



Investigating Barriers to Industry 5.0 Adoption for Enhancing Resilience and Agility in the Manufacturing Industry

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Abstract. This paper examines the major challenges to Industry 5.0 (I5.0) implementation to drive resilience and agility in the manufacturing industry. A mixed-method design was utilized with a detailed literature review combined with Analytic Hierarchy Process (AHP) to designate and rank ten most vital barriers. The results show that the most serious obstacles are gaps in cybersecurity and standardization, financial, and unreadiness to be digitized. Sensitivity analysis proves the strength of the rankings in different strategic conditions. The findings are useful to managers and policymakers to focus on interventions and facilitate successful I5.0 implementation. These barriers require a concerted approach by technological innovation, the formulation of policies, and upskilling of the workforce. Stressing on the collaboration between industry stakeholders can speed up the process of adoption and reduce the risks of implementation. The next step of research ought to be dynamic frameworks capable of adapting to the changing I5.0 technologies and market trends that can be used to maintain a competitive edge.

Keywords: Industry 5.0; Barriers; Agile Manufacturing, Resilient Manufacturing, Analytical Hierarchy Process

1 Introduction

Industry 5.0 is becoming increasingly conceptualized as a paradigm that supports agility and resilience in manufacturing, thus extending digital transformation into human-centered and sustainability as well as system resilience into production networks [1,2]. However, the real-world application of these values often faces scaling problems on the part of organisations, especially where disruptive environments compel organisations to have to reconfigure faster, make decisive governance choices, and have their shop floors and supply chains interconnected securely [3]. The first challenge is the increased vulnerability to cyber risk, which is caused by the increased integration of Internet of Things, artificial intelligence, cyber-physical systems, and inter-connected platforms. With more and more processes being networked, the spread of the attack surface is forcing companies to simultaneously address cybersecurity awareness, gov-

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ernance, and controls and strive to achieve operational goals [4]. Secondly, implementation I5.0 means that human operators will have to work in harmony with machines, a fact that presupposes the development of new skills, specific training, and efficient change management to eliminate opposition and the under-use of advanced systems [1]. Third, organisations face data and interoperability barriers including divided legacy systems, different data standards, and intra-organisation visibility, thus hindering real-time responsiveness and undermining agility outcomes [3].

Moreover, I5.0 requires risk-aware digitalisation of supply chains to build resilience, yet many businesses cannot combine the approaches that can assess how risks caused by complexity, dependency on technology, and cascading impacts are likely to happen and ranked [5]. Lastly, there is the issue of strategic alignment: companies need to balance productivity with sustainability and human-centered aims and invest in the empowering technologies and governance systems that will help to make the long-term change [2]. Addressing them is necessary to operationalise the concepts of I5.0 and ensure the long-term sustainability of the industrial sector [6,7]. This development will result in a smart, yet flexible, safe, and resolute manufacturing system in the presence of uncertainty.

The current research is valuable as it bridges a significant gap in research on the subject of I5.0, namely, the empirical identification and prioritization of obstacles to its deployment in agility and resilience improvement in the manufacturing industry. The study presents a validated and quantitative model using a mixed-method strategy supplemented with the Analytic Hierarchy Process (AHP), thus, allowing managers and policymakers to focus on the most urgent technological, financial, and organisational concerns. Such prioritisation will help make better decisions, thus enhancing the transformation of I5.0 with real-world insights to create a robust and adaptable manufacturing system. There are six major sections in the paper. The Introduction section outlines the setting and importance of the I5.0 adoption issues. The Theoretical Background is an overview of fundamental knowledge and understanding of I5.0 and its obstacles. The Research Methodology details the mixed-method research design, identification of barriers, and the use of AHP. Result Analysis & Discussion gives the results of the prioritisation and clarifies the implications. Sensitivity Analysis evaluates the strength of the results in different situations. Lastly, the Conclusion highlights the contributions and practical recommendations, as well as the path on which I5.0 is to be implemented.

