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Prioritizing the Barriers to the Implementation of Industry 5.0 in the Supply Chain with AHP

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Abstract: *Industry 5.0 is the latest industrial revolution that harnesses the collaboration between humans and machines. Through Industry 5.0, companies will be able to enhance their operations to become more productive and efficient, offering user-oriented systems and solutions that maximize profitability. However, there are several barriers that hinder individuals and businesses from adopting Industry 5.0. In this context, the aim of this study is to prioritize the barriers to Industry 5.0 implementation within the supply chain. Following a comprehensive literature review, four main barriers and twenty-five sub-barriers were identified. The Analytic Hierarchy Process (AHP) method was employed to evaluate these barriers. The identified criteria were assessed by three supply chain experts in accordance with the methodological steps. According to the results, the most significant main barrier is the resilience barrier. When both main and sub-barriers are considered together, the most critical obstacle is rigid organizational structures. This is followed by market competition, data privacy and security, and technological acceptance and trust, respectively.*

Keywords: Analytical Hierarchy Process, Industry 5.0, Supply Chain, Turkey

I. INTRODUCTION

Industry 5.0 is rooted in Industry 4.0, which emerged in Germany in 2011 as a forward-looking initiative. It reflects the value of human care by blending human subjectivity and intelligence with the efficiency, precision, and artificial intelligence of machines in industrial production (Ling et al., 2022). This new paradigm aspires to forge more efficient, flexible, and sustainable production systems by combining the strengths of both humans and machines (Nasimi &Vargourani, 2025). Industry 5.0 fundamentally embraces the enhancement of process performance through the integration of human cognitive abilities and creativity with machines, aiming to maximize productivity (Güdek, 2023). From this perspective, while automation stands as the primary focus in Industry 4.0, Industry 5.0 cultivates a synergy between humans and autonomous machines. Industry 5.0 envisions a human-centric system alongside the machine-driven model of Industry 4.0, assigning cognitively demanding tasks to human thinkers, while relegating repetitive tasks to integrated machines and robots equipped with swift and accurate information technologies (Kumar et al., 2023).

Accordingly, the literature presents various definitions of Industry 5.0. One such definition characterizes it as a thoughtful concept envisioning the future of industry through a human-centric, sustainable, and resilient manufacturing system (Breque et al., 2021). According to Nahavandi (2019), industry 5.0 entails a close collaboration between human labor and machines within a factory setting, where smart systems integrate workflows to leverage human creativity and intellect for enhanced process efficiency. By respecting the limits of our planet and placing the well-being of industrial workers at the core of production, Industry 5.0 acknowledges the power of industry to serve societal goals beyond employment and growth, aiming to act as a provider of adaptive welfare (Zengin & Zengin, 2022).

The Industry 5.0 revolution encompasses a network of interconnected devices and systems across the supply chain, designed to support intelligent manufacturing tailored to customers' specific needs (Dwivedi et al., 2023). Industry 5.0 particularly focuses on optimizing energy consumption, material processing procedures, and product life cycles in alignment with sustainable supply chain principles (Barata & Kayser, 2023). It also aims to enhance production sustainability, improve economic outcomes, and strengthen supply chain resilience by leveraging technological integration and intelligent, automated, and cognitive digital systems. In a study by Frederico (2021), it is highlighted that Industry 5.0 will advance the supply chain by personalizing it—not only increasing customer satisfaction but also boosting profitability. It does so by utilizing more up-to-date data to reduce risks and waste, allowing supply chain and logistics units to devote more time to strategic innovation rather than grappling with fundamental operational challenges, thereby enhancing supply chain integration.

In this context, it becomes crucial to investigate the barriers hindering the implementation of Industry 5.0 in supply chains. Therefore, the aim of this study is to prioritize the barriers that impede the adoption of Industry 5.0 within supply chains. To this end, the Analytic Hierarchy Process (AHP) approach has been implemented.

