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HUMAN RESOURCE MANAGEMENT STRATEGIES IN PORTS TO ADDRESS OPERATIONAL DIGITALIZATION AND MODERN AUTOMATION IN THE GLOBAL CONTEXT

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ABSTRACT
This study is motivated by the rapid advancement of digitalization and automation in the port sector, which has significantly transformed operational systems and human resource management (HRM) practices. These changes create challenges such as digital competency gaps, organizational resistance, workforce restructuring, and the need for adaptive digital leadership. Therefore, this study aims to analyze and formulate effective HRM strategies to address operational digitalization and modern automation in ports within a global context. The research employs a qualitative approach using a literature review method, analyzing relevant academic sources through thematic analysis to identify key patterns, challenges, and strategic HRM practices in digitalized port operations. The findings reveal that effective HRM strategies include continuous digital competency development, the implementation of electronic HRM (e-HRM), structured change management, workforce transition planning, and the integration of technology with human capital. Furthermore, the study demonstrates that Indonesian ports still face structural and institutional challenges compared with global smart ports, particularly in long-term workforce transformation and digital capability readiness. The novelty of this study lies in the formulation of an integrated HRM strategy framework that combines reskilling, digital organizational culture, human-centered automation, and collaborative governance as interconnected elements to support sustainable smart port transformation. These findings contribute not only to HRM literature in the maritime sector but also provide strategic policy insights for governments and port authorities in developing adaptive and globally competitive digital port ecosystems.

INTRODUCTION

Digital transformation has become a global phenomenon that significantly reshapes various industrial sectors, including the maritime and port industries (Margaretha et al., 2024). Digitalization, involving technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, enables improved operational efficiency and data-driven decision-making in modern ports (Korniyenko, 2023; Raam, 2014). In the context of global trade, ports are required to rapidly adapt to technological advancements to enhance competitiveness and logistics performance (Amuka & Ezinna, 2021). This transformation not only affects

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operational systems but also influences organizational structures and human resource management (HRM) within the port sector (Rachida, 2020).

The development of automation and digitalization in ports has driven the emergence of the smart port concept, which integrates advanced technologies into operational activities (Ricardianto & Sonny, 2021). The implementation of automated systems, such as automated terminals and digital platforms, can improve service efficiency and reduce human errors in operational processes (Ugrinov et al., 2025). However, these changes also create new challenges, particularly regarding workforce readiness, which must possess adequate digital competencies (Bachtiar, 2025). The skills gap has become a critical issue, as a large portion of the port workforce is not yet fully prepared to meet the demands of new technologies (Asiati et al., 2018).

Furthermore, the digitalization of port operations requires a paradigm shift in human resource management, moving from conventional approaches to technology-driven and competency-based approaches (Al-Qassem et al., 2025). The HR function is no longer limited to administrative roles but has evolved into a strategic partner in supporting organizational digital transformation (Mykhailovska et al., 2024). The use of technology in HR practices, such as digital recruitment systems, e-learning-based training, and data-driven performance analytics, has become increasingly essential for improving organizational effectiveness. Therefore, adaptive HR management strategies are crucial to ensuring the success of digital transformation in ports.

On the other hand, the implementation of digitalization and automation also impacts workforce structures, including the potential reduction of labor due to the replacement of human roles by machines (Poisat et al., 2024). Nevertheless, digitalization also creates new opportunities for technology-based jobs and enhances workforce productivity (Gadzali et al., 2023). This condition necessitates HR development strategies that focus on digital skill enhancement, continuous training, and organizational change management (Mankidy, 1985). Thus, the successful implementation of technology in ports largely depends on the readiness and quality of human resources.

The urgency of this research lies in the need to formulate human resource management strategies that comprehensively address the challenges of digitalization and automation in the port sector (Tanimu et al., 2025). Without appropriate strategies, digital transformation may lead to competency gaps, organizational resistance, and declining operational performance. In addition, the demand for adaptive and innovative human resources is increasingly critical in responding to the dynamics of the highly competitive global maritime industry (Margaretha et al., 2024). Therefore, this research is relevant in contributing to the development of HR policies and practices in port management.

