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Assessing Readiness for Hospital 5.0: Identifying and Prioritizing Key Indicators for the Future of Healthcare

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Abstract

Background: The transition toward Hospital 5.0 represents a major shift in healthcare, integrating advanced digital technologies with human-centered, sustainable, and resilient approaches. Despite increasing global attention to this emerging concept, a practical framework for assessing hospital readiness for such transformation remains limited.

Objectives: The present study aimed to identify and prioritize key indicators influencing hospital readiness for the transition to Hospital 5.0 and to design a practical model that can guide both policymakers and hospital managers.

Methods: A mixed-methods design was employed. First, a systematic review following PRISMA guidelines was conducted to identify readiness and maturity indicators from Industry 4.0 and 5.0 contexts. Based on expert input, a conceptual framework for Hospital 5.0 readiness was then developed. Finally, decision-making techniques under uncertainty [grey best-worst method (GBWM)] were applied to prioritize the main and sub-dimensions of the model.

Results: The final readiness model includes four main dimensions and twenty-six sub-dimensions. The most influential dimension was technological readiness (49%), followed by human-centric organizational development (23%), resilience (16%), and sustainability (13%). Experts emphasized that while technology is the key driver, the long-term success of Hospital 5.0 depends on the development of human skills, organizational culture, and staff engagement. The designed model allows hospital managers to assess each sub-dimension separately, helping them identify operational strengths and weaknesses more effectively. It also provides a roadmap for improvement planning and resource allocation based on priority areas.

Conclusions: The model designed in this study offers a comprehensive and applicable tool for assessing readiness and guiding the transition toward Hospital 5.0. Although technological investment is essential, true transformation requires balanced attention to human, resilient, and sustainable aspects. The findings can assist health authorities in shaping national strategies and help hospitals apply the model as a self-assessment and strategic planning framework for future development.

Keywords: Hospital 5.0, Systematic Review, Best-Fit Framework, Readiness Assessment, Healthcare 5.0, Grey Best-Worst Method

1. Background

Since the 19th century, the world has experienced several industrial revolutions, each transforming production processes and resource management. The Fourth Industrial Revolution focused on digital technologies and efficiency. However, it often overlooked human needs, sustainability, and resilience, which affected employee well-being and natural resources (1-3). Industry 5.0 has emerged to address these issues, focusing on human-centered processes, collaboration between humans and machines, sustainability, and resilience (4). The emerging concept of Industry 5.0 in healthcare is known as "Healthcare 5.0". It integrates advanced technologies into healthcare services to improve sustainability, reduce costs, and enhance patient outcomes (5).

Healthcare 5.0 represents an integrated and adaptive framework for delivering healthcare services. Hospital 5.0, as a core component of this system, focuses on

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enhancing patient and staff experiences through advanced technologies and human-centered processes. It serves as a central driver in achieving the goals of Healthcare 5.0 (5).

Transitioning to Hospital 5.0 can reduce healthcare costs. This can be achieved through preventive care, early interventions, smart technologies, telehealth, and robotic-assisted surgeries. These strategies enhance access to healthcare, lower system expenses, and improve public health outcomes (6).

Success in implementing Hospital 5.0 requires readiness in healthcare. This involves the hospital's capacity for digital transformation, adoption of innovations, and optimization of resources for continuous improvement (7).

Readiness and maturity models have been examined in both Industry 4.0 and Industry 5.0 contexts. Readiness and maturity are distinct concepts. Readiness reflects an organization's preparedness to begin implementation, while maturity indicates the level of development already achieved (8). This study focuses on readiness in defining the model's dimensions and indicators for Hospital 5.0. However, the study also used maturity models to develop the final model and analyzed all dimensions and sub-dimensions according to the concept of readiness.

In Industry 4.0, several models have been proposed to assess readiness. For instance, the IMPULS model (9) was designed to evaluate digital transformation in the manufacturing sector. The Conform model (10) examined the readiness of construction companies for Industry 4.0 and identified human capital as the most critical success factor. Also, a readiness model for smart hospitals examined their preparedness for Industry 4.0 and assessed key factors for successful implementation (11). Another study examined digital transformation and the impact of digital technologies on management in the field of smart healthcare (12). Another quantitative study evaluated the readiness of public sector healthcare systems to adopt digital and AI technologies and examined their potential impact on productivity (13). Other studies, including the future university maturity model (14) and assessments of government organizations in Indonesia (13), have focused on technical and strategic readiness in manufacturing and service sectors. However, readiness assessments in Industry 4.0 have mainly emphasized technological and technical aspects, with limited attention to human-centered factors, employee well-being, and social and environmental considerations (15).

Readiness assessment models are generally applied in manufacturing industries, while service sectors such as hospitals have received less attention (10). Several studies have examined readiness for Industry 5.0. However, none of the existing models comprehensively address readiness for all four core dimensions of Industry 5.0 — advanced technologies, human-centricity, sustainability, and resilience (16-19).

Therefore, previous studies have mainly focused on manufacturing and technical aspects, and no comprehensive model exists that addresses all key dimensions of Industry 5.0. To fill these gaps, this study develops a practical model for hospitals, defining key readiness dimensions and indicators.

2. Objectives

The present study pursues two objectives: (1) To develop a comprehensive model to assess readiness for implementation of Hospital 5.0; and (2) to prioritize and weight its dimensions and sub-dimensions. Prioritization is important as it helps managers identify and focus on the most critical areas for effective implementation.

3. Methods

This study employed a mixed-methods approach to develop a readiness assessment model for Hospital 5.0. First, a systematic review was conducted to identify and analyze existing models and indicators from Industry 4.0 and 5.0. The systematic review served both to select a base model and to extract complementary components and indicators. In the next step, the selected base model was adapted using the best-fit framework synthesis method. This combination of methods is appropriate for this study. It ensures the model is conceptually strong and practically relevant for Hospital 5.0. Finally, the indicators of the developed model were prioritized using the grey best-worst method (GBWM).

3.1. Systematic Review

The systematic review was conducted according to PRISMA guidelines to ensure clarity and transparency. In the following sections, we describe the search strategy. All studies were independently screened by two reviewers, and any disagreements were resolved through discussion or consultation with a third reviewer when necessary.

3.1.1. Search Strategy

To identify studies related to Hospital 5.0 readiness and maturity, a systematic search was conducted in three major databases: Web of Science, Scopus, and PubMed. The applied restrictions included document

type (research articles and reviews), language (English), and publication years from 2015 to 2025. The search was also purposefully limited to specific categories: Medicine, nursing, computer science, biomedical engineering, health management, and health information technology. This selection reflects the direct focus of Hospital 5.0 on clinical care, advanced technologies, and organizational management. The keywords used in the search included: "Hospital 5.0", "Future Hospital", "Healthcare 5.0", "Readiness Assessment 4.0", "Readiness Assessment 5.0", "Maturity Assessment 4.0", "Maturity Assessment 5.0", "Hospital and Industry 5.0", and "Hospital and Industry 4.0". All studies were independently reviewed by two reviewers, and in cases of disagreement, the issue was resolved through discussion or consultation with a third reviewer.

The quality of the selected studies was systematically evaluated using the CASP framework. According to this framework, ten key domains were assessed, including study objectives, design, data collection, analysis, ethical considerations, evidence support, transparency, value, limitations, and transferability of results. The final selected studies received quality scores ranging from 8 to 10, indicating high methodological rigor and strong scientific validity.

3.2. The Best-Fit Framework

The best-fit framework is a structured approach for integrating existing frameworks and developing a practical model for a specific research context. In this study, it involved three main steps: Selecting a base framework, customizing it for Hospital 5.0, and validating the model (20, 21).

