Evaluating Smart Manufacturing Readiness: A Maturity Model Perspective

Muhammad Yahya Hammad[1], Syed Radzi Bin Rahmaddulla[1*], Puteri Fadzline Muhammad Tamyez[1], Azim Azuan Bin Osman[2], Ahmad Nazif Noor Kamar[1]

[1]Universiti Malaysia Pahang Al-Sultan Abdullah

[2]Universiti Utara Malaysia.

[*]Corresponding Author

DOI: https://dx.doi.org/10.47772/IJRISS.2025.90300183

Received: 19 March 2025; Accepted: 25 March 2025; Published: 06 April 2025

ABSTRACT

The emergence of Industry 4.0 has transformed the manufacturing sector, necessitating established frameworks to appraise digital preparedness. To fill in the gaps in current models that ignore the particular obstacles faced by small and medium-sized businesses (SMEs) and urban manufacturing firms, this study suggests a customized Urban Smart Factory (USF) maturity model. The approach incorporates essential elements, including sustainability, resilience, digitalization, and workforce competencies, providing a thorough assessment of smart manufacturing preparedness. Key research trends were diagnosed by bibliometric analysis, and case studies from several manufacturing sectors were used to validate the suggested model. According to the findings, a large number of firms inadequately use the instruments necessary to evaluate workforce and technology readiness, which leads to irregular attempts at digital transformation. By offering an organized framework for distinguishing technology gaps, assessing organizational adaptability, and facilitating the creation of strategic roadmaps for Industry 4.0 adoption, the USF maturity model fills this gap. By highlighting the connections between technology, human capital, and administrative processes, the study advances our acquiesce of digital transformation in the urban manufacturing framework and adds to the theoretical conversation. The recognition of the model provides useful information for businesses perceiving to advance their digital maturity while negotiating the challenges of smart manufacturing. Future studies should concentrate on incorporating cutting-edge technology like blockchain and artificial intelligence while broadening the model's application through many businesses and geographical areas. Conclusively, our research creates the groundwork for manufacturing ecosystems that are robust, sustainable, and technologically sophisticated, spurring long-term growth and innovation.

Keywords- *Readiness Assessment, Maturity Model, Smart Manufacturing, Digitalization, Sustainability*

INTRODUCTION

The industrial sector is perceiving a profound shift due to the implementation of Industry 4.0 technologies, propelled by innovations in automation, digitalization, and artificial intelligence. The goal of this reform is to improve industrial processes' flexibility, capability, and productivity [1]. However, industries now have to cope with more global issues in conjunction with energy scarcity, climate crisis, and exclusive desires, which call for creative solutions for sustainable manufacturing. The Urban Smart Factory (USF), which combines smart manufacturing concepts with urban infrastructure to demonstrate resilient, sustainable, and human-centered industrial settings, is one potential strategy. Even while a lot of businesses understand the potential of digital transformation, they frequently find it difficult to evaluate their level of Industry 4.0 readiness, which makes it rigorous to put strategic changes into practice [2].

While maturity models have been used extensively to estimate digital readiness, their applicability in contemporary assembling environments is limited by the fact that they do not specifically address the USF hypothesis. The adoption of Industry 4.0 technologies requires a methodical avenue to assess a company's innovation readiness, digital transformation, and innovation cubage. Traditional maturity models have a rugged emphasis on large-scale sectors while ignoring the particular objections encountered by urban manufacturing firms and small and medium-sized enterprises (SMEs). These models usually neglect important sustainability and resilience factors that are essential to modern smart manufacturing [3]. In addition, many producers lack the configuration and tools necessary to evaluate their infrastructure, technical gallantry, and personnel readiness for the transition to smart urban factories. Without a defined plan, companies may invest in Industry 4.0 technologies without fully comprehending their impact, which could lead to less-than-ideal results and ineffective achievement. There is an urgent need for a comprehensive maturity model that considers the unique attributes of urban smart factories to help firms assess their readiness and make informed decisions (Bibby et al., 2018).

This paper suggests a new maturity model generated specifically for Urban Smart Factories (USF) to bridge this gap by overcoming the downside of traditional frameworks. The model integrates characteristics like plugger capability, digitization, justifiability, and resilience to offer an orderly framework for measuring the preparation of manufacturing companies. By assessing these characteristics, the recommended framework will assist companies in distinguishing their benefits, drawbacks, and areas for improvement, facilitating a smooth transition to Industry 4.0 and smart manufacturing. Additionally, by testing the USF maturity model through case studies in many manufacturing industries, the study will show how applicable it is in real-world scenarios **(Vreede et al., 2015).** The consequence of this study will aid in the creation of a systematic evaluation instrument that will direct industries on their path to digital transformation and elevate manufacturing ecosystems that are sustainable and prepared for the future.

The demand for personalization, environmental concerns, and changing worker requirements are the main reasons why manufacturing companies are finding it increasingly difficult to adapt to Industry 4.0 [6]. A solution that emphasizes resilience, sustainability, and digital variation in industrial processes is the idea of Urban Smart Factories (USF). But current maturity models don't fully figure a company's preparedness to apply smart manufacturing concepts in urban locale. Many businesses find it difficult to appraise their labor, organizational, and technology readiness, which results in inefficient digital transformation plans [7]. Manufacturers lack a systematic approache to assess their Industry 4.0 adoption levels in the absence of an Urban Smart Factory-specific maturity model, which makes it rigorous to pinpoint important areas for improvement. Existing readiness assessment instruments largely target large-scale enterprises and fall short in addressing the particular difficulties faced by SME and urban manufacturing **[8]**.

Inefficiencies, higher investment risks, and a sluggish espousal of digital solutions are the outcomes of this disparity. To ensure a planned and determined shift to Industry 4.0, a new maturity model that precisely assesses USF readiness must be developed immediately. Finding the critical elements that influence manufacturing companies' preparedness for Urban Smart Factory (USF) is the foremost goal of this study. to measure Industry 4.0 preparedness by evaluating the shortcomings of current maturity models. to investigate the difficulties manufacturing companies encounter in becoming prepared for the Urban Smart Factory (USF).

Problem Statement

Industries are increasingly challenged by the rapid digital transformation brought by Industry 4.0, yet many firms, especially small and medium-sized enterprises (SMEs) and urban manufacturing units, struggle to assess their readiness for this shift. Existing maturity models often focus on large scale industries and fail to address the unique constraints of SMEs, such as limited resources, technological gaps, and workforce adaptation. Without a structured approach to evaluating their digital preparedness, these firms risk inefficient adoption of Industry 4.0 technologies, leading to fragmented digital transformation efforts. This study aims to bridge this gap by developing a comprehensive Urban Smart Factory (USF) maturity model that integrates sustainability, resilience, and digital capability assessments, providing a tailored framework for evaluating smart manufacturing readiness.

