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Research Article

Integration of Smart Monitoring Systems in Marine Engineering: A Management Approach to Edge Computing and Sensor Technologies

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ABSTRACT

This study aimed to investigate how these smart monitoring technologies can be effectively implemented in marine engineering practice through a structured, management-oriented approach. The study utilized a descriptive-correlational approach with the participation of selected 106 marine engineering personnels within the Philippines. The study was focused on human resource and competency development, process optimization, system integration management, and project implementation supervision among maritime companies in the Philippines. The study used various statistical methods to analyze the profile of the respondents and evaluate the identified problems and best practices such as frequencies, percentages, and weighted means. The Pearson Product-Moment Correlation Coefficient (r) was employed to test the relationship existing between the level of difficulty and change in the best practices in the four major areas. The results indicated that the project implementation monitoring was the most difficult with the mean of 3.13, whereas system integration management was the least with the mean of 2.42. The management's best practices regarding system integration received the highest score of 3.50, which is significant for the technology's integration effectiveness. Although the issues of human resource and competency development showed weak and insignificant correlations with the related best practices, several other areas, especially system integration management, process optimization, and project implementation oversight, showed stronger correlations This means that when difficulties arise in these areas, the organization will be more willing to adopt flexible, effective best practices to maintain operational performance and promote the successful adoption of technology in maritime engineering operations. This indicate that it is essential to perceive challenges as the opportunity to enhance the operational performance and promote the usage of intelligent monitoring systems. It emphasizes the importance of talent development programs, structured integration frameworks, and strategic project

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management for maximizing the benefits of innovative technology in the Philippine marine engineering industry.

***Keywords**: Smart Monitoring Systems, Marine Engineering, Sensor Technologies, Management Approach, Maritime Operations, Technology Integration*

Rationale

The maritime industry is significant to the global economy and the foundation of global trading. According to Rodrigue et al. (2022), 70 percent of the value and 80 percent of the international trade volume is attributed to the marine routes. This shows that the maritime route is important in maintaining international trade. Competitiveness by shipping firms in marine industry is also on the increase as they focus on offering faster and more dependable, and cheaper transportation. According to Arias et al., (2021), it is already becoming digitalized as the demands of consumers to be more sustainable, efficient, and safe are growing. Majority of the marine engineering today that has been based on mechanical systems and human judgment, is now integrating the latest sensor technology to enhance operational efficiency. These improvements are changing the manner in which the maritime operations can be carried out and offers real-time insights and data-driven decisions (Chen, 2024).

Moreover, the integration of smart monitoring systems is changing with their introduction. Such systems enable the real-time monitoring of ship and equipment, as well as the key on-board system. These provides an actionable information, which helps to make decisions based on data and take proactive maintenance (Ferreira and Martins, 2019). Smart monitoring systems can calculate the anomaly by collecting and processing big amounts of data onboard equipment sensors, preventing equipment failures and optimizing the processes, which results in improved seaworthiness and safety. Such systems are edge computing which permits local processing of data on ships to facilitate prompt response to variations in the operation a central attribute in remote maritime environments. It addresses important parameters all the time, fuel consumption, engine performance, emissions, and water quality and ensures the optimization of the performance and the adherence to the regulations. Ficili et al., (2025), believe that such technologies provide information that decreases downtimes, makes better use of the resources, and fosters predictive maintenance. The implementation of these innovations is very challenging regardless of their potential. The primary problems that should be addressed included the risk of cybersecurity attacks, multifaceted data management, system compatibility, and unskilled staff. According to Durlik et al., (2023), introduction of edge computing and sensor technologies requires proper project management, strategic leadership and flexible workforce that is able to adjust according to new technologies.

This study aimed to investigate how edge computing and sensor technologies can effectively integrate to realize the maritime engineering industry. The emphasis will be put on the following areas: system integration management, process optimization, human resource and competency development, and project implementation oversight. These dimensions will help the study to guide the maritime companies to realize the potential of the intelligent monitoring systems as well as address the operational, technical and human components of digitization transformation in a proper manner.

Theoretical and Conceptual Framework

This section explains the fundamental theories that support the study. The variables considered in the study included system integration management, process optimization, human resource and competency development and project implementation oversight. These variables were investigated using three primary theoretical perspectives: Socio-Technical Systems Theory, Theory of Constraints, and Systems Theory.

Socio-Technical Systems Theory

The Socio-Technical Systems (STS) Theory offers a powerful paradigm for understanding the interplay between technical and social networks in firms (Trist, 1981). It argued that organizational innovation was only a viable practice when social and technological subsystems were synchronized (Carayon, 2015). The most innovative and hi-tech technical solutions will never provide guaranteed benefits until they are correlated with the work processes, interactions among the team members, the corporate culture, and the place of a human being. In the field of marine engineering, predictive maintenance, real-time safety warnings, and fuel optimization are just some of the valuable benefits that can be achieved through the use of intelligent monitoring systems, including edge computing devices. The ability of edge computing on board a ship is not limited to the data processing effects, but the capability of the crew to believe in what can be offered by the data and apply it to the implementation of new technologies (Ferreira and Martins, 2019). The system may be used badly without training the crew members since workers do not know everything about it and its advantages, and, in fact, they may tend to resist it because of being afraid to lose their jobs, work harder, and have less control over the processes (Mestrovic, 2024). These human factors can undermine the performance of the maritime company's technological investments.

Moreover, organizational-level factors such as leadership style, communication channels, job redesign, and incentive systems should also adapt to new technologies. This serves as a reminder to marine practitioners that digital transformation is not a mere technical development. However, the nature of the change is the alteration of how people work, how they make decisions, and how they interact with the environment (Theotokas et al., 2024). Change outcomes cannot provide long-term benefits unless the technical and social aspects of change are put into consideration when undertaking integration efforts (Ojukwu and Bednar, 2020). This will be a repeat of the necessity of organization as well as the introduction of technology and employee engagement, training, and change management strategies. It is also a holistic basis of marine industry regarding safety, compliance, and collaboration which is major in developing integration strategies that are technically feasible and socially sustainable.