2 Theoretical Background

I5.0 is placed in a strategic position concerning a period characterized by intense turbulence in the manufacturing sector whereby companies must remain competitive amidst shocks as diverse as natural disasters and pandemics to supply-chain shocks. Unlike antecedent paradigms where automation efficiency was pre-empted, I5.0 attempts to combine new digital technologies with human-machine interaction and sustainability-focused activity and create new production systems that can be both highly efficient and adaptive to uncertainty [3]. I5.0 is increasingly being conceptualised as an extension of Industry 4.0 in terms of value-adding, but human-centric, sustainable and

resilient industrial systems [1,8]. In the manufacturing sector, the paradigm predicts a human-Machine collaboration, where human ambivalence and creativity are combined with machine accuracy and hi-tech technologies, including AI, digital twins, blockchain, and IoT, to create responsive and safer manufacturing conditions [1]. In this context, the term resilience refers to the ability of a manufacturing system to endure, adapt, and recover following the occurrence of disruptions, i.e. pandemics, disasters, or supply shocks, whereas agility refers to how quickly and responsively firms sense and react to dynamic customer and market needs. Theorised, I5.0 strengthens both capabilities by enhancing digitisation, automation and sophisticated analytics with decentralised decision-making and empowered human functions [3]. However, the implementation of I5.0 is a socio-technical revolution, meaning that there are not only technological barriers, but also organisational and ecosystem ones that hinder the process [8]. Among the most common barriers, (1) lack of digital infrastructure and the readiness of cyber-physical systems, as well as the lack of specific implementation frameworks to execute tasks at scale [8]; (2) workforce shortages and training deficits, especially in the area of cybersecurity and advanced digital operations [4]; (3) interoperability and legacy integration shortages, and those hinder the secure connection at an extended network scale [4]. These barriers need to be understood on a theoretical level because any unresolved constraints can intervene with the projected improvements of I5.0 in its resilience and agility production performance. Table 1 presents the identified barriers to I5.0 adoption along with their descriptions and supporting literature, forming the conceptual foundation for the subsequent AHP analysis.

Table 1. Identified Barrier

| Bar-rier Code | Barrier | Description | APA Citation |
|----------------------|--|---|---------------------|
| BA1 | <i>Resistive Organizational Culture</i> | <i>Resistance to change among employees and management limits adoption of I5.0 technologies, especially when firms lack a learning-oriented culture.</i> | [8,9] |
| BA2 | <i>Insufficient Digitization & Automation Readiness</i> | <i>Legacy systems and inadequate digital infrastructure make it difficult to integrate cyber-physical systems and real-time analytics, slowing agility.</i> | [10] |
| BA3 | <i>Integration Challenges Across the Value Chain</i> | <i>Weak collaboration, poor data sharing, and low trust among supply-chain partners hinder ecosystem-wide resilience.</i> | [5,11] |
| BA4 | <i>Weak Link Between Real and Virtual Systems</i> | <i>Ineffective synchronization between digital twins and physical assets limits visibility, predictive maintenance, and rapid reconfiguration.</i> | [8] |

| | | | |
|------|--|---|------------|
| BA5 | Human–Robot Collaboration Complexity | <i>Designing safe and adaptive human robot interaction systems is technically challenging and operationally risky.</i> | [8,12] |
| BA6 | Infrastructure & Reconfiguration Burden | <i>Upgrading manufacturing infrastructure for I5.0 demands major financial and technical investment, especially for SMEs.</i> | [8,13] |
| BA7 | Cybersecurity & Standardization Gaps | <i>Lack of cybersecurity standards, inconsistent data governance, and interoperability issues expose firms to risks and hinder trust.</i> | [4,5,8] |
| BA8 | Weak Sustainability Orientation | <i>Limited emphasis on sustainability and circularity reduces I5.0's long-term value contribution to resilient operations.</i> | [9,12] |
| BA9 | Safety Risks in Automation | <i>Poor feedback mechanisms in automated systems can increase accident risks and threaten safe human–machine collaboration.</i> | [4,8] |
| BA10 | Financial & Investment Constraints | <i>High costs of digital technologies and lack of financial incentives deter firms from investing in I5.0 transitions.</i> | [10,14,15] |