METHODOLOGY

Applying mathematical and statistical techniques to books, papers, and other communication channels to analyse scientific publications is known as bibliometrics [9]. A well-liked and exacting technique for looking through and evaluating vast amounts of scientific data is bibliometric analysis. It allows us to examine the subtleties of a particular topic's progress while illuminating new developments within that field [10]

1. **Bibliographic coupling:** The process of identifying conceptual parallels while referencing a document is known as bibliographic coupling. Recent research publications, which have fewer citations, are also taken into account. When a document appears in the references of two or more other papers, it is said to be bibliographically connected [11]. Bibliographic coupling is the term used to describe how connected two objects are based on how many references they have in common. The more citations a document obtains, the stronger the relatedness (coupling) becomes. It shows how the subjects of the two books are similar in terms of documents, sources, authors, organisations, and nations.

2. **Co-word analysis:** Co-word analysis is a method is used to understand how each research theme has developed and to identify possible avenues for future investigation, the co-word analysis is employed [12]. Citation analysis is predicated on the idea that any number of research articles that cite one another, are regularly referenced together, or have a large number of shared cited references are indicative of an underlying research theme [13]

3. Paper is solely bibliometric analysis based and no other method is used. The two methods used to identify key concepts and potential areas of research within a field are co-word analysis and bibliographic coupling. Co-word analysis examines frequently discussed areas and links between them by exploring the co-occurrence of keywords in research articles. By connecting research articles with respect to the number of citations they have in common, bibliographic coupling identifies relevant conceptual connections. A data-driven methodology, bibliometric analysis focuses on links, structures, and themes discovered in the data. Content is organized through techniques for clustering like network visualization, factor evaluation, and hierarchical grouping. Research mapping, technology projections, and scientific evaluation of impact all make frequent use of such methods. Studies that use co-word analysis and bibliographic coupling do not involve the formulation of hypotheses due to the main goal is to classify research trends and evaluate systems of knowledge [14], [15].

Table 1: Search string in Scopus database

No	Keywords	Justification
1	**“Readiness Assessment”**	To identify studies that focus on evaluating readiness in various contexts.
2	**“Maturity Model”**	To explore frameworks used to assess different stages of development or readiness.

FINDINGS AND DISCUSSION

The line graph Figure 1 drawn from CSV file of 279 documents shows the number of documents produced per year from 2014 to 2025, highlighting a general upward trend with some fluctuations. From 2014 to 2016, the number of documents steadily increased, peaking at around 15 in 2016. However, there was a slight decline in 2017, followed by a gradual rise from 2018 onwards. The number of documents reached its highest point in 2021, with about 40 documents. After this peak, the trend fluctuated slightly, with a minor drop in 2022, a rise in 2023, and a slight decrease in 2024. Notably, 2025 experienced a sharp decline, bringing the document count lose to the levels observed in 2014. This pattern indicates an overall growth in document production over the years, despite some periods of decline.

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue III March 2025

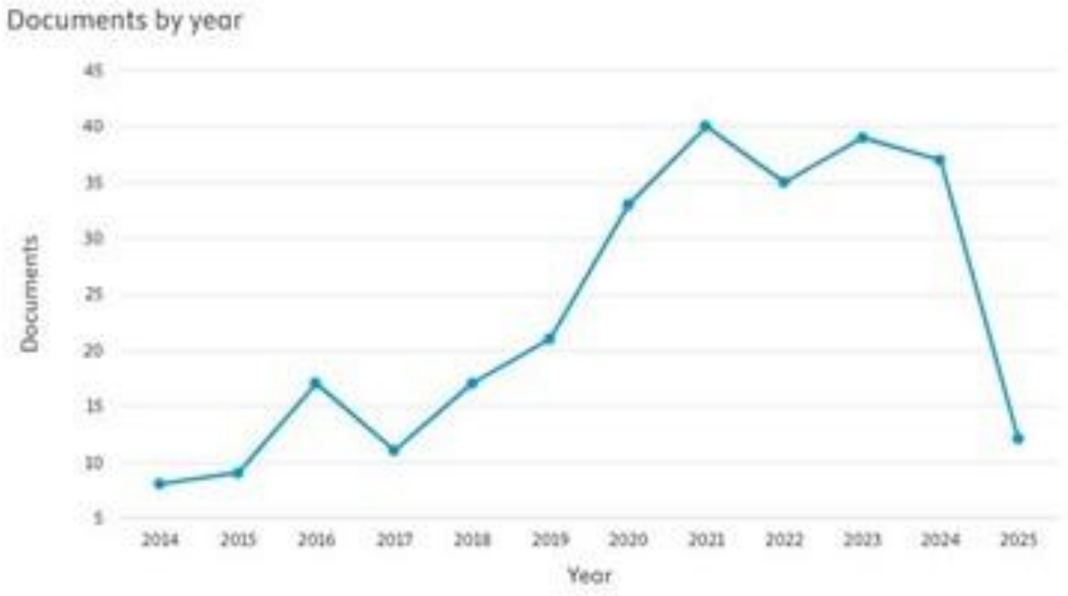

Figure 1: Number of papers published per year

Bibliographic Coupling

Of the 279 documents, 30 of them had at least 44 citations. These 30 documents form four clusters. According to total link strength (TLS), rank first through third. In this bibliographic coupling, the top ten documents are shown in Table 2. The strength of the coupling between linked documents is known as bibliographic coupling; hence, the more significant the documents in the network, the higher the total link strength (TLS).

Table 2: Top 10 documents in bibliographic coupling analysis

Rank	Publication	Scope	Citation	TLS
1	Pirola et al., (2019)	An analysis of Italian SMEs' digital readiness using a case study	169	59
2	Wagire et al., (2021)	Creation of a maturity model to evaluate Industry 4.0 implementation: integrating theory and practice	175	52
3	Caiado et al., (2021)	An enterprise built on imprecise rules 4.0 supply chain and operations management maturity model	223	52
4	Mittal et al., (2018a)	A critical analysis of Industry 4.0 maturity models and smart manufacturing: What they mean for new and small businesses	829	41
5	Saad, Bahadori, Jafarnejad, et al., (2021)	Intelligent Production Scheduling and Management: Evaluation of Technological Preparedness	48	38
6	Hein-Pensel et al., (2023)	Industry 5.0 maturity assessment: An examination of current maturity models	102	35
7	Amaral & Peças, (2021)	A Structure for Evaluating Industry 4.0 Maturity in Manufacturing SMEs	67	32
8	Schumacher et al., (2019)	Developing a roadmap for industrial digitalisation in manufacturing firms using an Industry 4.0 maturity model	199	30

9	Lee et al., (2012)	Using the maturity model to evaluate smart manufacturing readiness: a case study of Taiwanese businesses	66	29
10	Kayikci et al., (2022)	Evaluating small and medium-sized businesses' preparedness and maturity level for smart circular supply chains	49	27

Source: Authors' own creation/own work

The network visualization of bibliographic coupling is shown in Figure 2. It reveals four multiple clusters representing distinct research areas. The clusters highlight key contributions to the study of Urban Smart Factory (USF) readiness and Industry 4.0. Prominent publications, such as Schumacher (2016) and Mittal (2018), serve as central nodes, indicating their strong influence within the network. The clusters are labeled using inductive interpretation by analyzing representative articles and identifying shared themes and research streams.