II. LITERATURE REVİEW

Industry 5.0 represents the most advanced phase in the evolution of the manufacturing sector, distinguished by the seamless integration of cutting-edge technologies—such as artificial intelligence, big data, the Internet of Things, and cyber-physical systems—into production environments. Industry 5.0 is currently conceptualized as a paradigm that harnesses the unique creativity of human experts to collaborate with powerful, intelligent, and precise machines (Maddikunta et al., 2022). Industry 5.0 will significantly increase production efficiency and create versatility between humans and machines, enabling interaction and continuous monitoring of activities. Collaboration between humans and machines aims to rapidly increase production.

The literature includes a limited yet growing body of research that investigates the barriers impeding the adoption of Industry 5.0 within supply chain contexts. Sharma et al. (2024), in their study on the pharmaceutical manufacturing industry, identified 17 critical barriers and engaged three managerial experts to evaluate them. Utilizing the Analytic Hierarchy Process (AHP), a multi-criteria decision-making methodology, the study concluded that the most significant barrier was the challenge of linking virtual reality with reality. This was followed in importance by the lack of CPS standards and specifications, the absence of collaborative model, and insufficient incorporation of ethics robot/system.

Sarkar, Sharma, and Shardeo (2024) identified 18 barriers to the adoption of Industry 5.0-enabled digital food supply chains aimed at enhancing traceability. The study revealed that limited digital and physical infrastructure constitutes the most prominent barrier. This was followed by the intricate of supply chain frameworks, inadequate capital investments, and limited governmental support.

Majiwala and Kant (2025), in their study into the barriers and potential solutions for the implementation of Industry 5.0-driven circular supply chains, categorized 32 sub-barriers under six principal barriers: strategic, technological, operational, social, economic, and environmental and regulatory. Employing the SF-SWARA method for weight assessment, their findings identified environmental and regulatory barriers as the most consequential, followed by strategic, operational, social, technological, and economic barriers. At the sub-barrier level, the absence of rigorous governmental regulations, legislation, and policy frameworks for circular supply chains within the Industry 5.0 landscape emerged as the most critical concern.

The integration of Industry 4.0 within supply chains—commonly referred to as Supply Chain 4.0 or Digital Supply Chains—entails the deployment of advanced technologies to enhance process efficiency and inter-organizational collaboration. The evolution toward Industry 5.0 has given rise to the notion of supply chain 5.0 (Kumar & Singh, 2025). In their empirical analysis of the barriers and enablers of supply chain 5.0, Kumar and Singh (2025) identified five primary barriers: acceptance and adaptability of robots and other machinery, lack of green initiatives, security and privacy, heterogeneity of system, and social heterogeneity in the value chain. Their application of the GINA method determined the acceptance and adaptability of robots and machines as the most important barrier, followed by security and privacy, the lack of green initiatives, social heterogeneity, and heterogeneity of sytem.

Nasimi and Vargourani (2025) used the DEMANTEL method in their study with 10 managers operating in the manufacturing industry. In the study, which evaluated 10 barriers, the most important barriers to Industry 5.0 applications were, respectively, lack of management support, lack of capabilities and organizational commitment, security concerns, risk in data ownership and data security, and lack of government support.

Laddha and Agrawal (2025), through interviews with supply chain professionals, identified ten barriers inhibiting the integration of Industry 5.0 into supply chain systems. Applying the DEMATEL approach to assess interrelations among these barriers within the context of sustainable supply chains in India, they identified implementation costs as the most critical barrier. This barrier is followed by the barrier of management support, the barrier of Inadequate knowledge of disruptive technologies, and the barrier of lack of reliable information and technological.

Lastly, Chrifi-Alaoui et al. (2025) conducted a comprehensive study to identify and prioritize the barriers to implementing Industry 5.0 within sustainable supply chains. Based on a systematic literature review, four main barriers and 26 sub-barriers were established, with prioritization conducted via the Fuzzy AHP method. The four main criteria are human-centricity barriers, resilience barriers, sustainability barriers and technological barriers. The study determined that the most significant main barrier was related to human-centricity. The most important sub-barrier is lack of human-centric design. This is followed by health and safety concerns, mental and physical workload, technological acceptance and trust, and resistance to change.

The present study also adopts the barrier framework developed by Chrifi-Alaoui et al. (2025). However, the sub-criterion of "Maintenance Complexity" under resilience category was excluded from expert evaluation. Consequently, four main criteria and 25 sub-criteria were utilized, as presented in Table 1 (Chrifi-Alaoui et al., 2025).