Previous studies indicate that digitalization in the maritime sector positively impacts operational efficiency and industrial competitiveness (Margaretha et al., 2024; Ugrinov et al., 2025). Other studies emphasize the importance of human resource competency development through education and training to support technological implementation in ports (Ricardianto & Sonny, 2021). Additionally, research on the adoption of technologies such as AI and ERP systems in ports shows that successful implementation is strongly influenced by workforce readiness and management support (Abdel Ghany et al., 2021). However, there is still a lack of studies that specifically examine integrated HR management strategies in addressing digitalization and automation within the port sector.

Based on the above background, this study aims to analyze and formulate effective human resource management strategies to address operational digitalization and modern automation in ports within a global context. This research is expected to contribute theoretically to the development of HRM knowledge and practically to port managers in designing adaptive, innovative, and sustainable human resource management strategies.

METHOD

This study employed a qualitative approach using a literature review method to examine human resource management (HRM) strategies in ports facing operational digitalization and modern automation. The study collected secondary data from scientific journal articles, conference proceedings, academic books, and institutional reports indexed in reputable databases such as Scopus, Web of Science, and Google Scholar.

These databases were selected because they provide peer-reviewed and internationally recognized publications, ensuring the credibility, validity, and academic quality of the analyzed sources (Almasri et al., 2021). The literature search focused on publications related to port digitalization, automation, smart ports, digital HRM,

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workforce transformation, and change management in the maritime sector.

The selection of articles followed the PRISMA approach, including identification, screening, eligibility, and inclusion stages. Inclusion criteria consisted of: (1) articles published in English between 2015–2025, (2) studies discussing digitalization, automation, and HRM in ports or maritime industries, and (3) publications from peer-reviewed journals or reputable academic sources. Meanwhile, exclusion criteria included non-academic articles, duplicated studies, publications lacking methodological clarity, and studies not directly related to HRM strategies in port digital transformation. The collected data were analyzed using qualitative thematic analysis through coding, categorization, and interpretation to identify major patterns, challenges, and strategic HRM practices in digitalized port operations (Bowen, 2009; Chandrasekar et al., 2024).

RESULT AND DISCUSSION

The analysis of the literature indicates that operational digitalization and modern automation have fundamentally transformed port operations, requiring a strategic shift in human resource management (HRM). Digital technologies such as artificial intelligence (AI), Internet of Things (IoT), and automated terminal systems significantly enhance operational efficiency, reduce human error, and improve decision-making processes in ports (Raam, 2014). However, these advancements simultaneously create challenges related to workforce readiness, skill mismatches, and organizational adaptation. Therefore, HRM strategies must evolve from traditional administrative functions toward a more strategic and technology-driven role.

Workforce Digital Competency Development

Workforce digital competency development is a fundamental pillar in ensuring the successful implementation of digitalization and automation in port operations. In the context of global maritime transformation, ports are increasingly adopting advanced technologies such as terminal operating systems (TOS), automated container handling, and integrated logistics platforms. These changes require not only technical skills but also cognitive, analytical, and adaptive competencies among port workers (Heilig et al., 2017). However, empirical studies indicate that many port employees, especially in developing countries, still rely on conventional operational knowledge and lack sufficient digital literacy, creating a significant competency gap that can hinder the effectiveness of technological adoption (Notteboom et al., 2022). Therefore, structured and continuous workforce development programs become essential to bridge this gap.

From an HRM perspective, digital competency development should not be limited to short-term training but must be embedded in a long-term strategic framework. This includes reskilling (upgrading existing skills), upskilling (adding new competencies), and cross-skilling (developing multi-functional capabilities) aligned with Industry 4.0 requirements (World Bank, 2019). Training programs should cover areas such as data analytics, cybersecurity awareness, automation system operations, and digital decision-making tools. Moreover, the use of digital learning platforms, simulation-based training, and collaborative learning ecosystems can significantly enhance the effectiveness of training programs (Baldassarre et al., 2017). In addition, partnerships between port authorities, universities, and vocational institutions are crucial to ensure that training curricula remain relevant to industry needs and technological developments.

