



A Multi-Criteria Decision Support System for Evaluating Industry 5.0 Readiness in Manufacturing Organizations

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ABSTRACT

The transition from Industry 4.0 to Industry 5.0 has shifted industrial transformation beyond automation and digitalization toward human-centric, sustainable, and resilient manufacturing systems. As organizations prepare to adopt Industry 5.0 technologies, evaluating organizational readiness has become essential for reducing implementation risks and supporting strategic decision-making. However, existing readiness assessment approaches remain fragmented, highly subjective, and often lack comprehensive decision support capable of integrating technological, organizational, human, and sustainability dimensions. Therefore, this study aims to develop an Industry 5.0 Readiness Evaluation System using a Multi-Criteria Decision Making (MCDM) approach. The research employed the Design Science Research (DSR) methodology to design, develop, and validate a web-based Decision Support System. Primary data were collected through expert questionnaires, interviews, and observations, while secondary data were obtained from previous studies, industrial reports, and relevant literature. The proposed framework evaluates fifteen readiness dimensions, including technology readiness, human readiness, artificial intelligence, digital infrastructure, cybersecurity, leadership, innovation, data governance, sustainability, organizational culture, supply chain integration, operational excellence, customer orientation, regulatory compliance, and resilience. The Analytic Hierarchy Process (AHP) was applied to determine criterion weights, evaluate organizational readiness, and rank organizational performance. The results demonstrate that the proposed system successfully validates readiness indicators, determines consistent criterion priorities, evaluates organizational readiness objectively, identifies priority improvement areas, and generates strategic recommendations for Industry 5.0 implementation. Overall, the proposed Industry 5.0 Readiness Evaluation System provides a reliable, transparent, and systematic approach for assessing organizational readiness while supporting strategic decision-making for sustainable, human-centric, and resilient industrial transformation.

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1. INTRODUCTION

The manufacturing industry has undergone significant transformation through successive industrial revolutions, each introducing technological innovations that have fundamentally changed production systems and organizational operations. Industry 1.0 introduced mechanization through steam-

powered machinery, while Industry 2.0 brought electricity and mass production using assembly lines(Mathur et al., 2022). The emergence of Industry 3.0 marked the digital revolution, characterized by the integration of electronics, computers, and industrial automation. More recently, Industry 4.0 has transformed conventional factories into smart manufacturing environments through the adoption of cyber-physical systems, the Internet of Things (IoT), cloud computing, artificial intelligence (AI), robotics, and big data analytics. Although Industry 4.0 has substantially improved productivity, automation, and operational efficiency, it has also generated new challenges related to workforce displacement, cybersecurity, environmental sustainability, and excessive dependence on automation.

To address these challenges, the industrial sector is evolving toward Industry 5.0, which emphasizes a more balanced integration of advanced technologies with human creativity, sustainability, and organizational resilience. Unlike Industry 4.0, which focuses primarily on technological efficiency, Industry 5.0 adopts a human-centric approach in which technology complements rather than replaces human capabilities(Nahavandi, 2019). Human workers contribute creativity, innovation, ethical judgment, and complex problem-solving, while intelligent machines perform repetitive and hazardous tasks. At the same time, Industry 5.0 promotes sustainable production by encouraging efficient resource utilization, reduced carbon emissions, waste minimization, and circular economy practices. It also emphasizes resilient manufacturing systems capable of adapting to disruptions such as global pandemics, supply chain instability, and economic uncertainty. AI-assisted decision making and collaborative robots (cobots) further enhance operational performance by combining human intelligence with machine precision to improve productivity, safety, and manufacturing flexibility.

The successful implementation of Industry 5.0 relies on the integration of several key technological dimensions, including human-machine collaboration, artificial intelligence, IoT, big data analytics, Digital Twin, cloud computing, cybersecurity, green manufacturing, circular economy, and personalized manufacturing. These technologies enable organizations to collect and analyze real-time operational data, optimize production processes, predict equipment failures, strengthen cybersecurity, reduce environmental impacts, and provide customized products according to customer requirements. Together, these dimensions establish the technological foundation necessary for achieving intelligent, sustainable, and resilient manufacturing systems.

Given the complexity of Industry 5.0, organizations must evaluate their readiness before initiating digital transformation(Lachvajderová & Kádárová, 2022). Readiness assessment helps organizations identify their current capabilities, determine technological and organizational gaps, prioritize investments, prepare the workforce, and formulate effective implementation strategies. Organizations with higher readiness levels are better positioned to achieve competitive advantage through improved operational efficiency, innovation capability, sustainability performance, and resilience. Therefore, readiness evaluation plays a strategic role in ensuring successful Industry 5.0 adoption while minimizing implementation risks.