3 Research Methodology

3.1 Research Gap

The existing studies on I5.0 are still largely conceptual and uncoordinated, with a lack of empirical studies of their interdependence and priority to impediments on the resilience and agility of manufacturing. This results in the apparent gap of validated frameworks or models that rely on the context and can map the causal relationship of adoption barriers in a systematic manner and inform implementation road maps. The gap needs to be filled by means of strict empirical research that provides a systemic discovery and measurement of obstacles in particular industrial settings. Strong frameworks will be created that will allow the practitioners to understand how these barriers interact dynamically and how they impact the manufacturing results. Therefore, these models may guide specific approaches that make the process of I5.0 adoption more resilient and more responsive.

3.2 Research Design

The research design adopted in this study is a mixed-methods research design, which includes both qualitative information of a comprehensive review of the literature and quantitative hierarchical modeling. It will use a sequential hierarchy methodology

where major Industry 0.0 drivers will first be discovered by conducting a systematic literature search and then ranked by their relative significance based on an Evaluation Framework that is based on an AHP. The mixed-method research will enable an in-depth investigation and analysis of the key drivers of I5.0. During the qualitative stage, intense and comprehensive literature review provides a strong theoretical base by generalizing the available knowledge and identifying new themes and trends that are applicable within the field. The next quantitative step uses a hierarchical modeling process based on the AHP that ranks the identified drivers. Sequential hierarchy method provides systematic evaluation, whereby the comparative significance of each driver is measured producing a definite list in terms of expert opinion or objective statistics. Such a combination of qualitative and quantitative approaches can improve the quality and reliability of the results and offer the depth and quantifiable prioritization to make strategic decisions during the implementation of I5.0.

3.3 Analytical Hierarchy Process (AHP)

The AHP is unique because it offers an organized and systematic method of decision-making since the process breaks down complex issues into hierarchical standards and options. They utilize the Pairwise comparison matrices, based on the expert judgment and on the nine-point scale introduced by Saaty, to determine the relative importance of the factors; priority weights are calculated by the principal eigenvalues analysis, and consistency is determined by the Consistency Index and Consistency Ratio and thus provide a consistent and sound judgment. As a result, the methodology allows ranking the drivers or alternatives and allows identifying the most significant factors, especially those ones that can help the implementation of I5.0 within the given environment. Step by Step Process is given below:

Step 1: Involves clearly defining the research objective and structuring the decision problem into a hierarchical model comprising the overall goal and the identified barriers.

Step 2: Includes designing pairwise comparison matrices based on expert evaluations, using Saaty's nine-point scale to capture relative importance.

Step 3: Focuses on computing priority weights by deriving the principal eigenvalues of the comparison matrices.

Step 4: Assesses the consistency of expert judgments by calculating the Consistency Index (CI) and Consistency Ratio (CR) ($CR < 0.1$ indicates acceptable consistency).

Step 5: Ranks the drivers based on normalized weights, enabling identification of the most influential drivers supporting I5.0 adoption.

3.4 Data Collection

The data was collected by way of a structured survey of experts that would give credible judgments that can be used in an AHP. The sampling procedure used was purposive, which guaranteed that the respondents had a lot of experience in manufacturing, Industry 4.0/5.0 technologies, supply-chain management, or digital-transformation projects.

Inclusion criteria were set to improve the validity of response, such that professional or academic experience was minimum. Primary data were collected using questionnaires of pair-wise comparison that were distributed electronically via email as well as the web. Multiple expert responses were aggregated using geometric means and as a result, the individual bias was reduced, resulting in a stronger collection of pairwise comparisons. This sampling method in turn resulted in informed judgments, methodological rigor and the strength of the final data.