The IMPULS model (9) was selected as the base framework based on the comparative analysis of Industry 4.0/5.0 readiness models. It covers six dimensions — strategy, smart factories, smart operations, smart products, data-driven services, and employees — with detailed sub-dimensions. The model was then customized with healthcare-specific indicators and validated through expert consultation. Its comprehensive structure, focus on both technological and human aspects, and empirical support made it suitable for adaptation to Hospital 5.0.

3.3. Prioritization and Weighting of Model Dimensions and Sub-dimensions

Grey system theory, introduced by Julong in the 1980s, provides a mathematical framework for handling uncertainty in multi-criteria decision-making. It converts vague expert judgments into measurable grey numbers, enabling reliable prioritization even with incomplete information (22, 23). In this study, grey system techniques were applied to prioritize the dimensions and sub-dimensions of the proposed Hospital 5.0 readiness model, effectively managing uncertainty in expert evaluations.

The GBWM is a multi-criteria decision-making technique used to prioritize dimensions and sub-dimensions under uncertainty. Experts first identify the most (best) and least (worst) important criteria. They then make pairwise comparisons between the best criterion and others, and between all criteria and the worst, using grey numbers to capture imprecision. The method optimizes consistency between these comparisons to calculate final weights, reflecting the relative importance of each criterion (24, 25). The formulas used to derive the weights are provided in Appendix 1 in Supplementary File.

4. Results

4.1. Systematic Review

The process of identifying and selecting studies for inclusion in this systematic review is illustrated in the PRISMA flowchart (Figure 1). Initially, a total of 430 studies were identified through database searches. After removing duplicates (162 studies) and patents (26 studies), 273 studies remained for screening. After screening the titles and abstracts, 223 studies were considered potentially eligible for inclusion. A total of 50 studies were included for full-text evaluation. Subsequently, 29 of these studies were excluded. Ultimately, 21 studies were included in the final analysis. Table 1 presents the 21 included studies, including the model's name, year, article type, and field of study.

Analysis of Table 1 shows that most of the reviewed models focus on the manufacturing industry, SMEs, or information technology. Their application in the healthcare sector is limited or indirect. Moreover, most models pertain to Industry 4.0, while dedicated models for Industry 5.0 are less developed. To date, no model has been specifically developed to assess Hospital 5.0 readiness.

4.2. The Best-Fit Framework Results

Based on the systematic review, we selected the IMPULS model as the base model in the best-fit framework. We chose it because (1) It has a comprehensive structure that connects Industry 4.0's technology focus with human-centered goals; (2) it is widely cited and proven as a readiness (rather than

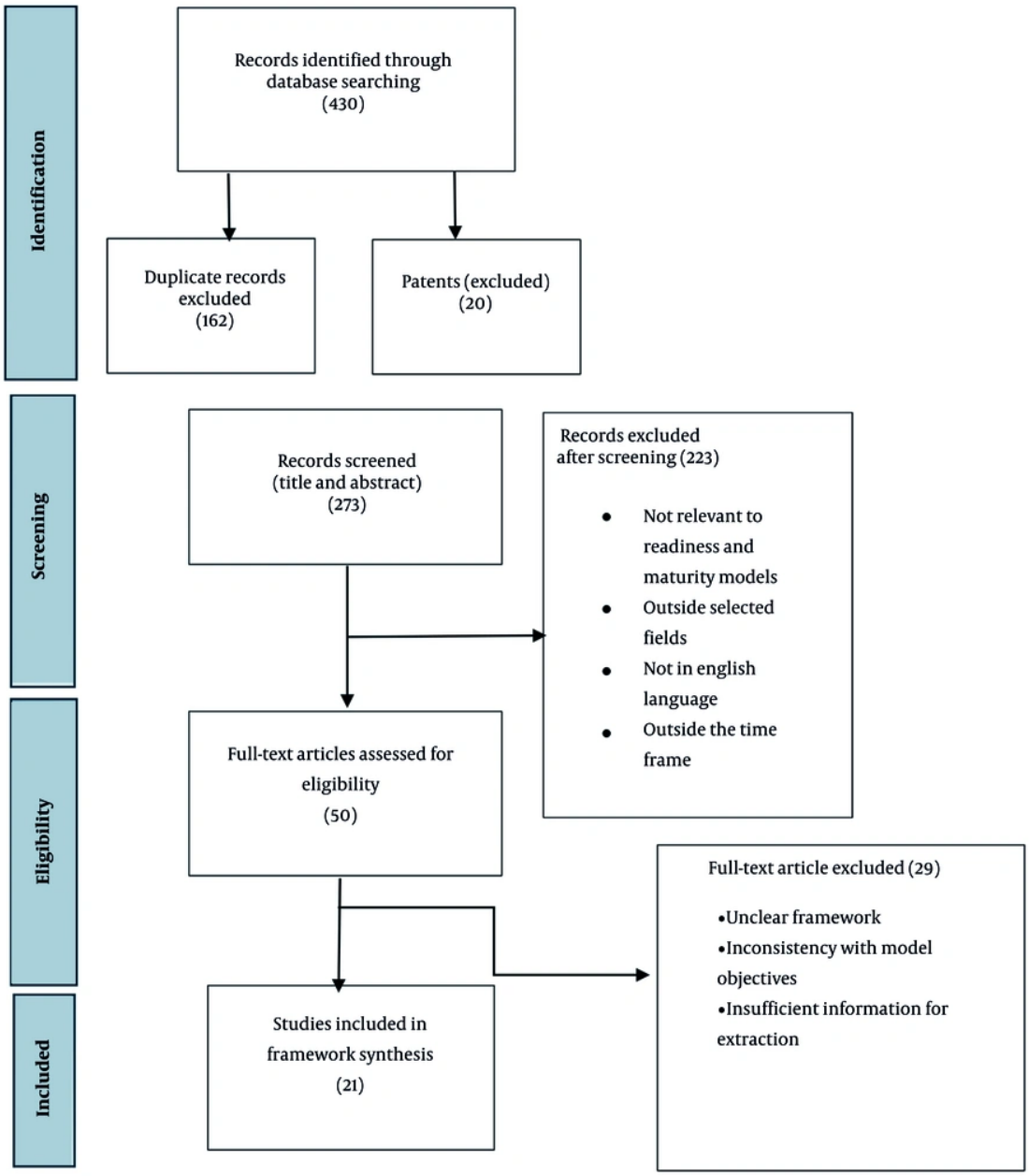

Figure 1. PRISMA flow diagram of the systematic review

maturity) model; and (3) its holistic dimensions fill gaps in other frameworks by including workforce and operational factors. Its diagnostic accuracy and empirical validation make it well-suited for assessing hospitals' digital transformation readiness.

During the localization process, several sub-dimensions were extracted from the original IMPULS

Table 1. Overview of the Selected Readiness and Maturity Models Identified in the Systematic Review

