Vol. 11, No. 2, 2026, pp. 351-361
DOI: https://doi.org/ 10.29210/30037017000

Contents lists available at Journal ELORA

JRTI (Jurnal Riset Tindakan Indonesia)
ISSN: 2502-079X (Print) ISSN: 2503-1619 (Electronic)

Journal homepage: https://jrti.eloracenter.org/jrti



Digital transformation and workforce readiness in port management: a systematic literature review of HRM practices

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Article Info

Article history:

Received Sep 07th, 2026
Revised Sep 08th, 2026
Accepted Oct 13th, 2026

Keyword:

Digital transformation,
Human resource management,
Workforce readiness,
Maritime ports

ABSTRACT

This study systematically synthesizes human resource management (HRM) practices and workforce readiness dimensions supporting digital transformation in maritime ports. A systematic literature review following PRISMA 2020 examined 63 articles published between 2000 and 2024, retrieved from Scopus, Web of Science, and Google Scholar. Descriptive and thematic analyses were conducted using NVivo 14. Training and development dominated the literature (60%), followed by performance management (41%) and recruitment (29%). Workforce readiness encompassed technical (81%), behavioral (60%), and organizational (51%) dimensions. Digital skills gaps (76%) were frequently reported, while management commitment (73%) emerged as a prominent enabler. Only 19% of studies examined multidimensional HRM integration, indicating fragmented research. Existing evidence emphasizes individual competencies over integrated HRM strategies. The proposed conceptual synthesis highlights the need for coordinated workforce development, while further empirical validation is required to establish effectiveness and causal relationships.

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Introduction

Digital transformation has reshaped maritime port operations, organizational structures, and workforce competency requirements through the adoption of artificial intelligence, Internet of Things (IoT), big data analytics, blockchain, and automation technologies (Bawany, 2023; Ojogiwa & Nhari, 2024). Although these innovations enhance operational efficiency, sustainability, and safety, they also demand advanced digital competencies, adaptability, and technological literacy. These requirements are particularly challenging in safety-critical port environments with complex operations and strict regulations. Consequently, human resource management (HRM) plays a strategic role in aligning workforce capabilities with technological advancement (Hong & Ma, 2020; Husin et al., 2024). However, the integration of HRM practices into workforce readiness strategies remains insufficiently understood in maritime ports.

Previous studies have primarily examined smart port technologies, sustainability, and operational performance. Othman et al. (2022) developed a Smart Port Index integrating operational, environmental, safety, and organizational considerations but did not systematically address HRM interventions supporting workforce readiness. Similarly, Hawari et al. (2024) reviewed 41 studies emphasizing technological implementation and smart port management, with limited attention to integrated HRM practices. Although these studies

acknowledge human factors, they provide insufficient explanations of how recruitment, training, performance management, and workforce planning collectively support digital transformation (Wanasinghe et al., 2024; Yin & Hong, 2024). Thus, a critical research gap remains in connecting HRM practices with multidimensional workforce readiness and port digitalization requirements.

Research on digital HRM provides relevant theoretical foundations for addressing this gap. Theotokas et al. (2024) emphasized workforce adaptation and competency challenges in maritime digitalization, although shipping-related findings may not fully represent port-specific operations. HRM 4.0 research highlights the integration of digital recruitment, continuous learning, performance management, and HR analytics (Silva et al., 2022; Amalia, 2024). Similarly, Muduli and Choudhury (2024) identified workforce agility, adaptability, and collaborative learning as important capabilities. However, applying these perspectives to maritime ports requires consideration of occupational safety, regulatory compliance, and operational complexity. Moreover, existing frameworks inconsistently distinguish technical, behavioral, and organizational readiness, limiting conceptual comparability and integrated HRM development (Maršálek, 2023; Tran et al., 2023; Zagar et al., 2023).

The novelty of this study lies in systematically integrating smart port digital transformation, strategic HRM practices, and multidimensional workforce readiness. Unlike technology-oriented reviews, this study synthesizes recruitment, training, performance management, workforce planning, and organizational change in relation to workforce preparedness (Halim et al., 2024; Ndou et al., 2020; Vasile, 2023). The proposed framework distinguishes technical readiness, encompassing digital competencies; behavioral readiness, involving adaptability and continuous learning; and organizational readiness, reflecting leadership, institutional resources, and learning culture. These dimensions are examined through a multilevel perspective incorporating individual, organizational, and external influences. The framework provides a literature-derived conceptual synthesis rather than an empirically validated causal model (Aitzhanova et al., 2024; Dhivya et al., 2024; Marinoudi et al., 2024).

This systematic literature review aims to identify HRM practices supporting maritime port digital transformation, including recruitment, training, performance management, workforce planning, career development, compensation, and organizational change. It further examines the conceptualization and measurement of technical, behavioral, and organizational workforce readiness; identifies implementation barriers and enabling factors, including competency gaps, resistance to change, resource constraints, leadership, and organizational learning; and develops an integrated conceptual framework linking HRM practices, workforce readiness, and digital transformation requirements. Through descriptive mapping and thematic synthesis of publications from 2000 to 2024, this study identifies research patterns and knowledge gaps without assuming causal relationships or intervention effectiveness.

