

Analysis of the Problems Encountered in the Widespread Use of IoT Technology in Manufacturing through the SWARA-DEMATEL Methods

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ABSTRACT

The Internet of Things (IoT) is among the key technologies introduced by Industry 4.0 and is rapidly becoming embedded in every aspect of modern life. Despite its growing importance, there are still several challenges hindering the widespread use of IoT technology. This study aims to weight the problems that impede the widespread adoption of IoT technology, which is of considerable importance for businesses, and to determine their levels of influence. For this purpose, nine criteria identified through an extensive literature review were analyzed using the SWARA and DEMATEL methods after consulting expert opinions. The findings revealed that the most significant barrier to the use of IoT technology is standardization. This criterion was followed, respectively, by network performance and service quality, interoperability and integration, and security and privacy. The analysis further showed that the challenges with the lowest weights were data quality and volume and management and configuration.

Keywords: Internet of Things; Manufacturing; Technology Adoption Barriers; Multi-Criteria Decision Making; SWARA; DEMATEL

1. INTRODUCTION

The Internet of Things (IoT) emerged as a new paradigm in internet services, introduced by Ashton in 1999. Rapid advances in telecommunications technologies have enabled data-generating devices such as sensors and actuators to be more easily integrated into everyday life. Communication among these data-generating devices has made the Internet of Things (IoT) paradigm increasingly important (Singhvi, 2025). IoT is based on the idea of integrating electronic devices through a network while simultaneously enabling interaction between devices and users (Bloomberg Intelligence, 2025).

Internet of Things (IoT) applications constitute a set of systems that enable the integration of the cyber world with the physical world. By offering services such as identification, sensing, networking, and control, this technology adds value to technological innovation by personalizing users' interactions with various objects (Rathi et al., 2025; Lv et al., 2020: 1957). The Internet of Things refers to a network structure in which devices or machines share data with one another, exchange information, and make decisions using the collected data without any need for external intervention (Bassi, 2025).

Through IoT technology, real-time information collected through networks formed by integrating various information-sensing devices, such as radio frequency identification devices and sensors, is delivered to end users for the purposes of intelligent identification, distribution, monitoring, and management (Adeoye, 2025; Al-Momani et al., 2018: 52; Gubbi et al., 2013: 1645). With this technology, a future is envisioned in which the digital and physical worlds can be connected through appropriate information and communication technologies in order to realize a wide range of applications and services (Hamidi and Jahanshahifard, 2018: 25). Through the Internet of Things, physical objects are seamlessly integrated into information networks and become active participants in business processes (Özdemir and Özgüner, 2018: 41).

The Internet of Things draws on numerous technologies to enable autonomous data exchange among embedded devices. IoT primarily consists of radio frequency identification (RFID) systems and wireless sensor networks (WSNs). RFID enables the design of microchips for wireless data communication, whereas WSNs are low-cost, low-power, miniature devices used in remote sensing applications (Lin and Shi, 2014: 186; Gubbi et al., 2013: 1651).

Businesses should view the Internet of Things, which is an integral part of the future of the internet, as an important source of revenue (Dijkman et al., 2015: 672). The most important reason for businesses to adopt IoT technology is its potential to improve the financial efficiency of production. For this reason, businesses should employ business models and techniques that create value from IoT technology. The sectoral and organizational potential value of IoT technology was projected to reach USD 14.4 trillion by 2023. More specifically, IoT was expected to increase global industry profitability by 21%. According to Business Insider's 2018 IoT Report, there were projected to be more than 55 billion IoT devices by 2025. It can also be stated that 94% of companies using IoT achieved a return on their investment. Taken together, these figures suggest that this technology will continue to grow (Soori et al., 2023; Hamidi and Jahanshahifard, 2018: 25; Rymaszewska et al., 2017: 92).

Rapid technological development has increased the popularity of IoT, and owing to the benefits it offers both today and in the future, it is becoming an increasingly important application. Nevertheless, the complex structure of these technology-intensive applications gives rise to certain challenges in the use of IoT technology (Van Kranenburg and Bassi, 2012: 1). Some of the challenges encountered in the implementation of IoT technology may be expressed as standardization, global cooperation, technological inadequacies, weak business models, low data quality, reliability and privacy issues, high investment costs, difficulties in integrating cyber-physical systems, sensor-related issues, and government support (Van Kranenburg and Bassi, 2012: 1; Yan et al., 2014: 121; Friha et al., 2021).