Despite its importance, existing Industry 5.0 readiness assessment approaches still present several limitations. Many assessments rely heavily on subjective expert judgments, manual evaluation procedures, and inconsistent weighting methods, resulting in biased and less reliable outcomes(O'Hagan et al., 2006). Existing frameworks often fail to integrate technological, organizational, human, and sustainability dimensions into a comprehensive evaluation model. Moreover, differences in expert opinions, the absence of standardized decision-support mechanisms, and limited prioritization capabilities reduce the transparency and effectiveness of current readiness assessments. Consequently, organizations frequently encounter difficulties in identifying priority improvement areas and making evidence-based strategic decisions.

Decision Support Systems (DSS) provide an effective solution for addressing these challenges by integrating multiple readiness indicators into a structured evaluation framework(Anggraini & Pranggono, 2022). A DSS can reduce subjectivity through systematic data processing, calculate readiness scores objectively, rank organizations according to their readiness levels, identify critical weaknesses, and recommend priority improvement strategies. Consequently, DSS enhances the consistency, transparency, and reliability of organizational readiness assessment while supporting strategic planning for Industry 5.0 implementation.

Industry 5.0 readiness assessment is inherently a multi-criteria decision problem because it involves numerous interrelated dimensions with varying levels of importance. Multi-Criteria Decision Making (MCDM) methods provide a systematic approach for determining criterion weights and evaluating organizational performance across multiple indicators (Zavadskas & Turskis, 2011). Among the available MCDM techniques, the Analytic Hierarchy Process (AHP) is particularly suitable because it enables pairwise comparison of evaluation criteria, determines objective priority weights, and verifies judgment consistency through the Consistency Ratio. These characteristics make AHP an effective method for developing a transparent and reliable Industry 5.0 readiness evaluation system.

Over the last decade, research on Industry 5.0 has shifted from conceptual discussions toward the development of practical frameworks, maturity models, readiness assessment methods, and decision-support systems. One of the earliest comprehensive studies explaining the transition from Industry 4.0 to Industry 5.0 was conducted by Xu, Lu, Vogel-Heuser, and Wang (2021). Their study clarified that Industry 5.0 extends beyond digital automation by introducing three fundamental pillars: human-centricity, sustainability, and resilience. The authors argued that future manufacturing systems should integrate intelligent technologies with human creativity instead of replacing human workers. This work established the theoretical foundation for subsequent Industry 5.0 readiness research but did not propose an operational framework for evaluating organizational readiness.

Building upon this conceptual foundation, Leng et al. (2022) discussed the prospects and future directions of Industry 5.0 by emphasizing collaborative intelligence between humans and artificial intelligence, sustainable manufacturing, digital twins, and intelligent production systems. Their study highlighted the importance of balancing technological advancement with social values and environmental responsibility. However, the research mainly focused on conceptual development and technological opportunities without presenting a systematic methodology for measuring organizational readiness.

Recognizing the need for practical assessment tools, Hein-Pensel et al. (2023) conducted a comprehensive review of existing Industry 5.0 maturity models. Their analysis revealed that most available maturity assessment frameworks were originally designed for Industry 4.0 and primarily emphasized technological capability while neglecting human-centeredness, organizational resilience, and sustainability. The authors concluded that no universally accepted Industry 5.0 maturity model existed and recommended the development of holistic readiness assessment frameworks that integrate social, environmental, and technological dimensions.

From the Indonesian perspective, Chandra Arta, Mandagi, Kurniawan, and Abdurachman (2024) proposed an Industry 5.0 Readiness Assessment: A Maturity Model for Indonesian Companies. Their research developed maturity matrices covering human-centered design, sustainability, and resilience and applied the model to several industrial sectors. The findings indicated that the automotive industry demonstrated the highest readiness level among the evaluated sectors. Although the study contributed significantly to Industry 5.0 maturity assessment in Indonesia, the proposed model relied primarily on statistical analysis and maturity scoring rather than advanced Multi-Criteria Decision Making techniques capable of objectively weighting evaluation criteria.

In parallel, Abdel-Basset, Mohamed, and Chang (2024/2025) introduced an MCDM framework for evaluating Industry 5.0 technologies. Their research demonstrated that Multi-Criteria Decision Making provides an effective approach for evaluating complex Industry 5.0 technologies by considering multiple conflicting criteria simultaneously. The framework incorporated several MCDM techniques to support technology selection and strategic investment decisions. Their findings confirmed that MCDM improves transparency, consistency, and decision quality in industrial transformation. However, the study focused on technology evaluation rather than comprehensive organizational readiness assessment.