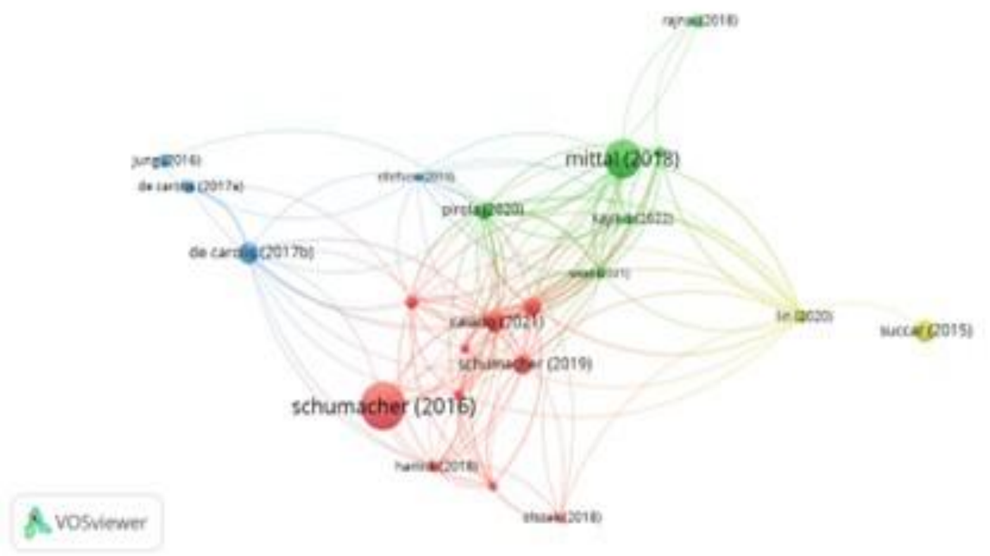

Figure 2: Bibliographic coupling of evaluating smart manufacturing readiness: a maturity model perspective

Source: Authors' Own creation/own work

Cluster 1 (Red): Industry 4.0 readiness drives digital transformation and innovation

Industry 4.0 drives digital transformation by enhancing innovation in value chain management and human-machine interaction. The readiness of Malaysian SMEs for this shift is assessed using the IMPULS maturity model across six dimensions. Data collected through questionnaires help determine their maturity levels, ultimately supporting market sustainability and profitability [26]. A tentative framework based on a temporal dimension is used to evaluate the adoption of big data in companies. The Temporal Big Data Maturity Model (TBDMM) was elaborated with the assistance of a literature inspection and qualitative research that included in-depth interviews with 15 enterprises. To improve big data use, this model divides enterprises into five maturity levels based on an appraisal of their data assets, IT solutions, and sustainability readiness (Mach-Król et al., 2018).

Research on Industry 4.0 has primarily concentrated on technology change, frequently overlooking the function of employees. Because they were spawned for larger organizations, existing maturity models aren't always appropriate for SMEs. By reviewing current models, a new maturity scale specifically designed for SMEs is created to close this gap and offer a more amiable framework for evaluating Industry 4.0 preparedness (Trotta et al., 2019). Manufacturing companies predict Industry 4.0 to have a significant impact, but they frequently find it difficult to understand its intricacies. A technology-focused Industry 4.0 maturity model with seven dimensions and 38 maturity items is created for Indian manufacturing companies to address this. A 'Digital Novice' maturity level is revealed by the model's validation in an auto component manufacturing company, signifying its applicability for self-evaluation [17].

Cluster 2 (Green): Technological readiness enhances digital adoption strategies and competitiveness

Hasty technology breakthroughs are wrangling Industry 4.0, which poses serious problems for businesses. Businesses must evaluate their preparedness for digital transformation to stay competitive. Organizations can measure their progress and create crucial roadmaps for effective Industry 4.0 adoption with the aid of readiness estimation and maturity models (Rajnai et al., 2018). With an accentuation on intelligent product design, the Smart SME Technology Readiness Assessment (SSTRA) methodology was created to assess SMEs' awareness of Industry 4.0. It ranks requirements and evaluates technological capabilities using the analytic hierarchy approach and Industry 4.0 Technology Readiness Levels (TRLs). SSTRA, which has been tested in a manufacturing setting, offers a readiness profile that lowers investment risks while assisting decision-makers in identifying strengths, weaknesses, and gaps for a balanced transition to Industry 4.0 (Saad et al., 2021). A comprehensive assessment model evaluates SMEs' digital readiness for Industry 4.0, focusing on modularity and ease of application. Case studies with 20 manufacturing SMEs reveal an intermediate readiness level, with companies aware of Industry 4.0 but still defining their strategic approach. Progress requires investment in skill development, data infrastructure, and decision-making capabilities to fully leverage digital transformation opportunities [16].

Cluster 3 (Blue): Digital readiness assessment supports smart manufacturing performance improvement

Digital technologies drive manufacturing transformation in Industry 4.0, but successful implementation depends on a company's readiness. A maturity assessment model, inspired by the CMMI framework, evaluates digital readiness across five key areas: design and engineering, production, quality, maintenance, and logistics management. The model ranks practices from low to high maturity, using a scoring method to identify challenges and guide improvements in digital transformation (Carolis et al., 2017a). Artificial Intelligence (AI) is increasingly relevant in production and warehousing, with its maturity levels linked to Logistics 4.0. A survey conducted in Polish and Norwegian companies assesses AI readiness, revealing that most firms remain at an early stage, lacking proactive AI integration. The study proposes the concept of Artificial Intelligence 4.0 to highlight AI's role in Industry 4.0 and Logistics 4.0, emphasizing the need for strategic implementation to optimize big data and operational challenges [32].

Industry 4.0 is mostly driven by digital technology thus, industrial enterprises must evaluate their existing level of awareness before making investments in digital solutions. Based on the CMMI framework, the DREAMY (Digital Readiness Assessment Maturity) model assesses digital readiness by highlighting its odds, obstacles, and areas for development. This model's case studies give businesses information about their readiness levels and help them create strategic plans for a successful digital transformation (Carolis et al., 2017b). Smart manufacturing relies on continuous performance improvement through data-driven decision-making and adaptive technologies. With an increasing number of available technologies, manufacturers must prioritize and implement them effectively. A readiness assessment method is proposed to evaluate a factory's preparedness for smart manufacturing, comparing it to a reference model. By identifying their current state, manufacturers can develop strategic plans to enhance readiness, leading to improved operational performance [34].

Cluster 4 (Yellow): Maturity models guide industrial growth and technological development

Industry 4.0, launched by the German government in 2013, has driven digital transformation in manufacturing. The Singapore Smart Industry Readiness Index serves as a maturity model for self-assessment, helping companies align with digital advancements. An analysis of 80 Taiwanese enterprises reveals a strong correlation between process, technology, and organization, with most companies still in early or partial maturity stages. These insights guide businesses in refining transformation strategies and enhancing Industry 4.0 adoption [24]. Building Information Modelling (BIM) adoption is expanding within organizations and the construction industry, yet large-scale assessment remains limited. Conceptual models, matrices, and charts have been introduced to evaluate BIM adoption across markets and support country-specific policy development systematically. Through expert input from multiple countries, these models refine assessment tools and provide structured insights for policymakers to enhance BIM diffusion strategies (Succar et al., 2015).