Model Name	Year	Field of Study	Article Type	Source
IMPULS Industry 4.0 readiness model	2015	Manufacturing and engineering	Empirical study	(9)
Industry 4.0 maturity/digital operations self-assessment model	2016	Manufacturing and engineering	Industry report/survey	(26)
The connected enterprise maturity model	2014	Manufacturing and engineering	Industry report	(27)
Industry 4.0 maturity model	2016	Manufacturing and engineering	Empirical study	(8)
Industry 4.0 readiness assessment model for SMEs	2018	SMEs	Empirical/tool development study	(28)
Industry 4.0 readiness model for tool management	2017	Tool management	Conceptual/framework	(29)
Industry 4.0 readiness analysis	2018	Manufacturing and engineering	Empirical/tool development study	(30)
Industry 4.0 maturity model	2018	Manufacturing (with potential adaptability to other industries)	Empirical	(31)
Health information systems maturity model	2018	Healthcare	Conceptual/review	(32)
Industry 4.0 maturity model	2019	Manufacturing	Empirical	(33)
Health information systems maturity model	2019	Healthcare	Empirical	(34)
AI innovation maturity model	2020	Multi-sector/not domain-specific	Conceptual	(35)
University 5.0 maturity model	2020	Education	Conceptual	(14)
Digital maturity assessment model for hospitals	2021	Healthcare	Empirical	(36)
Smart hospital readiness assessment model	2022	Healthcare	Empirical	(11)
Comprehensive Industry 4.0 readiness model	2023	Multi-sector	Empirical/mixed-method	(37)
Industry 4.0 maturity model for SMEs	2022	SMEs	Empirical	(38)
Quality 4.0 readiness assessment framework	2024	Healthcare	Empirical/mixed-method	(39)
Industry 4.0 readiness assessment model	2024	Construction/manufacturing	Empirical	(10)
Industry 5.0 maturity model	2024	Manufacturing	Empirical	(40)
Industry 5.0 readiness assessment	2024	Food industry/SMEs	Empirical	(17)

dimensions and subsequently adapted to the hospital and healthcare context. These adaptations primarily focus on technology and staff training. For instance, technological infrastructure corresponds to smart factory; emerging technologies and organizational innovation correspond to strategy and organization; security and privacy and automatization of management processes correspond to smart operations and data-driven services; advanced technology training and resource flexibility correspond to employees; change acceptance corresponds to employees and strategy and organization; telemedicine corresponds to smart product; and technological adaptability corresponds to employees and smart factory. These adaptations primarily focus on technology and staff training.

The final model was structured around four key pillars of Industry 5.0: Technological readiness, sustainability, resilience, and human-centered organizational development (17). Accordingly, all indicators identified in the systematic review — whether based on the base model or those added to complete and redefine the model — were assigned to one of these four groups to reflect their characteristics. Table 2 presents the final indicators of the Hospital 5.0 readiness assessment model, and Figure 2 illustrates the overall model framework. Each indicator in the "Reference Models" column shows which of the 21 readiness and maturity models it was derived from. We added indicators that are not linked to any specific model. These indicators are based on the literature in Healthcare 5.0 and Industry 5.0 and align with the research objectives and the specific needs of Hospital 5.0.

To validate the proposed model, a panel of five experts in healthcare management and digital transformation reviewed the Hospital 5.0 readiness model. They provided structured feedback in two rounds, assessing the clarity, relevance, and practical applicability of each dimension and sub-dimension. Modifications were made based on consensus, ensuring alignment with both theoretical foundations and real-world hospital practices.

4.3. Validity of the Model

To ensure the relevance of the proposed indicators for Hospital 5.0, all items were carefully adapted to the healthcare context, with terminology and descriptions

Table 2. Hospital 5.0 Readiness Assessment Model Indicators

Main and Sub-dimensions	Description	Reference Models	Sources
Technology readiness			
Health technology infrastructure	Systems and technologies required to support digital and intelligent hospital processes.	IMPULS/Industry 4.0 maturity model for SMEs	(9, 38)
Emerging health technologies	New technologies, such as IoT, AI, and Big Data, that improve the efficiency and quality of health services.	IMPULS/Industry 4.0 maturity model/AI innovation maturity model	(8, 9, 35)
Patient data protection	Rules and procedures for protecting patient and sensitive data	IMPULS/AI innovation maturity model	(8, 9)
Automation of hospital processes	Using technology to automate and optimize hospital management processes, improving efficiency and reducing errors.	IMPULS/Industry 4.0 maturity model/AI innovation maturity model/Industry 4.0 readiness model for tool management	(8, 9, 29, 35)
Personalized treatments	Treatment approaches that are designed based on the unique characteristics of each patient.	-	(5, 41)
Telemedicine	Providing medical services and consultations via technology, allowing remote patient access.	IMPULS	(8, 9, 42)
Human-centered organizational development			
Human-centered care	Designing and implementing systems that meet human needs to improve patient and staff experience.	-	(43)
Technological empowerment of staff	Training programs that help hospital staff understand and effectively use new technologies.	IMPULS/Industry 4.0 maturity model for SMEs	(9, 38)
Intersectoral collaboration	The interaction and collaboration between hospital departments to improve service quality and reduce response times.	The connected enterprise maturity model/Industry 4.0 maturity model for SMEs/Industry 4.0 readiness analysis	(27, 30, 38)
Innovation in healthcare services	The hospital's ability to develop and implement innovative ideas to improve services and processes.	IMPULS/Industry 4.0 maturity model	(8, 9)
Cultural readiness	The willingness of hospital staff to embrace new technologies and processes with a positive attitude.	IMPULS/Industry 4.0 maturity model	(8, 9, 44)
Participatory hospital governance	Creating an environment that involves staff and patients in decision-making and hospital policies.	-	(45-47)
Employee motivation and well-being	Systems of incentives and recognition that enhance staff motivation and job satisfaction.	Comprehensive Industry 4.0 readiness model	(37)
Sustainability			
Hospital environmental sustainability	Strategies aimed at conserving resources and promoting environmental sustainability in hospital operations.	-	(17, 48-50)
Optimal resource efficiency	Efficient management and allocation of human, financial, and physical resources in hospitals	-	(5, 48)
Digital sustainability	The use of digital solutions and new technologies to reduce environmental impact and improve resource efficiency.	-	(51-54)
Hospital waste management	Measures to minimize waste of resources and time in medical and administrative processes.	-	(5, 41, 42, 55)
Resilience			
Hospital resource flexibility	Employees with multiple skills who can work across different hospital departments.	IMPULS	(9, 42)
Hospital agility	The hospital's ability to quickly adapt to changes in environment, technology, or patient needs through flexible structures and rapid decision-making.	-	(56-58)
Technological adaptability	The hospital's ability to adopt and use new technologies within existing systems.	IMPULS	(9, 59)
Hospital crisis resilience	The hospital's ability to prepare for and handle crises and emergencies.	-	(60-62)
Continuous healthcare quality improvement	Ongoing efforts to enhance processes and service quality through regular evaluation and incremental innovation.	-	(5, 41, 63)
Healthcare system stakeholder engagement	Working together with all stakeholders — patients, staff, and the community — to enhance service quality.	-	(64-66)
Redundancy in critical hospital services	Presence of systems and processes that ensure services continue during malfunctions or issues.	-	(14, 67, 68)
Empowerment of healthcare staff	Creating opportunities for staff to develop skills and knowledge, improving individual and team performance.	-	(69, 70)
Financial robustness	Hospitals' ability to manage finances and deliver sustainable health services.	-	(71, 72)

reflecting hospital processes and human-centered care. A panel of 12 healthcare experts then evaluated each indicator for its necessity. The agreement measure, known as the content validity ratio (CVR) (73), ranged

Figure 2. Hospital 5.0 implementation readiness assessment model

from 0.67 to 1.00 across all indicators, confirming that they were considered essential or highly relevant. These results, summarized in Table 3, demonstrate that the framework is appropriate for hospital settings and captures the unique characteristics of Hospital 5.0 rather than merely adopting Industry 4.0 indicators.

4.4. Prioritization and Weighting of Model Dimensions and Sub-dimensions

This study uses a questionnaire based on the GBWM, as detailed in Appendix 2 in Supplementary File, to weight the indicators. The best-worst method is designed to be effective with a limited number of experts (usually between 5 and 10), making it a logical and cost-effective choice for studies with constrained resources (74).