Table 1. Industry 5.0 implementation barriers in Supply Chain

Human Centricity Barriers (HCB)	Mental and Physical Workload	The stress and exhaustion workers face due to the rising demands of Industry 5.0 technologies.
	Health and Safety Concerns	Potential health and safety hazards associated with working alongside emerging I5.0 technologies.
	Lack of Skills and Training	A lack of the necessary skills and expertise to effectively implement and utilize I5.0 solutions.
	Lack of Human-Centric Design	Designs that fail to consider the human element and user experience within the I5.0 framework.
	Resistance to Change	Hesitation among individuals and organizations to embrace new technological advancements and workflows.
	Technological Acceptance and Trust	The degree of trust and readiness among stakeholders to adopt and rely on I5.0 technologies.
Resilience Barriers (RB)	Regulatory Challenges	Legal and regulatory barriers that hinder the deployment of I5.0 innovations.
	Market Competition	Intense competitive pressures on businesses attempting to integrate I5.0 strategies.
	Rigid Organizational Structures	Organizational rigidity that conflicts with the agile and adaptive nature of I5.0.
	Inadequate Agility	A lack of operational flexibility and responsiveness required for successful I5.0 integration.
	Resource Scarcity	Limited availability of essential resources for I5.0 implementation
Sustainability Barriers (SB)	Economic Uncertainty	Uncertainty and fluctuation in financial markets disrupting investments in I5.0.
	Inconsistent Regulations	Inconsistencies in regulatory policies across regions that complicate I5.0 adoption.
	Environmental Impact	Negative environmental impacts linked to the deployment of I5.0 technologies
	Inefficient Reverse Logistics	Difficulties in effectively reintegrating returned products and materials into the supply chain.
	Lack of Sustainability Awareness	Insufficient awareness of sustainable practices and principles.
	Lack of Management Support	Insufficient executive or managerial support for transitioning toward I5.0 initiatives.
	High Costs of Implementation	The high financial burden involved in adopting and deploying I5.0 systems.
Technological Barriers (TB)	Technological Immaturity	Complexities in operating and maintaining sophisticated I5.0 technologies.
	Integration Complexity	Challenges in integrating various I5.0 tools with legacy infrastructure
	Cybersecurity Concerns	Cyber security threats and vulnerabilities within I5.0 ecosystems.
	Data Integrity and Confidentiality	The challenge of ensuring both data accuracy and confidentiality in I5.0 environments
	Data Privacy and Security	Protecting personal and organizational data in the context of I5.0.
	Trust and Transparency	Safeguarding sensitive personal and corporate information amid I5.0 transformation
	Customization Complexity	Complexities in operating and maintaining sophisticated I5.0 technologies.

Source: Chrifi-Alaoui et al., 2025, pp.2648

III. RESEARCH METHODOLOGY

The purpose of this study is to prioritize the barriers to implementing Industry 5.0 in the supply chain. For this purpose, barriers obtained from the literature will be prioritized using the Analytical Hierarchy Process (AHP) method. AHP is multi-criteria decision-making methods. AHP was developed by Saaty to determine the weights or relative priorities to be assigned to different alternatives and criteria that make up a decision (Lin & Yang, 1996). The method is based on a hierarchically structured evaluation model and makes pairwise comparisons to measure the relative importance of the factor at each level of the hierarchy. When making pairwise comparisons, the expert or decision-maker evaluates the criteria against each other and assigns a score between 1 and 9 based on their importance. The meaning of these scores is shown in Table 2 (Satty, 1994).

Table 2. The Fundamental Scale

Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong Importance	Experience and judgment strongly favor one activity over another
7	Very strong Importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocal	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

In the hierarchy created, firstly the main criteria are compared, then the sub-criteria related to each main criterion, and finally the alternatives are compared (Baylavlı, 2011). The second phase of the AHP methodology entails determining the relative weights of the criteria. The term 'relative' is used because the priority assigned to each criterion is evaluated in relation to the others, as will be elaborated upon in the subsequent section. According to the Matrix 1, pairwise comparison matrix is created.