A Summary of bibliographic coupling analysis is presented in Table 3, comprising cluster number and color, cluster label, number of publications and representative publications.

Table 3: Bibliographic coupling analysis in Evaluating Smart Manufacturing Readiness

Cluster color and number	Cluster label	Number of publications	Representative publication
1 Red	Industry 4.0 readiness drives digital transformation and innovation	10	Hamidi et al., (2018), Olszak & Mach-Król (2018), Trotta & Garengo, (2019), Wagire et al., (2021).
2 Green	Technological readiness enhances digital adoption strategies and competitiveness	6	Rajnai & Kocsis (2018), Saad et al., (2021), Pirola et al., (2019)
3 Blue	Digital readiness assessment supports smart manufacturing performance improvement	4	Carolis et al., (2017a), Ellefsen et al., (2019), Carolis et al., (2017b), Jung et al., (2016)
4 Yellow	Maturity models guide industrial growth and technological development	2	Lee et al., (2012), Succar & Kassem, (2015)

Source: Authors' Own creation/own work

Co-word analysis

Using the same database, the co-word analysis produced four clusters with 33 out of 2100 keywords meeting 10 criteria. The terms "maturity model" (111 occurrences), "Industry 4.0" (81 occurrences), and "management" (46 occurrences) are the most often occurring keywords. The top 15 keywords from the co-occurrence of keywords analysis are displayed in table 4.

Table 4: Top 15 keywords in the co-occurrence of keyword analysis

Rank	Keyword	Occurrences	Total link strength
1	Maturity model	111	289
2	Industry 4.0	81	248
3	Readiness assessment	46	147
4	Digital transformation	43	126
5	Maturity assessments	37	109
6	Decision making	21	73
7	Manufacturing companies	13	72

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue III March 2025

8	Smart manufacturing	16	65
9	Digitalization	13	61
10	Sustainable development	12	56
11	Manufacturing	13	51
12	Manufacture	12	50
13	Readiness	16	47
14	Readiness models	14	45
15	Maturity models	14	45

Source: Authors' Own creation/own work

The network structure of the co-word analysis in Figure 3 reveals three distinct clusters, each representing a unique topic. The clusters are visually distinguished by different colors and labeled according to the authors' inductive interpretation.

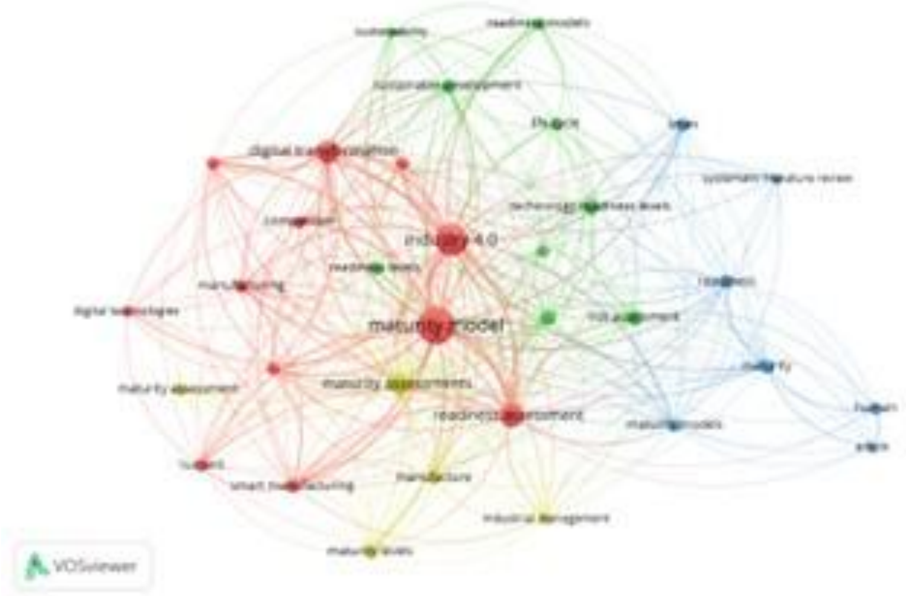

Figure 2: Co-word analysis of evaluating smart manufacturing readiness: a maturity model perspective

Source: Authors' Own creation/own work

Cluster 1(Red): Digital transformation and maturity assessment in manufacturing industries

Digital technologies drive manufacturing transformation, but companies struggle to assess their digital maturity. A framework called **DREAMY**, inspired by **CMMI**, helps evaluate readiness and develop a digitalization roadmap. Using literature reviews, expert input, and case studies, it identifies strengths, weaknesses, and improvement areas. This supports a structured transition toward Industry 4.0 and Industry 5.0 [31]. IoT environments are highly diverse, creating challenges for enterprises in strategy, structure, and technology adoption. Existing **Maturity Models (MMs)** help assess readiness but lack IoT-specific approaches. A new **IoT maturity assessment framework** is proposed, addressing research gaps with **five levels, five dimensions, and 62 criteria**. A practical self-assessment tool is also developed to guide companies in structured IoT transformation [36].

The manufacturing industry faces global challenges like customization, climate change, and energy scarcity. The **Urban Smart Factory (USF)** concept integrates **Industry 4.0** for sustainability, resilience, and human-centric manufacturing. Existing maturity models are inadequate, so a new **USF-specific model** is proposed and tested through case studies. This model helps assess manufacturing readiness and guides future research on smart urban factories (Noh et al., 2024). The transformation of digital technologies has enhanced industrial efficiency, flexibility, and cost optimization. A comparative analysis of digitalization in Russia's Ural Federal District industrial complex highlights key digitalization elements and maturity levels. Limiting factors for digital adoption are identified, and enterprises are categorized based on their readiness for digital solutions. More digitally mature enterprises demonstrate greater flexibility, with tailored implementation strategies proposed for different maturity levels (Smirnova et al., 2023).

Cluster 2(Green): Sustainability and technological readiness models for development

A corporate sustainability maturity model (CSMM) has been developed to help organisations assess their sustainability readiness and transition into mature sustainable entities. The model includes various maturity domains, sub-domains, and indicators for evaluation. A systematic literature review, pilot study, expert interviews, and practitioner feedback were used to refine the model. Indonesian organisations were found to engage in sustainability activities without strategic planning, influenced mainly by external and internal pressures rather than awareness or reputation [39]. Industry 4.0 has significantly impacted the construction sector, necessitating the implementation of advanced technologies. A multi-criteria decision-making model, ConFIRM, has been introduced to assess the strategic readiness of construction firms for Industry 4.0. Unlike previous models, ConFIRM specifically evaluates strategic readiness using a five-stage approach with the modified AHP-TOPSIS technique. Expert evaluations from the Malaysian construction industry highlighted human capital intellectual agility, knowledge, skills, and competencies as the most critical factors for successful implementation [40].