The data collection plan was carefully planned to ensure reliability and validity of expert judgements, which were included in the AHP analysis. Purposive sampling was conducted to select the experts, and the emphasis was on those people who possess the necessary experience in the professional or academic field related to the main areas of interest involved in manufacturing, Industry 4.0/5.0 technologies, supply-chain management, and digital transformation. Such a selective process of recruiting participants made sure that they had the required domain knowledge to present credible and informed judgments. Additionally, to enhance the quality of the data, eligibility criteria used a limit on years of related experience, which removes less qualified respondents and provides rigor in the study. The pairwise-comparison questionnaires were used to collect primary data; the questionnaires were distributed through emails and internet media to ensure that many experts can participate and to make the exercise convenient. The reactions of various experts were then combined with a geometric-mean, which is a classical statistical tool that reduces the risk of individual bias, but equalizes divergent views. This mode of aggregation helped in making the results robust and consistent, so that the end results were based on overall expert opinion and no single opinion. Taken as a whole, this extensive sampling and data-collection plan was a sound basis of the ensuing AHP analysis, hence, facilitating methodological soundness and acceptability.

4 Result Analysis and Discussion

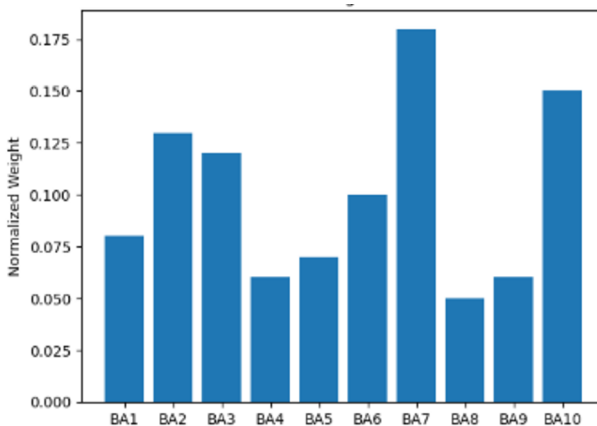
The pairwise comparison analysis using the AHP given in Table 2 identifies a prioritized list of the 10 barriers that have been identified to I5.0 adoption with comparison to their relative impact on the achievement of resilient and agile manufacturing systems (Table 3). The most significant obstacle, Cybersecurity & Standardization Gaps (BA7; weight = 0.18), proves the fact that secure, standardised digital infrastructure is the most important requirement to I5.0 implementation. I5.0 relies on highly connected cyber-physical systems, digital twins, and decentralised systems; without well-developed systems to manage cybersecurity and interoperability, the manufacturing systems can still be vulnerable to cyber-attacks and outages, thus a direct hit to resilience. Figure 1 visually depicts the weight and rank distribution of the I5.0 adoption barriers, enabling an intuitive comparison of their relative significance.

Table 2. Pair-wise Comparison Matrix

| Barrier | BA1 | BA2 | BA3 | BA4 | BA5 | BA6 | BA7 | BA8 | BA9 | BA10 |
|----------------|-------------|-------------|-------------|-------------|-------------|------------|-------------|------------|-------------|-------------|
| BA1 | <i>1</i> | <i>0.62</i> | <i>0.67</i> | <i>1.33</i> | <i>1.14</i> | <i>0.8</i> | <i>0.44</i> | <i>1.6</i> | <i>1.33</i> | <i>0.53</i> |
| BA2 | <i>1.6</i> | <i>1</i> | <i>1.08</i> | <i>2.17</i> | <i>1.86</i> | <i>1.3</i> | <i>0.72</i> | <i>2.6</i> | <i>2.17</i> | <i>0.87</i> |
| BA3 | <i>1.5</i> | <i>0.93</i> | <i>1</i> | <i>2</i> | <i>1.71</i> | <i>1.2</i> | <i>0.67</i> | <i>2.4</i> | <i>2</i> | <i>0.8</i> |
| BA4 | <i>0.75</i> | <i>0.46</i> | <i>0.5</i> | <i>1</i> | <i>0.86</i> | <i>0.6</i> | <i>0.33</i> | <i>1.2</i> | <i>1</i> | <i>0.4</i> |
| BA5 | <i>0.88</i> | <i>0.54</i> | <i>0.58</i> | <i>1.17</i> | <i>1</i> | <i>0.7</i> | <i>0.39</i> | <i>1.4</i> | <i>1.17</i> | <i>0.47</i> |
| BA6 | <i>1.25</i> | <i>0.77</i> | <i>0.83</i> | <i>1.67</i> | <i>1.43</i> | <i>1</i> | <i>0.56</i> | <i>2</i> | <i>1.67</i> | <i>0.67</i> |
| BA7 | <i>2.25</i> | <i>1.39</i> | <i>1.5</i> | <i>3</i> | <i>2.57</i> | <i>1.8</i> | <i>1</i> | <i>3.6</i> | <i>3</i> | <i>1.2</i> |
| BA8 | <i>0.63</i> | <i>0.38</i> | <i>0.42</i> | <i>0.83</i> | <i>0.71</i> | <i>0.5</i> | <i>0.28</i> | <i>1</i> | <i>0.83</i> | <i>0.33</i> |
| BA9 | <i>0.75</i> | <i>0.46</i> | <i>0.5</i> | <i>1</i> | <i>0.86</i> | <i>0.6</i> | <i>0.33</i> | <i>1.2</i> | <i>1</i> | <i>0.4</i> |
| BA10 | <i>1.88</i> | <i>1.15</i> | <i>1.25</i> | <i>2.5</i> | <i>2.14</i> | <i>1.5</i> | <i>0.83</i> | <i>3</i> | <i>2.5</i> | <i>1</i> |