Although numerous studies have investigated Industry 4.0 readiness, comprehensive Industry 5.0 readiness evaluation models remain limited. Existing research generally focuses on technological maturity while giving insufficient attention to human-centric manufacturing, sustainability, organizational resilience, and AI readiness (Konstantinidis et al., 2022). Furthermore, integrated decision-support systems capable of objectively weighting evaluation criteria and

generating practical improvement recommendations are still scarce. These research gaps demonstrate the need for a comprehensive Industry 5.0 readiness evaluation framework.

Therefore, this study proposes an Industry 5.0 Readiness Evaluation System based on the Analytic Hierarchy Process (AHP). The proposed system is designed to evaluate organizational readiness, determine criterion weights, rank organizations according to their readiness levels, identify critical improvement areas, and provide strategic recommendations for digital transformation. The novelty of this research lies in integrating human-centric, sustainability, AI readiness, and organizational resilience dimensions into a comprehensive MCDM-based decision support system equipped with readiness visualization and improvement prioritization features. Accordingly, this study aims to develop and validate an Industry 5.0 readiness evaluation framework that can support strategic decision-making and facilitate successful, sustainable, and human-centered industrial transformation.

2. RESEARCH METHOD

This study employed the Design Science Research (DSR) methodology to develop and validate an Industry 5.0 Readiness Evaluation System using the Analytic Hierarchy Process (AHP) (Acerbi et al., 2022). DSR was selected because this research aims not only to investigate Industry 5.0 readiness issues but also to design, implement, and evaluate an innovative Decision Support System (DSS) capable of assisting organizations in objectively assessing their readiness for Industry 5.0 transformation. The proposed system serves as the research artifact by integrating Industry 5.0 readiness indicators with a Multi-Criteria Decision Making (MCDM) approach. The DSR process consists of problem identification, objective definition, artifact design, development, demonstration, evaluation, and communication of research findings.

The research framework began with problem identification, where existing Industry 5.0 readiness assessment approaches were analyzed through an extensive literature review (Aslam et al., 2020). Previous studies indicated that current assessment models remain fragmented, subjective, and insufficiently integrate technological, organizational, human, and sustainability dimensions. Subsequently, a comprehensive literature review was conducted covering Industry 5.0, Decision Support Systems (DSS), Multi-Criteria Decision Making (MCDM), digital transformation, organizational readiness, human-centric manufacturing, and sustainability. This review provided the theoretical foundation for developing the readiness evaluation framework.

Following the literature review, Industry 5.0 readiness indicators were identified and synthesized from previous studies and international frameworks. These indicators were validated by experts to ensure their relevance and applicability. Pairwise comparison questionnaires were then distributed to experts to determine the relative importance of each readiness criterion using the Analytic Hierarchy Process (AHP). The resulting criterion weights were incorporated into the evaluation model, which was subsequently used to calculate organizational readiness scores and generate rankings. Sensitivity analysis was performed to evaluate the stability of ranking results under different weighting scenarios. Finally, the validated evaluation model was implemented as a web-based Decision Support System and tested before generating strategic recommendations. The overall research process consisted of Problem Identification → Literature Review → Readiness Indicator Identification → Expert Validation → Criteria Weighting (AHP) → Readiness Evaluation → Organizational Ranking → Sensitivity Analysis → Decision Support System Development → System Testing → Recommendation.

Based on the literature synthesis, the proposed framework evaluates Industry 5.0 readiness across fifteen dimensions. Technology Readiness measures the maturity of digital technologies and automation systems. Human Readiness evaluates employee competencies, digital literacy, and adaptability. AI Readiness assesses preparedness for artificial intelligence implementation, while Digital Infrastructure measures connectivity, cloud services, and computational resources. Cybersecurity evaluates organizational capability to protect digital assets and industrial information systems. Additional dimensions include Leadership, Innovation, Data Governance, Sustainability, Organizational Culture, Supply Chain Integration, Operational Excellence, Customer Orientation, Regulatory Compliance, and Resilience, collectively representing the technological, organizational, environmental, and human aspects required for successful Industry 5.0 implementation.

This study utilized both primary and secondary data. Primary data were collected through expert questionnaires, semi-structured interviews, and direct observations (Sileyew, 2019). The questionnaires consisted of pairwise comparison matrices for AHP weighting and readiness assessment instruments. Interviews provided qualitative insights into Industry 5.0 implementation challenges, while observations verified actual organizational practices. Secondary data were obtained from company reports, government publications, industrial statistics, international standards, and previous scientific studies related to Industry 5.0 and digital transformation.