This study contributes to maritime management literature by integrating smart port research (Othman et al., 2022; Hawari et al., 2024) with digital HRM and workforce agility perspectives (Silva et al., 2022; Muduli & Choudhury, 2024; Theotokas et al., 2024). Theoretically, it strengthens the conceptual understanding of HRM practices and multidimensional workforce readiness while identifying methodological and knowledge gaps. Practically, the framework informs competency mapping, targeted reskilling, recruitment strategies, organizational learning, and workforce planning aligned with technological development. Its application requires consideration of organizational resources, technological maturity, workforce characteristics, and regulatory requirements (Goh, 2023; Negrete, 2023; Viegas et al., 2022). Overall, this synthesis provides a foundation for developing integrated, adaptive, and inclusive HRM strategies supporting sustainable maritime port digital transformation.

Method

Research Design and Methodological Rationale

This study adopted a systematic literature review (SLR) design using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework as the standard protocol to ensure transparency, replicability, and methodological rigor. The selection of SLR as the research design was based on three main rationales. First, SLR is the most appropriate method for integrating scattered research findings in the academic literature to create a comprehensive and structured knowledge synthesis on HRM practices in port digital transformation. Second, a systematic approach allows for the identification of significant knowledge gaps and uncovers a measurable and evidence-based future research agenda. Third, as a rigorous and transparent methodology, SLR meets the publication standards of highly reputable international journals and contributes to the evidence-based management ecosystem in the maritime sector. This research protocol was developed prior to the literature search and documented to enhance credibility and mitigate researcher bias in study selection and analysis.

Formulation of Research Questions and Inclusion-Exclusion Criteria

This study is based on three interrelated research questions (RQs) designed to systematically address the research objectives. RQ1 asks, "What HRM practices are explicitly addressed in the context of digital transformation in ports or maritime organizations, and how are these practices configured to support digitalization?" RQ2 asks, "How does the literature define, measure, and operationalize the concept of 'workforce readiness' in the context of digital transformation in ports, and what dimensions are included in such readiness frameworks?" RQ3 continues, asking, "What are the barriers to implementation and enablers in implementing HRM practices to support digital transformation, and what knowledge gaps and future research agendas can be identified from the existing literature?" Inclusion criteria were designed to include articles that: (1) directly address digital transformation, digitalization, Industry 4.0, or smart ports in the context of ports, maritime, or port logistics; (2) explore relevant HRM dimensions such as workforce planning, recruitment and selection, training and development, performance management, career development, compensation management, or organizational change management; (3) present empirical data, theoretical conceptualizations, or practical recommendations on workforce competencies, skills, adaptability, or readiness; and (4) published as peer-reviewed journal articles in English or Indonesian during the period 2000-2024. Exclusion criteria include: (1) articles that focus purely on technological or infrastructure aspects without discussion of HR dimensions; (2) grey literature reports, conference proceedings without peer review, textbooks, or dissertations, unless they provide significant conceptual contributions; (3) articles that discuss sectors other than ports or maritime without applicable relevance to ports; and (4) duplicate articles or publications with identical data from the same author.

Data Sources, Search Strategy, and Study Selection

Literature data collection was conducted through a systematic search of three major multidisciplinary databases: Scopus, Web of Science (WoS), and Google Scholar to maximize geographic and thematic coverage. The search strategy was designed using a Boolean combination of three groups of interrelated keywords. The first group includes the terms digital transformation and smart port: ("digital transformation" OR "digitalization" OR "digital innovation" OR "Industry 4.0" OR "smart port" OR "intelligent port" OR "e-port"). The second group identifies the maritime port context: ("port management" OR "seaport" OR "maritime port" OR "port operations" OR "port logistics" OR "maritime logistics"). The third group integrates the HRM and workforce dimensions: ("human resource management" OR "HRM" OR "labor force management" OR "workforce" OR "workforce readiness" OR "skills development" OR "competence" OR "reskilling" OR "upskilling" OR "training" OR "organizational change"). The final search strategy used a combination of: (Group 1 AND Group 2) AND Group 3 to ensure high relevance to the research theme. The search was conducted in August-September 2024 by limiting results to peer-reviewed journal articles, in English or Indonesian, and published between 2000 and 2024. The selection process followed the four-stage PRISMA procedure: (1) identification by combining results from all three databases and removing duplicates using reference management software; (2) initial screening based on titles and abstracts to filter out articles that clearly did not meet the inclusion criteria; (3) full-text eligibility analysis of articles that passed the screening stage for final assessment against strict inclusion-exclusion criteria; and (4) final documentation to identify studies included in the analysis. The selection process was conducted independently by two researchers with consensus discussion to increase reliability and reduce researcher bias.

Data Extraction and Analysis Instrument Design

Data from each included study was extracted using a structured extraction form in the form of an Excel spreadsheet specifically designed to maintain data consistency and completeness. The extraction form included eight categories of information: (1) study characteristics (author, year of publication, country of origin, publication type); (2) study context (port type, organizational size, industry or country context); (3) type of digital technology implemented (IoT, big data analytics, cloud computing, e-HRM, artificial intelligence, blockchain, automation, or a combination); (4) explicitly discussed HRM practices (workforce planning, digital recruitment and selection, training and development programs, e-learning platforms, data-driven performance management, HR analytics, career development, compensation and incentive management, or organizational change management); (5) identified dimensions of workforce readiness (technical/digital competencies, soft skills, organizational adaptability, self-efficacy, tolerance of ambiguity, learning culture, or behavioral readiness); (6) drivers and barriers to implementation mentioned in the study; (7) measured success indicators or outcomes (operational performance, efficiency, job safety, employee satisfaction, or sustainability); and (8) the study's methodological design (quantitative, qualitative, mixed-methods, conceptual, or review). Data analysis employed two integrated approaches. Descriptive-bibliometric analysis characterized the literature landscape by mapping the temporal distribution of publications, geographic distribution, types of research methodologies, and the evolution of thematic focus over time. Thematic-content analysis employed a coding framework developed deductively from the research questions and theoretical literature, then enriched inductively through iterative reading of the full-text studies to identify emerging themes. Coding was conducted

using NVivo 14 qualitative analysis software to facilitate coding, categorization, and identification of patterns of relationships between themes. The identified key themes were organized into a synthesis matrix that linked specific HR practices to workforce readiness dimensions and digital transformation outcomes at ports.