Theory of Constraints

Theory of Constraints (TOC) is a systems-based management philosophy that aims to find, manage and keep on improving the one most important constraint to the total system performance (TOC Institute, 2024). It aims at determining the biggest bottleneck in a system, which must be continuously reinforced, as augmenting the areas that do not constrain the system does not benefit much (Luiz et al., 2025). TOC promotes constant improvement and makes sure that the funds of the organization are re-focused on the spheres with the greatest influence. It is a five-step process that goes through several steps, which include identifying the constraint, maximizing its capacity, coordinating other processes to assist it, improving it, and transferring the process to the emerging constraints (Chamrada and Kollmann, 2023).

Theory of constraints (TOC) has emerged as an important and strategic tool in the marine engineering field in identification and removal of serious constraints to efficient management of the marine sector. These limitations may involve human factors, which can be limited technical knowledge or resistance to change, absence of real time analysis processing capability or bandwidth on an on-board device or an antique legacy system that cannot be linked to existing technologies. The capabilities of the human resource have been actually mentioned as the first or the primary constraint among these potential barriers as the lack of highly trained and experienced staff members will result in the inability of the most advanced digital tools to operate efficiently (Cox, 2021). It is worth noting that the digital transformation in the maritime industry can be carried out successfully only with the help of specific training, upskilling, and change management solutions. With the advent of digital systems as the focus of many operations, digital capabilities demanded amongst the employees of many maritime businesses are wanting, which poses a human resource bottleneck (Bhardwaj, 2023). The most desired expertise in the staff in the maritime sector includes automation, robotics, cybersecurity, and IT-related skills, and the Theory of Constraints encouraged special training and development efforts. Technical mismatch integration barriers can be solved with the aid of supported solutions. This makes sure that the execution strategy was kept in track, and the resources were not wastage in the non-constraining areas.

Systems Theory

Systems Theory emphasizes the interactive aspects of people, organizations, and technologies as interrelated parts of a greater whole (von Bertalanffy, 1968). The theory is concerned with the relations among systems, which promotes the holistic approach that creates the complexity of subsystems in a broader context and their mutual dependency. It is concerned with systems-level interactions and inter-systems interactions, promotes a holistic view, also taking into account the boundaries of a system, interrelations, interactions, and emergent behaviors (Won and Kim, 2023). A system has its external environment, which is defined by boundaries, distinguished by boundary of the system and defines the inner components and interactions of the system. Interrelatedness emphasizes the idea that the elements of a system are mutually affecting and dependent, such that a phenomenon in one element may spread to other elements of the system affecting the performance and behavior of other elements (Kunc, 2024). The concept underlines the significance of being integrated in the management and the analysis being holistic because any form of action will have unpredictable consequences to the rest of the system.

Furthermore, the system should also be considered as a whole, as the dynamics between its components develops emergent properties that are greater than the dynamic of their components. The Systems Theory concentrates on how the different levels of the surrounding influence human growth (Sheerin et al., 2023). It offers an optimistic approach regarding the interaction and cooperation between the technical, organizational, human, and ecological subsystems in order to attain the successful integration of new monitoring systems (Selin & Selin, 2022). It is impossible to achieve such integration without not only the technology itself but also the crew preparation, compliance with the regulations, the organizational culture, and conditions of the environment. The introduction of edge computing can have an impact on the work processes, communication lines, or compliance processes within the system. It was used to assess the dynamics of management, technology as well as human behavior in effective integration endeavors.

Theoretical Framework

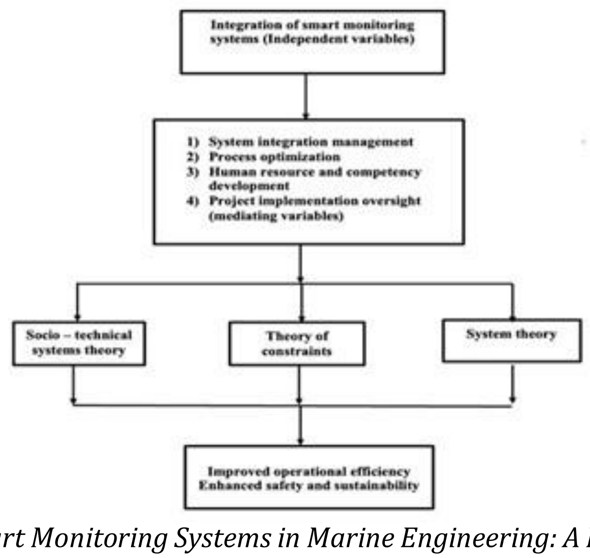

Figure 1. Integration of Smart Monitoring Systems in Marine Engineering: A Management Approach to Edge Computing and Sensor Technologies

Research Objectives

This study aimed to determine the level of integration of smart monitoring systems in marine engineering and to learn how these technological advancements were perceived and potentially adopted by the industry.
Specifically, it endeavored to answer the following specific inquiries:

1 What is the demographic profile of the respondents in terms of:
  a. Role in Organization
  b. Length of service in the maritime industry
  c. Size of Organization
  d. Actively using smart monitoring systems in operational activities
2. What challenges and best practices currently affect smart monitoring systems in marine engineering, in terms of:
  a. System integration management
  b. Process optimization
  c. Human resource and competency development
  d. Project implementation oversight
3. Is there a significant relationship between current challenges and best practices associated with smart monitoring systems across the four identified areas?
4. What strategic actions can be implemented to advance human resource capacity and boost technical readiness in support of intelligent system adoption within the maritime industry?

Statement of the Null and Alternative Hypotheses

The following hypotheses were subjected to tests at a 0.05 level of significance:

HO1: There is no significant relationship between the current challenges and best practices in smart monitoring systems across the four identified areas.

H11: There is a significant relationship between the current challenges and best practices in smart monitoring systems across the four identified areas.