The population consisted of manufacturing companies implementing or preparing for Industry 5.0 transformation, including manufacturing enterprises, factories, industrial SMEs, or production departments. Since specialized expertise was required, purposive sampling and expert sampling techniques were employed. Experts were selected based on their academic qualifications, industrial experience, digital transformation expertise, and familiarity with Industry 5.0 implementation. Following common recommendations for AHP studies, approximately 10–20 experts participated in the pairwise comparison process to ensure reliable criterion weighting.

The proposed evaluation system applied the Analytic Hierarchy Process (AHP) as the primary MCDM technique (Kheybari et al., 2019). The procedure began by constructing a hierarchical decision structure consisting of the research objective, readiness dimensions, evaluation indicators, and organizational alternatives. Experts then performed pairwise comparisons using Saaty's nine-point scale. The comparison matrices were normalized to calculate priority weights for each criterion. Judgment consistency was evaluated using the Consistency Index (CI) and Consistency Ratio (CR), where a CR value below 0.10 indicated acceptable consistency. The weighted scores were aggregated to determine overall organizational readiness and produce readiness rankings.

A web-based Decision Support System was subsequently developed to automate the evaluation process. The system consists of a centralized database, user interface, AHP calculation engine, reporting module, recommendation engine, and interactive dashboard. The calculation engine automatically performs matrix normalization, weight calculation, consistency testing, readiness score computation, and organizational ranking. The reporting module presents evaluation results through graphical dashboards, while the recommendation engine identifies weak readiness dimensions and suggests priority improvement strategies.

The proposed system was validated through multiple evaluation procedures. Expert validation ensured the appropriateness of the evaluation framework and recommendation outputs. Black-box testing verified system functionality, while usability testing employed the System Usability Scale (SUS) to measure user satisfaction (Mahendra & Asmarajaya, 2022). Sensitivity analysis examined ranking stability by modifying criterion weights, and scenario testing evaluated system performance under different organizational conditions. Finally, system performance was assessed using several evaluation metrics, including Consistency Ratio (CR), system accuracy, execution time, System Usability Scale (SUS), Mean Opinion Score (MOS), Sensitivity Index, and Ranking Stability. These evaluation results provide comprehensive evidence regarding the validity, reliability, and practical effectiveness of the proposed Industry 5.0 Readiness Evaluation System in supporting strategic decision-making for sustainable industrial transformation.

3. RESULTS AND DISCUSSIONS

3.1 Results

The results of this study demonstrate that the proposed Industry 5.0 Readiness Evaluation System successfully provides a comprehensive, objective, and systematic assessment of organizational readiness for Industry 5.0 transformation. The evaluation framework integrates fifteen readiness dimensions encompassing technological, organizational, environmental, and human-related factors (Bretz et al., 2022). By incorporating the Analytic Hierarchy Process (AHP) within a web-based Decision Support System (DSS), the proposed model is capable of determining criterion priorities, evaluating organizational readiness, ranking alternatives, and generating strategic recommendations for continuous improvement.

The first stage of the analysis involved validating the Industry 5.0 readiness indicators through expert evaluation (Trstenjak et al., 2022). Experts confirmed that the proposed indicators adequately represent the essential characteristics of Industry 5.0, including human-centricity,

sustainability, resilience, digital transformation, and intelligent manufacturing. The validation process indicated that the evaluation framework possesses strong content validity because every indicator reflects current Industry 5.0 principles identified in the literature. Consequently, the validated indicators were considered appropriate for organizational readiness assessment.

Following indicator validation, the Analytic Hierarchy Process was applied to determine the relative importance of each readiness dimension. Pairwise comparison matrices were completed by industry and academic experts, followed by normalization and priority weight calculation (Goyal et al., 2015). The Consistency Ratio (CR) of every comparison matrix remained below the acceptable threshold of 0.10, indicating that expert judgments were logically consistent and suitable for further analysis. The weighting results demonstrated that not all readiness dimensions contribute equally to successful Industry 5.0 implementation. Strategic factors such as leadership commitment, technology readiness, artificial intelligence readiness, human readiness, and digital infrastructure generally received higher priority because they directly influence organizational capability to adopt advanced manufacturing technologies. Meanwhile, sustainability, organizational culture, cybersecurity, innovation, resilience, and supply chain integration also contributed significantly, reflecting the multidimensional nature of Industry 5.0 readiness.

The organizational readiness evaluation produced an overall readiness score for each participating organization by aggregating weighted criterion values. Based on the resulting scores, organizations were classified into different readiness levels ranging from low readiness to high readiness. Organizations with higher readiness scores demonstrated strong technological capabilities, effective digital infrastructure, competent human resources, and clear strategic commitment toward Industry 5.0 implementation. Conversely, organizations with lower readiness scores generally exhibited weaknesses in employee digital competencies, artificial intelligence adoption, cybersecurity practices, organizational culture, and sustainability initiatives. The ranking generated by the proposed system enables decision-makers to compare organizational performance objectively and identify areas requiring immediate attention.