$$[a_{ij}] = \begin{bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & a_{23} & \dots & a_{2n} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \frac{1}{a_{3n}} & \dots & 1 \end{bmatrix}_{nxn} \quad (\mathbf{1})$$

Each criterion is equally important when compared with itself. After creating the pairwise comparison matrix, each element in this matrix is divided by the sum of its column, resulting in a matrix. The resulting matrix is called the normalized pairwise comparison matrix. The arithmetic mean of the element in each row of this matrix is then calculated. Thus, the value of each row represents the priority value of that row and is called the priority vector. Each element of the weighted total vector is divided by its corresponding priority value. The maximum eigenvalue $\lambda_{MAX}$is found by taking the arithmetic mean of the values obtained from this process.

After these steps, it is necessary to check that they are consistent. AHP calculates a consistency ratio (CR) comparing the consistency index (CI) of the matrix in question (the one with our judgments) versus the random consistency İndex (RI). CI is calculated as follow formulation.

$$CI = \frac{\lambda_{MAX} - n}{n - 1} (\mathbf{2})$$

The consistency ratio is defined as CR where

$$CR = \frac{CI}{RI} (\mathbf{3})$$

According to Saaty (1987), the results are consistent if CR ≤ 0.10, in which case the pairwise comparison matrix is considered consistent. As a result of studies conducted by Saaty, the random consistency index (RI) shown in Table 3 were found (Saaty, 1994). n represents the matrix size, that is, the number of criteria.

Table 3. Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Random Consistency Index	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

IV. RESULTS

In this study, conducted to prioritize the barriers to implementing Industry 5.0 within supply chains, interviews were held with supply chain managers from three different companies. The managers individually assessed four main criteria and twenty-five sub-criteria, upon which pairwise comparison matrices were constructed. The consistency of each manager's evaluations was verified. Subsequently, the pairwise comparisons from the three managers were aggregated using the geometric mean. The resulting pairwise comparison matrix for the main criteria and their corresponding weights are presented in Table 4.

Table4. Pairwise Comparison Matrix and Criteria Weights of Main Barriers

Main Criteria	Human Centricity Barriers	Sustainability Barriers	Resilience Barriers	Technological Barriers	**Weight**
Human Centricity Barriers	1,000	1,063	0,362	0,464	**0,1527**
Sustainability Barriers	0,941	1,000	0,585	0,550	**0,1744**
Resilience Barriers	2,759	1,710	1,000	1,186	**0,3593**
Technological Barriers	2,154	1,817	0,843	1,000	**0,3135**

The main criteria consist of human centricity, sustainability, resilience, and technological barriers. According to the calculations performed using Excel, the consistency ratio (CR) for the main criteria was determined to be 0.0094. Since this value is below 0.1, it indicates that the pairwise comparison matrix is consistent. The results reveal that the most critical overarching barrier is resilience barriers. These are followed by technological barriers, sustainability barriers, and, lastly, human-centricity barriers.

Given the consistency of the main criteria, the same analytical process was applied to the sub-criteria under each main category. The human centricity barrier comprises the following sub-barriers: mental and physical workload, health and safety concerns, lack of skills and training, lack of human-centric design, and resistance to change. The pairwise comparison matrix and the corresponding weights of these sub-criteria are presented in Table 5. The consistency ratio for the human centricity barrier was calculated as 0.0830.

Table 5. Pairwise Comparison Matrix and Criteria Weights of Human Centricity Barriers

Human Centricity Barriers	Mental and Physical Workload	Health and Safety Concerns	Lack of Skills and Training	Lack of Human-Centric Design	Resistance to Change	Technologica l Acceptance and Trust	**Weight**
Mental and Physical Workload	1,000	0,420	0,160	0,237	0,199	0,437	**0,0675**
Health and Safety Concerns	2,381	1,000	0,500	0,836	0,598	0,315	**0,1459**
Lack of Skills and Training	6,257	2,000	1,000	1,077	0,920	0,397	**0,2578**
Lack of Human-Centric Design	4,217	1,197	0,928	1,000	0,794	0,368	**0,2050**
Resistance to Change	5,013	1,671	1,087	1,260	1,000	1,817	**0,3238**
Technological Acceptance and Trust	2,289	3,175	2,520	2,714	0,550	1,000	**0,3973**

The sustainability barrier encompasses the following sub-criteria: technological acceptance and trust, economic uncertainty, inconsistent regulations, environmental impact, inefficient reverse logistics, lack of sustainability awareness, lack of management support, and high implementation costs. The pairwise comparison matrix and the corresponding weights of these sub-criteria are presented in Table 6. The consistency ratio for the sustainability barrier was calculated as 0.0392.

