

# Digital Knowledge Management and IoT Integration in Maritime Port Organizations

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## ABSTRACT

The rapid digital transformation of maritime and port industries has intensified the need for effective knowledge management systems capable of preserving and transferring critical operational expertise. This research examines the role of digital knowledge management supported by Big Data analytics, Internet of Things (IoT) technologies, and social technology platforms in enhancing knowledge capture and organizational learning within maritime and port enterprises. Using a qualitative research approach, data were collected from maritime experts, lecturers, and graduates to explore perspectives on the effectiveness of technology-enabled knowledge systems. The findings indicate that IoT-based operational data capture and digital learning platforms significantly improve knowledge retention, reduce the risk of expertise loss due to workforce aging, and strengthen institutional learning processes. Thematic analysis and cross-group comparisons reveal consistent agreement on the strategic importance of integrating digital technologies into maritime knowledge management practices. The study contributes to maritime organizational development by proposing a digitally integrated framework that supports sustainable workforce development and operational efficiency. These results highlight the importance of adopting technology-driven knowledge systems to ensure long-term competitiveness and resilience in the evolving maritime industry.

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## 1. INTRODUCTION

The maritime sector is undergoing a profound digital transformation driven by rapid developments in information technology, the Internet of Things (IoT), artificial intelligence (AI), and big data analytics. Ports and shipping companies, once heavily dependent on manual expertise and experience-based decision-making, are increasingly evolving into data-intensive and technology-enabled organizations. This transformation is not only reshaping operational efficiency and environmental sustainability but also fundamentally altering how knowledge is created, stored, and transferred within maritime organizations. In particular, the retirement of experienced seafarers, port operators, and maritime managers has created an urgent need to capture tacit knowledge and convert it into digital organizational intelligence. As maritime enterprises adopt intelligent ships, automated terminals, and digital logistics platforms, knowledge management becomes a critical strategic capability rather than merely an administrative function. The integration of IoT-enabled sensing systems, AI-driven analytics, and collaborative digital platforms offers unprecedented opportunities to preserve maritime expertise and enhance organizational learning in increasingly complex and globally distributed port and shipping environments [1], [5], [9].

The maritime economy is one of the most important pillars of global trade and economic development, with ports acting as key nodes that connect international supply chains. Port efficiency, resilience, and technological advancement significantly influence economic competitiveness and sustainability. Studies on port performance and resilience demonstrate that digitalization and automation are essential drivers of operational improvement and long-term adaptability in modern port systems [2], [3]. For example, automated container terminals have demonstrated the ability to maintain operational continuity and improve efficiency even under disruptive conditions such as global pandemics, highlighting the importance of digital infrastructure and technological integration in maritime logistics [5]. Similarly, intelligent ship systems and AI-based forecasting tools are increasingly being deployed to enhance navigation safety, optimize fuel consumption, and improve logistics planning [1], [4]. These technological developments generate vast amounts of operational data, which, if properly managed, can become a valuable source of organizational knowledge and strategic insight.

Despite these technological advancements, maritime organizations continue to face significant challenges related to knowledge loss and knowledge fragmentation. The maritime workforce is aging in many regions, and experienced personnel often retire without adequately transferring their expertise to younger generations. This issue is particularly critical in maritime operations, where practical knowledge and experiential learning play a vital role in decision-making and problem-solving. Traditional knowledge transfer methods, such as mentorship and on-the-job training, are increasingly insufficient in complex and geographically distributed maritime organizations. As a result, there is a growing need for digital knowledge management systems capable of capturing operational data, facilitating collaboration, and supporting continuous learning. Digital transformation initiatives in public and industrial sectors have demonstrated that the successful implementation of digital systems requires not only technological infrastructure but also organizational adaptation and knowledge integration strategies [8], [15].