A key aspect of digital competency development is the shift toward competency-based HRM, where employee performance and career progression are measured based on measurable digital skills and capabilities. This approach enables organizations to map skill gaps more accurately and design targeted training interventions (Stahl et al., 2020). Furthermore, fostering a culture of continuous learning is essential, as digital technologies evolve rapidly and require employees to constantly update their knowledge and skills. Organizations that successfully implement lifelong learning strategies tend to demonstrate higher adaptability and innovation capacity in the face of technological disruption (Schwab, 2017).

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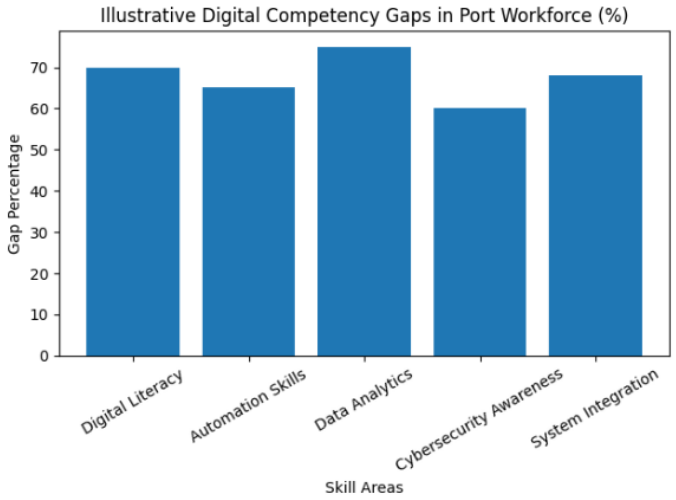

Figure 1. Digital Competency Gaps in Port Workforce

Digital transformation in Indonesian ports can be seen in PT Pelabuhan Indonesia (Pelindo) after the merger of Pelindo I–IV in 2021. Pelindo implemented systems such as the Terminal Operating System (TOS) and Integrated Billing System to improve efficiency and transparency, but challenges emerged due to limited employee readiness for digital processes (Lasse et al., 2024). To overcome this, Pelindo introduced training and certification programs focused on digital competencies, automation, and data-based decision making, while also collaborating with educational institutions to support smart port development (Pratiwi et al., 2024).

Another example is the Inaportnet system, a national digital platform designed to integrate port services and simplify ship clearance processes. Its success depends on the digital competencies of port workers and continuous organizational support through training and adaptation programs (Iman et al., 2022). These cases show that digital transformation in ports requires not only technology adoption but also strong human resource development strategies.

In comparison with global smart ports such as the Port of Rotterdam, Port of Singapore, and Port of Hamburg, the challenges faced by Indonesian ports are not only technological but also structural and institutional. Global smart ports have integrated advanced automation systems supported by highly skilled digital workforces, real-time data analytics, and continuous competency certification programs (Heilig et al., 2017. In contrast, many Indonesian ports are still in the transitional stage, where digital infrastructure development often progresses faster than workforce capability enhancement. This imbalance creates a technological adoption gap, in which digital systems are available but are not fully optimized due to limited digital literacy, insufficient technical expertise, and uneven training distribution among employees. As a result, reskilling and upskilling initiatives in Indonesia tend to remain reactive and operational rather than strategic and innovation-oriented.

Furthermore, global port operators generally implement long-term talent development frameworks that integrate universities, vocational institutions, and industry-based certification systems into maritime digital transformation strategies. For example, the Port of Singapore emphasizes continuous workforce transformation through structured digital learning ecosystems and predictive workforce planning to anticipate future competency demands. By comparison, Indonesian ports still face challenges related to fragmented training systems, limited investment in digital human capital, and dependence on conventional work practices. Consequently, reskilling programs in Indonesia often focus on short-term adaptation to newly introduced systems instead of preparing workers for emerging roles related to artificial intelligence, big data analytics, cybersecurity, and smart logistics management.