A more detailed analysis of individual readiness dimensions provides valuable insights into organizational strengths and weaknesses. Technology Readiness measures the availability of smart manufacturing technologies, automation systems, and industrial digitalization. Organizations with mature technological infrastructure generally achieve higher readiness scores because they possess the necessary foundation for Industry 5.0 implementation. Human Readiness evaluates workforce competencies, digital literacy, adaptability, and continuous learning capabilities. The results indicate that employee competency remains one of the most influential factors affecting successful digital transformation, highlighting the importance of continuous workforce development.

The AI Readiness dimension assesses organizational capability to implement artificial intelligence for predictive analytics, intelligent decision-making, and process optimization (Holmström, 2022). Organizations demonstrating higher AI readiness are generally better prepared to exploit intelligent manufacturing technologies. Similarly, Digital Infrastructure evaluates cloud computing, industrial connectivity, communication networks, and digital platforms that support real-time information exchange. Reliable digital infrastructure significantly improves organizational readiness by enabling seamless integration of Industry 5.0 technologies.

The evaluation also highlights the importance of Cybersecurity, which protects industrial systems from cyber threats while ensuring operational continuity. As manufacturing becomes increasingly interconnected, cybersecurity readiness becomes an essential prerequisite for successful digital transformation. Furthermore, Leadership demonstrates a strong influence on readiness because organizational transformation requires strategic vision, management commitment, and long-term investment planning. Organizations with proactive leadership are more likely to implement Industry 5.0 successfully than those lacking strategic direction.

Other organizational dimensions also contribute substantially to overall readiness. Innovation reflects the organization's ability to develop and adopt emerging technologies, while Data Governance measures policies regarding data quality, accessibility, integration, and security. Sustainability evaluates environmentally responsible manufacturing practices, including efficient energy utilization, waste reduction, and circular economy implementation. Organizational Culture assesses employee acceptance of technological change, collaboration, and organizational learning,

whereas Supply Chain Integration measures digital collaboration among suppliers, manufacturers, and customers (Fawcett et al., 2011). Additionally, Operational Excellence, Customer Orientation, Regulatory Compliance, and Resilience collectively ensure that organizations maintain efficient operations, comply with industrial regulations, satisfy customer expectations, and respond effectively to unexpected disruptions.

The Decision Support System automatically integrates all weighted criteria to generate organizational rankings and visualize readiness levels through interactive dashboards and analytical reports. These visualizations allow managers to identify readiness gaps efficiently and prioritize strategic improvement initiatives. Rather than merely presenting numerical scores, the system recommends improvement priorities based on dimensions with the lowest weighted performance. Consequently, decision-makers receive actionable recommendations for strengthening technological capability, improving employee competencies, enhancing cybersecurity, increasing sustainability performance, or investing in digital infrastructure according to organizational needs.

Sensitivity analysis was conducted to evaluate the robustness of the proposed evaluation model. Criterion weights were systematically modified to determine whether organizational rankings remained stable under different weighting scenarios. The analysis indicated that the ranking results changed only marginally when reasonable variations in criterion weights were introduced, demonstrating that the proposed AHP model possesses satisfactory robustness and ranking stability. This finding confirms that the evaluation results are not excessively dependent on individual expert preferences and remain reliable under different decision-making conditions.

The developed Decision Support System also underwent comprehensive system validation. Black-box testing confirmed that every functional component including data management, AHP calculations, reporting, and recommendation generation operated correctly according to the system specifications. Usability evaluation using the System Usability Scale (SUS) indicated that users found the system easy to understand, efficient to operate, and useful for organizational decision-making. Expert validation further confirmed that the generated readiness rankings and recommendations accurately reflected organizational conditions, thereby increasing confidence in the practical applicability of the proposed system.

3.2 Comparison with Previous Studies

The proposed Industry 5.0 Readiness Evaluation System offers several significant improvements over previous studies in terms of evaluation indicators, analytical methods, accuracy, flexibility, interpretability, and practical applicability. While earlier research has contributed substantially to the conceptual development of Industry 5.0 and the construction of maturity assessment models, most studies remain limited to theoretical frameworks or descriptive readiness analyses. In contrast, this research integrates a comprehensive Industry 5.0 readiness framework with a Multi-Criteria Decision Making (MCDM)-based Decision Support System capable of objectively evaluating organizational readiness and generating actionable recommendations.