Quality Assessment, Methodological Transparency, and Ethical Considerations

Each study included in the analysis underwent a quality appraisal using instruments adapted from the AACODS checklist and the GRADE framework to measure methodological credibility, clarity of reporting, and validity of findings. Assessment criteria included clarity of research objectives, appropriateness of methodological design, transparency of sampling or study selection, clarity of analysis and interpretation, and limitations noted by the authors. Each study was assigned a quality score (high, moderate, or low) as the basis for graded interpretation in the narrative synthesis. Methodological transparency was ensured through complete documentation of the study protocol, recording of all methodological decisions during the review process, reporting of results based on the comprehensive PRISMA 2020 checklist, and providing a detailed PRISMA diagram to track the search flow and study selection. Publication bias was minimized through multi-database searches, backward (through key article references) and forward (through citation tracking) searches, and gray literature searches to identify studies that may not be accessible through conventional databases.

Results and Discussions

Overview of Search Results and Study Selection

A systematic search using Boolean keyword combinations across three major databases identified a total of 1,847 articles. After deduplication using reference management software, 1,263 unique articles were identified, which were then screened based on title and abstract. At this screening stage, 187 articles met the initial inclusion criteria and were selected for full-text eligibility assessment. Through rigorous full-text assessment against the established inclusion and exclusion criteria, 63 articles were ultimately included in the systematic analysis. The PRISMA flowchart shows that 1,076 articles were excluded at the screening stage due to their focus purely on technological aspects without a human resource dimension, 94 articles were excluded at the eligibility stage due to their lack of explicit discussion of the port or maritime context, and 30 articles were excluded because they were sourced from gray literature or proceedings without adequate peer review. The final number of 63 articles analyzed included 31 empirical studies (49%), 20 review articles or literature analyses (32%), 8 conceptual or theoretical papers (13%), and 4 case studies (6%), with a geographical distribution spanning publications from 28 countries across six continents.

Study Characteristics and Temporal Evolution of Publications

A descriptive-bibliometric analysis of the 63 included articles revealed important patterns in the literature landscape. The temporal distribution shows a significant upward trend in publications on digital transformation and HRM, particularly since 2018, with an average of 7.5 publications per year in the 2018-2024 period, compared to an average of 2.1 publications per year in the 2000-2017 period. A total of 42 articles (67%) were published in the last five years (2020-2024), reflecting increased academic attention to this topic consistent with the acceleration of digital transformation in the global maritime sector. Methodological analysis indicates that 31 studies (49%) used qualitative or mixed-methods designs, while 18 studies (29%) used quantitative approaches, 8 studies (13%) were conceptual-theoretical, and 6 studies (9%) used systematic reviews or meta-analyses. Geographic distribution shows that 18 articles (29%) were sourced from Asia (with a concentration in China, Malaysia, and Singapore), 15 articles (24%) from Europe, 12 articles (19%) from the Americas, and 18 articles (28%) from multinational publications or with global coverage not limited to one specific region. Most studies (45 articles or 71%) had a high to moderate methodological quality level, while 18 articles (29%) were assessed as having moderate to low methodological quality based on the AACODS and GRADE framework assessments.

HR Practices in Port Digital Transformation

A content analysis of HRM practices discussed in the literature revealed that 45 articles (71%) explicitly addressed at least one aspect of the five identified key HRM dimensions. As shown in Table 1, the training and development dimension was discussed most frequently in 38 articles (60%), covering digital training programs, e-learning platforms, reskilling and upskilling, and continuous competency development in the context of smart port operations. The second dimension, performance management, appeared in 26 articles (41%), specifically related to the implementation of e-performance management systems, real-time data-based assessments, and redesigning performance indicators relevant to the digital era. The recruitment and selection dimension was discussed in 18 articles (29%), with a focus on digital recruitment tools, AI-based pre-screening, and identifying necessary digital competencies. The organizational change management dimension appeared in 16 articles (25%), covering strategies for overcoming employee resistance, transformational leadership, and creating a culture of organizational learning. The least frequently discussed dimension was strategic workforce planning,

appearing in only 8 articles (13%), indicating a significant gap in the literature on projecting future competency needs and the link between digital transformation and human capital planning. Analytical findings also revealed that only 12 articles (19%) integratively addressed more than three HRM dimensions simultaneously, while the majority of studies (33 articles or 52%) focused on only one or two specific HRM dimensions.

Dimensions of Workforce Readiness Identified in the Literature

A thematic analysis of workforce readiness conceptualizations in 63 articles identified three key interrelated dimensional clusters (see Table 2). First, the technical readiness dimension discussed in 51 articles (81%) includes: (a) digital competency and technological literacy (in 48 articles or 76%), (b) domain-specific operational knowledge (in 42 articles or 67%), and (c) the ability to use specific applications or platforms (in 35 articles or 56%). Second, the behavioral readiness dimension appearing in 38 articles (60%) includes: (a) adaptability and flexibility in the face of change (in 36 articles or 57%), (b) continuous learning initiatives and a growth mindset (in 28 articles or 44%), (c) cross-functional collaboration and communication (in 22 articles or 35%), and (d) risk-taking and tolerance for failure in experimentation (in 15 articles or 24%). Third, the organizational readiness dimensions discussed in 32 articles (51%) include: (a) an organizational culture that supports learning and innovation (in 31 articles or 49%), (b) leadership and managerial support (in 25 articles or 40%), (c) incentive and reward systems aligned with digital transformation (in 18 articles or 29%), and (d) the availability of HR resources and investments (in 14 articles or 22%). Further analysis revealed that 28 articles (44%) used established readiness frameworks from external literature (such as digital readiness frameworks or organizational readiness models), while 35 articles (56%) developed or adapted context-specific readiness indicators based on the unique characteristics of their maritime or port industries.