This study aims to identify and weight the problems that constrain the widespread use of IoT technology in manufacturing according to their importance levels. Identifying and prioritizing the challenges encountered in further expanding the implementation of IoT, which is known to provide significant benefits for both business and human life, and in enabling businesses to rapidly integrate IoT technology into their production processes, is particularly important. It is believed that determining the weights and impact levels of the problems encountered in practice will provide guidance for decision-makers in making strategic decisions regarding IoT. Within this framework, the challenges identified through an extensive literature review were weighted using the SWARA method after obtaining expert opinions, and their impact levels were subsequently determined through DEMATEL analysis.

2. LITERATURE REVIEW

This section reviews the studies available in the literature concerning the problems and challenges encountered in the widespread use of IoT technology.

Cui et al. (2021), in their study aimed at identifying the challenges encountered in the use of Internet of Things technology in the circular economy, concluded that the most important challenge stemmed from sensor technologies, followed by infrastructure standardization. In their study on the challenges of Internet of Things technologies in smart agriculture, Tao et al. (2021) found that the most significant challenges were infrastructure standardization, technological inadequacies, and reliability. Raghuvanshi et al. (2021) conducted a study to identify the challenges encountered in various applications of the Internet of Things. Their results indicated that increasing demand for smart devices, data quality, information security, and privacy were among the main challenges. Almajali et al. (2018) stated that the challenges encountered in IoT applications mainly arise from standardization and integration among systems. Schuck (2021) emphasized that issues such as the standardization of cyber-physical systems and interoperability constitute major obstacles to IoT applications.

Mellit and Kalogirou (2021) reported that challenges such as system integration, network quality, and technological infrastructure are among the difficulties encountered in IoT applications. Villa-Henriksen et al. (2020) identified interoperability, high cost, difficulties in virtualization, scalability, complexity, poor data quality, the need for smart devices, lack of infrastructure, and poor network structure as challenges associated with IoT applications. Taivalsaari and Mikkonen (2017), in their study investigating the challenges encountered in the IoT era, stated that infrastructure standardization, interoperability, and system integration are major challenges. Mehta et al. (2018) noted that complex network structures, system integration, virtualization, and data security are among the barriers to the widespread use of IoT applications. Viriyasitavat et al. (2019) stated that data processing and storage issues are among the challenges of IoT. Albishi et al. (2017) reported that infrastructure standardization, virtualization of systems, reliability, integration, and inadequate network performance are among the barriers to the implementation of IoT.

3. METHOD

In order to weight the challenges encountered in the implementation of Internet of Things technology, the SWARA method, which is one of the Multi-Criteria Decision-Making methods, was employed. Subsequently, the DEMATEL method was used to determine the mutual influence among the weighted criteria, and the weights were recalculated accordingly.

3.1. SWARA Method

The most significant strength of the SWARA method, which is easy to apply, is the high accuracy of the results obtained through it (Zolfani and Saparauskas, 2013: 409). Because of these advantages, the SWARA method was preferred in this study. The SWARA method, used in multi-criteria decision-making problems, is a criterion-weighting technique based on expert judgment. For this reason, it is frequently preferred in applications that require subjective evaluations. Experts determine the weights of the criteria by ranking them from the most important to the least important according to their knowledge and experience (Zolfani et al., 2015; Prajapati et al., 2019). The steps of the SWARA method are presented below (Keršulienė et al., 2010; Maghsoodi et al., 2019; Zolfani and Saparauskas, 2013).

The method makes it possible to coordinate expert evaluations and to aggregate the data obtained from them. In this study, the SWARA method was employed to determine criterion weights by comparing the criteria in a consistent and stepwise manner based on expert evaluations. In the application of the method, expert judgment serves as the main determinant. Accordingly, each expert ranks the criteria according to his or her own views, opinions, knowledge, and experience, with the most important criterion placed first and the least important criterion placed last. The overall ranking is then calculated by considering the average values. Following the overall ranking, the criteria are compared by each decision-maker, and the criterion weights are determined.

Step 1: The criteria related to the decision problem are ranked by the experts or decision-makers in descending order of importance. An overall ranking is then obtained by taking the geometric mean of the individual rankings.

Step 2: The relative importance of each criterion is determined. In this context, the j th criterion is compared with the $j + 1$ th criterion to determine how much more important it is than the latter. This is denoted by s_j and represents the comparative importance of the average value.