This comparison indicates that the primary challenge for Indonesian ports is not merely adopting digital technology, but building an adaptive HR ecosystem capable of sustaining long-term digital transformation. Without a more integrated strategy combining technological investment with systematic workforce transformation, Indonesian ports risk lagging behind global smart port standards in terms of productivity, innovation, and operational competitiveness. Therefore, HRM strategies should move beyond conventional training approaches

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toward strategic workforce planning that emphasizes lifelong learning, digital talent mapping, and stronger collaboration between government, industry, and educational institutions.

Strategic Role of HRM in Digital Transformation

The role of Human Resource Management (HRM) in the era of digital transformation has shifted fundamentally from a traditional administrative function to a strategic partner that actively drives organizational change. In the context of port digitalization, HRM is no longer limited to managing payroll, recruitment, or compliance, but is increasingly responsible for aligning human capital strategies with technological innovation and business transformation goals. This shift is essential because digital transformation is not solely a technological process but also a socio-organizational transformation that requires changes in mindset, culture, and competencies (Bondarouk & Brewster, 2016). As a result, HRM must play a central role in ensuring that employees are not only capable of using new technologies but are also engaged in the transformation process.

One of the most critical dimensions of this strategic role is the adoption of digital HRM (e-HRM) practices. Digital HRM integrates information systems into HR processes, including e-recruitment, e-training, digital performance management, and HR analytics. These systems enable organizations to make data-driven decisions regarding workforce planning, talent management, and performance evaluation (Marler & Parry, 2016). In the port industry, where operational efficiency and real-time decision-making are crucial, HR analytics can help identify skill gaps, predict workforce needs, and optimize labor allocation. Furthermore, digital platforms facilitate faster recruitment processes and allow organizations to attract talent with specialized digital skills required in smart port environments.

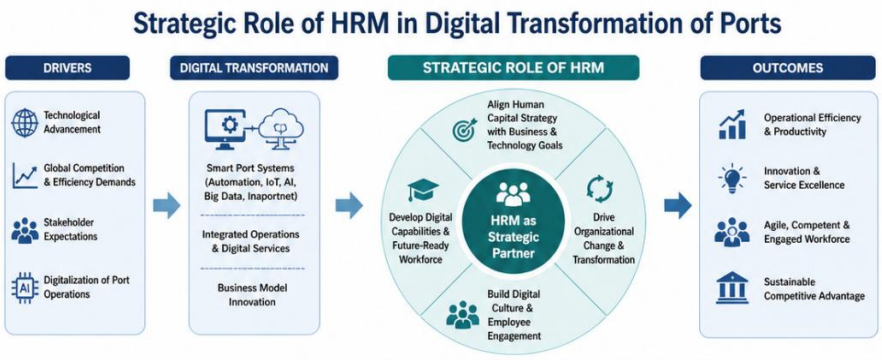

Figure 2. Strategic Role of HRM in Digital Transformation of Ports

In addition, HRM plays a key role in organizational change management, which is critical in digital transformation initiatives. Resistance to change is a common challenge, particularly among employees who are accustomed to manual or conventional systems. HRM must design and implement structured change management strategies, including communication programs, leadership development, and employee engagement initiatives, to ensure smooth transitions (Kotter, 2012). Leadership alignment is particularly important, as leaders act as change agents who influence employee attitudes toward digital transformation. Studies show that organizations with strong leadership support and clear communication strategies are more successful in implementing digital initiatives (Verhoef et al., 2021).

Another important aspect is the development of a digital organizational culture, where innovation, collaboration, and continuous learning are embedded in daily practices. HRM must foster an environment that encourages experimentation, knowledge sharing, and adaptability. This can be achieved through performance management systems that reward innovation, as well as through internal communication platforms that support collaboration across departments (Vial, 2021). In port operations, where coordination among multiple stakeholders is essential, a strong digital culture enhances operational integration and efficiency.