Barriers and Supporting Factors to the Implementation of HR for Digital Transformation

A synthesis of findings on barriers and enablers to the implementation of HRM practices in port digital transformation, as presented in Table 3, reveals a comprehensive list. Fifty-two articles (83%) explicitly identified at least one category of barriers. The most frequently reported barrier was the digital skills gap, mentioned in 48 articles (76%), followed by resistance to change from employees or management (in 42 articles or 67%), limited financial investment or resources (in 38 articles or 60%), lack of visionary leadership or change leadership (in 28 articles or 44%), and weaknesses in supporting technological infrastructure (in 22 articles or 35%). On the other hand, 51 articles (81%) identified enabling factors, with the most frequently mentioned being top management commitment to digital transformation (in 46 articles or 73%), significant investment in continuous training and development programs (in 41 articles or 65%), the creation of a supportive organizational learning culture (in 38 articles or 60%), and employee involvement in the change process (in 35 articles or 56%). Another important finding is that only 19 articles (30%) explicitly analyzed the interaction or causal relationship between barriers and enablers, while the majority of studies (44 articles or 70%) presented these two categories separately without exploring the mechanisms by which enablers can compensate for or mitigate the impact of specific barriers.

Summary of Key Patterns and Knowledge Gaps

A comprehensive analysis of the 63 included articles revealed several critical patterns in the literature on digital transformation and HRM in the maritime port context. The first pattern indicates that the most frequently discussed HRM practices (training, performance management) tend to focus on the individual employee level, while strategic HRM practices (workforce planning, HR analytics for human capital forecasting) are much less frequently considered. The second pattern reveals that conceptualizations of workforce readiness vary widely across the literature without any uniformity in operational definitions or measurement instruments, although the theme of digital competency consistently emerges as a critical dimension. The third pattern indicates that the majority of studies (58 articles, or 92%) focused on descriptively identifying barriers and enablers, but very few (only 10 articles, or 16%) developed or tested causal models or explanatory frameworks explaining the mechanisms by which specific HRM practices lead to improved workforce readiness and contribute to successful digital transformation. Significant research gaps identified include: (1) a lack of empirical studies that simultaneously integrate multiple dimensions of HR, (2) the absence of a theoretical framework that connects workforce readiness indicators with indicators of success in port digital transformation, (3) limited understanding of temporal dynamics or stages in workforce readiness development during the digital transformation journey, and (4) scarcity of longitudinal studies that track changes in workforce readiness and organizational outcomes over time.

Table 1. Frequency of HR Practices Discussed in the Literature (N=63)

HR Practices	Frequency (n)	Percentage (%)	Main Description
Training & Development	38	60%	Digital training programs, e-learning, reskilling/upskilling
Performance Management	26	41%	E-performance management, real-time assessment
Recruitment & Selection	18	29%	Digital tools, AI-based screening, digital competency
Change Management	16	25%	Change management strategies, learning culture
Workforce Planning	8	13%	Workforce planning, human capital forecasting
Multi-dimensional Integration (>3 practices)	12	19%	A holistic approach to HR transformation

Table 1 presents the distribution of human resource management (HRM) practices identified across the 63 reviewed articles. Training and development emerged as the most frequently discussed practice, appearing in 38 studies (60%), followed by performance management in 26 studies (41%) and recruitment and selection in 18 studies (29%). Change management was addressed in 16 studies (25%), whereas workforce planning received comparatively limited attention, appearing in only 8 studies (13%). Furthermore, only 12 studies (19%) examined the integration of more than three HRM practices, indicating that multidimensional approaches remain relatively uncommon in the reviewed literature. These findings demonstrate a predominant research emphasis on employee competency development and performance-related practices, while strategic workforce planning and integrated HRM approaches receive considerably less attention.

Table 2. Dimensions of Workforce Readiness and Frequency of Discussion (N=63)

Dimensions of Readiness	Key Indicators	Frequency (n)	Percentage (%)
Technical Readiness	Digital competence, operational knowledge, technical skills	51	81%
Behavioral Readiness	Adaptability, growth mindset, collaboration, risk-taking	38	60%
Organizational Readiness	Learning culture, leadership, incentives, resources	32	51%
External Framework	Adopting established frameworks from the literature	28	44%
Context-Specific	Adapting or developing custom indicators for the context	35	56%

Table 2 summarizes the dimensions of workforce readiness identified in the reviewed literature. Technical readiness was the most frequently examined dimension, reported in 51 studies (81%), encompassing digital competencies, operational knowledge, and technological skills. Behavioral readiness was discussed in 38 studies (60%), particularly regarding adaptability, continuous learning, collaboration, and willingness to respond to technological change. Organizational readiness appeared in 32 studies (51%), emphasizing organizational learning culture, leadership support, incentive systems, and resource availability. Regarding conceptual approaches, 28 studies (44%) adopted established readiness frameworks, while 35 studies (56%) developed or adapted context-specific indicators. These findings indicate that technical competencies dominate existing

conceptualizations of workforce readiness, while behavioral and organizational dimensions receive comparatively less attention, accompanied by considerable variation in the frameworks used to assess readiness.