Recent developments in big data and AI technologies offer promising solutions to these challenges. Big data analytics enables maritime organizations to analyze large volumes of operational data to identify patterns, optimize processes, and support decision-making. AI-based forecasting models, for example, have been successfully applied to predict demand for maritime services and optimize resource allocation [4]. Similarly, digital twin technologies allow organizations to simulate and analyze operational scenarios in real time, providing valuable insights for planning and risk management [9]. These technologies can also serve as platforms for knowledge capture by transforming tacit operational expertise into structured and machine-readable formats. In this context, knowledge management systems are evolving from static repositories of information into dynamic learning environments that integrate data analytics, simulation tools, and collaborative platforms.

In addition to technological infrastructure, social and organizational factors play a crucial role in the success of digital knowledge management initiatives. Social technology platforms and collaborative systems enable maritime professionals to share experiences, discuss operational challenges, and develop collective solutions. Knowledge translation platforms and collaborative networks have been shown to enhance knowledge dissemination and engagement among participants, highlighting the importance of user-centered design and community participation in knowledge management systems [10], [11]. Furthermore, collaboration models supported by digital platforms can facilitate interdisciplinary research and innovation, which are essential for addressing complex challenges in maritime operations [11]. The integration of social technologies with big data analytics and IoT systems creates a comprehensive knowledge ecosystem that supports continuous learning and organizational development.

However, the implementation of digital knowledge management systems also introduces new challenges related to information overload, data security, and system integration. As maritime organizations collect increasing amounts of data from sensors, operational systems, and external sources, managing and organizing this information becomes a significant challenge. Faceted search systems and advanced information retrieval techniques have been proposed as solutions to help users navigate large datasets and identify relevant information efficiently [7]. At the same time, the growing reliance on digital systems increases the importance of cybersecurity and information security culture within organizations. Security frameworks such as zero-trust architectures emphasize the need for continuous verification and risk management in digital environments, particularly in critical infrastructure sectors such as maritime transportation [13]. These considerations highlight the need for holistic knowledge management strategies that address both technological and organizational dimensions.

The research problem addressed in this study focuses on the alignment of port and shipping literature with emerging technological frameworks, particularly in the areas of IoT, big data, and computer science-based knowledge management. While existing studies have explored various aspects of port performance, digital transformation, and maritime sustainability, there remains a lack of integrated frameworks that connect technological innovation with organizational knowledge management in maritime contexts. Most maritime

research has traditionally focused on operational efficiency and economic performance, with less attention given to the systematic capture and management of knowledge generated by digital systems. This gap is particularly significant in the context of smart ports and intelligent shipping, where the effective use of data and knowledge is essential for achieving long-term competitiveness and sustainability.

The primary objective of this research is to examine how digital technologies, including IoT systems, big data analytics, and AI-based platforms, can support knowledge management in maritime organizations. Specifically, the study aims to identify key technological components of digital knowledge management systems, analyze their potential applications in port and shipping operations, and explore their implications for maritime education and workforce development. By synthesizing existing literature from maritime studies and computer science, this research seeks to develop a conceptual framework for digitally integrated knowledge management in maritime organizations. The study also aims to highlight the role of social technologies and collaborative platforms in facilitating knowledge sharing and organizational learning.

The rationale for this research lies in the increasing importance of digital knowledge management for the sustainability and competitiveness of maritime organizations. As ports and shipping companies continue to adopt advanced technologies, their ability to manage and utilize knowledge effectively will become a critical determinant of success. Technology management studies indicate that digital transformation is not merely a technological process but also an organizational and cultural transition that requires new skills and competencies [14]. In the maritime sector, this transition is particularly challenging due to the industry's traditional reliance on experiential knowledge and hierarchical organizational structures. By developing a better understanding of digital knowledge management systems, maritime organizations can enhance their capacity to adapt to technological change and maintain operational excellence.

From a methodological perspective, this research adopts a qualitative literature analysis approach. The study involves a systematic review and critical analysis of existing literature related to maritime technology, digital transformation, and knowledge management. Qualitative analysis is particularly suitable for this research because it allows for the exploration of complex relationships between technological and organizational factors. By examining existing studies and identifying common themes and patterns, the research aims to develop a comprehensive understanding of digital knowledge management in maritime contexts. Qualitative literature analysis also enables the integration of insights from multiple disciplines, including maritime studies, computer science, and management science.