Methods

Design

This study utilized a descriptive-correlational research design to investigate the integration and management of smart monitoring systems and edge computing, in marine engineering industry operations in the Philippines. The design was adequate to establish the current state of affairs, the current practice and the relationship between important variables such as the system integration management, process optimization, human resource development, and the project implementation oversight. A quantitative survey with structured Likert-scale questionnaires was conducted among selected marine engineers from various maritime companies, port authorities, and technology service providers. In order to determine and to assess technology adoption, management strategies, staff competency, and operational effectiveness among the respondents. Quantitative data were analyzed using descriptive and correlational statistics, including Pearson's correlation.

Respondents

The study was conducted among marine industry professionals working in various maritime-related organizations in the Philippines. From a total population of 144, a sample of 106 respondents was selected.

The following are the inclusion criteria was considered in this research:

1. must be a bonafide maritime professionals engaged in smart monitoring and edge computing technologies in the Philippines
2. must be of legal age;
3. must have been employed for a minimum of one year;
4. willing to participate; and
5. Provide voluntary consent.

Those who fail to fit within the bounds of the inclusion criteria are considered to be excluded from the conduct of this research.

Environment

This study was conducted within the context of marine engineering operations in Cebu, Philippines. The research environment included selected maritime companies, port authorities, and technology service providers involved in marine operations nationwide. These institutions represent a range of operational environments where innovative monitoring systems and edge computing technologies are being explored or adopted to improve efficiency, safety, and sustainability. Cebu provides a strategic backdrop for this study due to its archipelagic geography, which necessitates advanced marine infrastructure and effective vessel management systems.

Data Gathering Procedure

The researcher sought the permission from the Dean of Graduate Studies for Engineering and clearance of the research ethics by the Research Ethics Committee prior to undertaking the study. The participating marine companies were asked for permission, and all respondents provided informed about the objectives of the study, confidentiality and voluntariness. Data were collected electronically through online survey platforms such as Google Forms, supplemented by virtual meetings via Zoom or Google Meet for clarification. Upon completion, responses were organized, tabulated, and statistically analyzed with the assistance of a qualified statistician. The findings were given in tables and graphs in accordance with the objectives of the study.

Data Analysis

The study employed the following statistical treatments:

Simple frequencies and percentages were utilized when it comes to profile information of the respondents. The focus on the central tendency and variability of responses to the level of system integration, process optimization, human resource competency development, and project implementation oversight was also determined using the weighted mean. These questions gave a good picture of the degree of challenges and best practices that the respondents had to deal with. To have a more detailed analysis, inferential statistics were used to test significant differences and associations among variables. Also, Pearson Product-Moment Correlation Coefficient (r) was employed in order to test the correlation between challenges and best practices in smart monitoring systems. The objective of this treatment was to determine the existence of correlation between augmentations in difficulties and a subsequent addition in best practice in the four categories that were identified.

All statistical works were done through proper statistical programs under the supervision of a trained statistician to ensure that the results are accurate, reliable, and interpreted properly. The data under analysis were represented in tables and graphs to be able to present the results of each particular sub-problem of the research visually, in a structured manner.

Scoring Procedure

Table 1. Scoring Procedure

Scale	Range	Descriptive Equivalent	Interpretation Equivalent
4	3.25 – 4.00	Strongly Agree	The respondent strongly agrees that addressing challenges and best practices is vital for effective smart monitoring system integration.
3	2.50 - 3.24	Agree	The respondent agrees that addressing challenges and best practices is vital for effective smart monitoring system integration.
2	1.75 - 2.49	Disagree	The respondent does not agree that addressing challenges and best practices is vital for effective smart monitoring system integration.

Scale	Range	Descriptive Equivalent	Interpretation Equivalent
1	1.00 - 1.74	Strongly Disagree	The respondent strongly disagrees that addressing challenges and best practices is vital for effective smart monitoring system integration.

Results and Discussion

Table 2. Current Role in the Organization

Current role in the Organization	f	Percentage
Marine Engineer	46	43.4
Technical Manager	16	15.1
IT/Systems Specialist	22	20.8
Project Supervisor	20	18.9
Other	2	1.9

Table 2 presents the respondents current roles within their organizations. The findings indicate that the largest percentage of the respondents were the marine engineers, compromising 43.4% of the total population. Marine engineers are the primary responsible for shipyard machinery, system maintenance and troubleshooting. They are the primary focus of intelligent monitoring systems adoption and practical implementation. Their strong influence on the study gives a substantial weight, being able to present first-hand information insights into challenges related to system integration, process optimization and operational advantages or constraints of smart technologies in marine engineering. This aligns with assertion that marine engineers are pivotal in the application and oversight of maritime technologies (Stopford ,2020).

Conversely, smallest portion with a representation of 1.9 % of the of the population belongs to "others". These are individuals whose roles do not directly fall under core operational, technical, or supervisory functions. These professionals who do not directly work within the scope of the main functions of the company, have a minimum role in the process of incorporating smart monitoring systems. Such people can be the administrative staff or ancillary personnel, who are typically indirectly involved with such technologies. This highlights the fact that smart monitoring systems are a more specialized role. Profiling respondents based on their role in the organization is necessary to establish the context of how these professional roles might affect their attitudes and the ability to embrace technological innovations in the maritime industry (Creswell and Creswell, 2018).

Table 3. Years of Experience in the Maritime Industry

Years of Experience in Maritime Industry	f	Percentage
Below 2 years	22	20.8
2 – 5 years	36	34.0
6 – 10 years	34	32.1
More than 10 years	14	13.2

Table 3 shows the years of experience in the maritime industry among the respondents. It shows that between 2-5 years in the maritime industry is the highest with 34.0 % of the total population. This suggest that a high portion of the respondents are still in their early careers. who are nevertheless well exposed to provide relevant insights into current operational practices and the potential integration of smart monitoring systems. Their answers likely reflect the balance between the new information on the modern technologies and the practical experience in the sea.