Step 3: The coefficient k_j is calculated using the following equation:

$$k_j = \begin{cases} 1, & j=1 \text{ if} \\ s_j + 1, & j>1 \text{ if} \end{cases}$$

Step 4: At this stage, the value of q_j is determined using the following equation:

$$q_j = \begin{cases} 1, & j=1 \text{ if} \\ \frac{x_{j-1}}{k_j}, & j>1 \text{ if} \end{cases}$$

Step 5: Using the following equation, the value of w_j , which represents the relative weight of the j th criterion, is calculated.

$$w_j = \left\{ \begin{array}{l} 1, \\ \frac{q_j}{\sum_{j=1}^n q_j}, \end{array} \right. \begin{array}{l} j=1 \text{ if} \\ j>1 \text{ if} \end{array} \right\}, (j = 1, 2, \dots, n)$$

For the determination of weights through the SWARA method, it was deemed appropriate to consult the opinions of five decision-makers. In this context, the weights of the decision criteria were determined separately for each decision-maker, and then the arithmetic and geometric means of these weights were calculated in order to obtain results reflecting the group decision (Uludağ and Doğan, 2021). Therefore, in the following section, the weights were first determined for the decision-makers (DM1, DM2, DM3, DM4, and DM5), and subsequently, results reflecting the group decision were obtained based on the weights identified for each decision-maker. The above-mentioned stages were followed in the implementation of the SWARA method.

3.2. DEMATEL Method

As a type of structural modeling method, DEMATEL is used to analyze and reveal the cause-and-effect relationships among the components of a system. The DEMATEL method is applied to analyze the variables affecting a particular system and to make use of expert knowledge in order to better understand the interrelationships and interdependencies among factors. The method not only transforms the interdependencies among factors into cause-and-effect relationships, but also identifies the critical components of a system with the help of impact-relation diagrams (Gabus and Fontela, 1972; Chauhan et al., 2018).

To apply the DEMATEL method, the complex system must first be defined, and then the factors affecting the system (that is, the criteria in the DEMATEL method) must be identified. These criteria can be obtained through a literature review or expert opinions. In addition, a measurement scale should be developed to express the relationships among these factors and the strength of those relationships. For this purpose, a typical scale ranges from 0 to 4, corresponding respectively to “no influence,” “low influence,” “medium influence,” “high influence,” and “very high influence” (Maqbool & Khan, 2020; Tzeng et al., 2007).

Researchers are advised to follow the steps below when applying the DEMATEL method (Tzeng et al., 2007; Sumrit and Anuntavoranich, 2013; Kumar and Dash, 2016; Gue et al., 2022):

Table 1. DEMATEL Steps

STEPS	DEMATEL
Step 1	Construction of the Direct-Relation Matrix (D) $D = \begin{bmatrix} d_{11} & d_{1j} & \dots & d_{1s} \\ d_{i1} & d_{ij} & \dots & d_{is} \\ \vdots & \vdots & \dots & \vdots \\ d_{s1} & d_{sj} & \dots & d_{ss} \end{bmatrix} (i, j=1, 2, \dots, s)$
Step 2	Normalization of the Decision Matrix $n = \frac{1}{\max \sum_{j=1}^s d_{ij}}, (i, j=1, 2, \dots, s)$ $\tilde{D} = n(.)D$

Step 3	Construction of the Total-Relation Matrix $T = \tilde{D}(I - \tilde{D})^{-1}$
Step 4	Construction of the Cause-and-Effect Matrix $R = [\sum_{j=1}^s t_{ij}]_{sx1}$ $C = [\sum_{j=1}^s t_{ij}]_{1xs}$ Calculation of alpha (threshold value) $\alpha = \frac{\sum_{i=1}^s \sum_{j=1}^s [t_{ij}]}{S}$
Step 5	Obtaining the interdependence matrix and the impact-relation diagram $R_i + C_i, R_i - C_i$ $C_i = \sqrt{((R_i + C_i)^2 + (R_i - C_i)^2)}$
Step 6	Determination of the criterion weights $w_i = \frac{C_i}{\sum_{i=1}^s C_i}$

In the final stage, the criterion weights obtained using the relevant formula are normalized. In this way, the weights of the factors, that is, the w_i values, are calculated.

4. APPLICATION

At this stage of the study, the problems hindering the widespread use of IoT technology in the manufacturing sector were first identified for analysis. Within this scope, the numerous problem factors identified through the literature review were reduced to nine following expert consultation and were then included in the analysis. The problems (criteria) determined for the study and their explanations are presented below.

Table 2. Criteria (Challenges)

Challenges	Descriptions	Sources
Standardization	Variations in technologies and cyber-physical systems are identified as one of the greatest challenges in the development of IoT applications. The standardization of IoT architecture and communication technologies is regarded as a backbone for future IoT development. Since this technology uses a wide variety of heterogeneous devices, coordination can become quite difficult when different standards and protocols are employed. Therefore, ensuring standardization and enhancing interoperability among IoT applications are of great importance.	(Al-Fuqaha et al., 2015: 2354; El-Basioni et al., 2020: 190196).