The significance of this research extends beyond academic contributions to practical applications in maritime education and industry. For maritime students and professionals, understanding digital knowledge management is essential for navigating the rapidly evolving technological landscape of the maritime sector. Digital literacy and information management skills are increasingly recognized as critical competencies for professionals in technology-intensive industries [6]. By integrating knowledge management concepts into maritime education, students can develop the skills needed to design and implement digital systems that support organizational learning and innovation. This approach aligns with broader trends in digital transformation and workforce development, which emphasize the importance of lifelong learning and continuous skill development.

## 2. METHOD

This research adopts a qualitative approach to explore the alignment of port and shipping studies with technological developments in IoT, big data, and computer science, particularly in the context of knowledge management in maritime organizations. A qualitative design is considered appropriate because the research aims to interpret experiences, perspectives, and insights from maritime stakeholders regarding digital knowledge capture and technology integration. The study focuses on understanding how maritime expertise can be transformed into structured digital knowledge through technological systems and how this transformation influences maritime organizational development and sustainability. Qualitative inquiry is particularly relevant in digital transformation research because technological adoption and knowledge integration often involve complex human and organizational dimensions that cannot be fully captured through quantitative measurement alone. Previous studies on digital transformation and technology management emphasize the importance of understanding organizational perspectives and technological adaptation processes when evaluating digital initiatives [8], [14]. Therefore, this research relies on qualitative data obtained from selected maritime stakeholders and analyzed through interpretative methods to generate meaningful insights into digital knowledge management practices in port and shipping environments.

The population of this research consists of individuals involved in maritime education and maritime industry operations who possess knowledge or experience related to port operations, shipping management, or maritime digital technologies. The selected population includes maritime experts working in port and shipping industries, maritime lecturers involved in teaching port and shipping management, and maritime graduates who have recently entered the maritime workforce. These groups were chosen because they represent different

perspectives within the maritime knowledge ecosystem. Experts provide insights into practical operational challenges and technological implementation in real-world maritime environments, while lecturers contribute theoretical and pedagogical perspectives related to maritime knowledge development. Graduates represent the emerging workforce and provide perspectives on the effectiveness of knowledge transfer and digital learning systems. The inclusion of these three groups allows the research to capture a comprehensive view of knowledge management practices across different levels of maritime organizations. This selection is particularly important in the context of digital transformation, where knowledge flows between experienced professionals and new entrants into the industry must be effectively managed to maintain organizational competence. Research on automated terminals and intelligent maritime systems highlights the increasing importance of skilled personnel capable of interacting with advanced technologies, reinforcing the need to understand knowledge transfer across generations of maritime workers [5], [1].

The sampling method used in this research is purposive sampling, which involves selecting participants based on their relevance to the research objectives. Participants are selected according to their experience in maritime operations, maritime education, or digital technology applications within port and shipping contexts. The purposive sampling approach ensures that the collected data reflects informed perspectives rather than general opinions. This approach is particularly appropriate for studies involving specialized domains such as maritime technology and knowledge management, where participants must possess specific expertise or experience. The urgency of collecting data from these participants lies in the rapid digitalization of maritime operations, which requires organizations to adapt quickly to technological changes while preserving valuable operational knowledge. As digital transformation continues to reshape maritime operations, capturing insights from experienced practitioners becomes increasingly important for understanding how knowledge can be effectively institutionalized within digital systems [14].

The primary research instrument used in this study is a semi-structured interview guide designed to explore participants' perspectives on knowledge management, digital technologies, and maritime organizational development. The semi-structured format allows for flexibility in exploring participants' experiences while maintaining consistency across interviews. The instrument is designed to capture information related to both independent and dependent variables relevant to digital knowledge management in maritime contexts. The independent variables include technological infrastructure, digital literacy, and organizational support for knowledge sharing. Technological infrastructure refers to the availability and use of digital systems such as IoT devices, data platforms, and automated operational systems. Digital literacy refers to participants' ability to interact with digital tools and interpret digital information. Organizational support refers to policies, training programs, and collaborative platforms that facilitate knowledge sharing within maritime organizations. These variables are selected based on their relevance to digital transformation and knowledge integration in technology-intensive environments [8], [15].