Table 3. Validated Indicators for the Hospital 5.0 Framework

Indicators	No. of Experts Rating "Essential"	CVR	Result
Health technology infrastructure	12	1.00	Accepted
Emerging health technologies	11	0.83	Accepted
Patient data protection	12	1.00	Accepted
Automation of hospital processes	10	0.67	Accepted
Personalized treatments	11	0.83	Accepted
Telemedicine	12	1.00	Accepted
Human-centered care	10	0.67	Accepted
Technological empowerment of staff	11	0.83	Accepted
Intersectoral collaboration	12	1.00	Accepted
Innovation in healthcare services	11	0.83	Accepted
Cultural readiness	10	0.67	Accepted
Participatory hospital governance	12	1.00	Accepted
Employee motivation and well-being	11	0.83	Accepted
Hospital environmental sustainability	12	1.00	Accepted
Optimal resource efficiency	10	0.67	Accepted
Digital sustainability	12	1.00	Accepted
Hospital waste management	10	0.67	Accepted
Hospital resource flexibility	12	1.00	Accepted
Hospital agility	11	0.83	Accepted
Technological adaptability	10	0.67	Accepted
Hospital crisis resilience	12	1.00	Accepted
Continuous healthcare quality improvement	11	0.83	Accepted
Healthcare system stakeholder engagement	10	0.67	Accepted
Redundancy in critical hospital services	12	1.00	Accepted
Empowerment of healthcare staff	11	0.83	Accepted
Financial robustness	10	0.67	Accepted

Abbreviation: CVR, content validity ratio.

To ensure a comprehensive evaluation of the Hospital 5.0 indicators using the GBWM, a panel of five experts with diverse and complementary professional backgrounds was carefully selected. The panel included:

- A hospital manager aged 40 - 49 with over 15 years of experience in hospital administration.

- An IT director aged 40 - 49 with more than 15 years of experience in healthcare information systems.

- A department supervisor aged 50+ with over 15 years of clinical management experience.

- A faculty member from Shiraz University in the Health Management Department, aged 40 - 49 with more than 15 years of academic and managerial experience.

- A hospital manager aged 40 - 49 with 10 - 15 years of experience in hospital administration.

Including experts from clinical, managerial, academic, and technological domains ensured that the assessment captured not only technological perspectives but also human-centered and operational aspects of hospital management. This careful selection mitigated any bias toward purely IT-focused views and provided a robust, multi-dimensional validation of the proposed Hospital 5.0 framework. The final weights of the dimensions are presented in Tables 4 and 5. The obtained weights represent the global weights (the global weight of each sub-dimension is calculated by multiplying the weight of the main dimension by the weight of the sub-dimension within that dimension) of the sub-dimensions, which are relatively small.

Table 4. Main Dimension Weights

Main Dimensions	Final Weights
Technology readiness	0.49
Human-centered organizational development	0.23
Sustainability	0.13
Resilience	0.16

Table 5. Sub-dimension Weights

Sub-dimensions	Final Weights
Health technology infrastructure	0.160
Emerging health technologies	0.090
Patient data protection	0.060
Automation of hospital processes	0.100
Personalized treatments	0.040
Telemedicine	0.040
Human-centered care	0.059
Technological empowerment of staff	0.032
Intersectoral collaboration	0.023
Innovation in healthcare services	0.040
Cultural readiness	0.051
Participatory hospital governance	0.004
Employee motivation and well-being	0.019
Hospital environmental sustainability	0.026
Optimal resource efficiency	0.030
Digital sustainability	0.052
Hospital waste management	0.022
Hospital resource flexibility	0.019
Hospital agility	0.020
Technological adaptability	0.024
Hospital crisis resilience	0.016
Continuous healthcare quality improvement	0.028
Healthcare system stakeholder engagement	0.011
Redundancy in critical hospital services	0.018
Empowerment of healthcare staff	0.011
Financial robustness	0.013

5. Discussion

5.1. Results and Findings

Analysis of the dimension weighting based on expert opinions shows that “Technological Readiness” is the most important dimension in assessing Hospital 5.0 readiness, accounting for 50% of the total weight. Within this dimension, the highest importance is assigned to technological infrastructure (16%) and automation of hospital processes (10%), while sub-indicators such as telemedicine (4%) and personalized treatments (4%) receive lower weights. This distribution indicates that experts primarily focus on strengthening technical infrastructure and leveraging new technologies, whereas emerging areas like telemedicine and personalized treatments currently have a lesser emphasis.

One of the key and frequently mentioned strategies in the reviewed studies for enhancing this dimension is the optimization and maximum utilization of existing infrastructures and equipment. By improving the quality of software systems and management platforms, as well as enhancing communication networks, hospitals can increase their capacity to adopt emerging technologies and the internet of things without incurring excessive costs. This approach not only reduces the workload of healthcare staff but also improves the ability to provide specialized services to patients with specific needs (75, 76).

In second place, "Human-Centered Organizational Development" holds a 23% share. Within this dimension, the highest emphasis is on human-centered care (6%), intersectoral collaboration (2%), and innovation (4%). In contrast, indicators such as employee incentive and recognition systems (2%) and participatory hospital governance (1%) are considered less important. This indicates that experts prioritize strategic alignment and fostering a culture of collaboration and innovation, while softer cultural indicators, like organizational democracy, receive less attention.

Studies have shown that developing strategies to maintain and enhance the physical and mental well-being of employees, as well as preparing them to embrace change, are key factors in strengthening the human-centered organizational development dimension (77).

Resilience (0.016) ranks third among the main dimensions. Within this dimension, "Technological Adaptability" (0.024) is identified as the most critical sub-dimension, while "stakeholder engagement" (0.011) is the least critical. Overall, this distribution highlights that experts emphasize the hospital’s ability to adapt technologically, whereas participatory processes are considered less critical in the current assessment. According to previous studies, the response time of hospitals to changes — such as the implementation of new technologies in clinical and managerial processes and the execution of crisis management programs — plays a crucial role in enhancing organizational resilience (60, 78).

Sustainability ranks third with a (13%) share. Within this dimension, resource efficiency (3%) and digital sustainability (0.05%) are identified as the top priorities, while waste reduction (0.02%) and hospital environmental sustainability (0.02%) have lower shares. This distribution indicates that experts focus more on optimizing resource use and managing sustainable

Table 6. Measurement Indicators of the Main Dimensions of the Proposed Model

Main Dimension	Indicators	Operational Definition/Brief Analysis	Source
Technological readiness	Network capability for leveraging emerging technologies; Quality of technological infrastructure in reducing staff workload; Adoption and utilization of emerging technologies; Degree of administrative task automation	These indicators assess the hospital's technological preparedness, including the effectiveness of communication networks for emerging technologies, IT infrastructure supporting staff efficiency, adoption of innovations like IoT and AI, and automation of routine administrative tasks. Collectively, they link digital readiness with operational and human-centered outcomes.	(5, 75, 76, 81-83)
Human-centered organizational development	Strategies for enhancing the wellbeing of staff, patients, and the community; Access to advanced technology training; Mechanisms supporting innovation; Readiness for organizational change	These indicators evaluate the hospital's focus on human-centered management, including staff well-being initiatives, training in emerging technologies, mechanisms to promote and support innovation, and overall readiness of employees to accept organizational changes. Collectively, they capture not only the technological and operational aspects but also the wellbeing and engagement of staff, patients, and the broader community.	(77, 84-87)
Sustainability	Degree of application of emerging technologies to decrease environmental impacts; Implementation of circular waste management practices; Degree of setting environmental sustainability goals	These indicators collectively evaluate the hospital's readiness for digital and operational sustainability, its commitment to minimizing environmental impact and waste through circular management practices, and its organizational focus on achieving defined sustainability goals.	(81, 88-90)
Resilience	Effectiveness and efficiency of crisis response programs; The degree of redundancy in health system; The degree of hospital financial reserve	These indicators collectively capture the hospital's resilience, reflecting its ability to respond effectively and efficiently to unexpected events, maintain backup systems, and preserve financial resources to ensure continuity.	(60, 91, 92)

technologies rather than on high-level policymaking or waste reduction. This distribution indicates that experts emphasize optimizing resource use and managing sustainable technologies.