Meanwhile, only 13.2 % have over 10 years of experience. It indicating fewer highly experienced professionals among the participants. Although they are less in numbers, their views present more profound technical experience and practical skills. Their years of experience in the maritime industry are a significant variable and might influence the perceptions and their willingness to use smart monitoring systems. Mostly they can compare their traditional practices with how the modern monitoring systems works. It raises the importance of management to offer the balance between training and adoption programs among personnel. Gavalas and Roumpis (2022), states that the less-experienced maritime professionals are more open to digital, while highly experienced personnel prioritize the reliability of practice and risk-based adaptation.

Table 4. Number of employees

Number of employees	f	Percentage
1 – 49 (small)	32	30.2
50 – 249 (medium)	38	35.8
250 and above (large)	36	34.0

Table 4 shows that the largest percentage of population having 35.8 % are from medium-sized organizations with 50-249 employees in an organization. This indicates that a significant share of participants comes from companies likely to have a balanced mix of resources, organizational structure, and adaptability.

On the contrary, small organizations (less than 50 employees) take up 30.2% of the total population. This means that smaller organizations may be underrepresented but have higher constraints in terms of financial resources, technical skill and human capital to adopt new advanced technologies like edge computing as well as sensor systems. The findings highlight the importance of considering the organizational size when examining the implementation and management of smart monitoring systems in maritime industry. Categorizing respondents based on organizational size helps to show both the opportunities and the challenges that influence comprehensive and sustainable adoption of a smart monitoring system in marine engineering (Almeida, 2023).

Table 5. Type of Vessel

Type of Vessel	Frequency	Percentage
Cargo/container vessel	56	52.8
Tanker	48	45.3
Other	2	1.9

Table 5 shows that the highest having 52.8 % of the total population operate on cargo or container vessels. This implies that the study reflects the perspectives of the organizations involved in the large-scale cargo operations, where efficiency and monitoring systems are essential. Smaller types of vessels, including non-cargo carriers and tankers, on the other hand, encompass the lowest percentage of 1.9%. This implies that the small-scale operations are less likely to install sophisticated surveillance systems on-board than larger commercial fleets. This could be because of restricted funds, lower technological preparedness or operational priorities.

Further, the above results indicate that the implementation and operation of smart monitoring systems in marine engineering are being perceived more in terms of cargo or container ships. This means that the large-scale commercial shipping is vital to it, whereby efficiency in operations, safety, and real-time monitoring are important. Given that these types of vessels represent the highest number of maritime activities, their views can provide a good understanding of how smart technologies (edge computing and sensor systems) can be introduced to high-demand high-capacity activities. This aligns with digital transformation trends that prioritize high-impact maritime industry (Ferrarini et al., 2025).

Table 6. Number of vessels currently using smart monitoring systems

Number of vessels currently using SMS	f	Percentage
Yes	102	96.2
No	4	3.8

Table 6 above indicates that 96.2 % of the respondents claimed that their organizations already have smart monitoring systems, while only 3.8% responded the opposite. This massive adaptation rate means that smart monitoring systems have become a common practice in maritime industry. This reflects the strong recognition of the industry on the benefits of the systems in terms of system integration management, process optimization, and operational safety. The findings suggests that the maritime sector is shifting towards digital transformation, and smart monitoring as a vital basis. However, the study also identifies the need to establish strategic management methods that would see to it that even the technologies are well incorporated and fully harnessed. It thus enhances safer, tougher and efficient maritime practices. According to Register (2021), digital transformation requires not only advanced technologies but also to organize the institutions of the mechanism of government and training, as well as developing the strategy of managing resources to make everything sustainable in the long term within the maritime industry.

Table 7. System integration management in terms of its challenges

Indicators	Weighted Mean	Interpretation
Our old ship systems are difficult to make work with new ones.	2.58	Agree
The new and old equipment on board can’t share data properly.	2.38	Disagree
Connecting different systems in the engine room takes longer than expected.	2.40	Disagree
Software or system updates cause problems with our work.	2.42	Disagree
We wait a long time for suppliers or service crews to fix system connection issues.	2.32	Disagree
Total Average Mean	**2.42**	**Disagree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that effectively addressing challenges is essential for the successful integration of smart monitoring systems.;
2.50 – 3.24 = The respondent agrees that effectively addressing challenges is essential for the successful integration of smart monitoring systems;
1.75 – 2.49 = The respondent does not agree that effectively addressing challenges is essential for the successful integration of smart monitoring systems;
1.00 - 1.74 = The respondent strongly disagree that effectively addressing challenges is essential for the successful integration of smart monitoring systems;

The results in table 7 above shows that the highest-rated system-integration challenge was " Our old ship systems are difficult to make work with new ones " with a mean of 2.58. This indicates that the respondent finds it necessary to incorporate smart monitoring systems. Respondents therefore see compatibility issues between the legacy and modern systems as the most significant integration challenge. Such incompatibilities complicate modernization efforts and may hinder efficiency. trouble suggests that the shift toward newer technologies is complicated with the help of the outdated equipment, which can slow down the efficiency and deteriorate the results in general.

Conversely, the least rated indicator was “We wait a long time for suppliers or service crews to fix system connection issues”, with a weighted mean of 2.32. It implies that the respondent does not find it important to integrate smart monitoring systems. It means that although there are some technical complications, the waiting periods in the external assistance do not seem to be a serious issue. The comparatively low score can imply that the suppliers or service providers are friendly enough to address the problems quickly in order to reduce the operational stress on the ship personnel.

Moreover, the study’s findings having a total average mean score of 2.42. Indicating that the respondents do not perceive system integration management challenges as highly significant. It means that the modernization process that will prioritize updating outdated systems to ensure smoother integration, reduce interruptions, and improve operational efficiency. Old equipment often lacks digital compatibility, leading to inefficiencies, manual workarounds, and a higher risk of system failures during critical operations. These legacy systems cannot easily align with modern platforms that require seamless data transfer and automation (Venancio et al., 2023; Stephenson, 2021).