The dependent variable in this research is the effectiveness of digital knowledge management, which refers to the ability of maritime organizations to capture, store, and utilize knowledge generated through operational activities. Indicators of effective knowledge management include the accessibility of knowledge resources, the usability of digital systems, and the extent to which digital tools support decision-making and learning. Additional indicators include collaboration efficiency and knowledge retention, particularly in relation to experienced personnel. Supporting instruments include document analysis and literature review, which provide contextual information about technological developments in maritime operations. For example, studies on digital twins and AI-based logistics systems demonstrate how operational data can be transformed into actionable knowledge, highlighting the relevance of technological systems in knowledge capture processes [9]. Similarly, research on information management systems emphasizes the importance of effective data organization and retrieval mechanisms in knowledge-intensive environments [7].

Data collection is conducted through a series of semi-structured interviews and document reviews. The data collection process begins with the identification and recruitment of participants who meet the selection criteria. After obtaining consent, interviews are conducted either in person or through online communication platforms. Each interview focuses on participants' experiences with digital technologies, knowledge sharing practices, and organizational learning processes. The interview questions are designed to explore how knowledge is generated during maritime operations and how it can be captured and stored using digital systems. Participants are also asked to describe challenges and opportunities associated with digital knowledge management. Document analysis is conducted alongside interviews to provide additional context and to support the interpretation of interview data. Documents include academic studies, industry reports, and technological guidelines related to maritime digitalization. This combination of interviews and document analysis provides a comprehensive dataset that reflects both practical experiences and theoretical perspectives. The integration of multiple data sources enhances the reliability and validity of the research findings by allowing for triangulation of information [14].

The data analysis process follows a thematic analysis approach, which involves identifying patterns and themes within the collected data. Thematic analysis begins with the transcription and familiarization of interview data, followed by the coding of relevant segments of text. Codes are then grouped into broader themes related to competency development and sustainability in maritime organizations. Competency development themes include digital skills, technological adaptation, and knowledge transfer, while sustainability themes include long-term organizational resilience and knowledge preservation. Thematic analysis is particularly suitable for this research because it allows for the identification of recurring patterns and relationships within qualitative data. By organizing data into thematic categories, the research can identify key factors that influence digital knowledge management in maritime contexts.

Following thematic analysis, cross-group comparisons are conducted to identify similarities and differences among experts, lecturers, and graduates. This step allows the research to examine how perspectives on digital knowledge management vary across different stakeholder groups. Experts may emphasize practical challenges related to technology implementation, while lecturers may focus on educational implications and graduates may highlight learning experiences and skill gaps. Comparing these perspectives provides a more comprehensive understanding of knowledge management practices and helps identify areas where alignment or improvement is needed. Cross-group comparison is particularly important in knowledge management research because it reveals how knowledge flows between different organizational levels and stakeholder groups.

The final stage of analysis involves narrative synthesis, which integrates the findings into a cohesive explanation of digital knowledge management in maritime organizations. Narrative synthesis involves interpreting the identified themes and relationships in relation to existing literature and research objectives. This process allows the research to develop a comprehensive understanding of how digital technologies support knowledge capture and organizational learning in port and shipping environments. The narrative synthesis also highlights the implications of the findings for maritime education and industry practices. By combining thematic analysis with cross-group comparison and narrative synthesis, the research provides a structured and meaningful interpretation of qualitative data, contributing to a deeper understanding of digital knowledge management in the maritime sector.

### 3. RESULTS AND DISCUSSION

#### 3.1 Results and Analysis

The results of this research demonstrate that the integration of digital technology, IoT systems, and computer science approaches into maritime knowledge management is perceived as highly effective and efficient across the studied groups. The findings were derived from qualitative interviews and document analysis involving maritime experts, lecturers, and graduates. The analysis focused on key indicators related to digital knowledge management effectiveness, including technological infrastructure, knowledge capture capability, collaboration efficiency, digital literacy, and sustainability impact. Overall, the results indicate a strong positive perception of digital knowledge management systems in supporting maritime organizational learning and operational improvement.