According to the studies, the optimal use of human, financial, and physical resources to reduce energy consumption, along with the adoption of advanced technologies to minimize negative environmental impacts, are two key strategies for enhancing the sustainability of Smart Hospital 5.0 (79, 80). The first strategy is less costly than the second one. Therefore, optimizing resource efficiency is considered an effective and practical approach, particularly suitable for Iranian hospitals facing financial constraints.

5.2. Managerial Implications

In this section, key indicators are introduced to operationalize the main dimensions of the Hospital 5.0 framework, providing measurable metrics to assess, monitor, and improve hospital performance. These indicators provide practical measures to guide hospital assessment and improvement. Table 6 presents selected, representative indicators for each of the four main dimensions.

5.3. Theoretical Implications

Although the proposed Hospital 5.0 indicators are designed to be conceptually universal, their practical application requires contextual interpretation. Previous studies emphasize that core dimensions such as technological readiness, human-centered development, sustainability, and resilience maintain cross-context validity across healthcare systems. For example, Baihaqy and Subriadi (93) highlight the universal relevance of digital transformation indicators in hospitals; Kovesdi et al. (94) demonstrate that human-technology integration metrics apply across diverse health systems; Dolcini et al. (95) and Verma et al. (96) identify environmental sustainability and resilience as globally shared priorities for next-generation hospitals.

However, when the indicators are used for assessment, prioritization, and policy decision-making, contextual adaptation becomes necessary. Local infrastructure maturity, financial capacity, regulatory frameworks, and workforce characteristics can significantly influence how the same indicator manifests in different hospital environments.

For instance, in the context of Iran, even if the technological readiness dimension is universally defined, its operationalization must reflect local constraints. If the assessment reveals a low level of technological readiness — especially due to limited digital infrastructure or financial constraints — hospitals may prioritize low-cost, high-impact interventions such as:

- Transitioning from paper-based documentation to basic electronic health record modules instead of full-scale AI-based systems

- Adopting open-source or locally developed digital tools instead of expensive commercial platforms

- Investing in targeted staff training programs rather than large-scale hardware upgrades.

This example illustrates how universal indicators guide the conceptual framework, while local conditions shape implementation pathways. Therefore, the framework maintains theoretical universality, yet the

managerial implications require contextual customization to ensure feasibility and effectiveness in different healthcare systems.

5.4. Conclusions

In this study, a Hospital 5.0 readiness assessment model was first developed using a systematic review and the best-fit framework. The model indicators were then prioritized. The results showed that technological readiness and human-centered organizational development received the highest weights, followed by resilience and sustainability. This pattern aligns with the experience of developed countries, where technological infrastructure and capable human resources are established first, followed by the implementation of resilience and crisis preparedness programs.

From this perspective, the transition to Hospital 5.0 is viewed by experts as a technology-driven process, strengthened by human resource empowerment, while sustainability and resilience play complementary and supportive roles. The findings of this study can serve as a practical guide for hospitals to prioritize investments in technology and human resource development. They can also support planning efforts to enhance organizational resilience and sustainability. At the national level, the results provide an evidence-based framework for the Ministry of Health to develop policies and strategies for the transition toward smart hospitals.

The study's limitations include the use of literature primarily in English and a limited number of experts. Although only five experts participated, this is reasonable given the novelty of the Hospital 5.0 concept. However, involving more experts could improve the generalizability of the results. The proposed model was specifically designed for hospitals but could be adapted for smaller healthcare centers. Future research could apply case studies across multiple hospitals to evaluate and prioritize readiness levels for the transition to Hospital 5.0.

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

Footnotes

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References

1. Mourtzis D, Angelopoulos J, Panopoulos N. A Literature Review of the Challenges and Opportunities of the Transition from Industry 4.0 to Society 5.0. *Energies*. 2022;**15**(17):6276. https://doi.org/10.3390/en15176276.
2. Xu X, Lu Y, Vogel-Heuser B, Wang L. Industry 4.0 and Industry 5.0—Inception, conception and perception. *J Manuf Syst*. 2021;**61**:530-5. https://doi.org/10.1016/j.jmsy.2021.10.006.
3. Ghobakhloo M, Iranmanesh M, Mubarak MF, Mubarik M, Rejeb A, Nilashi M. Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values. *Sustain Prod Consum*. 2022;**33**:716-37. https://doi.org/10.1016/j.spc.2022.08.003.
4. Horvat D, Jäger A, Lerch CM. Fostering innovation by complementing human competences and emerging technologies: an industry 5.0 perspective. *Int J Prod Res*. 2024;**63**(3):1126-49. https://doi.org/10.1080/00207543.2024.2372009.
5. Gomathi L, Mishra AK, Tyagi AK. Industry 5.0 for Healthcare 5.0: Opportunities, Challenges and Future Research Possibilities. *7th International Conference on Trends in Electronics and Informatics (ICOEI)*. Tirunelveli, India. 2023. p. 204-13.
6. Gardner J. Hospitals of the future. In: Petersen A, editor. *Handbook on the Sociology of Health and Medicine*. Cheltenham, UK: Edward Elgar Publishing; 2023. p. 541-54.
7. Kolasa K. *The Digital Transformation of the Healthcare System*. London, UK: Routledge; 2023. https://doi.org/10.4324/b23291.
8. Schumacher A, Erol S, Sihn W. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP*. 2016;**52**:161-6. https://doi.org/10.1016/j.procir.2016.07.040.
9. Lichtblau K, Stich V, Bertenrath R, Blum M, Bleider M, Millack A, et al. *[Industry 4.0 Readiness]*. Frankfurt, Germany: Impuls-Stiftung; 2015. Dutsch.
10. Mansour H, Aminudin E, Mansour T. Implementing industry 4.0 in the construction industry- strategic readiness perspective. *Int J Constr*

Manag. 2021;**23**(9):1457-70. https://doi.org/10.1080/15623599.2021.1975351.