Table 3. Barrier Weight & Rank

| Barrier | Normal-ized Weight | Rank |
|-------------|--------------------|-----------|
| BA1 | <i>0.08</i> | <i>6</i> |
| BA2 | <i>0.13</i> | <i>3</i> |
| BA3 | <i>0.12</i> | <i>4</i> |
| BA4 | <i>0.06</i> | <i>8</i> |
| BA5 | <i>0.07</i> | <i>7</i> |
| BA6 | <i>0.1</i> | <i>5</i> |
| BA7 | <i>0.18</i> | <i>1</i> |
| BA8 | <i>0.05</i> | <i>10</i> |
| BA9 | <i>0.06</i> | <i>9</i> |
| BA10 | <i>0.15</i> | <i>2</i> |

Fig. 1. Weight & Rank of Barrier

The second greatest impediment, Financial & Investment Constraints (BA10; weight = 0.15) highlights the nature of the I5.0 change as capital intensive. High financial demands are placed on capital expenditure on high automation, collaborative robotics, artificial intelligence, cybersecurity and the transformation of the workforce, especially on small and medium-sized enterprises (SMEs). Financial capacity at low levels limits the capability of firms to build redundancy and reconfigurability, which is needed in the agile and resilient manufacturing. The third and fourth place goes to the lack of Digitisation & Automation Readiness (BA2; weight = 0.13) and Integration Challenges Across the Value Chain (BA3; weight = 0.12), respectively. These results indicate that I5.0 will not be able to work efficiently without a solid digital infrastructure and smooth

collaboration between the suppliers, manufacturers, and logistics partners. Disjointed systems and data silos reduce real-time awareness and responsiveness to disruptions, which undermines agility.

Infrastructure and Reconfiguration Burden (BA6; weight= 0.10) and Resistive Organizational Culture (BA1; weight= 0.08) are two middle-ground barriers that indicate the two-fold nature of the challenge of physical preparedness and human acceptance. Although the core of resilience relates to the reconfigurable manufacturing systems, they can be slowed down by frequent changes in infrastructure and cultural barriers. The less central barriers, such as Human-Robot Collaboration Complexity (BA5; weight =0.07), Weak Link Between Real and Virtual Systems (BA4; weight =0.06), Safety Risks in Automation (BA9; weight =0.06) and Weak Sustainability Orientation (BA8; weight =0.05); are nonetheless, consequential with regard to long-term system optimisation, worker trust, and sustainable resilience. The fact that they are lower in weights means that these issues will be more serious after the underlying technological, financial, and integration problems have been resolved. Generally speaking, the AHP findings give rise to the notion that technological security, financial capacity, and digital-organisational adoption are the most significant obstacles to I5.0 implementation in the resilient and agile manufacturing frameworks. It is possible to achieve a high level of success in I5.0 transformation by prioritizing high-priority barriers at an initial stage. The evaluation also brings to light a hierarchical organization where financial and investment constraints turned out to be important impediments. The capital-consuming requirements related to adopting sophisticated technologies e.g., collaborative robotics, artificial intelligence, and cybersecurity create high financial risks, particularly to SMEs that usually have small budgets. This economic strain limits the ability of firms to invest in such capabilities as redundancy and reconfigurability that are critical in building agile and resilient manufacturing systems. Without proper financing, companies find it hard to shift fast to changes or disruptions in the market, hence compromising the essence of the I5.0 transformation.