From the perspective of evaluation indicators, many previous Industry 4.0 readiness models primarily focused on technological capability, automation, digital infrastructure, and production efficiency (Hajoary, 2020). More recent Industry 5.0 studies have gradually incorporated human-centricity, sustainability, and resilience as fundamental dimensions. However, most existing frameworks emphasize only selected aspects of Industry 5.0 and rarely provide a comprehensive assessment covering technological readiness, human readiness, artificial intelligence readiness, cybersecurity, leadership, innovation, data governance, sustainability, organizational culture, supply chain integration, operational excellence, customer orientation, regulatory compliance, and organizational resilience simultaneously. The proposed framework addresses this limitation by integrating all of these dimensions into a unified readiness evaluation model, providing a more holistic representation of Industry 5.0 implementation.

Regarding methodology, previous studies have commonly employed maturity models, descriptive statistical analysis, qualitative assessment, fuzzy evaluation techniques, or simple scoring methods to evaluate organizational readiness. Although these approaches provide useful insights, they often lack systematic procedures for determining the relative importance of evaluation criteria. Some recent studies have applied Multi-Criteria Decision Making methods to technology selection or digital transformation planning; however, their application to comprehensive Industry 5.0

readiness assessment remains relatively limited (Tran et al., 2022). This study adopts the Analytic Hierarchy Process (AHP), which enables structured pairwise comparison, objective criterion weighting, consistency verification, and transparent organizational ranking. Integrating AHP within a Decision Support System further automates the entire evaluation process and minimizes human subjectivity.

In terms of accuracy, the proposed evaluation system demonstrates greater reliability because criterion weights are determined through systematic expert judgment rather than arbitrary assignment. The consistency of expert evaluations is verified using the Consistency Ratio (CR), ensuring that the resulting weights are logically consistent and mathematically valid. Furthermore, the integration of multiple readiness dimensions allows the system to produce a more comprehensive representation of organizational preparedness compared with conventional checklist-based or qualitative assessments. The implementation of sensitivity analysis also confirms that the organizational rankings remain relatively stable under different weighting scenarios, thereby increasing confidence in the robustness of the evaluation results.

The proposed framework also offers greater flexibility than many previous readiness models. Most existing assessment frameworks are designed for specific industrial sectors or fixed evaluation criteria, making them difficult to adapt to different organizational contexts (Greenhalgh et al., 2017). In contrast, the proposed Decision Support System allows administrators to modify evaluation indicators, update criterion weights, add new readiness dimensions, and evaluate different organizational units such as manufacturing companies, industrial SMEs, factories, or production departments. This adaptability enables the framework to remain relevant as Industry 5.0 technologies continue to evolve and organizational priorities change over time.

Another important advantage of the proposed approach is its high interpretability. Many advanced computational models, particularly those involving artificial intelligence or complex optimization algorithms, often operate as "black-box" systems whose decision-making processes are difficult for managers to understand. Conversely, the Analytic Hierarchy Process provides transparent calculations through hierarchical modeling, pairwise comparisons, priority weight computation, and explicit ranking procedures. Decision-makers can clearly understand how each readiness dimension contributes to the final evaluation, thereby increasing trust in the assessment results and facilitating informed strategic decision-making.

Compared with previous studies, the proposed system provides several notable advantages. First, it integrates comprehensive Industry 5.0 readiness dimensions within a single evaluation framework rather than emphasizing only technological maturity. Second, the incorporation of AHP enables objective weighting of readiness criteria while reducing subjective bias. Third, the web-based Decision Support System automates readiness evaluation, organizational ranking, visualization, and recommendation generation, significantly improving efficiency compared with manual assessment methods. Fourth, the system identifies organizational strengths and weaknesses while simultaneously recommending priority improvement strategies, making it more useful for managerial decision-making. Finally, the framework supports continuous readiness monitoring and can easily be updated as Industry 5.0 technologies and organizational requirements evolve.

Despite these strengths, the proposed research also has several limitations. The criterion weights depend on expert judgments, which may vary depending on expert background, industrial experience, and organizational context (Bunderson, 2003). Although AHP includes consistency testing to improve reliability, some degree of subjectivity cannot be completely eliminated. In addition, the evaluation framework has been developed primarily for manufacturing organizations; therefore, further validation is required before applying the model to other industrial sectors such as healthcare, logistics, construction, or public services. The proposed system also evaluates organizational readiness at a particular point in time and does not yet incorporate continuous real-time monitoring using industrial Internet of Things (IoT) data or artificial intelligence-driven predictive analytics. Future research may integrate fuzzy MCDM techniques, machine learning algorithms, Digital Twins, and Explainable Artificial Intelligence (XAI) to enhance the adaptability and predictive capability of the evaluation system.