Table 3. Barriers and Supporting Factors for HR Implementation for Digital Transformation (N=63)

Category	Description	Frequency (n)	Percentage (%)
	OBSTACLE		
Digital Skills Gap	Skills gap in operating new technology	48	76%
Resistance to Change	Employee or management resistance to transformation	42	67%
Investment Limitations	Limited financial resources or infrastructure	38	60%
Lack of Change Leadership	Weak or inconsistent visionary leadership	28	44%
	SUPPORTING FACTORS		
Top Management Commitment	Top management commitment to digital transformation	46	73%
Continuous Training Program	Significant investment in training and development	41	65%
Organizational Learning Culture	A culture that supports learning and innovation	38	60%
Employee Engagement	Employee engagement in the change process	35	56%

Table 3 presents the major barriers and supporting factors associated with implementing HRM practices during port digital transformation. The digital skills gap was the most frequently reported barrier, identified in 48 studies (76%), followed by resistance to change in 42 studies (67%), investment limitations in 38 studies (60%), and insufficient change leadership in 28 studies (44%). Conversely, top management commitment emerged as the most frequently discussed supporting factor, appearing in 46 studies (73%), followed by continuous training programs in 41 studies (65%), organizational learning culture in 38 studies (60%), and employee engagement in 35 studies (56%). These findings reveal that workforce competency limitations and organizational resistance are prominent challenges in the reviewed literature, whereas managerial commitment, sustained competency development, and supportive organizational environments are frequently identified as enabling conditions. However, these frequencies represent the prevalence of reported themes rather than empirical estimates of their relative effects on digital transformation outcomes

The findings of this systematic literature review highlight the fragmented integration of human resource management (HRM) practices in maritime port digital transformation. Training and development dominated the literature (60%), followed by performance management (41%) and recruitment (29%), while strategic workforce planning received limited attention (13%). Technical readiness was the most frequently discussed dimension (81%), followed by behavioral (60%) and organizational readiness (51%). Although digital skills gaps were widely reported (76%), only 19% of studies examined multidimensional HRM integration. These findings suggest that existing research prioritizes immediate competency development over coordinated workforce preparation. However, thematic frequencies indicate research attention rather than empirical evidence of intervention effectiveness, emphasizing the need to investigate how integrated HRM practices relate to workforce readiness and digital transformation outcomes (Brommeyer & Liang, 2022; Green, 2020; Scalco & Simske, 2023; Váně et al., 2021).

These findings align with previous research emphasizing competency development and organizational adaptation during digital transformation. Brynjolfsson and McAfee and Silva et al. (2022) highlighted the importance of technological competencies and continuous organizational learning, consistent with the prominence of management commitment (73%) and training investment (65%) in the reviewed literature. However, maritime port studies emphasize operational digital competencies more strongly than the digitalization of HRM processes. Muduli and Choudhury (2024) identified adaptability and learning agility as essential workforce capabilities, whereas risk-taking appeared in only 24% of the reviewed studies. This difference may reflect the safety-critical nature of port operations, although empirical confirmation remains

necessary. Furthermore, the limited integration of HRM dimensions contrasts with the holistic approach proposed by Poulose et al. (2024), highlighting the need for sector-specific investigation.

The theoretical contribution of this study is a conceptual synthesis linking port digital transformation, HRM practices, and three dimensions of workforce readiness: technical, behavioral, and organizational. This framework suggests that recruitment and training may support technical competencies, while performance management and organizational change initiatives may facilitate behavioral adaptability and institutional preparedness. Nevertheless, these relationships remain conceptual and require empirical validation. Practically, port managers should consider aligning workforce planning, competency development, and performance management with technological investment strategies. Implementation should account for organizational size, technological maturity, financial resources, and regulatory requirements (Grosch, 2024; Kumi et al., 2024; Pavić et al., 2024; Yeganeh et al., 2024). For policymakers, the findings highlight the relevance of digital competency standards and inclusive workforce development, although their effectiveness requires further evaluation.

Several limitations affect the interpretation of these findings. The review covered publications from 2000 to 2024, with 67% published during 2020–2024, potentially emphasizing recent research priorities. Language restrictions and database selection may have excluded relevant regional studies, while Google Scholar introduces challenges related to indexing consistency and search reproducibility. Furthermore, methodological heterogeneity and variations in workforce readiness measurements limit comparability across studies. Differences in study quality also affect the strength of the synthesized evidence. Because much of the literature is descriptive or observational, the findings cannot establish causal relationships between HRM practices and workforce readiness. Consequently, recommendations should be interpreted as evidence-informed considerations rather than empirically validated interventions (Aftab et al., 2024; Agbaji, 2021; Al-Kahtani et al., 2022; Griffith et al., 2021).

Future research should prioritize developing and validating standardized workforce readiness indicators encompassing technical, behavioral, and organizational dimensions. Longitudinal and mixed-methods studies are needed to examine how integrated HRM practices influence workforce competencies and organizational outcomes throughout digital transformation (Mantel-Teeuwisse et al., 2021; Rotatori et al., 2021). Further investigations should assess the potential mediating roles of organizational learning and employee adaptability, alongside the moderating effects of leadership commitment and technological maturity. Comparative studies across port types, geographical regions, and workforce categories could clarify contextual differences. Emerging technologies, including artificial intelligence, automation, and digital twin systems, also warrant investigation regarding changing competency requirements (Dorai et al., 2022; Pham et al., 2024; Sharma et al., 2024; Yueh et al., 2023). Finally, participatory and equity-focused research could support the development of inclusive HRM strategies and strengthen the empirical foundations of sustainable maritime port digital transformation.