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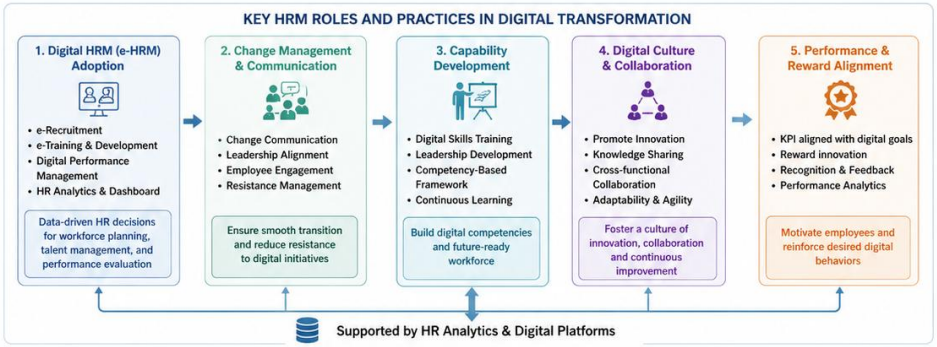

Figure 3. Key HRM Roles and Practices in Digital Transformation

A concrete example of the strategic role of HRM in digital transformation can be seen in PT Pelabuhan Indonesia (Pelindo) after the merger of Pelindo I–IV. Pelindo implemented integrated digital systems and automation technologies, while HRM supported the transformation through Human Capital Management (HCM) systems for recruitment, training, and performance evaluation. The company also applied competency-based HR frameworks to align employee skills with digital port operations.

To support change management, Pelindo introduced leadership development, digital mindset training, and employee engagement programs to reduce resistance to technological change. HRM also encouraged collaboration and knowledge sharing across operational units.

Similarly, the implementation of Inaportnet, Indonesia's national port digital platform, highlights the importance of HRM in training personnel, standardizing competencies, and supporting stakeholder coordination. Without effective HRM strategies, digital systems may face challenges related to limited user capability and organizational resistance. These cases show that HRM acts as a strategic enabler in integrating technology, people, and organizational transformation.

Compared with leading global smart ports, HRM practices in Indonesian ports are still relatively focused on administrative adaptation rather than strategic digital transformation. Major international ports such as Rotterdam and Shanghai have implemented integrated digital HR ecosystems that utilize workforce analytics, AI-based recruitment systems, and predictive talent management to support long-term organizational competitiveness. In contrast, HRM implementation in many Indonesian ports remains concentrated on operational efficiency and basic digitalization processes, with limited integration between HR analytics and strategic decision-making. This condition reduces the ability of organizations to anticipate future workforce demands in increasingly automated port environments.

Moreover, global smart ports generally position HRM as a transformation driver that actively shapes innovation culture and digital leadership capabilities. Indonesian ports, however, still face organizational barriers such as hierarchical management structures, resistance to change, and uneven digital leadership competencies across operational units. As a result, digital transformation initiatives often depend heavily on top management policies without being fully supported by organization-wide cultural transformation. This indicates that HRM in Indonesian ports still needs to evolve from a supporting administrative function into a strategic institutional actor capable of accelerating innovation, organizational agility, and sustainable digital adaptation.

Workforce Restructuring and Change Management

Workforce restructuring is an inevitable consequence of digitalization and automation in port operations, as technological advancements fundamentally alter job roles, skill requirements, and organizational structures. In modern ports, the adoption of automated container terminals, artificial intelligence (AI), and integrated logistics systems reduces the need for manual and repetitive tasks while simultaneously increasing demand for highly skilled labor capable of operating, managing, and maintaining advanced technologies. This transformation leads to a job polarization effect, where low-skilled jobs decline while high-skilled, technology-oriented roles expand (Autor, 2015). As a result, HRM must strategically manage workforce restructuring to ensure that the transition does not disrupt organizational performance or create social instability among employees.