11. Ronaghi MH. Toward a model for assessing smart hospital readiness within the Industry 4.0 paradigm. *J Sci Technol Policy Manag*. 2022;**15**(2):353-73. https://doi.org/10.1108/jstpm-09-2021-0130.
12. Handrean IE, Rian Pratama I, Rahma Sumarna D, Fakhrazi R, Rejauw S, Paramarta V. Digital Transformation in Hospital Management: Building Readiness for Society 5. *Int J Health Pharm*. 2025;**5**(1):39-45. https://doi.org/10.51601/ijhp.v5i1.398.
13. Cheema MAM, Ahmed R, Iqbal Q, Naz M. Evaluating readiness for digital and AI technology integration to adopt Industry 4.0 and its effect on productivity in public sector healthcare operations. *Policy Res J*. 2025;**3**(3):510-9.
14. Panizzon M, Barcellos PFP. Critical Success Factors of the University of the Future in a Society 5.0: A Maturity Model. *World Futur Rev*. 2020;**12**(4):410-26. https://doi.org/10.1177/1946756720976711.
15. Kadarisman M, Wijayanto AW, Sakti AD. Government Agencies' Readiness Evaluation towards Industry 4.0 and Society 5.0 in Indonesia. *Soc Sci*. 2022;**11**(8):331. https://doi.org/10.3390/socsci11080331.
16. Hein-Pensel F, Winkler H, Brückner A, Wölke M, Jabs I, Mayan IJ, et al. Maturity assessment for Industry 5.0: A review of existing maturity models. *J Manufact Syst*. 2023;**66**:200-10. https://doi.org/10.1016/j.jmsy.2022.12.009.
17. Madhavan M, Sharafuddin MA, Wangtueai S. Measuring the Industry 5.0-Readiness Level of SMEs Using Industry 1.0–5.0 Practices: The Case of the Seafood Processing Industry. *Sustainability*. 2024;**16**(5):2205. https://doi.org/10.3390/su16052205.
18. Brückner A, Wölke M, Hein-Pensel F, Schero E, Winkler H, Jabs I. Assessing industry 5.0 readiness—Prototype of a holistic digital index to evaluate sustainability, resilience and human-centered factors. *Int J Inf Manag Data Insights*. 2025;**5**(1). https://doi.org/10.1016/j.jjimei.2025.100329.
19. Bartuś K, Kocot M, Sączewska-Piotrowska A. Assessment and Insights into the Awareness and Readiness of Organizations to Implement the Assumptions of Industry 5.0: An Examination of Five Polish Sectors. *Sustainability*. 2025;**17**(3):903. https://doi.org/10.3390/su17030903.
20. Keenavinna H, Wickramarachchi R. Assessing Organizational Readiness for Industry 5.0 in the Sri Lankan Large-Scale Apparel Companies: Challenges and Opportunities. *2025 International Research Conference on Smart Computing and Systems Engineering (SCSE)*. kelaniya, Sri Lanka. 2025. p. 1-6.
21. Carroll C, Booth A, Leaviss J, Rick J. "Best fit" framework synthesis: refining the method. *BMC Med Res Methodol*. 2013;**13**:37. [PubMed ID: 23497061]. [PubMed Central ID: PMC3618126]. https://doi.org/10.1186/1471-2288-13-37.
22. Liu S, Forrest JYL. *Grey systems: theory and applications*. Heidelberg, Berlin: Springer; 2010.
23. Liu S. *Grey Systems Analysis*. Gateway East, Singapore: Springer Nature; 2025. https://doi.org/10.1007/978-981-97-8727-2.
24. Mahmoudi A, Mi X, Liao H, Feylizadeh MR, Turskis Z. Grey Best-Worst Method for Multiple Experts Multiple Criteria Decision Making Under Uncertainty. *Informatica*. 2020:331-57. https://doi.org/10.15388/20-infor409.
25. Petrudi SHH, Ahmadi HB, Rehman A, Liou JJH. Assessing suppliers considering social sustainability innovation factors during COVID-19 disaster. *Sustain Prod Consum*. 2021;**27**:1869-81. [PubMed ID: 36118163]. [PubMed Central ID: PMC9464291]. https://doi.org/10.1016/j.spc.2021.04.026.
26. Geissbauer R, Vedso J, Schrauf S. *Industry 4.0: Building the digital enterprise*. London, UK: PwC; 2016. Available from: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf.
27. Rockwell Automation. *The Connected Enterprise® Maturity Model: Metrics that Matter*. Machelen, Belgium: Rockwell Automation; 2014. Available from: https://www.rockwellautomation.com/en-nl/company/news/blogs/the-connected-enterprise-maturity-model--metrics-that-matter.html.
28. Brozzi R, D'Amico RD, Pasetti Monizza G, Marcher C, Riedl M, Matt D. Design of Self-assessment Tools to Measure Industry 4.0 Readiness. A Methodological Approach for Craftsmanship SMEs. *Product Lifecycle Management to Support Industry 4.0*. Cham, Germany: Springer; 2018. p. 566-78. https://doi.org/10.1007/978-3-030-01614-2_52.
29. Schaupp E, Abele E, Metternich J. Potentials of Digitalization in Tool Management. *Procedia CIRP*. 2017;**63**:144-9. https://doi.org/10.1016/j.procir.2017.03.172.
30. Horvat D, Stahlecker T, Zenker A, Lerch C, Mladineo M. A conceptual approach to analysing manufacturing companies' profiles concerning Industry 4.0 in emerging economies. *Procedia Manuf*. 2018;**17**:419-26. https://doi.org/10.1016/j.promfg.2018.10.065.
31. Akdil KY, Ustundag A, Cevikcan E. Maturity and Readiness Model for Industry 4.0 Strategy. In: Ustundag A, Cevikcan E, editors. *Industry 4.0: Managing The Digital Transformation*. Cham, Germany: Springer; 2018. p. 61-94. https://doi.org/10.1007/978-3-319-57870-5_4.
32. Gomes J, Romao M. Information System Maturity Models in Healthcare. *J Med Syst*. 2018;**42**(12):235. [PubMed ID: 30327955]. https://doi.org/10.1007/s10916-018-1097-0.
33. Santos RC, Martinho JL. An Industry 4.0 maturity model proposal. *J Manuf Technol Manag*. 2019;**31**(5):1023-43. https://doi.org/10.1108/jmtm-09-2018-0284.
34. Carvalho JV, Rocha Á, van de Wetering R, Abreu A. A Maturity model for hospital information systems. *J Bus Res*. 2019;**94**:388-99. https://doi.org/10.1016/j.jbusres.2017.12.012.
35. Yams NB, Richardson V, Shubina GE, Albrecht S, Gillblad D. Integrated AI and Innovation Management: The Beginning of a Beautiful Friendship. *Technol Innov Manag Rev*. 2020;**10**(11):5-18. https://doi.org/10.22215/timreview/1399.
36. Erdal B, İhtiyar B, Mıstıkoğlu ET, Gül S, Temur GT. Digital Maturity Assessment Model Development for Health Sector. In: Durakbasa NM, Gençyılmaz M, editors. *Digitizing Production Systems*. Cahm, Germany: Springer; 2022. p. 131-47. https://doi.org/10.1007/978-3-030-90421-0_11.
37. Antony J, Sony M, McDermott O. Conceptualizing Industry 4.0 readiness model dimensions: an exploratory sequential mixed-method study. *TQM J*. 2021;**35**(2):577-96. https://doi.org/10.1108/tqm-06-2021-0180.
38. Simetinger F, Basl J. A pilot study: An assessment of manufacturing SMEs using a new Industry 4.0 Maturity Model for Manufacturing Small- and Middle-sized Enterprises (I4MMSME). *Procedia Comput Sci*. 2022;**200**:1068-77. https://doi.org/10.1016/j.procs.2022.01.306.
39. Kandasamy V, Rohani JM, Syahrial E. Quality 4.0 Readiness Evaluation of Medical Technology Companies in Malaysia. *5th Asia Pacific Conference on Industrial Engineering and Operations Management*. Tokyo, Japan. 2024.
40. Oleskow-Szlapka J, Kretkowska L, Zielinska A. Industry 5.0 Maturity Models: Towards Sustainable Development – Theoretical Review and Case Study in a Selected Company. *Eur Res Stud J*. 2024;**XXVII**(Issue 1):807-27. https://doi.org/10.35808/ersj/3729.
41. Tyagi A, Kukreja S, Nair MM, Tyagi AK. Machine learning: Past, present and future. *Neuroquantol*. 2022;**20**(8):4333-57.
42. Avdan G, Onal S. Lean Thinking in Healthcare 5.0 Technologies: An Exploratory Review. *9th North American Conference on Industrial Engineering and Operations Management*. Washington D.C., United States. 2024.