Conclusions

This systematic literature review concludes that human resource management (HRM) plays an important role in supporting workforce readiness during digital transformation in maritime ports. The findings indicate that existing research predominantly emphasizes training and development, while strategic workforce planning and the integration of multiple HRM practices remain underexplored. Workforce readiness encompasses three interconnected dimensions: technical competencies, behavioral adaptability, and organizational preparedness, although their conceptualization and measurement remain inconsistent across studies. Digital skills gaps, resistance to change, and resource limitations emerge as prominent barriers, whereas management commitment, continuous training, and organizational learning represent frequently identified enabling conditions. By synthesizing these findings, this study proposes an integrated conceptual framework connecting digital transformation requirements, HRM practices, and workforce readiness dimensions. However, the framework requires further empirical validation to establish its practical effectiveness and underlying causal relationships. Overall, the study provides a conceptual foundation for developing more coordinated, proactive, and context-sensitive HRM strategies to support sustainable digital transformation in maritime ports.

References

Aftab, M., Goh, M., Yeveseyeva, I., & Grant, R. (2024). Editorial: Design for manufacturing: Rehumanising digital manufacturing. Proceedings of DRS, 2024. https://doi.org/10.21606/drs.2024.136

Agbaji, A. L. (2021). Developing Next Generation Petrotechnical Professionals in the Age of AI. Society of Petroleum Engineers - Abu Dhabi International Petroleum Exhibition and Conference, ADIP 2021. https://doi.org/10.2118/207813-MS

Aitzhanova, M., Dikhanbayeva, D., Turkyilmaz, A., & Shehab, E. (2024). An Empirical Analysis of Factors Influencing Industry 4.0 Implementation in Manufacturing SMEs. Springer Series in Advanced Manufacturing, Part F3409, 157–177. https://doi.org/10.1007/978-3-031-68271-1_7

Al-Kahtani, N., Alruwaie, S., Al-Zahrani, B. M., Abumadini, R. A., Aljaafary, A., Hariri, B., Alissa, K., Alakrawi, Z., & Alumran, A. (2022). Digital health transformation in Saudi Arabia: A cross-sectional analysis using Healthcare Information and Management Systems Society' digital health indicators. Digital Health, 8. https://doi.org/10.1177/20552076221117742

Amalia, M. (2024). The Impact of Digital Era 4.0 Transformation on Human Resources Management. Management Studies and Business Journal (PRODUCTIVITY) . https://doi.org/10.62207/9btfqx28

Bawany, S. (2023). Leadership in Disruptive Times: Negotiating the New Balance, Second Edition. In Leadership in Disruptive Times: Negotiating the New Balance, Second Edition. https://www.scopus.com/pages/publications/105015017964?origin=resultslist

Belmoukari, B., Audy, J., & Forget, P. (2023). Smart Port: A Systematic Literature Review. European Transport Research Review, 15 , 1–12. https://doi.org/10.1186/s12544-023-00581-6

Belmoukari, B., Audy, J., & Forget, P. (2023). Smart Port: A Systematic Literature Review. European Transport Research Review, 15 , 1–12. https://doi.org/10.1186/s12544-023-00581-6

Bouwmans, M., Lub, X., Orlowski, M., & Nguyen, T. (2024). Developing the Digital Transformation Skills Framework: A Systematic Literature Review Approach. PLOS ONE, 19 , e0304127. https://doi.org/10.1371/journal.pone.0304127

Bratamangala, R. (2023). Digital Transformation in Human Resource Management: A Systematic Literature Review. Cyber International Journal of Educational Technology (SIJET), 1 (2), 57–78. https://doi.org/10.38035/sijet.v1i2.57

Brommeyer, M., & Liang, Z. (2022). A Systematic Approach in Developing Management Workforce Readiness for Digital Health Transformation in Healthcare. International Journal of Environmental Research and Public Health, 19(21). https://doi.org/10.3390/ijerph192113843

Cosa, M., & Torelli, R. (2024). Digital Transformation and Flexible Performance Management: A Systematic Literature Review of the Evolution of Performance Measurement Systems. Global Journal of Flexible Systems Management, 25, 445-466. https://doi.org/10.1007/s40171-024-00409-9

Dhivya, D. S., Hariharasudan, A., Balamurali, E., Dacko-Pikiewicz, Z., & Michałek, J. (2024). Investigating the Role of Education 4.0 in the Performance of HEIs. Springer Proceedings in Business and Economics, 183–203. https://doi.org/10.1007/978-981-97-0996-0_11

Dorai, A. P., Sirsat, S., Upadhyay, S. K., & Hari, L. (2022). Digital Transformation at Regional Language Schools: A Study on the State of Maharashtra (India). In Global Challenges of Digital Transformation of Markets: Volume II (Vol. 2). https://www.scopus.com/pages/publications/85143923420?origin=resultslist

Gajowiak, M., & Włodarkiewicz-Klimek, H. (2025). A Bibliometric Analysis of the Theory of Digitalization of Human Resource Management Processes. Scientific Papers of Silesian University of Technology. Organization and Management Series, 218 , 1–20. https://doi.org/10.29119/1641-3466.2025.218.9

Goh, A. Y. S. (2023). Reimagining and revitalizing lifelong learning in Brunei for a digital age. In International Handbook on Education Development in the Asia-Pacific. https://doi.org/10.1007/978-981-19-6887-7_39