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A critical challenge in workforce restructuring is job displacement and role redefinition. Automation in port operations, such as automated guided vehicles (AGVs) and remote-controlled cranes, reduces the need for traditional dock labor while creating new roles in system control, data analysis, and IT maintenance. This shift requires HRM to redesign job descriptions, redefine competency standards, and implement workforce planning strategies that align with technological changes. Without proper planning, organizations risk losing valuable human capital or facing resistance from employees who feel threatened by automation. Therefore, workforce restructuring must be conducted gradually and inclusively, ensuring that employees are given opportunities to transition into new roles through reskilling and redeployment programs.

Another major aspect is organizational change management, which plays a central role in ensuring the success of workforce restructuring. Resistance to change is a natural response, particularly when employees perceive digital transformation as a threat to job security. According to Kotter (2012), successful change management requires a structured approach that includes creating a sense of urgency, building a guiding coalition, communicating a clear vision, and empowering employees to participate in the transformation process. In the context of ports, HRM must act as a facilitator of change by implementing communication strategies that emphasize the benefits of digitalization, such as improved safety, efficiency, and career opportunities. Employee engagement programs, participatory decision-making, and transparent communication are essential to reduce resistance and build trust.

Figure 4. Workforce Restructuring and Change Management in Digitalized Ports

Furthermore, organizational culture transformation is a key component of change management. Traditional port operations are often characterized by hierarchical structures and routine-based work practices, which may not be compatible with the flexibility and innovation required in digital environments. HRM must foster a culture that encourages adaptability, continuous learning, and openness to technological change. This includes revising performance management systems to reward innovation, promoting cross-functional collaboration, and supporting leadership development programs that prepare managers to lead digital transformation initiatives. Leaders play a crucial role as change agents, as their attitudes and behaviors significantly influence employee acceptance of new technologies.

Workforce restructuring and change management in Indonesian ports can be seen in PT Pelabuhan Indonesia (Pelindo) after the merger of Pelindo I–IV. The implementation of digital systems and automation required employee reallocation, job redesign, and competency adjustments. However, resistance emerged among workers accustomed to manual processes. To address this, Pelindo introduced training, communication programs, and reskilling initiatives to help employees adapt to digital roles.

Similarly, the implementation of Inaportnet changed port operations from manual to digital processes. Its success depends on training, stakeholder coordination, and organizational readiness. Without effective change management, digital transformation may face resistance and inefficiency.

In global smart ports, workforce restructuring is generally implemented through proactive transition strategies that prioritize workforce sustainability and social protection. Ports such as Antwerp and Singapore have introduced anticipatory workforce planning models, where employees are prepared for automation risks through continuous competency mapping, digital career pathways, and government-supported reskilling schemes before technological changes are fully implemented. In contrast, workforce restructuring in Indonesian ports tends to be more reactive, where training and redeployment programs are often introduced only after operational changes occur. This reactive approach increases the risk of employee anxiety, resistance to change, and adaptation delays

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during digital transformation processes.

Additionally, global ports increasingly emphasize human-centered automation, where technology is designed to complement human capabilities rather than simply replace labor. However, in Indonesia, automation is still frequently perceived by workers as a threat to employment security due to limited communication, insufficient participation in decision-making, and the absence of long-term workforce transition policies. This difference demonstrates that successful digital transformation is not determined solely by technological readiness, but also by institutional capacity to manage social impacts and maintain workforce trust. Therefore, Indonesian port authorities need to strengthen participatory change management strategies, labor protection mechanisms, and inclusive communication frameworks to ensure that automation supports both operational efficiency and workforce sustainability.

Integration of Technology and Human Capital

The integration of technology and human capital represents a critical success factor in the digital transformation of port operations. While advanced technologies such as Enterprise Resource Planning (ERP), Terminal Operating Systems (TOS), blockchain, and automated logistics platforms offer significant improvements in efficiency and transparency, their effectiveness largely depends on how well they are aligned with human competencies, organizational processes, and institutional readiness. Digital transformation in ports is therefore not merely a technological upgrade, but a socio-technical system transformation, where human capabilities and technological systems must co-evolve.