43. Samanta I, Patil DJ, More CB. Assessment of vitamin D levels in patients with oral potentially malignant disorders and oral squamous cell carcinoma-A cross-sectional study. *J Oral Biol Craniofac Res*. 2024;**14**(1):27-32. [PubMed ID: 38130424]. [PubMed Central ID: PMC10733696]. https://doi.org/10.1016/j.jobcr.2023.11.005.
44. Hajoary PK. Industry 4.0 Maturity and Readiness Models: A Systematic Literature Review and Future Framework. *Int J Innov Tech Manag*. 2021;**17**(7). https://doi.org/10.1142/s0219877020300050.
45. Kasych A, Cherniavska O, Ruban D, Glukhova V, Golub V, Nefedova T. Artificial intelligence as a tool of local self-government and democracy development during the formation of Industry 5.0 and Society 5.0. *2023 IEEE 5th International Conference on Modern Electrical and Energy System (MEES)*. Kremenchuk, Ukraine. 2023. p. 1-6.
46. Angurala M, Khullar V. Introduction and Role of Society 5.0 in Human-Centric Development. In: Khullar V, Sharma V, Angurala M, Chhabra N, editors. *Artificial Intelligence and Society 5.0*. New York, USA: Chapman and Hall/CRC; 2023. p. 1-8. https://doi.org/10.1201/9781003397052-1.
47. Carayannis EG, Canestrino R, Magliocca P. From the Dark Side of Industry 4.0 to Society 5.0: Looking "Beyond the Box" to Developing Human-Centric Innovation Ecosystems. *IEEE Tran Eng Manag*. 2024;**71**:6695-711. https://doi.org/10.1109/tem.2023.3239552.
48. Shehzad N, Ramtiyal B, Jabeen F, Mangla SK, Vijayvargy L. Metaverse adoption as a cornerstone for sustainable healthcare firms in the industry 5.0 epoch. *J Enterp Inf Manag*. 2024;**37**(4):1254-81. https://doi.org/10.1108/jeim-10-2023-0559.
49. Vamshikrishna A, Ramesh D, Mishra R, Mohammad N. Sustainable Healthcare 5.0: Integration of IoT and Blockchain Technology with Federated Learning Model for Securing Healthcare Data. In: Misra S, Siakas K, Lampropoulos G, editors. *Artificial Intelligence of Things for Achieving Sustainable Development Goals*. Cham, Germany: Springer; 2024. p. 161-80. https://doi.org/10.1007/978-3-031-53433-1_9.
50. Martini B, Bellisario D, Coletti P. Human-Centered and Sustainable Artificial Intelligence in Industry 5.0: Challenges and Perspectives. *Sustainability*. 2024;**16**(13):5448. https://doi.org/10.3390/su16135448.
51. Gigauri I, Janjua LR. Digital and Sustainable Products to Achieve Sustainable Business Goals Along the Path to Industry 5.0. In: Akkaya B, Andreea Apostu S, Hysa E, Panait M, editors. *Digitalization, Sustainable Development, and Industry 5.0*. Leeds, UK: Emerald Publishing; 2023. p. 25-40. https://doi.org/10.1108/978-1-83753-190-520231003.
52. Faggini M, Cosimato S, Nota FD, Nota G. Pursuing Sustainability for Healthcare through Digital Platforms. *Sustainability*. 2018;**11**(1):165. https://doi.org/10.3390/su11010165.
53. Dymyt M, Wincewicz-Bosy M. A Concept of a Sustainable Digital Healthcare System. In: Ziemba E, Wątróbski J, editors. *Adoption of Emerging Information and Communication Technology for Sustainability*. Florida, USA: CRC Press; 2023. p. 87-104. https://doi.org/10.1201/9781003316572-6.
54. Dhandayuthapani V B. AI, IoT, and Smart Technologies forEnvironmental Resilience and Sustainability —Comprehensive Review. *Int J Inf Eng Electron Bus*. 2024;**16**(5):75-84. https://doi.org/10.5815/ijieeb.2024.05.04.
55. Verma SS, Sharma K, Rao S, Dogra S, Rani L, Sharma A, et al. Low-density neutrophils in hidradenitis suppurativa: insights from immunophenotyping and activation markers. *Arch Dermatol Res*. 2024;**316**(7):345. [PubMed ID: 38847889]. https://doi.org/10.1007/s00403-024-03133-7.
56. Jassem S. Artificial Intelligence in Accounting Practices in the Industry 5.0 Era from a Dynamic Capabilities Perspective: Role of Strategic Foresight, Agility, and Flexibility. In: Alareeni B, Elgedawy I, editors. *Opportunities and Risks in AI for Business Development*. Cham, Germany: Springer; 2024. p. 149-60. https://doi.org/10.1007/978-3-031-65203-5_14.
57. Maciaszczyk M, Makieła Z, Miśkiewicz R. Industry 5.0. In: Rzepka A, editor. *Innovation in the Digital Economy*. London, UK: Routledge; 2023. p. 51-61. https://doi.org/10.4324/9781003384311-5.
58. Boumsisse I, Benhadou M, Haddout A. Study of synergies between behavioral and organizational factors impacting operational excellence in the context of Industry. *J Electr Syst*. 2024;**20**(10s):6305-14.
59. Wang X, Huang L, Wang D, Liu L, Guo P. Smart Elderly Healthcare Services in Industry 5.0: A Survey of Key Enabling Technologies and Future Trends. *IEEE Access*. 2025;**13**:139419-32. https://doi.org/10.1109/access.2025.3596694.
60. Emami SG, Lorenzoni V, Turchetti G. Towards Resilient Healthcare Systems: A Framework for Crisis Management. *Int J Environ Res Public Health*. 2024;**21**(3):286. [PubMed ID: 38541286]. [PubMed Central ID: PMC10970665]. https://doi.org/10.3390/ijerph21030286.
61. Bek Yağmur Ö, Aydıntuğ Myrvang N. The effect of organizational agility on crisis management process and organizational resilience: Health sector example. *Int J Disaster Risk Reduct*. 2023;**96**. https://doi.org/10.1016/j.ijdrr.2023.103955.
62. Mizrak KC. Crisis Management and Risk Mitigation. In: Mızrak F, editor. *Trends, Challenges, and Practices in Contemporary Strategic Management*. Pennsylvania, USA: IGI Global Scientific Publishing; 2024. p. 254-78. https://doi.org/10.4018/979-8-3693-1155-4.ch013.
63. Tyagi AK, Arumugam SK, Prasad P, Sharma A. The Position of Digital Society, Healthcare 5.0, and Consumer 5.0 in the Era of Industry 5.0. In: Sharma AK, Chanderwal N, Prajapati A, Pancham S, Kansal M, editors. *Advancing Software Engineering Through AI, Federated Learning, and Large Language Models*. Pennsylvania, USA: IGI Global Scientific Publishing; 2024. p. 262-80. https://doi.org/10.4018/979-8-3693-3502-4.ch017.
64. Rehman A, Umar T. Literature review: Industry 5.0. Leveraging technologies for environmental, social and governance advancement in corporate settings. *Corp Gov-Int J Bus Soc*. 2024;**25**(2):229-51. https://doi.org/10.1108/cg-11-2023-0502.
65. Guise V, Aase K, Chambers M, Canfield C, Wiig S. Patient and stakeholder involvement in resilient healthcare: an interactive research study protocol. *BMJ Open*. 2021;**11**(6). e049116. [PubMed ID: 34083349]. [PubMed Central ID: PMC8183273]. https://doi.org/10.1136/bmjopen-2021-049116.
66. Guise V, Chambers M, Lyng HB, Haraldseid-Driftland C, Schibevaag L, Fagerdal B, et al. Identifying, categorising, and mapping actors involved in resilience in healthcare: a qualitative stakeholder analysis. *BMC Health Serv Res*. 2024;**24**(1):230. [PubMed ID: 38388408]. [PubMed Central ID: PMC10882781]. https://doi.org/10.1186/s12913-024-10654-4.
67. Bastan O, Fiedler P, Benesl T, Arm J. Redundancy as an important source of resilience in the Safety II concept. *IFAC-PL*. 2019;**52**(27):382-7. https://doi.org/10.1016/j.ifacol.2019.12.690.
68. Bradaschia M, Pereira SCF. Building Resilient Supply Chains Through Flexibility: a Case Study in Healthcare. *J Oper Supply Chain Manag*. 2015;**8**(2):120-33. https://doi.org/10.12660/joscmv8n2p120-133.
69. Usher K, Jackson D, Walker R, Durkin J, Smallwood R, Robinson M, et al. Indigenous Resilience in Australia: A Scoping Review Using a Reflective Decolonizing Collective Dialogue. *Front Public Health*. 2021;**9**:630601. [PubMed ID: 33869128]. [PubMed Central ID: PMC8044395]. https://doi.org/10.3389/fpubh.2021.630601.
70. Zhai X, Zhu CJ, Zhang MM. Mapping promoting factors and mechanisms of resilience for performance improvement: The role of strategic human resource management systems and psychological empowerment. *Appl Psychol*. 2022;**72**(3):915-36. https://doi.org/10.1111/apps.12411.
71. Zhang T, Said J, Zakaria NB, Li X. Enhancing Financial Resilience in Chinese Public Hospitals: Role of dynamic capabilities. *Environ Behav*

Proceed J. 2025;**10**(31):179-86. https://doi.org/10.21834/e-bpj.v10i31.6536.