Table 8. System integration management in terms of its best practices

Indicators	Weighted Mean	Verbal Interpretation
Our crew follows standard procedures to make different systems work together.	3.49	Agree
We check systems regularly to make sure they work well together.	3.64	Strongly Agree
We inform the right people quickly when integration problems happen.	3.57	Strongly Agree
We test new equipment or systems before using them fully.	3.38	Agree
We share information with suppliers early to avoid connection problems.	3.42	Agree
Total Average Mean	**3.50**	**Strongly Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that best practices are important for effective smart monitoring system integration;
2.50 – 3.24 = The respondent agrees that best practices are important for effective smart monitoring system integration;
1.75 – 2.49 = The respondent does not agree best practices are important for effective smart monitoring system integration;
1.00 - 1.74 = The respondent strongly disagrees that best practices are important for effective smart monitoring system integration.

The above table 8 shows the best practices in integrating a smart monitoring system. The highest-rated indicator in the study was “We check systems regularly to make sure they work well together,” with a weighted mean of 3.64. This implies that the respondent is more concerned with continuous monitoring and preventive maintenance to avoid integration issues. This will lead that the systems reliable and minimizes the chances of disruption occurring unpredictably. According to Bousdekis et al., (2019), predictive maintenance implies regular check-ups and early diagnosis, and it makes the downtime possible and operational risks unlikely.

Conversely, the lowest with a weighted mean of 3.38, as "We test new equipment or systems before fully using them". This shows that there is a high perception of the respondents that the integration of smart monitoring systems is significant. This may mean that this would have gaps in preventive assessment prior to complete deployment, and this may result in the crew being exposed to integration aspect after new equipment is operational. Liu and Wang (2021), emphasize that insufficient testing can lead to system vulnerabilities and long-term integration issues.

Additionally, the total average mean score is 3.50 that shows that the respondents have a high level of commitment to monitoring and coordination. This also shows the need to put more emphasis on pre-implementation testing in order to improve the system integration practices further. Ghosh et al., (2021), observed that that system integration in complex environments, such as maritime engineering, requires precise coordination between multiple systems.

Table 9. Process optimization challenges

Indicators	Weighted Mean	Verbal Interpretation
Unstable internet or network slows down our data reporting or monitoring.	3.11	Agree
Too much sensor data makes our system run slowly.	2.70	Agree
System breakdowns stop us from working efficiently.	3.21	Agree
Mistakes in data entry or reports cause delays.	3.21	Agree
The system sends alerts too late for us to act quickly.	2.53	Agree
Total Average Mean	**2.95**	**Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that process optimization of smart monitoring systems is important.
2.50 –3.24 = The respondent agrees that process optimization of smart monitoring systems is important;
1.75 – 2.49 = The respondent does not agree that process optimization of smart monitoring systems is important;
1.00 - 1.74 = The respondent strongly disagree that process optimization of smart monitoring systems is important.

Table 9 above reveals the problems that arise in streamlining processes by operation of on-board monitoring systems. The most rated challenges were the ones that had a weighted mean of 3.21 and were shown as "System breakdowns stop us working efficiently "and" Mistakes in data entry or reports cause delays". This implies that the optimization of the process of smart monitoring systems is important to the respondent. These findings emphasize that system failures and human factors errors are still the major obstacles to digital efficiency in maritime surveillance. Gausdal and Makarova (2023), emphasize the need for human-centered digital practices and dependable systems.

Conversely, the indicator with the least rating was "The system notifies us too late to respond promptly" with the mean of 2.53. The results shows that the optimization of smart monitoring systems is significant to the respondents. Despite the fact that delayed alerts are also a problem, the respondents did not view them as disruptive to system failures and reporting errors. It implies that, although real-time monitoring contributes to the overall awareness of the work functioning, it is time to concentrate on the reliability of the work and accuracy of the reporting as those aspects are more significant in the overall efficiency of the working process. Decentralized data processing is crucial in the development of the process of enhancing effectiveness and responsiveness. According to Lee et al., (2015), decentralized data processing plays a critical role in improving operational effectiveness and responsiveness, especially within the maritime environment where network reliability cannot always be assured

In addition, the results shows that the total average mean of 2.95 indicates that most respondents agrees that process optimization of smart monitoring systems is important. It implies that such problems as system breakdown and inaccurate data management are a colossal burden to productivity and therefore, should be corrected promptly. It means that the management should be concentrated on the reduction of system downtime and enhance the accuracy of data using its training and maintenance. The unprofessional staff can also be educated on how to process data and investing in efficient system maintenance measures can do a long way in eliminating inefficiencies. According to Sharma (2022), digital optimization must be performed by balancing technological reliability with human expertise.

Table 10. Process optimization best practices

Indicators	Weighted Mean	Verbal Interpretation
We use local controls or tools to process data faster when the network is slow.	3.23	Agree
We perform maintenance before a machine breaks down.	3.42	Agree
We use automation to reduce manual work.	3.43	Agree
We make sure data is clean and clear before sending it.	3.32	Agree
We switch to backup systems when the main system is down	3.47	Agree
Total Average Mean	**3.37**	**Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that process optimization of smart monitoring systems is important.
2.50 –3.24 = The respondent agrees that process optimization of smart monitoring systems is important;
1.75 – 2.49 = The respondent does not agree that process optimization of smart monitoring systems is important;
1.00 - 1.74 = The respondent strongly disagree that process optimization of smart monitoring systems is important.

The table above illustrates the process optimization practices shows that the highest-rated practice was “We switch to backup systems when the main system is down,” with a weighted mean of 3.47). This indicates strong awareness of operational resilience and risk management. The findings indicate that crews pay attention to resilience and risk management in regard to tackling the possible system failures. Zhang et al., (2021), noted that backup systems are critical towards maintaining operational integrity in both maritime and industrial scenarios where downtimes may become great safety concerns and cost-wise damages.