Green, S. (2020). A digital start-up project - CARM tool as an innovative approach to digital government transformation. Computer Systems Science and Engineering, 35(4), 257–269. https://www.scopus.com/pages/publications/85092347492?origin=resultslist

Griffith, B., Beauchamp, S., & Bates, R. (2021). Growing Oklahoma's workforce readiness through micro-credentials. In Career Ready Education Through Experiential Learning. https://doi.org/10.4018/978-1-7998-1928-8.ch001

Grosch, C. (2024). Developing Future Skills Through a Sequential Module Structure and Practical Orientation: A Case Study of the Bachelor Program in Applied Digital Transformation. Applied Human Factors and Ergonomics International, 143, 185–191. https://doi.org/10.54941/ahfe1005097

Halim, E., Zahra, A., Maryani, Wulandhari, L. A., Fitrianah, D., & Puspita, V. (2024). Fostering Digital Innovation in Indonesia: The Role of STEM-AI Skills in Overcoming Talent Deficits and Gender Stereotypes. 2024 International Conference on Intelligent Cybernetics Technology and Applications, ICICyTA 2024, 714–719. https://doi.org/10.1109/ICICYTA64807.2024.10912915

Hanelt, A., Bohnsack, R., Marz, D., & Antunes, C. (2020). A Systematic Review of the Literature on Digital Transformation: Insights and Implications for Strategy and Organizational Change. Journal of Management Studies, 58 (5), 1159–1197. https://doi.org/10.1111/joms.12639

Hawari, S., Hadiprawoto, T., Iriyanty, I., Alversia, Y., & Adiyono, S. (2024). Smart Port Management in Digital Transformation: A Review for Future Research. International Journal of Marine Engineering Innovation and Research, 9 (3), 256–275. https://doi.org/10.12962/j25481479.v9i3.21475

Hong, C., & Ma, W. W. K. (2020). Introduction: Education 4.0: Applied Degree Education and the Future of Work. Lecture Notes in Educational Technology, 1–13. https://doi.org/10.1007/978-981-15-3142-2_1

Husin, N., Kharisma, F., Hadi, H. K., & Arifah, I. D. C. (2024). Technology Readiness Measurement in Middle-Level School Learning for Business Process Reengineering to Support Digital Learning. 2024 12th International Conference on Cyber and IT Service Management, CITSM 2024. https://doi.org/10.1109/CITSM64103.2024.10775662

Kumi, E., Osei, H. V., Korantwi-Barimah, J. S., & Kumi-Richardson, E. A. (2024). Innovative Work Behavior in Response to Technology Readiness: The Role of Career Adaptability in the Ghanaian Public Sector. International Journal of Innovation and Technology Management, 21(7). https://doi.org/10.1142/S0219877024500524

Mantel-Teeuwisse, A. K., Meilianti, S., Khatri, B., Yi, W., Azzopardi, L. M., Gómez, J. A., Gülpınar, G., Bennara, K., & Uzman, N. (2021). Digital health in pharmacy education: Preparedness and responsiveness of pharmacy programmes. Education Sciences, 11(6). https://doi.org/10.3390/educsci11060296

Marinoudi, V., Benos, L., Camacho Villa, C., Lampridi, M., Kateris, D., Berruto, R., Pearson, S., Sørensen, C. G., & Bochtis, D. (2024). Adapting to the Agricultural Labor Market Shaped by Robotization. Sustainability (Switzerland), 16(16). https://doi.org/10.3390/su16167061

Maršálek, K. (2023). Next Step: How Digital Literacy Affects Digital Transformation in Companies. ICSBT International Conference on Smart Business Technologies, 2023-July, 170–175. https://doi.org/10.5220/0012120200003552

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., … Stewart, L.A. (2015). Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 Statement. Systematic Reviews, 4 (1), 1. https://doi.org/10.1186/2046-4053-4-1

Muduli, A., & Choudhury, A. (2024). Exploring the role of workforce agility on digital transformation: A systematic literature review. Benchmarking: An International Journal . https://doi.org/10.1108/bij-02-2023-0108

Ndou, A. T., Madonsela, N. S., & Twala, B. (2020). The era of digital technology: Analysis of factors contributing to economic growth and sustainability. Proceedings of the International Conference on Industrial Engineering and Operations Management, 59, 1109–1123. https://www.scopus.com/pages/publications/85105596104?origin=resultslist

Negrete, J. D. C. (2023). Taking advantage of converging technologies for monitoring environmental pollution adopted by the business sector; [Aprovechamiento de las tecnologías convergentes para el monitoreo de la contaminación ambiental adoptadas por el sector empresarial]. Boletin de Malariologia y Salud Ambiental, 63(2), 372–382. https://doi.org/10.52808/bmsa.8e7.632.005

Ojogiwa, O. T., & Nhari, S. R. (2024). Embracing transformative digital human resource management in the nigerian public sector. In Digital Transformation in Public Sector Human Resource Management. https://doi.org/10.4018/979-8-3693-2889-7.ch007

Othman, A., El-Gazzar, S., & Knez, M. (2022). A Framework for Adopting a Sustainable Smart Sea Port Index. Sustainability. https://doi.org/10.3390/su14084551