72. Garg PK. The Future Healthcare Technologies: A Roadmap to Society 5.0. In: Kumar Garg P, Tripathi NK, Kappas M, Gaur L, editors. *Geospatial Data Science in Healthcare for Society 5.0*. Gateway East, Singapore: Springer; 2022. p. 305-18. https://doi.org/10.1007/978-981-16-9476-9_14.
73. Lawshe CH. A Quantitative Approach to Content Validity. *Pers Psychol*. 2006;**28**(4):563-75. https://doi.org/10.1111/j.1744-6570.1975.tb01393.x.
74. Trivedi P, Shah J, Čep R, Abualigah L, Kalita K. A Hybrid Best-Worst Method (BWM)—Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Approach for Prioritizing Road Safety Improvements. *IEEE Access*. 2024;**12**:30054-65. https://doi.org/10.1109/access.2024.3368395.
75. Arasti M, Garousi Mokhtarzadeh N, Jafarpanah I. Networking capability: a systematic review of literature and future research agenda. *J Bus Ind Market*. 2021;**37**(1):160-79. https://doi.org/10.1108/jbim-06-2020-0273.
76. Maganga DP, Taifa IW. The readiness of manufacturing industries to transit to Quality 4.0. *Int J Qual Reliab Manag*. 2022;**40**(7):1729-52. https://doi.org/10.1108/ijqrm-05-2022-0148.
77. Passalacqua M, Pellerin R, Magnani F, Doyon-Poulin P, Del-Aguila L, Boasen J, et al. Human-centred AI in industry 5.0: a systematic review. *Int J Prod Res*. 2024;**63**(7):2638-69. https://doi.org/10.1080/00207543.2024.2406021.
78. Wiig S, O'Hara JK. Resilient and responsive healthcare services and systems: challenges and opportunities in a changing world. *BMC Health Serv Res*. 2021;**21**(1):1037. [PubMed ID: 34602063]. [PubMed Central ID: PMC8487709]. https://doi.org/10.1186/s12913-021-07087-8.
79. Agrawal A, Sharma A, Sarkar B. Business Strategies for Sustainable Development: Leveraging Industry 5.0 and Circular Pharmaceutical Supply Chains to Overcome Medicine Waste. *Bus Strateg Environ*. 2025;**34**(4):4291-311. https://doi.org/10.1002/bse.4202.
80. Psillaki M, Apostolopoulos N, Makris I, Liargovas P, Apostolopoulos S, Dimitrakopoulos P, et al. Hospitals' Energy Efficiency in the Perspective of Saving Resources and Providing Quality Services through Technological Options: A Systematic Literature Review. *Energies*. 2023;**16**(2):755. https://doi.org/10.3390/en16020755.
81. Mbunge E, Muchemwa B, Jiyane S, Batani J. Sensors and healthcare 5.0: transformative shift in virtual care through emerging digital health technologies. *Glob Health J*. 2021;**5**(4):169-77. https://doi.org/10.1016/j.glohj.2021.11.008.
82. Matha R, Mukherjee S, Panigrahi RR, Shrivastava AK. A bibliometric analysis of industry 5.0 and healthcare supply chain research: Emerging opportunities and future challenges. *Supply Chain Anal*. 2025;**10**. https://doi.org/10.1016/j.sca.2025.100125.
83. Temjanovski R, Loku A, Bezovski Z. Transforming Human Resource Management in Healthcare: The Role of Artificial Intelligence and Industry 5.0. *J Econ*. 2025;**10**(1):54-71. https://doi.org/10.46763/JOE2510154t.
84. Panahi O. Health in the Age of AI: A Family and Community Focus. *Arch Commun Fam Med*. 2025;**8**(1):11-20. https://doi.org/10.22259/2638-4787.0801003.
85. Lima RKD, Heckler WF, Francisco R, Barbosa JLV. Integrating Collaborative Learning and Advanced Technology in Industry 5.0: A Systematic Mapping Study and Taxonomy. *Int J Hum Comput Interact*. 2024;**41**(1):707-22. https://doi.org/10.1080/10447318.2024.2321406.
86. Li L, Duan L. Human centric innovation at the heart of industry 5.0 – exploring research challenges and opportunities. *Int J Prod Res*. 2025:1-33. https://doi.org/10.1080/00207543.2025.2462657.
87. Traub K, Ulrich PS. Unlocking the Future: Exploring Employee Acceptance of Emerging Technologies in the Shift to Industry 5.0. *Pacific Asia Conference on Information systems*. Kuala Lumpur, Malaysia. 2025.
88. Priyadarshini J, Singh RK, Mishra R, He Q, Braganza A. Implementation of Additive Manufacturing in the Healthcare Supply Chain for Circular Economy Goals: Paradoxical Tensions and Solutions from an Industry 5.0 Perspective. *Inf Syst Front*. 2024:1-23. https://doi.org/10.1007/s10796-024-10482-1.
89. Majiwala H, Kant R. Evaluating Sustainable Development Goals Achieved Through Industry 5.0-Enabled Circular Practices. *Environ Qual Manag*. 2025;**34**(3). https://doi.org/10.1002/tqem.70069.
90. Kasinathan P, Pugazhendhi R, Elavarasan RM, Ramachandaramurthy VK, Ramanathan V, Subramanian S, et al. Realization of Sustainable Development Goals with Disruptive Technologies by Integrating Industry 5.0, Society 5.0, Smart Cities and Villages. *Sustainability*. 2022;**14**(22):15258. https://doi.org/10.3390/su142215258.
91. Sambowo AL, Hidayatno A. Resilience Index Development for the Manufacturing Industry based on Robustness, Resourcefulness, Redundancy, and Rapidity. *Int J Technol*. 2021;**12**(6). https://doi.org/10.14716/ijtech.v12i6.5229.
92. Daniyarova AD, Nurekenova ES. Analysis of the Financial State of Healthcare. *Improving the Quality of Education, Modern Innovations in Science and Production*. Kemerovo Oblast, Russia. 2021. p. 301-3.
93. Baihaqy A, Subriadi AP. Development of digital transformation model in hospital. *Technol Sustain*. 2024;**4**(1):1-29. https://doi.org/10.1108/techs-04-2024-0028.
94. Kovesdi CR, Spangler R, Murray P, Mohon J. Development of a Human and Technology Integration Methodology That Enables Work Optimization at Nuclear Power Plants. *Proc Hum Factors Ergon Soc Annu Meet*. 2024;**68**(1):817-21. https://doi.org/10.1177/10711813241262015.
95. Dolcini M, Brambilla A, Mangili S, Capolongo S. Environmental Sustainability in Next-Generation Hospitals. Identifying Needs and Requirements from Healthcare Organizations and Industry Stakeholders. *Ann Ig*. 2025;**37**(5):565-73. [PubMed ID: 40357533]. https://doi.org/10.7416/ai.2025.2708.
96. Verma U, Diamant A, Imanirad R, Verma A, Razak F. *Resilience and Adaptation: Assessing the Effects of COVID-19 on Hospital Efficiency and Quality*. 2025. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5396361.