Conversely, the least rated was the practice where" We use local controls or tools to process data faster when the network is slow "with a weighted mean of 3.23. This is to say that optimization of smart monitoring systems as perceived by the respondent is important. This suggests that crews view local controls as temporary solutions and prefer more automated or integrated approaches.

Furthermore, the data in the above having a total average mean of 3.37, indicates a high level of awareness of the significance of process optimization. The emphasis on backup systems is backed up by a strong emphasis on the continuity of operations. The reduced rating of the local controls point to the future orientation of automation and prevention instead of manual options. The lower emphasis on manual controls reflects a preference for automation, consistent with modern digitalization trends (Udeh et al., 2024).

Table 11. Human resource and competency development challenges

Indicators	Weighted Mean	Verbal Interpretation
Our crew lacks enough training to use some monitoring systems.	2.57	Agree
Training provided is not enough to keep up with new technology.	2.64	Agree
Some crew members resist using new equipment or systems.	2.49	Disagree
Many trained people leave, making it harder to maintain skills on board.	2.66	Agree
There is not enough on-the-job coaching or mentoring for new skills.	2.66	Agree
Total Average Mean	**2.60**	**Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that developing human resources and competencies in using smart monitoring systems is important;
2.50 – 3.24 = The respondent agrees that developing human resources and competencies in using smart monitoring systems is important.;
1.75 – 2.49 = The respondent does not agree that developing human resources and competencies in using smart monitoring systems is important.;
1.00 - 1.74 = The respondent strongly disagrees that developing human resources and competencies in using smart monitoring systems is important.;

Table 11 above shows the human resource and competency development challenges faced by the crew when using monitoring systems on board a vessel in the Philippines. The highest-rated indicators were “Many trained people leave, making it harder to maintain skills on board” and “There is not enough on-the-job coaching or mentoring for new skills”, both with a weighted mean of 2.66. The finding suggests that the respondents emphasize gaps in crew retention and training. Mentorship is crucial for developing technical competency and ensuring smooth technological transitions (Brown et al., 2020).

On the other hand, the least weighted indicator was the lowest rated, which is "Some crew members resist using new equipment or systems" with a weighted mean of 2.49. This shows that resistance to change is not a major issue; rather, inadequate training is the more significant barrier. The low score suggests that the crew is generally open to the implementation of new systems. Maritime personnels are willing to engage with digital tools but often lack proper training support (Perera and Bal, 2022).

Furthermore, the results of the study show that having the total average mean is 2.60, indicate that the respondents recognize the importance of developing human resources and competencies in using smart monitoring systems. The maritime industry must strengthen its retention, mentoring, and training programs, as existing gaps limit the crew's ability maximize in using the smart monitoring systems. This shows that the issue is not resistance to technology but the need for sustained skills development and continuous learning. Enhancing capacity building and addressing skill disparities will improve workforce readiness for advanced monitoring systems. As emphasized by Kim and Park (2020), ongoing upskilling and effective knowledge transfer are essential for the long-term success of digital transformation in technical industries.

Table 12. Human resource and competency development best practices

Indicators	Weighted Mean	Verbal Interpretation
Our crew takes part in hands-on training to improve skills.	3.38	Agree
We work with other departments to solve problems.	3.25	Agree
We help each other when someone struggles with technology.	3.37	Agree
We use online or self-study resources to learn new systems.	3.23	Agree
We ask more experienced crew members for guidance on new equipment.	3.46	Agree
Total Average Mean	**3.34**	**Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that human resource and competency development in using smart monitoring systems is important.
2.50 – 3.24 = The respondent agrees that human resource and competency development in using smart monitoring systems is important;
1.75 – 2.49 = The respondent does not agree that human resource and competency development in using smart monitoring systems is important;
1.00 - 1.74 = The respondent strongly disagrees that human resource and competency development in using smart monitoring systems is important;

Table 12 above demonstrates that the human resource and competency development among the respondents to improve their capabilities to use monitoring systems is essential. The highest-rated practice is "We seek advice from more experienced crew members when using new equipment" with a weighted mean of 3.46. It means that the respondent vehemently experiences the understanding that human resource and competency development in the utilization of smart monitoring systems is significant. In the maritime work environment, digital self-learning is not used enough because of the poor connectivity and the tendency to work together and rather pursue practical solutions (Shi & Fan, 2021).

Conversely, the least rated practice was is "We use online or self-study materials to learn new systems" at a weighted mean of 3.23. This is an indication that the respondent feels that the human resource and competency development of using smart monitoring systems is significant. The findings suggest that the respondent's preference for practical, interactive learning rather than independent digital training. Maritime professionals favor face-to-face instruction due to limited connectivity and the complexity of onboard tasks (Sijabat et al., 2024).

Moreover, the total average mean of 3.34 indicates strong recognition of both collaborative and independent learning, although experiential mentoring is more valued. This shows that the respondent strongly feels that the human resource and competency development in utilization of smart monitoring systems is significant. Blended learning models combining mentorship and digital tools are recommended (Tripolca, 2023).

Table 13. Project implementation oversight challenges

Indicators	Weighted Mean	Verbal Interpretation
Lack of funds delays our work or projects.	3.11	Agree
No clear timeline makes it hard to finish tasks on time.	3.04	Agree
Poor planning for risks causes problems during our work.	3.13	Agree
Poor communication between departments slows down projects.	3.26	Agree

Indicators	Weighted Mean	Verbal Interpretation
Changes to plans during a job make it harder to finish.	3.11	Agree
Total Average Mean	**3.13**	**Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that project implementation in using smart monitoring systems is important.
2.50 –3.24 = The respondent agrees that project implementation in using smart monitoring systems is important.
1.75 – 2.49 = The respondent does not agree that project implementation in using smart monitoring systems is important.
1.00 - 1.74 = The respondent strongly disagrees that project implementation in using smart monitoring systems is important

The table 13 above outlines shows the difficulties that are faced in the supervision of project implementation. The highest-rated challenge is "Poor communication between departments slows down projects" with the weighted mean of 3.26. This indicates that the most critical aspect influencing the implementation of projects is the occurrence of communication gaps which necessitates the need to have proper coordination and information exchange among teams in order to have the project completed in time and efficiently. Clear coordination and timely information flow are essential for successful technological projects (Too and Weaver, 2021).