Blockchain technology offers new possibilities for land administration by integrating smart contracts with existing registry systems. A hybrid approach minimizes disruptions while maximizing benefits, as seen in case studies from Sweden, Australia, and Canada. Key challenges include regulatory adherence, stakeholder trust, and legal frameworks. Adoption requires sector-wide collaboration and strategic alignment [41]. Prospective life cycle assessment (LCA) is essential for evaluating the environmental impact of emerging technologies. Traditional LCA methods lack stakeholder engagement and forward-looking perspectives. Uncertainty, data availability, and methodological challenges vary with technology and market maturity. Effective implementation requires collaboration with technology developers and end-users for informed innovation (Yousefzadeh et al., 2021). Model predictive control (MPC) technologies offer significant advantages for power electronics but require careful assessment for industrial adoption. A technology readiness and risk assessment framework helps evaluate their maturity and integration potential. Key developments in MPC for power electronics are mapped across readiness levels. Case studies in medium-voltage motor drives highlight performance and economic benefits [43].

Cluster 3 (Blue): Readiness assessment and systematic reviews in organizations

A critical review of Smart Manufacturing (SM) and Industry 4.0 maturity models highlights their limitations in addressing the needs of SMEs. Many models fail to reflect SMEs' actual digital maturity, necessitating a new "level 0" for a realistic starting point. The transition from this base level requires mindset shifts and tailored roadmaps. Customizing maturity models for SMEs can lower entry barriers and support successful Industry 4.0 adoption [44].Vietnamese SMEs face challenges in implementing data governance due to resource constraints and existing models designed for larger enterprises. A new data maturity model tailored to their needs helps improve data literacy, governance policies, security compliance, and cloud integration. SMEs with higher maturity levels reported a 20% increase in business performance. This framework also supports compliance with Decree 13/2023/ND-CP while enhancing competitiveness [45]. A knowledge-based model helps suppliers assess offer confidence in Engineering-to-Order projects by evaluating technology readiness, risk levels, skills, and risk aversion, improving decision-making in tender processes (Sylla et al., 2017).

Cluster 4 (Yellow): Maturity models in industrial management and growth

Cloud computing is increasingly adopted in the financial sector to enhance efficiency in payment transactions, risk management, and business processes. Developed countries are leading this shift, while less developed nations are gradually embracing the technology. Successful implementation requires careful consideration of security, privacy, compliance, deployment models, and vendor selection. Evaluating migration readiness is essential to aligning with organizational strategies and meeting stakeholder requirements (Alruwaili et al., 2018). A systematic methodology is introduced for assessing the maturity of manufacturing technologies. Inspired by a capability maturity model from software engineering, it evaluates individual processes and their interfaces. Applied in the micro and nano manufacturing domains, the approach proved effective in identifying suitable process pairs and their weaknesses. This enables better integration within process chains [48]. Artificial Intelligence (AI) is increasingly influencing production and warehousing, yet its maturity levels are not widely understood, particularly in the context of Logistics 4.0 and Industry 4.0. Many companies remain at an early stage of AI adoption, lacking proactive integration and struggling to recognize its potential benefits. By emphasizing AI's critical role in digital transformation, strategic roadmaps can aid organizations in implementing AI effectively. The idea of "Artificial Intelligence 4.0" emphasizes how crucial AI is becoming to determining how industries will operate in the future [49]

A Summary of co-word analysis is presented in Table 5, comprising cluster number and color, cluster label, number of keywords and representative keywords.

Table 5: Summary of co-word analysis on Evaluating Smart Manufacturing Readiness

Cluster color and number	**Cluster label**	**Number of keywords**	**Representative Keywords**
1 (Red)	Digital transformation and maturity assessment in manufacturing industries	12	digital transformation, industry 4.0, manufacturing, digital technologies
2 (Green)	Sustainability and technological readiness models for development	9	Sustainability, readiness levels, life cycle, technology readiness levels.
3 (Blue)	Readiness assessment and systematic reviews in organizations	7	Readiness, SMEs, maturity model, maturity
4 (Yellow)	Maturity models in industrial management and growth	5	Maturity levels, manufacture, readiness assessment.

Source: Authors' Own creation/own work

IMPLICATIONS

Managerial Implications

The managerial implications of this study emphasize the critical role of structured assessment in guiding manufacturing firms through their Industry 4.0 journey [50] By identifying technical scarcity and personnel receptivity, managers can use the Urban Smart Factory (USF) maturity model to conduct a comprehensive evaluation of their company's digital readiness. This rigorous approach ensures that monies are given to areas with the greatest implicit impact, commissioning decision-makers to disperse resources wisely. Additionally, by identifying functional obstacles, the technique enables managers to create customized action plans that support their digital transformation objectives. By carefully assessing their readiness, organizations can lower the risk involved in implementing new technologies and increase overall persistence and efficiency (Espíndola et al., 2022).

The USF maturity model performs as a road map, helping businesses prioritize projects that promote aggression, sustainability, and innovation. In the end, adopting this paradigm fosters a proactive culture that upgrades long-term development and ongoing improvement.

Additionally, the suggested approach gives managers the means to handle the challenges of assimilating new technologies into current processes [52]. It helps administrators make better decisions by accelerating a greater grasp of the interactions between workforce, organizational procedures, and technology. This holistic approach is crucial for developing training programs that upskill employees and ensure they are prepared for the digital requirements of smart manufacturing. Managers can promote departmental affiliation and a unified digital transformation plan by utilizing these findings. The strategy also highlights the need for adaptability, calling on companies to embrace change and promote a lifelong learning mindset. By employing this systematic approach, companies magnified their capacity to respond promptly to market developments and position themselves as creative and adaptable entities in the competitive realm of Industry 4.0 [53].

This study also emphasizes how prominent data-driven decision-making is for improving managerial efficacy. Managers may compare their organization's progress to industry norms by using the USF maturity model, which gives them genuine data on the digital maturity of their company. Businesses can use this comparison analysis to find best practices and apply the knowledge gained from prosperous industries [54]. By establishing metrics for performance, the network helps managers evaluate the long-term efficiency of digital projects, strengthening strategic planning and creating the path for a more technologically advanced and sustainable future.

Theoretical Implication

The study's theoretical implications significantly add to the body of knowledge previously available on smart manufacturing and digital transformation. Current maturity models largely overlooked the issues faced by SMEs and Urban Smart Factories (USFs) with the objective of focusing on larger companies. This research overcomes this gap by bringing together individual skills, resilience, and endurability into an entire evaluation strategy. The suggested framework offers an innovative approach to measure Industry 4.0 readiness and offers researchers an enhanced understanding of the digital revolution in urban manufacturing industries [55].