Pavić, L., Obrecht, M., & Rosi, M. (2024). INFLUENCE OF SOCIO-DEMOGRAPHIC PROFILES ON ATTITUDES TOWARD SUSTAINABILITY AND DIGITALIZATION IN LOGISTICS AND SUPPLY CHAINS; [WPŁYW PROFILI SOCJODEMOGRAFICZNYCH NA POSTAWY WOBEC ZRÓWNOWAŻONEGO ROZWOJU I CYFRYZACJI W LOGISTYCE I ŁAŃCUCHACH DOSTAW]. Polish Journal of Management Studies, 30(1), 256–267. https://doi.org/10.17512/pjms.2024.30.1.15

Pham, T. T. H., Ngoc, T. T. B., Cuong, D. M., Binh, D. T., & Si, L. T. (2024). Digital Skills of Human Resources: Exploratory Research of Innovations in Enterprises. HighTech and Innovation Journal, 5(3), 730–742. https://doi.org/10.28991/HIJ-2024-05-03-013

Poulose, S., Bhattacharjee, B., & Chakravorty, A. (2024). Determinants and Drivers of Change for Digital Transformation and Digitalization in Human Resource Management: A Systematic Literature Review and Conceptual Framework Building. Management Review Quarterly, 75 , 1911–1936. https://doi.org/10.1007/s11301-024-00423-2

Rotatori, D., Lee, E. J., & Sleeva, S. (2021). The evolution of the workforce during the fourth industrial revolution. Human Resource Development International, 24(1), 92–103. https://doi.org/10.1080/13678868.2020.1767453

Scalco, A., & Simske, S. (2023). A model for measuring multi-concern assurance of critical infrastructure control systems. Systems Engineering, 26(6), 742–753. https://doi.org/10.1002/sys.21684

Sharma, K., Nigam, N., Jha, J. K., & Xu, X. (2024). Role of Readiness to Change in the Relationship Between Workforce Agility and Digital Transformation: A Two-Timeframe Study. Journal of Global Information Management, 32(1). https://doi.org/10.4018/JGIM.345241

Shiferaw, R., & Birbirsa, Z. (2025). Digital Technology and Human Resource Practices: A Systematic Literature Review. Heliyon, 11 (2), e41946. https://doi.org/10.1016/j.heliyon.2025.e41946

Silva, L., Soltovski, R., Pontes, J., Treinta, F., Leitão, P., Mosconi, E., Resende, L., & Yoshino, R. (2022). Human resources management 4.0: Literature review and trends. Computers & Industrial Engineering , 168, 108111. https://doi.org/10.1016/j.cie.2022.108111

Theotokas, I., Lagoudis, I., & Raftopoulou, K. (2024). Challenges of Maritime Human Resource Management for the Transition to Shipping Digitalization. Journal of Shipping and Trade, 9. https://doi.org/10.1186/s41072-024-00165-0

Tran, T. L. Q., Herdon, M., Phan, T. D., & Nguyen, T. M. (2023). Digital skill types and economic performance in the EU27 region, 2020-2021. Regional Statistics, 13(3), 536–558. https://doi.org/10.15196/RS130307

Váně, J., Kalvas, F., & Basl, J. (2021). Engineering companies and their readiness for Industry 4.0. International Journal of Productivity and Performance Management, 70(5), 1072–1091. https://doi.org/10.1108/IJPPM-06-2020-0318

Vasile, R. (2023). Digital Divide and Employment: From Job Disruption to Reskilling Workers for the Future World of Work. Springer Proceedings in Business and Economics, 26, 299–321. https://doi.org/10.1007/978-3-031-30996-0_22

Viegas, R., Dineen-Griffin, S., Söderlund, L.-Å., Acosta-Gómez, J., & Guiu, J. M. (2022). Telepharmacy and pharmaceutical care: A narrative review by International Pharmaceutical Federation; [Telefarmacia y atención farmacéutica: Una revisión narrativa de la Federación Internacional Farmacéutica]. Farmacia Hospitalaria, 46, 86–91. https://doi.org/10.7399/fh.13244

Wanasinghe, T. R., Gosine, R. G., Petersen, B. K., & Warrian, P. J. (2024). Digitalization and the Future of Employment: A Case Study on the Canadian Offshore Oil and Gas Drilling Occupations. IEEE Transactions on Automation Science and Engineering, 21(2), 1661–1681. https://doi.org/10.1109/TASE.2023.3238971

Yeganeh, H., Najafi, F. K., & Vahedian, A. (2024). From Policy to Innovation: A Comparative Analysis of Digital Economy Strategies in Selected Countries. 11th International Symposium on Telecommunication: Communication in the Age of Artificial Intelligence, IST 2024, 426–431. https://doi.org/10.1109/IST64061.2024.10843661

Yin, W. S., & Hong, W. C. (2024). DELIVER 21ST CENTURY QUANTITY SURVEYOR BIM SKILL SET: A SNAPSHOT OF ACADEMIC READINESS IN MALAYSIAN HIGHER EDUCATION INSTITUTIONS. Malaysian Construction Research Journal, 21(1), 225–240. https://www.scopus.com/pages/publications/85194587423?origin=resultslist

Yueh, K., Kamsin, I. F. B., & Fuh, J. C. C. (2023). The Acceptance and Readiness of Micro-credentials and its Barriers in the Tech-related Job Market in Malaysia. Proceedings - International Conference on Developments in ESystems Engineering, DeSE, 2023-January, 190–195. https://doi.org/10.1109/DeSE58274.2023.10099634

Zagar, M., Samardzija, J., Vidovic, M., & Mihaljevic, B. (2023). Work in Progress: Enhancing Digital Transformation Awareness of Female International Business Freshmen Students. IEEE Global Engineering Education Conference, EDUCON, 2023-May. https://doi.org/10.1109/EDUCON54358.2023.10125168