In addition, the least ranked threat was "No clear timeline makes it hard to finish tasks on time" with weighted mean of 3.04. It indicates that unclear schedules contribute to delays, but to a lesser extent compared to communication issues. It means that timelines are essential but the project implementation success depends on the cooperation and coordination of the works of the departments. This type of cross-functional cooperation is a key factor in organizational effectiveness because it helps teams solve complex problems, improve decision-making, and reduce project delivery time (Obodozie and Nwabufo, 2025).

Moreover, the total average mean of 3.13 shows that the respondents are aware of some of the major challenges in project oversight. This indicates that respondents believe communication between departments should be strengthened, and that risk planning and flexibility in project plans need improvement to enhance efficiency and effectiveness. Communication is one of the most important success factors in the context of project governance, as it had a direct effect on the performance of the team and the outcomes of the project, Muller et al., (2019)

Table 14. Project implementation oversight best practices

Indicators	Weighted Mean	Verbal Interpretation
Our crew tracks progress to keep tasks on schedule.	3.38	Agree
We get involved early when a new project starts.	3.38	Agree
We consider possible risks before starting a task.	3.42	Agree
We follow clear goals and deadlines for each stage of work.	3.45	Agree
Total Average Mean	3.41	Agree

Legend:
3.25 – 4.00 = The respondent strongly agrees that project implementation in using smart monitoring systems is important.
2.50 – 3.24 = The respondent agrees that project implementation in using smart monitoring systems is important

1.75 – 2.49 = The respondent does not agree that project implementation in using smart monitoring systems is important.
1.00 - 1.74 = The respondent strongly disagrees that project implementation in using smart monitoring systems is important

Table 14 above indicates the practices that the respondents used to implement the project effectively. The highest-rated practice is "We follow clear goals and deadlines at each stage of work" with a weighted mean of 3.45. This means that timelines are not as crucial as coordinated work of the departments as it is the implementation of a project. This type of cross-functional communication and alignment is always found to play a key role in the success of the project. Martinez et al., (2022), state that team collaboration and coordination are some of the most effective motivations of project performance in technology-intensive contexts.

On the other hand, the worst rated practices were "Our crew tracks progress to keep tasks on schedule" and "We get involved early when a new project starts" with weighted mean of 3.38. This implies that the respondent will strongly feel that introduction of smart monitoring systems is significant. These results suggest that early involvement and regular progress tracking are valued strategies for keeping a project on track, though they are considered slightly less important than goal-setting and meeting deadlines. The prompt integration in planning and continuous monitoring of project progress are highly beneficial to achieve project alignment, minimize risks, and deliver projects on time (Al-Nimer et al., 2024).

Furthermore, total average mean of 3.41 reflects high recognition of structured planning, proactive involvement, and risk governance in implementing smart monitoring systems. Strong planning and coordination significantly contribute to the success of the project in the maritime and complex operational context (Silvius and Schipper,2019).

Table 15. Summary Table on Current Challenges associated with smart monitoring systems in marine engineering

Indicators	Weighted Mean	Verbal Interpretation
System Integration Management Challenges	2.42	Disagree
Process Optimization Challenges	2.95	Agree
Human Resource and Competency Development Challenges	2.60	Agree
Project Implementation Oversight Challenges	3.13	Agree
Total Average Mean	2.78	Agree

Legend:
3.25 – 4.00 = The respondent strongly agrees that addressing current challenges associated with smart monitoring systems is important;
2.50 – 3.24 = The respondent agrees that addressing current challenges associated with smart monitoring systems is important;
1.75 – 2.49 = The respondent does not agree that addressing current challenges associated with smart monitoring systems is important;
1.00 - 1.74 = The respondent strongly disagrees that addressing current challenges associated with smart monitoring systems is important;

Table 15 above shows the perception of the respondents regarding the problems related to smart monitoring systems in marine engineering. The highest average score (3.13) means that the respondents believe that project implementation oversight challenges. Respondents consider project planning, coordination, and monitoring as the most significant obstacles to successful use of smart monitoring systems. This implies that in cases where sophisticated technologies are to be used, poor supervision and insufficient risk management can interfere with their successful adoption. Taresh et al., (2025), emphasize that information systems perform best under strong risk governance.

Conversely, system integration management issues got the least mean score of 2.42. This implies that the respondents do not see the integration of the new technologies with the current systems as a great challenge. This could be evidence of growing knowledge of smart technologies, the presence of technical solutions, or even a normal integration in the industry. Liu (2025) states that interoperable architectures facilitate smoother transitions to smart technologies.

Moreover, the overall mean of 2.78 indicates moderate recognition of current problems. This implies that organizations should focus on organized project management, communication and monitoring systems to gain maximum profits out of smart technologies. Organizations must strengthen project governance, communication, and system monitoring to fully maximize the benefits of smart monitoring technologies (Menon, 2024).

Table 16. Summary Table on best practices associated with smart monitoring systems in marine engineering

Indicators	Weighted Mean	Verbal Interpretation
System Integration Management Challenges	3.50	Strongly Agree
Process Optimization Challenges	3.37	Agree
Human Resource and Competency Development Challenges	3.34	Agree
Project Implementation Oversight Challenges	3.41	Agree
Total Average Mean	**3.41**	**Agree**

Legend:
3.25 – 4.00 = The respondent strongly agrees that best practices associated with smart monitoring systems are important.;
2.50 – 3.24 = The respondent agrees that best practices associated with smart monitoring systems are important.;
1.75 – 2.49 = The respondent does not agree that best practices associated with smart monitoring systems are important;
1.00 - 1.74 = The respondent strongly disagree that best practices associated with smart monitoring systems are important;

Table 16 above shows best practices for implementing smart monitoring systems. System integration practices received the highest mean of 3.50. This shows that the respondents view integration as the most critical area in implementation of smart monitoring systems. Proper planning, technical assessment, and integration management are crucial when combining new and existing systems. Xu et al.,(2019), highlight the complexity of integrating multiple technologies in marine environments. On the contrary, the least weighted mean is 3.34 indicates strong recognition of best practices in all four areas. This implies that the crew development is important, but not as pressing as integration or process management.