The model overcomes the gap between theoretical understandings and the actual execution of Industry 4.0 through enhanced theoretical discussion and facilitating research on the digital age by its compatibility with current production objectives (Kazemi et al., 2018). Adoption of modern technology continuously receives priority over business culture, employee's awareness, and infrastructure adaptability in the general database of research. By bringing these adaptive components to the maturity evaluation, this investigation improves theoretical frameworks and offers a more fair assessment of smart manufacturing readiness. By encouraging future scholars to study the relationships between organizational processes, technology, and human capital in more detail, the model's comprehensive approach enhances the variety of themes around digital transformation.

Moreover, the experimental support provided by case study testimony enhances the theoretical robustness of the USF maturity model. By demonstrating the model's applicability across multiple industrial sectors, this study lays the foundation for future comparative research and cross-sectoral analysis [57]. By inspiring researchers to look into variations in readiness levels across industries, geographical areas, and organizational sizes, the findings offer a deep comprehension of the routes leading to digital transformation. Furthermore, the study refines theoretical frameworks in the sectors of Industry 4.0 and smart manufacturing by offering new prospects for combining cutting-edge technologies like artificial intelligence and the Internet of Things into maturity assessments

LIMITATIONS

This study accommodates a number of limitations that should be taken into account regardless of its contributions. First, a small number of case studies were used to validate the suggested USF maturity model, which might not represent the variety of urban manufacturing environments (Carlson et al., 2005). Consequently, the results may not be generalizable to other geographical areas and industrial sectors. Second, the model largely focuses on organizational and technological preparedness, possibly ignoring other important factors, including market dynamics, regulatory frameworks, and sociocultural effects. These factors could have a big influence on how Industry 4.0 technologies are adopted and integrated with different settings.

Another deficiency is that digital technologies are substituting so quickly that the model might need to be updated frequently to stay current. The framework must be continuously improved and adapted in light of new technology, evolving worker dynamics, and changing market requisitions [59]. Last but not least, the study relies on qualitative data from specific case studies, which may add subjectivity and restrict how easily the results can be replicated. Larger sample sizes, quantitative measurements, and longitudinal studies should all be commingled into future research to improve the model's resilience and generalizability across wider production environs.

FUTURE RESEARCH AVENUES

To amend the USF maturity model's generalizability, future studies can analyze how well it applies to various industries and geographical areas. Studies comparing established and evolving economies may shed light on differences in the industry 4.0 adoption challenges [60]. Implementing modern innovations like blockchain, artificial intelligence, and twins of the model could increase the model's predictive ability. Investigating workforce shifts, training, and business culture with regard to digital adoption is additionally beneficial. Further investigations ought to reflect evaluate the effects of regulations from the government, monetary rewards, and legal frameworks on smart manufacturing readiness. The resilience and effectiveness of the model should be boosted by long-term research that monitor the growth of businesses over time as well using statistical techniques like analytics of big data.

CONCLUSION

The conclusions highlight the importance of thoroughly assessing readiness for smart manufacturing, especially for Urban Smart Factories (USF). The suggested maturity model for USFs takes into account worker skills, digital transformation, sustainability, and adaptability, offering a comprehensive tool to address the challenges faced by existing frameworks. By using this approach, manufacturing businesses can evaluate their readiness for digital transformation by identifying gaps in technology, workforce awareness, and infrastructure. This strategy not only supports sustainability but also improves operational efficiency, helping companies create effective strategies for adopting Industry 4.0. The model's practical usefulness is further demonstrated by the empirical validation through case studies, which makes it an invaluable tool for assisting enterprises in their journey toward digital transformation.

The study, backed by detailed insights and a few case studies, points out several limitations that could affect how widely the model's benefits can be applied. To improve the model's reliability, future research should expand the dataset and explore more regional examples. Also, integrating new technologies like blockchain could increase the model’s accuracy. Beyond contributing to the broader discussion, the study offers practical advice for businesses looking to implement smart manufacturing. Ultimately, by helping companies address concerns around Industry 4.0 and supporting the development of more sustainable, flexible, and tech-driven manufacturing systems, this research lays a solid foundation for future work on digital maturity

Use of AI tools declaration

We have not used artificial intelligence (AI) tools to create this article.

Acknowledgments

The Universiti Malaysia Pahang Internal Grant funds this study by Grant no RDU230307

Conflict of interest: No

REFERENCES

1. M. Javaid, A. Haleem, R. P. Singh, and R. Suman, “Enabling flexible manufacturing system (FMS)

through the applications of industry 4.0 technologies," Internet of Things and Cyber-Physical Systems, vol. 2, pp. 49–62, 2022, doi: 10.1016/j.iotcps.2022.05.005.
2. A. Moeuf, S. Lamouri, R. Pellerin, S. Tamayo-Giraldo, E. Tobon-Valencia, and R. Eburdy, "Identification of critical success factors, risks and opportunities of Industry 4.0 in SMEs," Int J Prod Res, vol. 58, no. 5, pp. 1384–1400, Mar. 2020, doi: 10.1080/00207543.2019.1636323.
3. S. Mittal, M. A. Khan, D. Romero, and T. Wuest, "Smart manufacturing: Characteristics, technologies and enabling factors," Proc Inst Mech Eng B J Eng Manuf, vol. 233, no. 5, pp. 1342–1361, Apr. 2019, doi: 10.1177/0954405417736547.
4. L. Bibby and B. Dehe, "Defining and assessing industry 4.0 maturity levels – case of the defence sector," Production Planning & Control, vol. 29, no. 12, pp. 1030–1043, Sep. 2018, doi: 10.1080/09537287.2018.1503355.
5. I. Boughzala and G.-J. de Vreede, "Evaluating Team Collaboration Quality: The Development and Field Application of a Collaboration Maturity Model," Journal of Management Information Systems, vol. 32, no. 3, pp. 129–157, Jul. 2015, doi: 10.1080/07421222.2015.1095042.
6. S. Saniuk, S. Grabowska, and B. Gajdzik, "Social Expectations and Market Changes in the Context of Developing the Industry 4.0 Concept," Sustainability, vol. 12, no. 4, p. 1362, Feb. 2020, doi: 10.3390/su12041362.
7. C. G. Machado, M. Winroth, P. Almström, A. Ericson Öberg, M. Kurdve, and S. AlMashalah, "Digital organisational readiness: experiences from manufacturing companies," Journal of Manufacturing Technology Management, vol. 32, no. 9, pp. 167–182, Dec. 2021, doi: 10.1108/JMTM-05-2019-0188.
8. D. Jutla, P. Bodorik, and J. Dhaliwal, "Supporting the e-business readiness of small and medium-sized enterprises: approaches and metrics," Internet Research, vol. 12, no. 2, pp. 139–164, May 2002, doi: 10.1108/10662240210422512.
9. A. Kalantari et al., "A bibliometric approach to tracking big data research trends," J Big Data, vol. 4, no. 1, p. 30, Dec. 2017, doi: 10.1186/s40537-017-0088-1.
10. N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," J Bus Res, vol. 133, pp. 285–296, Sep. 2021, doi: 10.1016/j.jbusres.2021.04.070.
11. N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," J Bus Res, vol. 133, pp. 285–296, Sep. 2021, doi: 10.1016/j.jbusres.2021.04.070.
12. P. Tan Luc, P. Xuan Lan, A. Nhat Hanh Le, and B. Thanh Trang, "A Co-Citation and Co-Word Analysis of Social Entrepreneurship Research," Journal of Social Entrepreneurship, vol. 13, no. 3, pp. 324–339, Sep. 2022, doi: 10.1080/19420676.2020.1782971.
13. R. Dwivedi, S. Nerur, and V. Balijepally, "Exploring artificial intelligence and big data scholarship in information systems: A citation, bibliographic coupling, and co-word analysis," International Journal of Information Management Data Insights, vol. 3, no. 2, p. 100185, Nov. 2023, doi: 10.1016/j.jjimei.2023.100185.
14. I. Zupic and T. Čater, "Bibliometric Methods in Management and Organization," Organ Res Methods, vol. 18, no. 3, pp. 429–472, Jul. 2015, doi: 10.1177/1094428114562629.
15. M. Callon, J. P. Courtial, and F. Laville, "Co-word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemsitry," Scientometrics, vol. 22, no. 1, pp. 155–205, Sep. 1991, doi: 10.1007/BF02019280.
16. F. Pirola, C. Cimini, and R. Pinto, "Digital readiness assessment of Italian SMEs: a case-study research," Journal of Manufacturing Technology Management, vol. 31, no. 5, pp. 1045–1083, Nov. 2019, doi: 10.1108/JMTM-09-2018-0305.
17. A. A. Wagire, R. Joshi, A. P. S. Rathore, and R. Jain, "Development of maturity model for assessing the implementation of Industry 4.0: learning from theory and practice," Production Planning & Control, vol. 32, no. 8, pp. 603–622, Jun. 2021, doi: 10.1080/09537287.2020.1744763.
18. R. G. G. Caiado, L. F. Scavarda, L. O. Gavião, P. Ivson, D. L. de M. Nascimento, and J. A. Garza-Reyes, "A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management," Int J Prod Econ, vol. 231, p. 107883, Jan. 2021, doi: 10.1016/j.ijpe.2020.107883.
19. S. Mittal, M. A. Khan, D. Romero, and T. Wuest, "A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs)," J Manuf