Table 6. Pairwise Comparison Matrix and Criteria Weights of Sustainability Barriers

Sustainability Barriers	Economic Uncertainty	Inconsistent Regulations	Environmental Impact	Inefficient Reverse Logistics	Lack of Sustainability Awareness	Lack of Management Support	High Costs of Implementation	**Weight**
Economic Uncertainty	1,000	0,382	0,275	0,275	0,177	0,147	1,260	**0,0453**
Inconsistent Regulations	2,621	1,000	0,397	0,397	0,265	0,191	1,442	**0,0713**
Environmental Impact	3,634	2,520	1,000	1,000	0,382	0,281	1,651	**0,1199**
Inefficient Reverse Logistics	3,634	2,520	1,000	1,000	0,382	0,281	1,651	**0,1199**
Lack of Sustainability Awareness	5,646	3,780	2,621	2,621	1,000	0,693	1,842	**0,2357**
Lack of Management Support	6,804	5,241	3,557	3,557	1,442	1,000	3,684	**0,3352**
High Costs of Implementation	0,794	0,693	0,606	0,606	0,543	0,271	1,000	**0,0726**

The resilience barriers comprise the sub-criteria of regulatory challenges, market competition, rigid organizational structures, inadequate agility, and resource scarcity. The pairwise comparison matrix and the weights of these sub-criteria are shown in Table 7. The consistency ratio for the resilience barrier was calculated as 0.0349.

Table 7. Pairwise Comparison Matrix and Criteria Weights of Resilience Barriers

Resilience Barriers	Regulatory Challenges	Market Competition	Rigid Organizational Structures	Inadequate Agility	Resource Scarcity	**Weight**
Regulatory Challenges	1,000	0,291	0,158	0,255	0,303	**0,053**
Market Competition	3,434	1,000	0,763	2,033	2,327	**0,257**
Rigid Organizational Structures	6,316	1,310	1,000	3,684	5,278	**0,426**
Inadequate Agility	3,915	0,492	0,271	1,000	1,587	**0,151**
Resource Scarcity	3,302	0,430	0,189	0,630	1,000	**0,113**

The technological barrier comprises the following sub-criteria: technological immaturity, integration complexity, cybersecurity concerns, data integrity and confidentiality, data privacy and security, trust and transparency, and customization complexity. The pairwise comparison matrix and the corresponding weights of these sub-criteria are presented in Table 8. The consistency ratio for the technological barrier was calculated as 0.0189.

Table 8. Pairwise Comparison Matrix and Criteria Weights of Technological Barriers

Technological Barriers	Technological Immaturity	Integration Complexity	Cybersecurity Concerns	Data Integrity and Confidentiality	Data Privacy and Security	Trust and Transparency	Customization Complexity	**Weight**
Technological Immaturity	1,000	1,186	0,721	1,651	0,437	0,830	4,610	**0,143**
Integration Complexity	0,843	1,000	0,693	1,357	0,333	0,630	3,780	**0,119**
Cybersecurity Concerns	1,387	1,145	1,000	1,260	0,550	1,339	4,160	**0,162**
Data Integrity and Confidentiality	0,606	0,737	0,794	1,000	0,500	1,442	2,714	**0,123**

Data Privacy and Security	2,289	3,000	1,817	2,000	1,000	1,747	4,762	**0,270**
Trust and Transparency	1,205	1,587	0,747	0,693	0,572	1,000	3,979	**0,143**
Customization Complexity	0,217	0,265	0,240	0,368	0,210	0,251	1,000	**0,039**

According to Table 4, the most significant main barrier is resilience, with a weight of 35.93%. This is followed by technological barriers (31.35%), sustainability barriers (17.44%), and human-centricity barriers (15.27%). In the context of this study, which aims to prioritize the barriers to the implementation of Industry 5.0 in supply chains, both main and sub-criteria were evaluated together. The global weights of each sub-criterion are presented in Table 9.