Furthermore, the total average mean of 3.41 indicates strong recognition of best practices in all four areas. The respondents view that the best practices related to smart monitoring systems are significant albeit not as imperative as it is in other fields. This suggests that the personnel development of skills and competencies is seen by the respondents as an issue, however, that can be addressed more efficiently or less pressing than technical integration or process management. Theotokas et al., (2024) note that digital transformation requires updates in management practices, training, and skill development.

Table 17. Relationship Between the Challenges and Best Practices Associated with Smart Monitoring Systems in Marine Engineering

System Integration Management Challenges	R-value	P-value	Interpretation
System Integration Management Best Practices	-.464**	0.000	Highly Significant
Process Optimization Best Practices	-0.193	0.166	Not Significant
Human Resource and Competency Development Best Practices	-.413**	0.002	Significant
Project Implementation Oversight Best Practices	-.371**	0.006	Significant
Process Optimization Challenges	**R-value**	**P-value**	**Interpretation**
System Integration Management Best Practices	0.238	0.087	Not Significant
Process Optimization Best Practices	.533**	0.000	Highly Significant
Human Resource and Competency Development Best Practices	.398**	0.003	Significant
Project Implementation Oversight Best Practices	.342*	0.012	Significant
Human Resource and Competency Development Challenges	**R-value**	**P-value**	**Interpretation**
System Integration Management Best Practices	-0.148	0.291	Not Significant
Process Optimization Best Practices	-0.079	0.574	Not Significant
Human Resource and Competency Development Best Practices	-0.085	0.544	Not Significant
Project Implementation Oversight Best Practices	-0.042	0.764	Not Significant
Project Implementation Oversight Challenges	**R-value**	**P-value**	**Interpretation**
System Integration Management Best Practices	.485**	0.000	Highly Significant
Process Optimization Best Practices	.647**	0.000	Highly Significant
Human Resource and Competency Development Best Practices	.650**	0.000	Highly Significant
Project Implementation Oversight Best Practices	.639**	0.000	Highly Significant

Table 17 above presents the correlation between various management challenges and best practices across four domains: system integration, process optimization, human resource and competency development, and project implementation oversight. The findings indicate that the null hypothesis (H0) is partially rejected. The implication of the results is that the four areas identified do not have strong correlations between the challenges and the best practice in smart monitoring systems. The findings reveal that the sub-topics of managing system integration and overseeing project implementation recorded there is a high degree of relationships. Conversely, the problem of human resource and competency development had no substantial connection with the best practices. These results indicate that the impact of the best practices on areas of challenge is related to quantifiable impacts on reducing or controlling challenges.

That is why it is worth considering challenges as not only obstacles but also drivers that can lead organizations to become better and change their practices and make them effective and reliable in the marine engineering. Tumpa and Tokgoz (2025), emphasize that the smart monitoring systems adoption is determined by high costs, complexity of integration, cybersecurity risks, and technical expertise requirements greatly.

On the other hand, the results of H11 that there exists a significant correlating between current challenges and best practices in smart monitoring systems in all the four areas identified. It demonstrates that the H11 is accepted in part. Correlations were noted significantly in n three areas, which were system integration management, process optimization and project implementation oversight and best practices. Nonetheless, the retention of the null hypothesis on this area is not entirely valid, as human resource issues are not much associated with the best practices. Silva-Campillo et al., (2023) also note that one of the key barriers to the use of advanced monitoring solutions is also the technological complexity and integration of the systems.

Conclusions

The results of this research show that smart monitoring in the maritime market is usually moving in the right direction. It shows the great value to which the notion of digitalization in enhancing operational performance, safety, and sustainability is attributed. However, the success of such technologies does not stay in their existence, but in their effective integration, optimization, and management on the organizational, technical, and human resource level.

Still ahead are such problems as integration of legacy system, technical failures, and loads of the data and network problems. However, they are effectively overcome by the aid of such measures as preventive maintenance, automation, check of data and efficient communication. In the meantime, the human resource preparedness turns out to be one of the most significant aspects. There are also high turnover, insufficient mentorship and practice training that prove the need to improve the competency development. Some of the strategies that are relevant in ensuring the operational competence is upheld include the use of modern training resources, mentorship, collaborative learning, and continuous professional development strategies.

The findings of the study indicate the necessity of the adoption of smart monitoring systems to be sustainable by strengthening technical systems and human capacities. The significance of enhancing the governance of projects, enhancing the level of communication, updating the outdated equipment, and refining the mentorship and skills development programs. By focusing on these domains, maritime organizations will have a chance to maximize the deployment of smart monitoring systems, which will result in safer, more efficient, and more resilient maritime operations in a more digital world.

Recommendations

The findings made led to the following recommendations made by the researcher:

1. To increase the competence of the crew in the operation and maintenance of smart monitoring systems including edge computing technology, the maritime organizations are advised to carry out structured training programs, simulations and workshops.
2. Create continuous education programs, certification programs, micro courses, and refresher courses, which will ensure the personnel is abreast with the prevailing technological developments.
3. Introduce mentorship, peer training, technical training and online knowledge bases in order to sustain institutional knowledge base and reduce loss of skills that arises during personnel changes.
4. The situation of sensor overload, system failures, and connection issues can be overcome by applying such best practices as preventive maintenance, automation, data backup and verification to effectively streamline the processes.
5. Facilitate open-line communication, pilot projects, and organizational support to defeat the resistance to new technologies that will contribute to forming a culture of using smart monitoring systems and establishing a more comprehensive supervision of the project implementation.

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