One of the key challenges in integrating technology and human capital is the alignment between system complexity and workforce capability. Advanced port technologies often require specialized skills in data analytics, system integration, and digital operations management. However, if the workforce lacks the necessary competencies, the implementation of such technologies may lead to underutilization, inefficiencies, or even operational disruptions. This highlights the importance of synchronizing technology adoption with human resource development through targeted training programs, competency mapping, and continuous learning systems. HRM must ensure that employees are not only trained to operate new systems but also understand the underlying processes and data flows that drive digital operations.

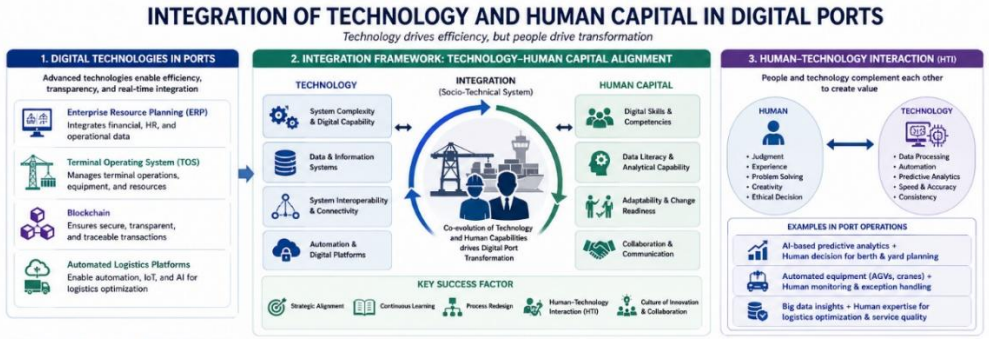

Figure 5. Integration of Technology and Human Capital in Digital Ports

Another important dimension is the development of human-technology interaction (HTI) capabilities. In modern ports, employees increasingly interact with digital interfaces, automated systems, and decision-support tools rather than performing manual tasks. This shift requires a redesign of work processes and job roles to optimize collaboration between humans and machines. According to (Davenport & Kirby, 2016), organizations that successfully integrate human intelligence with machine capabilities achieve higher levels of productivity and innovation. In port operations, this may involve combining human judgment with AI-based predictive analytics for cargo handling, scheduling, and logistics optimization. Therefore, HRM strategies must focus on enhancing employees' ability to work alongside technology, rather than being replaced by it.

Furthermore, the integration process requires strong organizational coordination and system interoperability. Ports operate as complex ecosystems involving multiple stakeholders, including port authorities, shipping companies, logistics providers, and government agencies. Digital platforms such as port community

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systems (PCS) and national logistics ecosystems enable real-time data sharing and coordination across these stakeholders. However, effective utilization of these systems depends on the ability of human resources to collaborate, communicate, and adapt to standardized digital processes. HRM plays a key role in facilitating this integration by promoting cross-functional teamwork, standardizing competencies, and supporting inter-organizational collaboration.

In addition, data-driven decision-making has become a central feature of digital port operations. Technologies generate large volumes of data that can be used to optimize operations, predict demand, and improve service quality. However, the value of data can only be realized if employees possess the skills to interpret and utilize it effectively. This requires the development of data literacy and analytical capabilities among port workers (Verhoef et al., 2021). HRM must therefore integrate data competency development into training programs and encourage a culture of evidence-based decision-making within the organization.

A prominent example of technology and human capital integration in Indonesia can be seen in PT Pelabuhan Indonesia (Pelindo). After its consolidation, Pelindo implemented digital systems such as Terminal Operating Systems (TOS), ERP systems, and integrated port service platforms to improve efficiency and service quality. However, challenges emerged due to limited employee competencies in adapting to new technologies. To address this, Pelindo introduced training programs, competency certification, and digital learning platforms to strengthen employees' technical skills and support knowledge sharing across operational units.