Syst, vol. 49, pp. 194–214, Oct. 2018, doi: 10.1016/j.jmsy.2018.10.005.

20. S. M. Saad, R. Bahadori, H. Jafarnejad, and M. F. Putra, “Smart Production Planning and Control: Technology Readiness Assessment,” Procedia Comput Sci, vol. 180, pp. 618–627, 2021, doi: 10.1016/j.procs.2021.01.284.
21. F. Hein-Pensel et al., “Maturity assessment for Industry 5.0: A review of existing maturity models,” J Manuf Syst, vol. 66, pp. 200–210, Feb. 2023, doi: 10.1016/j.jmsy.2022.12.009.
22. A. Amaral and P. Peças, “A Framework for Assessing Manufacturing SMEs Industry 4.0 Maturity,” Applied Sciences, vol. 11, no. 13, p. 6127, Jun. 2021, doi: 10.3390/app11136127.
23. A. Schumacher, T. Nemeth, and W. Sihn, “Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises,” Procedia CIRP, vol. 79, pp. 409–414, 2019, doi: 10.1016/j.procir.2019.02.110.
24. L.-C. Lee, Y.-Y. Lee, and Y.-C. Liaw, “Bibliometric analysis for development of research strategies in agricultural technology: the case of Taiwan,” Scientometrics, vol. 93, no. 3, pp. 813–830, Dec. 2012, doi: 10.1007/s11192-012-0833-3.
25. Y. Kayikci, Y. Kazancoglu, N. Gozacan-Chase, C. Lafci, and L. Batista, “Assessing smart circular supply chain readiness and maturity level of small and medium-sized enterprises,” J Bus Res, vol. 149, pp. 375–392, Oct. 2022, doi: 10.1016/j.jbusres.2022.05.042.
26. S. R. Hamidi, A. A. Aziz, S. M. Shuhidan, A. A. Aziz, and M. Mokhsin, “SMEs Maturity Model Assessment of IR4.0 Digital Transformation,” 2018, pp. 721–732. doi: 10.1007/978-981-10-8612-0_75.
27. C. M. Olszak and M. Mach-Król, “A Conceptual Framework for Assessing an Organization’s Readiness to Adopt Big Data,” Sustainability, vol. 10, no. 10, p. 3734, Oct. 2018, doi: 10.3390/su10103734.
28. D. Trotta and P. Garengo, “Assessing Industry 4.0 Maturity: An Essential Scale for SMEs,” in 2019 8th International Conference on Industrial Technology and Management (ICITM), IEEE, Mar. 2019, pp. 69–74. doi: 10.1109/ICITM.2019.8710716.
29. Z. Rajnai and I. Kocsis, “Assessing industry 4.0 readiness of enterprises,” in 2018 IEEE 16th World Symposium on Applied Machine Intelligence and Informatics (SAMI), IEEE, Feb. 2018, pp. 000225–000230. doi: 10.1109/SAMI.2018.8324844.
30. S. M. Saad, R. Bahadori, and H. Jafarnejad, “The smart SME technology readiness assessment methodology in the context of industry 4.0,” Journal of Manufacturing Technology Management, vol. 32, no. 5, pp. 1037–1065, Jul. 2021, doi: 10.1108/JMTM-07-2020-0267.
31. A. De Carolis, M. Macchi, E. Negri, and S. Terzi, “A Maturity Model for Assessing the Digital Readiness of Manufacturing Companies,” 2017, pp. 13–20. doi: 10.1007/978-3-319-66923-6_2.
32. A. P. T. Ellefsen, J. Oleśków-Szłapka, G. Pawłowski, and A. Toboła, “<title/>,” Logforum, vol. 15, no. 3, pp. 363–376, Sep. 2019, doi: 10.17270/J.LOG.2019.354.
33. A. De Carolis, M. Macchi, E. Negri, and S. Terzi, “Guiding manufacturing companies towards digitalization a methodology for supporting manufacturing companies in defining their digitalization roadmap,” in 2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC), IEEE, Jun. 2017, pp. 487–495. doi: 10.1109/ICE.2017.8279925.
34. K. Jung, B. Kulvatunyou, S. Choi, and M. P. Brundage, “An Overview of a Smart Manufacturing System Readiness Assessment,” 2016, pp. 705–712. doi: 10.1007/978-3-319-51133-7_83.
35. B. Succar and M. Kassem, “Macro-BIM adoption: Conceptual structures,” Autom Constr, vol. 57, pp. 64–79, Sep. 2015, doi: 10.1016/j.autcon.2015.04.018.
36. M. Benotmane, K. Elhari, and A. Kabbaj, “A review & analysis of current IoT maturity & readiness models and novel proposal,” Sci Afr, vol. 21, p. e01748, Sep. 2023, doi: 10.1016/j.sciaf.2023.e01748.
37. S. M. M. Sajadieh and S. Do Noh, “Towards Sustainable Manufacturing: A Maturity Assessment for Urban Smart Factory,” International Journal of Precision Engineering and Manufacturing-Green Technology, vol. 11, no. 3, pp. 909–937, May 2024, doi: 10.1007/s40684-023-00554-z.
38. O. Smirnova and L. Chesnyukova, “Impact of Digital Technologies on the Industrial Complex Development: The Russian Experience,” 2023, pp. 35–43. doi: 10.1007/978-3-031-30351-7_4.
39. Y. Sari, A. Hidayatno, A. Suzianti, M. Hartono, and H. Susanto, “A corporate sustainability maturity model for readiness assessment: a three-step development strategy,” International Journal of Productivity and Performance Management, vol. 70, no. 5, pp. 1162–1186, Jun. 2021, doi: 10.1108/IJPPM-10-2019-0481.