The financial challenges are supplemented by technological and organisational ones, including a lack of digitisation preparedness and integration challenges across the value chain. The absence of a resilient digital infrastructure and the disjointed data systems impede real-time visibility and coordination among the suppliers, manufacturers, and logistics providers, which undermine the overall manufacturing operation agility and responsiveness. Secondly, the intertwining between physical and human factors in this transition is also emphasized by mid-level barriers, i.e., infrastructure reconfiguration burden and organisational resistance. Though not so dominant, the problems related to the complexity of human-robot collaboration, virtual-real system connection, risk of safety and sustainability orientation are also of high interest in the long-term optimisation and trust formation. Therefore, financial stability, digital integration, and cultural preparedness should be given priority to overcome these multiple barriers and have a successful I5.0 implementation.

5 Sensitivity Analysis

Sensitivity analysis was conducted to test the strength of the AHP based rankings of barriers in different decision-making situations. Since the expert decision and organisational focus may vary in various situations, including those of technology-oriented and cost-oriented companies, the weights of the most essential barriers were manually adjusted keeping normalised proportionality among the rest of the barriers. This was aimed at typing consistency or substantive changes in the order of barriers. The three most ranked barriers, which included Cybersecurity and Standardisation Gaps (BA7), Financial and Investment Constraints (BA10), and Insufficient Digitisation and Automation Readiness (BA2) were focused on since they have the highest impact on I5.0 adoption. Several situations were created by adding and taking away the weights of these dominant barriers by 10-20 percent, which simulated changes in the strategic emphasis. The rankings that were obtained were then compared across the scenarios. Table 4 presents the variation in barrier weights across multiple sensitivity testing scenarios, reflecting changes under different strategic emphasis conditions.

Table 4. Instances of Weight

| | Original Weight | Test 1 | Test 2 | Test 3 | Test 3 | Test 4 |
|-------------|------------------------|---------------|---------------|---------------|---------------|---------------|
| BA1 | <i>0.08</i> | <i>0.07</i> | <i>0.07</i> | <i>0.08</i> | <i>0.08</i> | <i>0.08</i> |
| BA2 | <i>0.13</i> | <i>0.12</i> | <i>0.12</i> | <i>0.14</i> | <i>0.15</i> | <i>0.17</i> |
| BA3 | <i>0.12</i> | <i>0.11</i> | <i>0.11</i> | <i>0.12</i> | <i>0.13</i> | <i>0.12</i> |
| BA4 | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> |
| BA5 | <i>0.07</i> | <i>0.07</i> | <i>0.06</i> | <i>0.07</i> | <i>0.06</i> | <i>0.07</i> |
| BA6 | <i>0.1</i> | <i>0.09</i> | <i>0.09</i> | <i>0.1</i> | <i>0.09</i> | <i>0.1</i> |
| BA7 | <i>0.18</i> | <i>0.17</i> | <i>0.2</i> | <i>0.16</i> | <i>0.19</i> | <i>0.17</i> |
| BA8 | <i>0.05</i> | <i>0.05</i> | <i>0.05</i> | <i>0.05</i> | <i>0.05</i> | <i>0.05</i> |
| BA9 | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> | <i>0.06</i> |
| BA10 | <i>0.15</i> | <i>0.18</i> | <i>0.14</i> | <i>0.16</i> | <i>0.15</i> | <i>0.14</i> |