Another example is the implementation of Inaportnet, a national digital platform that integrates port services and enables real-time coordination among stakeholders. Its effectiveness depends on the readiness of human resources to adapt to digital workflows. Challenges such as low digital literacy, resistance to change, and coordination issues remain significant barriers to implementation.

Compared with advanced smart ports globally, the integration of technology and human capital in Indonesian ports remains uneven and fragmented. Global ports such as Rotterdam and Busan have successfully developed integrated digital ecosystems where automation systems, data platforms, and workforce competencies operate in a highly synchronized manner. These ports emphasize interoperability, digital collaboration, and data-driven organizational cultures supported by strong institutional coordination and continuous workforce innovation programs. Conversely, Indonesian ports still encounter challenges related to limited interoperability between digital systems, inconsistent digital competencies among employees, and varying levels of technological readiness across port regions.

Furthermore, the effectiveness of technology integration in global ports is strongly supported by advanced data literacy and analytical capabilities among workers and managers. In Indonesia, however, many employees are still adapting to basic operational digital systems, limiting their ability to maximize technologies such as predictive analytics, AI-based logistics optimization, and integrated port community systems. Consequently, digital transformation in Indonesian ports often focuses more on system implementation than on optimizing strategic value creation through human-technology collaboration. This condition indicates that future HRM strategies should prioritize not only technical training but also the development of analytical thinking, innovation capacity, and digital collaboration competencies to achieve global smart port standards.

To overcome these challenges, the Indonesian government and port authorities have implemented training programs, user support systems, and standard operating procedures to enhance human-technology integration. These efforts aim to ensure that digital platforms are not only implemented but also effectively utilized by all stakeholders. The case of Inaportnet demonstrates that technological integration must be accompanied by strong HRM strategies that focus on capacity building, stakeholder coordination, and continuous improvement.

CONCLUSION

Digital transformation and automation in the port sector represent not merely technological changes but comprehensive transformations involving human, organizational, and cultural dimensions. This study demonstrates that the success of technological implementation is highly dependent on the readiness and quality of human resources. HRM has evolved into a strategic partner that not only manages workforce administration but also drives organizational change through digital competency development, change management, and the integration of technology with human capabilities. Without adaptive HR strategies, digitalization may lead to skill gaps, employee resistance, and operational inefficiencies.

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From a practical perspective, port organizations should develop continuous training programs focused on enhancing digital skills, including data analytics, automated system operations, and cybersecurity awareness. The adoption of e-HRM systems should be strengthened to support data-driven decision-making in HR processes. Additionally, management should implement inclusive change management strategies through effective communication, employee engagement, and strong leadership support. Collaboration with educational and training institutions is also essential to ensure alignment between workforce competencies and industry needs.

From a broader policy perspective, the government plays a crucial role in supporting sustainable digital transformation in the port sector through long-term human capital development policies. National strategies should emphasize the establishment of integrated maritime digital competency frameworks, industry-based certification systems, and large-scale reskilling programs to prepare the workforce for future automation challenges. In addition, stronger collaboration between government agencies, port authorities, universities, and private industries is necessary to create adaptive education and training ecosystems aligned with global smart port standards. Investment in digital infrastructure should also be accompanied by labor protection policies and inclusive workforce transition programs to minimize social inequality and employment disruption caused by automation. Therefore, sustainable port digitalization requires not only technological investment but also comprehensive public policies that strengthen workforce resilience, innovation capacity, and long-term national maritime competitiveness.

Future research is recommended to conduct empirical studies using quantitative or mixed-method approaches to evaluate the effectiveness of HRM strategies in real-world port environments. Comparative studies across different countries or types of ports could provide broader insights into best practices. Furthermore, in-depth investigations into the social impacts of automation on port labor are necessary to better understand workforce transitions and policy implications.

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