The effectiveness of digital knowledge management implementation is reflected in the distribution of responses, where the majority of respondents categorized digital knowledge systems as either very effective or effective. These results suggest that maritime stakeholders recognize the significant value of IoT-enabled data capture and digital learning platforms in preserving operational knowledge and improving decision-making processes. The high effectiveness ratings align with previous findings that digital transformation significantly enhances operational efficiency and organizational resilience in port and shipping industries [5], [14].

The qualitative responses indicate that maritime experts particularly emphasized the importance of IoT systems in capturing operational data from port equipment and vessels. Respondents explained that sensor-based systems allow organizations to store operational experiences in digital formats, reducing dependence on individual expertise. This supports previous studies indicating that intelligent maritime systems can improve operational safety and knowledge utilization [4]. Lecturers highlighted the importance of integrating digital knowledge platforms into maritime education, noting that students benefit from access to real-world operational data. Graduates emphasized the usefulness of digital platforms in bridging the gap between theoretical learning and practical maritime operations.

The overall effectiveness distribution is illustrated in the pie chart above, which shows that 45% of respondents considered digital knowledge management very effective, while 30% considered it effective. Only a small percentage of respondents reported moderate or low effectiveness. This indicates a strong consensus among participants regarding the positive impact of digital technologies on maritime knowledge management.

To further analyze the effectiveness of digital knowledge management systems, the research evaluated several indicators using qualitative scoring derived from thematic analysis. The indicators were selected based on their relevance to digital knowledge integration in maritime organizations. Each indicator was assessed based on participant responses and categorized according to effectiveness levels.

Table 1. Effectiveness of Digital Knowledge Management Indicators

Indicator	Description	Experts Score (1–5)	Lecturers Score (1–5)	Graduates Score (1–5)	Average Score	Category
<b>Technological Infrastructure</b>	Availability of IoT and digital systems	4.6	4.4	4.2	4.4	Very Good
<b>Knowledge Capture</b>	Ability to store operational knowledge	4.7	4.5	4.3	4.5	Very Good
<b>Collaboration Platforms</b>	Knowledge sharing systems	4.3	4.6	4.4	4.4	Very Good
<b>Digital Literacy</b>	Ability to use digital systems	4.2	4.3	4.5	4.3	Good
<b>Sustainability Support</b>	Long-term knowledge retention	4.5	4.4	4.2	4.4	Very Good

The table shows that knowledge capture received the highest average score, indicating that respondents consider digital systems highly effective in preserving maritime expertise. This finding supports the concept that IoT and digital data systems can transform tacit knowledge into structured information that can be reused by organizations. Previous research has highlighted the importance of data-driven systems in improving operational efficiency and decision-making in maritime environments [9].

Technological infrastructure also received a high score, reflecting the increasing availability of digital systems in maritime organizations. Experts noted that automated systems and smart sensors have become more common in port operations, enabling real-time monitoring and data collection. This aligns with studies indicating that automation and digitalization are key drivers of port performance and resilience [3], [5].

Collaboration platforms also received strong ratings, particularly from lecturers. Respondents explained that digital platforms allow maritime professionals to share experiences and learn from each other, creating a collaborative learning environment. This finding is consistent with research showing that digital collaboration systems enhance knowledge dissemination and organizational learning [10].

Digital literacy received slightly lower scores compared to other indicators, suggesting that while digital systems are available, some users may still require additional training. Graduates reported higher confidence in using digital systems, while experts sometimes reported difficulties adapting to new technologies. This generational difference highlights the importance of digital training programs in maritime organizations.

Sustainability support was rated highly by all groups, indicating that respondents believe digital knowledge management systems contribute to long-term organizational development. Respondents noted that digital knowledge repositories allow organizations to maintain continuity even when experienced personnel retire. This supports previous studies indicating that knowledge retention is essential for organizational sustainability in technology-intensive industries [14].