Table 5. Sensitivity Rank

| | Base Rank | Test 1 | Test 2 | Test 3 | Test 4 |
|------------|------------------|---------------|---------------|---------------|---------------|
| BA1 | <i>6</i> | <i>6</i> | <i>6</i> | <i>6</i> | <i>6</i> |
| BA2 | <i>3</i> | <i>3</i> | <i>3</i> | <i>3</i> | <i>1</i> |
| BA3 | <i>4</i> | <i>4</i> | <i>4</i> | <i>4</i> | <i>4</i> |
| BA4 | <i>8</i> | <i>8</i> | <i>8</i> | <i>8</i> | <i>8</i> |

| | | | | | |
|-------------|----|----|----|----|----|
| BA5 | 7 | 7 | 7 | 7 | 7 |
| BA6 | 5 | 5 | 5 | 5 | 5 |
| BA7 | 1 | 2 | 2 | 1 | 2 |
| BA8 | 10 | 10 | 10 | 10 | 10 |
| BA9 | 9 | 9 | 9 | 9 | 9 |
| BA10 | 2 | 1 | 1 | 2 | 3 |

Table 5 shows the sensitivity-based ranking of barriers across test scenarios, demonstrating the stability and robustness of the AHP prioritization results. The results show that BA7 has the highest rank at most scenarios, which underlines its critical and non-compensatory character. BA10 and BA2 are moderately sensitive, and they sometimes switch positions based on the focus of priorities, i.e., financial or technological. Discussing the barriers at the middle tier, like BA3 and BA6, prove to be rather stable, but the ones at the bottom of the list have minimum impact on the whole hierarchy. The sensitivity analysis, in turn, supports the validity of the prioritisation results, thus supporting the soundness and reliability of the AHP findings. The analysis also shows that BA7 has a steadily dominant role in the majority of scenarios, which proves its necessary nature and means that it cannot be neutralized by other variables. This non-compensatory nature makes certain that the priority of BA7 does not change in response to the change in the context of the decision and this critical importance in the hierarchy is essential. Meanwhile, BA10 and BA2 are moderately sensitive to the shift in priorities; the ranking among them varies according to whether the financial or the technological aspect is given priority. This inconsistency implies that these obstacles are situational and sensitive to strategic focus changes, which indicates the subtle nature of the interaction among the various appraisal criteria. There are barriers that are in the middle tier like BA3 and BA6 and that have constant positions, which means medium but consistent impact that does not prevail or decline greatly in different circumstances. On the other hand, the lower-ranked barriers have insignificant effects on overall prioritisation, which proves their reduced relevance in the process of decision-making. This sensitivity analysis, hence, confirms the strength of the AHP findings in the sense that the ranking structure is highly consistent with only a small number of ranking elements having their rank variability associated with contextual priorities. This assurance increases the confidence of the reliability and validity of the prioritisation results, which can be used to make strategic decisions.

6 Conclusion

This paper used a systematic literature review to examine the obstacles to I5.0 implementation to promote resilience and agility in the manufacturing sector through a systematic AHP-based decision-making model. The results indicate that the process of I5.0 implementation is limited not by one factor but by a complex of mutually supporting

technological, financial, and organisational limitations. Cybersecurity and standardisation gaps were identified as the most severe impediment among them, revealing the increased vulnerability of interconnected cyberphysical systems and the necessity to have solid security architecture and interoperable standards [2,4]. The lack of financial and investment resources and digitisation preparedness also underlines the notion that I5.0 change will need a considerable input of economic and technological infrastructure to facilitate resilience and agility to operations. [3,7]. The results of the AHP with sensitivity analysis revealed how the prioritisation is sound, and the importance of the top-ranked barriers to stay in the center of attention under different strategic conditions are proved. This supports validity of the given approach and the fact that it can be applied in managerial decision-making. The research also addresses a major research gap presented in previous studies by avoiding theoretical discussions and providing a quantitative prioritisation of barriers, which is the contribution of the study to the I5.0 literature [5,8]. In practical terms, the results indicate that manufacturing companies and policymakers need to focus on investments into cybersecurity, standardisation and digital infrastructure at the same time that they need to deal with financial and integration issues.

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