Table 9. Final Weight of Barriers

Sub-Criteria	**Weight**
Rigid Organizational Structures	0,1531
Market Competition	0,0923
Data Privacy and Security	0,0847
Technological Acceptance and Trust	0,0607
Lack of Management Support	0,0585
Inadequate Agility	0,0542
Cybersecurity Concerns	0,0508
Resistance to Change	0,0495
Technological Immaturity	0,0450
Trust and Transparency	0,0448
Lack of Sustainability Awareness	0,0411
Resource Scarcity	0,0405
Lack of Skills and Training	0,0394
Data Integrity and Confidentiality	0,0386
Integration Complexity	0,0373
Lack of Human-Centric Design	0,0313
Health and Safety Concerns	0,0223
Environmental Impact	0,0209
Inefficient Reverse Logistics	0,0209
Regulatory Challenges	0,0192
High Costs of Implementation	0,0127
Inconsistent Regulations	0,0124
Customization Complexity	0,0123
Mental and Physical Workload	0,0103
Economic Uncertainty	0,0079

According to Table 9, in which the weight of each sub-criterion was calculated by multiplying it with the weight of its corresponding main criterion, the most critical sub-criterion is rigid organizational structures (15.31%). This is followed by market competition (9.23%), data privacy and security (8.47%), and technological acceptance and trust (6.07%).

V. CONCLUSION

Contemporary consumers no longer settle for merely customized products; rather, they expect entirely personalized goods and services tailored to their individual needs. This paradigm shift has amplified the role of the human element—both employees and customers—within supply chain management and has led to the emergence of a new conceptual framework that emphasizes the integration of human empathy and creativity with digital technologies to meet increasingly personalized demands. Customer-centric supply chains empowered by Industry 5.0 technologies have become a cornerstone in the transition toward personalized production.

In this context, Industry 5.0-enabled supply chains must be restructured through technologies and processes that prioritize the fundamental needs and well-being of humans (both workers and customers), promote personalization, and advance social responsibility and sustainability. Accordingly, the aim of this study is to prioritize the barriers to the implementation of Industry 5.0 within supply chains. Based on a comprehensive review of the literature, the barriers identified by Chrifi-Alaoui et al. (2025)—through both literature analysis and expert consultations—were adopted in this study. The research employed the Analytic Hierarchy Process (AHP) to evaluate both main and sub-barriers, with assessments conducted by three supply chain managers. Pairwise comparison matrices were developed in accordance with the procedural steps of AHP, and the consistency of expert evaluations was verified.

The findings indicate that resilience represents the most critical main barrier to the implementation of Industry 5.0 in supply chains. It is followed by technological barriers (31.35%), sustainability barriers (17.44%), and human-centricity barriers (15.27%). Among the sub-barriers, rigid organizational structures emerged as the most significant (15.31%). Organizational structure is a crucial determinant of how a workforce adapts to change, collaborates for new learning, and innovates across work and strategies (Varma, Vajpayee, & Sanghani, 2024). In some cases, organizational structures may be too rigid to accommodate the flexible nature of Industry 5.0, and this rigidity may vary across countries and enterprises.

The second most significant sub-barrier is market competition. As technology is increasingly seen as a vehicle for enhancing efficiency and productivity to remain competitive in global markets, industries implementing Industry 5.0 technologies are subject to intense competitive pressure.

Data privacy and security ranks third among the sub-barriers. This pertains to the protection of personal and organizational data. Since Industry 5.0 involves extensive data exchange over the internet among numerous interconnected devices, systems, collaborators, and interfaces, it inevitably raises concerns regarding data privacy and security (Kumar & Singh, 2024).

While Chrifi-Alaoui et al. (2025) identified human-centricity barriers as the most critical impediment in their study, the present research found resilience barriers to be the most significant. This discrepancy underscores the variability of perceived barriers depending on national contexts, industrial sectors, and sample characteristics. In light of this, the findings of this study are expected to serve as a practical guide for companies operating in Turkey. Moreover, future research would benefit from employing alternative multi-criteria decision-making methodologies to validate and enrich these findings.

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