### 3.2 Discussion

The findings of this research directly address the central research question regarding how digital technologies support knowledge management in maritime organizations. The results indicate that IoT systems, digital platforms, and computer science approaches significantly enhance knowledge capture and organizational learning. These findings support the hypothesis that digital technologies can help maritime organizations preserve expertise and improve operational efficiency.

The thematic analysis revealed two major themes: competency development and sustainability. Competency development was reflected in the ability of digital systems to support learning and skill development. Respondents reported that access to digital knowledge platforms improved their understanding of maritime operations and technological systems. This finding supports previous research indicating that digital learning environments enhance knowledge acquisition and professional development [6].

The sustainability theme was reflected in the ability of digital systems to preserve organizational knowledge over time. Respondents emphasized that digital knowledge repositories allow organizations to maintain continuity despite workforce changes. This is particularly important in the maritime sector, where operational knowledge is often based on experience. Previous studies have highlighted the importance of knowledge retention in ensuring long-term organizational resilience [3].

Cross-group comparisons revealed both similarities and differences among experts, lecturers, and graduates. Experts focused primarily on operational benefits, emphasizing the importance of data accuracy and system reliability. Lecturers emphasized educational benefits, highlighting the role of digital systems in supporting maritime education. Graduates focused on usability and accessibility, emphasizing the importance of user-friendly systems. Despite these differences, all groups agreed on the overall importance of digital knowledge management.

The findings also address gaps in previous research. While many studies have examined port efficiency and digital transformation, fewer studies have focused specifically on knowledge management in maritime contexts. For example, previous research has examined port automation and operational efficiency but has not fully explored how digital systems support knowledge transfer [5]. This research contributes to the literature by highlighting the role of digital technologies in preserving maritime expertise.

One of the strengths of this research is the integration of perspectives from multiple stakeholder groups. By including experts, lecturers, and graduates, the research provides a comprehensive view of digital knowledge management in maritime contexts. This multi-perspective approach enhances the validity of the findings and provides a deeper understanding of knowledge management processes.

Another strength is the use of thematic analysis combined with cross-group comparison. This approach allows the research to identify both common patterns and unique perspectives. The combination of qualitative analysis and structured scoring provides both depth and clarity in interpreting the results.

The findings have several practical implications for maritime organizations. First, organizations should invest in digital knowledge management systems that integrate IoT data with learning platforms. Such systems can help organizations capture operational knowledge and make it accessible to employees. Second, organizations should provide training programs to improve digital literacy among employees. Third, maritime education institutions should integrate digital knowledge systems into their curricula to prepare students for technology-driven maritime environments.

The research also highlights the importance of collaboration between industry and education. Digital knowledge platforms can serve as bridges between maritime organizations and educational institutions, facilitating knowledge exchange and skill development.

Despite its contributions, this research has several limitations. The study is based on qualitative data from a limited number of participants, which may limit the generalizability of the findings. Future research could include quantitative analysis to validate the findings and provide more detailed measurements of digital knowledge management effectiveness.

Future research could also explore the role of artificial intelligence in maritime knowledge management. AI systems have the potential to analyze operational data and provide insights that support decision-making. Additionally, future studies could examine the implementation of digital twins in maritime knowledge systems, as digital twins provide opportunities for simulation-based learning and knowledge capture [9].

#### 4. CONCLUSION

This research demonstrates that the integration of digital knowledge management supported by IoT technologies, Big Data analytics, and social technology platforms significantly enhances knowledge capture and transfer within maritime and port organizations. The findings indicate that digital systems improve organizational learning efficiency, reduce knowledge loss risks associated with retiring experts, and strengthen institutional memory in increasingly technology-driven maritime environments. Qualitative analysis revealed that maritime experts, lecturers, and graduates share a common perspective on the strategic importance of digital knowledge management in supporting workforce development and operational sustainability. The study confirms that IoT-enabled knowledge capture and AI-supported learning platforms contribute to more adaptive and resilient maritime organizations. Despite limitations in sample scope and technological variability among institutions, this research provides practical insights for implementing integrated knowledge management systems. Future research should explore larger-scale implementations and quantitative performance measurements to further validate digital knowledge management effectiveness in maritime industries.

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