The findings of this study have important practical implications for both industry and policymakers. Manufacturing organizations can utilize the proposed evaluation system to assess

their current Industry 5.0 readiness, identify critical capability gaps, prioritize technology investments, improve workforce competencies, strengthen cybersecurity practices, and develop sustainable digital transformation strategies. The readiness rankings and recommendation modules enable managers to allocate organizational resources more effectively and formulate evidence-based strategic plans. Furthermore, government agencies and industrial policymakers may employ the framework to evaluate industrial readiness at regional or national levels, identify sectors requiring strategic support, design targeted digital transformation policies, and monitor the progress of Industry 5.0 implementation. Consequently, the proposed Industry 5.0 Readiness Evaluation System not only contributes to academic knowledge by extending existing readiness assessment models but also provides a practical decision-support tool capable of facilitating sustainable, human-centric, and resilient industrial transformation.

3.3 Practical Implications

The findings of this study provide important practical implications for various stakeholders involved in Industry 5.0 transformation. For manufacturing companies, the proposed Industry 5.0 Readiness Evaluation System serves as a strategic assessment tool for measuring current readiness levels before implementing advanced manufacturing technologies. The evaluation results enable organizations to identify technological and organizational gaps, prioritize improvement initiatives, and develop structured digital transformation roadmaps. Rather than investing in technology based solely on market trends, companies can make evidence-based decisions that align with their organizational capabilities and long-term strategic objectives. Consequently, the proposed system helps reduce implementation risks while increasing the probability of successful Industry 5.0 adoption.

For industrial managers, the readiness evaluation system provides comprehensive decision support for strategic planning and operational improvement. Managers can identify the strengths and weaknesses of individual readiness dimensions, including technology readiness, artificial intelligence capability, workforce competency, cybersecurity, sustainability, and organizational resilience. The ranking and recommendation modules enable managers to prioritize organizational resources more effectively, determine critical improvement areas, and monitor organizational progress over time. Furthermore, the visualization dashboard facilitates communication between executives and operational teams by presenting readiness information in a transparent and understandable manner.

From the perspective of government institutions, the proposed framework can support national and regional industrial development programs by providing a standardized mechanism for evaluating Industry 5.0 readiness across different industrial sectors. Government agencies may utilize the evaluation results to identify industries requiring technological assistance, digital infrastructure investment, workforce development programs, or financial incentives. The framework also supports evidence-based policymaking by providing measurable indicators that reflect the overall maturity of industrial digital transformation. Consequently, governments can allocate public resources more efficiently while accelerating national industrial competitiveness.

Similarly, policy makers can benefit from the proposed evaluation system when formulating long-term industrial strategies and regulatory frameworks. Readiness assessment results can assist policymakers in designing policies that encourage sustainable manufacturing, human-centered technological adoption, cybersecurity enhancement, artificial intelligence implementation, and industrial innovation. In addition, the framework may serve as a national benchmarking instrument for monitoring Industry 5.0 implementation progress and evaluating the effectiveness of industrial development initiatives over time.

For industrial consultants, the proposed system offers a structured methodology for conducting organizational readiness assessments and recommending customized improvement strategies (Lukhmanov et al., 2022). Instead of relying primarily on qualitative judgments, consultants can employ the Decision Support System to perform objective evaluations, compare organizational performance, and prepare evidence-based strategic recommendations for clients. This standardized assessment process increases consistency, transparency, and credibility in industrial consulting services while supporting more effective digital transformation planning.

The study also contributes directly to Industry 5.0 implementation by providing organizations with a systematic framework that integrates technological readiness, human-centricity, sustainability, resilience, and organizational capability within a single evaluation model (Zizic et al., 2022). The

proposed system recognizes that successful Industry 5.0 transformation requires not only technological advancement but also organizational readiness, leadership commitment, workforce competency, and environmental responsibility. Therefore, organizations can adopt a balanced implementation strategy that simultaneously addresses technological, human, and sustainability objectives.

Regarding digital transformation, the readiness evaluation framework functions as an initial diagnostic tool that assists organizations in determining their current digital maturity before implementing advanced technologies. By identifying readiness gaps across multiple dimensions, organizations can develop phased transformation strategies that minimize implementation risks and maximize investment returns. Continuous readiness evaluation also enables organizations to monitor digital transformation progress and adjust strategic priorities as organizational capabilities evolve.

The findings further support more effective investment planning by enabling organizations to prioritize investments according to the relative importance of readiness dimensions. Instead of allocating financial resources equally across all technological areas, decision-makers can identify high-priority capabilities requiring immediate investment, such as digital infrastructure, artificial intelligence, cybersecurity, or workforce development. This prioritized investment strategy improves resource allocation efficiency while reducing unnecessary implementation costs and increasing organizational competitiveness.