40. H. Mansour, E. Aminudin, and T. Mansour, "Implementing industry 4.0 in the construction industry-strategic readiness perspective," International Journal of Construction Management, vol. 23, no. 9, pp. 1457–1470, Jul. 2023, doi: 10.1080/15623599.2021.1975351.
41. R. Bennett, T. Miller, M. Pickering, and A.-K. Kara, "Hybrid Approaches for Smart Contracts in Land Administration: Lessons from Three Blockchain Proofs-of-Concept," Land (Basel), vol. 10, no. 2, p. 220, Feb. 2021, doi: 10.3390/land10020220.
42. Z. Yousefzadeh and S. M. Lloyd, "Prospective life cycle assessment as a tool for environmentally responsible innovation," in 2021 IEEE International Symposium on Technology and Society (ISTAS), IEEE, Oct. 2021, pp. 1–9. doi: 10.1109/ISTAS52410.2021.9629146.
43. G. A. Papafotiou, G. D. Demetriades, and V. G. Agelidis, "Technology Readiness Assessment of Model Predictive Control in Medium- and High-Voltage Power Electronics," IEEE Transactions on Industrial Electronics, vol. 63, no. 9, pp. 5807–5815, Sep. 2016, doi: 10.1109/TIE.2016.2521350.
44. S. Mittal, M. A. Khan, D. Romero, and T. Wuest, "A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs)," J Manuf Syst, vol. 49, pp. 194–214, Oct. 2018, doi: 10.1016/j.jmsy.2018.10.005.
45. C. T. H. Hai, "A maturity assessment model for data governance in small and medium enterprises in Vietnam," Edelweiss Applied Science and Technology, vol. 9, no. 2, pp. 1931–1951, Feb. 2025, doi: 10.55214/25768484.v9i2.4982.
46. A. SYLLA, E. VAREILLES, M. ALDANONDO, T. COUDERT, L. GENESTE, and K. KIRYTOPOULOS, "Customer/Supplier Relationship: reducing Uncertainties in Commercial Offers thanks to Readiness, Risk and Confidence Considerations," 2017, pp. 1115–1122. doi: 10.1007/978-3-319-45781-9_111.
47. F. F. Alruwaili and T. A. Gulliver, "Secure migration to compliant cloud services: A case study," Journal of Information Security and Applications, vol. 38, pp. 50–64, Feb. 2018, doi: 10.1016/j.jisa.2017.11.004.
48. P. C. Vella, S. S. Dimov, R. Minev, and E. B. Brousseau, "Technology maturity assessment of micro and nano manufacturing processes and process chains," Proc Inst Mech Eng B J Eng Manuf, vol. 232, no. 8, pp. 1362–1383, Jun. 2018, doi: 10.1177/0954405416668922.
49. A. P. T. Ellefsen, J. Oleśków-Szłapka, G. Pawłowski, and A. Toboła, "<title/>," Logforum, vol. 15, no. 3, pp. 363–376, Sep. 2019, doi: 10.17270/J.LOG.2019.354.
50. J. Nagy, J. Oláh, E. Erdei, D. Máté, and J. Popp, "The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain—The Case of Hungary," Sustainability, vol. 10, no. 10, p. 3491, Sep. 2018, doi: 10.3390/su10103491.
51. O. Rodríguez-Espíndola, S. Chowdhury, P. K. Dey, P. Albores, and A. Emrouznejad, "Analysis of the adoption of emergent technologies for risk management in the era of digital manufacturing," Technol Forecast Soc Change, vol. 178, p. 121562, May 2022, doi: 10.1016/j.techfore.2022.121562.
52. D. Georgakopoulos, M. Hornick, and A. Sheth, "An overview of workflow management: From process modeling to workflow automation infrastructure," Distrib Parallel Databases, vol. 3, no. 2, pp. 119–153, Apr. 1995, doi: 10.1007/BF01277643.
53. H. S. Ismail, J. Poolton, and H. Sharifi, "The role of agile strategic capabilities in achieving resilience in manufacturing-based small companies," Int J Prod Res, vol. 49, no. 18, pp. 5469–5487, Sep. 2011, doi: 10.1080/00207543.2011.563833.
54. D. T. Matt, M. Molinaro, G. Orzes, and G. Pedrini, "The role of innovation ecosystems in Industry 4.0 adoption," Journal of Manufacturing Technology Management, vol. 32, no. 9, pp. 369–395, Dec. 2021, doi: 10.1108/JMTM-04-2021-0119.
55. M. Sony and S. Naik, "Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review," Benchmarking, vol. 27, no. 7, pp. 2213–2232, 2020, doi: 10.1108/BIJ-09-2018-0284.
56. H. Fatorachian and H. Kazemi, "A critical investigation of Industry 4.0 in manufacturing: theoretical operationalisation framework," Production Planning & Control, vol. 29, no. 8, pp. 633–644, Jun. 2018, doi: 10.1080/09537287.2018.1424960.
57. M. A. Qureshi, A. Khaskheli, J. A. Qureshi, S. A. Raza, and S. Q. Yousufi, "Factors affecting students' learning performance through collaborative learning and engagement," Interactive Learning Environments, vol. 31, no. 4, pp. 2371–2391, May 2023, doi: 10.1080/10494820.2021.1884886.
58. J. Carlson and R. R. Murphy, "How UGVs physically fail in the field," IEEE Transactions on Robotics, vol. 21, no. 3, pp. 423–437, Jun. 2005, doi: 10.1109/TRO.2004.838027.

59. G. Prastacos, K. Söderquist, Y. Spanos, and L. Van Wassenhove, “An Integrated Framework for Managing Change in the New Competitive Landscape,” European Management Journal, vol. 20, no. 1, pp. 55–71, Feb. 2002, doi: 10.1016/S0263-2373(01)00114-1.
60. J.-V. Tomás-Miquel, G. Maldonado-Gómez, and J. Capó Vicedo, “Industry 4.0 in emerging markets: a bibliometric review of the managerial literature and research agenda,” Benchmarking: An International Journal, Feb. 2025, doi: 10.1108/BIJ-12-2023-0907.