of alternative fuels such as hydrogen, green ammonia and biofuels. Real-time digital monitoring of greenhouse gas (GHG) emissions, energy efficiency management systems (SEEMP), digital monitoring of fuel consumption to meet IMO decarbonization standards, including digital energy efficiency audits and compliance with the new Carbon Intensity Indicators (CII) and EEXI.

The STCW Convention, which regulates the training, certification and watchkeeping of seafarers, is a fundamental pillar of maritime safety, but their skills need to evolve to operate in digitalized, cyber-secure environments and with autonomous systems. To this end, it needs to be updated:

- Cyber security and digital risk training. It is imperative that officers and crew receive mandatory cybersecurity training, including incident management, recovery of critical systems and data protection.

- Training in autonomous systems management and AI navigation, including training modules on artificial intelligence applied to navigation, autonomous ship management and oversight of machine based system learning.

- Certification in digital audits and operational data analysis. As ISM audits become more digitized, crews will need to be specifically trained to monitor and control digital records to ensure that ships comply in real time.

- Promote the use of virtual reality and simulation. STCW should incorporate virtual reality and augmented reality environments for emergency training and decision-making in highly digitized scenarios.

The Maritime Labour Convention (MLC). Crew welfare is an essential component of maritime safety and digitalization must not lead to operational overload for seafarers. The Maritime Labour Convention (MLC 2006) of the International Labour Organization (ILO) should be revised to include the effects of automation on crew fatigue, workload and adaptation to new systems, such as:

- Impact of digitalization on workload and fatigue. Automation should not lead to an excessive reduction in manning levels, resulting in increased operational pressure on seafarers. Digital workload limits and rest protocols should be established. adapted to the supervision of autonomous systems.
- Working conditions on highly digitized ships. There is a need to ensure that seafarers are adequately trained in the use of advanced technologies, without overburdening them with responsibilities not foreseen in their original role.
- Protection against technological stress and digital overload. The ILO should establish support mechanisms for the digital transition in the maritime industry to ensure that seafarers do not suffer from technological stress or burnout due to the complexity of new systems.

Conclusions.

The evolution of the ISM Code in the context of digitalization and new technologies represents a turning point in maritime safety. For decades the ISM Code has been the regulatory basis for the management of operational safety on ships.

It has ensured the implementation of structured procedures, rigorous audits and a safety culture that has significantly reduced the number of accidents in shipping. However, the advent of Industry 4.0, and more recently the transition to Industry 5.0, has introduced a new paradigm in which automation, artificial intelligence, the Internet of Things and cybersecurity not only optimize operations, but also completely redefine the way safety is managed, verified and audited in the maritime sector.

Digitalization has transformed safety management on board by introducing advanced systems that enable real-time monitoring of ship conditions, predictive maintenance of equipment, automatic verification of regulatory compliance and optimization of emergency response. The introduction of IoT sensors and data analysis using artificial intelligence has created tools that reduce crew workload and improve the ability to detect failures and risk situations at an early stage. However, this evolution also poses significant challenges in terms of technology dependency, the need for new crew skills and cybersecurity as a new threat front. Automation has led to a progressive reduction in manning levels on board, which has implications for direct human supervision and the need to ensure that safety procedures remain effective even with reduced crew intervention.

One of the most critical aspects of this change is the verification of ISM Code compliance in an environment where traditional on-site audits are no longer sufficient. Digital and remote audits have emerged as an innovative solution to assess the ship's status in real time, review records stored in blockchain and ensure the inalterability of maintenance and safety data. However, it remains essential to complement these processes with targeted physical inspections, functional testing of equipment and hands-on crew assessments, ensuring that reliance on automated systems does not compromise effective emergency response. Crew remain the key element in maritime security, but their role has changed dramatically; instead of performing repetitive manual tasks, officers and seafarers must be prepared to interpret digital data, monitor automated systems and react to technological failures or cyber-attacks.

Equipment maintenance and operability is another key focus in the modernization of the ISM Code. While sensors and artificial intelligence have improved early fault diagnosis and optimized maintenance planning, manual inspection of critical equipment remains a necessity to ensure the reliability of safety systems. The implementation of drones and thermal cameras for structural inspection, as well as continuous verification of operational parameters through cloud-based data analytics, represent advances that facilitate the identification of problems before they become catastrophic failures. However, the key question remains to what extent these advances can replace human intervention and whether the ISM Code should incorporate regulations mandating manual redundancies in all critical on-board systems.

On the horizon, Industry 5.0 poses a new challenge for maritime safety, introducing a model in which technology does not seek to replace the human factor, but to work with it to improve decision-making and optimize operational efficiency. The ISM Code will have to adapt to a scenario in which ships are more autonomous, management systems are intelligent and personalized and sustainability becomes a fundamental pillar of maritime transport. The inclusion of alternative fuels such as hydrogen, green ammonia and LNG will introduce new risks that will require updates to safety protocols and crew training for the handling of these substances. The convergence of comprehensive management systems based on ISO standards and the ISM Code will allow better harmonization of safety, quality and environmental standards and ensure a more efficient integration of digitalization in maritime operations.

The implementation of real-time audits and continuous verification of ship status through digital platforms will shape the future of the ISM Code. The reliability of these systems will depend heavily on cybersecurity, as automation and interconnectivity increase vulnerability to cyber-attacks that could compromise the safety of navigation. Crew training in digital security will be as important as their training in traditional emergency procedures. The ISM Code will need to evolve to include specific requirements for data protection, cyber incident management and recovery protocols for digital systems.

For the ISM Code to remain relevant in the digital age, it is essential that the IMO and ILO review and update key regulations to ensure that maritime safety evolves with digitalization, automation and sustainability.

Finally, the IMO must modernize SOLAS, MARPOL, STCW

and MLC to ensure that maritime safety not only keeps pace with technology, but also maintains a balance between digitalization, efficiency and the human factor. Without a comprehensive update of these regulations, the development of the ISM Code will be outdated in the face of the challenges and opportunities presented by Industry 5.0 in the maritime sector.

The main challenge is to find the right balance between technology and the human factor. It is not about replacing traditional oversight with automated audits, but about developing a hybrid model where digitalization improves efficiency without losing human control in safety management. Automation and artificial intelligence can reduce the administrative load and improve the accuracy of risk identification, but decision making in critical situations still requires human judgement and expertise. The evolution of the ISM Code must ensure that the transition to Industry 5.0 does not compromise safety, but enhances it through the integration of advanced tools, more rigorous verification protocols and a new maritime training model that prepares professionals to operate in a highly digitized environment.

In short, the ISM Code is facing the biggest change since its introduction in 1998. Digitalization is not an option but a necessity, but its success will depend on how it is integrated with existing procedures, Safety Management Systems (SMS) and without weakening crew responsiveness. The key to the future of maritime safety lies in a strategy of gradual adaptation in which technology is used to enhance the human factor, not to replace it. This is the only way to ensure that shipping continues to operate at the highest standards of safety, efficiency and sustainability in the age of automation and artificial intelligence.

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