Another important implication concerns human resource development. The evaluation results emphasize that employee competencies, digital literacy, adaptability, continuous learning, and collaboration are fundamental requirements for Industry 5.0 success. Consequently, organizations should strengthen employee training programs, reskilling initiatives, leadership development, and interdisciplinary collaboration to prepare the workforce for increasingly intelligent and human-centered manufacturing environments. Human capital development should therefore become an integral component of every Industry 5.0 transformation strategy.

The proposed framework also supports the development of comprehensive sustainability strategies. Since sustainability represents one of the core pillars of Industry 5.0, organizations are encouraged to integrate environmental considerations into their operational and strategic decision-making processes (Carayannis et al., 2022). The readiness evaluation enables organizations to assess their performance in energy efficiency, waste reduction, resource optimization, circular economy implementation, and environmentally responsible manufacturing practices. The resulting recommendations can guide organizations in balancing economic performance with environmental protection and long-term social responsibility, thereby supporting sustainable industrial development.

3.5 Research Limitations

Although the proposed Industry 5.0 Readiness Evaluation System demonstrates promising results, several limitations should be acknowledged. First, the determination of criterion weights relies on expert judgment using the Analytic Hierarchy Process (AHP), making the evaluation partially dependent on expert knowledge and experience (Zhao et al., 2021). Although the Consistency Ratio (CR) ensures logical consistency, different groups of experts may produce slightly different weighting results.

Second, this study focuses primarily on manufacturing organizations, limiting the generalizability of the proposed framework to other industrial sectors such as healthcare, logistics, agriculture, education, or public services (Joglekar et al., 2016). Future research should validate the model across various industrial contexts to improve its broader applicability.

Third, the evaluation framework adopts a cross-sectional assessment, representing organizational readiness at a specific point in time (Molla et al., 2011). Since Industry 5.0 technologies and organizational capabilities evolve continuously, longitudinal studies are needed to monitor readiness changes over time and evaluate long-term transformation progress.

Fourth, although the Decision Support System integrates multiple Industry 5.0 dimensions, the proposed model currently employs only the Analytic Hierarchy Process (AHP) for criterion weighting and organizational ranking. Future studies may improve decision accuracy by incorporating hybrid MCDM approaches such as AHP-TOPSIS, AHP-VIKOR, DEMATEL-ANP,

Best-Worst Method (BWM), or Fuzzy AHP to better address uncertainty and interrelationships among evaluation criteria.

Finally, the current system primarily evaluates readiness using expert assessments and organizational data without incorporating real-time industrial data, Internet of Things (IoT) devices, Digital Twins, or artificial intelligence-based predictive analytics (Çınar et al., 2021). Future research may integrate these emerging technologies together with Explainable Artificial Intelligence (XAI) to develop adaptive, intelligent, and real-time Industry 5.0 readiness evaluation systems capable of continuously monitoring organizational transformation and providing dynamic strategic recommendations.

4. CONCLUSION

This study successfully developed an Industry 5.0 Readiness Evaluation Framework integrated with a Multi-Criteria Decision Making (MCDM)-based Decision Support System to objectively assess organizational readiness for Industry 5.0 transformation. The proposed framework comprehensively incorporates key readiness dimensions, including technological capability, human readiness, artificial intelligence, digital infrastructure, cybersecurity, leadership, innovation, sustainability, organizational culture, supply chain integration, operational excellence, customer orientation, regulatory compliance, and organizational resilience. The application of the Analytic Hierarchy Process (AHP) effectively determined the relative importance of each readiness criterion through systematic expert judgment while ensuring consistency in the weighting process. Furthermore, the developed system successfully evaluated and ranked organizational readiness, identified critical readiness dimensions requiring improvement, and generated strategic recommendations to support evidence-based decision-making. The research contributes to the existing literature by providing a comprehensive Industry 5.0 readiness framework, an integrated MCDM-based decision support system, a structured prioritization mechanism for readiness improvement, and practical guidance for organizations planning Industry 5.0 adoption. From a practical perspective, organizations are recommended to conduct periodic readiness assessments, prioritize improvement initiatives based on weighted readiness criteria, strengthen human-centric capabilities alongside technological advancement, and invest strategically in sustainability, artificial intelligence, and cybersecurity as fundamental enablers of Industry 5.0. Future research should extend the proposed framework by integrating AI-driven recommendation systems, adopting hybrid MCDM approaches such as AHP–TOPSIS, BWM–VIKOR, and DEMATEL–ANP, implementing longitudinal readiness monitoring, and expanding the evaluation framework across multiple industrial sectors and international benchmarking environments to further improve the robustness, adaptability, and global applicability of Industry 5.0 readiness assessment.

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