Data Quality and Volume	Low data quality and limited usage volume constitute a significant barrier to the use of IoT applications. In particular, heterogeneous data, which is a consequence of big data, may reduce the success of IoT applications and increase the error rates of these applications.	(Severino et al., 2018: 271; Cadavid et al., 2018: 248).
Security and Privacy	In IoT applications, security concerns arise because raw and processed data are obtained from different sources and may be accessible. In this already complex technology, data security and privacy represent important issues that must be addressed. This problem can be mitigated through encryption algorithms, intrusion detection mechanisms, authentication practices, and various security protocols.	(Dhinari et al., 2017; Tzounis et al., 2017).
Interoperability and Integration	It is believed that the various solutions provided by different transmitters/providers in IoT applications lead to interoperability problems. In IoT applications, the issue of interoperability must be taken into account at all layers. To overcome this problem, an application with a standardized architecture should be used.	(Bhavana, 2015).
Usability	The frequent relocation of devices observed in IoT applications and changes in network topologies lead to mobility-related problems in IoT applications. On the other hand, the increasing environmental risks associated with the relocation of IoT devices may, over time, cause sensor failures and connectivity problems. The physical security of these relatively expensive devices and the protection of their networks are therefore necessary. It is highly important to establish a robust system that can adapt to dynamic relocations.	(Choi and Koh, 2016; Hamdan et al., 2020).
Scalability	Since IoT design and IoT systems are subject to continuous development, scalability has become an important issue. Facilitating the addition of new components and objects to the IoT system and ensuring seamless connectivity to support topology changes constitute another challenge in terms of scalability. To overcome this challenge, it is necessary to use highly scalable cloud-based platforms capable of storing very large amounts of data, that is, to benefit from cloud computing.	(Abdelwahab et al., 2016: 1112; Sarkar et al., 2014: 237).
Network Performance	Bandwidth, throughput, and latency are among the challenges associated with network performance and	(Saha et al., 2021).

and Service Quality	service quality. In addition, developments such as the increasing number of connected devices, higher data rates in wireless networks, and growing use of radio spectrum also give rise to network-related challenges. These developments create congestion in systems with inadequate network infrastructure and increase delays in the network.	
Modeling and Simulation	The modeling problem arising from the complex and heterogeneous structure of IoT systems is among the significant challenges. The absence of a standard methodology for modeling IoT systems constitutes an important problem. In addition, the lack of mathematical formulations that would enable integration between computing systems and IoT systems restricts IoT devices in terms of identification, sensing, networking, computing, and other capabilities.	(Batool and Niaz, 2017: 16).
Management and Configuration	Management and configuration are among the major challenges in IoT applications. The complex structure of IoT applications, the heterogeneous nature of data, and the large number of devices and volume of data traffic create serious difficulties, particularly in monitoring, control, and configuration. IoT software should effectively perform management and self-configuration functions so that it can identify smart objects and interact with them.	(Abu-Elkheir et al., 2013).

After the criteria to be used in the study had been determined, a group of five decision-makers consisting of academics and industry representatives was formed. The decision-makers were asked to compare the identified criteria and score them on a scale from 0 to 10. The criteria used in the study were coded as follows: Standardization (C1), Data Quality and Volume (C2), Security and Privacy (C3), Interoperability and Integration (C4), Usability (C5), Scalability (C6), Network Performance and Service Quality (C7), Modeling and Simulation (C8), and Management and Configuration (C9).

At this stage of the study, the SWARA method was employed to determine the weights of the problems encountered in the use of IoT technology in manufacturing. The findings of the analysis are presented below.

For the criteria evaluated and ranked by the decision-makers consulted in the study, the values of s_j , k_j , q_j , and w_j were calculated sequentially and are presented in the tables below. The decision-makers are denoted as DM1, DM2, DM3, DM4, and DM5.

After the criterion weights had been calculated for each decision-maker, the arithmetic means of these weights were taken in order to reach the overall judgment of the decision-maker

group. The criterion weights related to the challenges hindering the use of the Internet of Things are presented in Table 3.

Table 3. Criterion Weights Based on the Arithmetic Mean

Group Decision	Code	Arithmetic Mean	Importance Rank
Standardization	C1	0.197	1
Data Quality and Volume	C2	0.054	9
Security and Privacy	C3	0.129	4
Interoperability and Integration	C4	0.135	3
Usability	C5	0.072	7
Scalability	C6	0.094	6
Network Performance and Service Quality	C7	0.141	2
Modeling and Simulation	C8	0.108	5
Management and Configuration	C9	0.059	8

Table 4. Criterion Weights Based on the Arithmetic and Geometric Means

Group Decision	Code	Arithmetic Mean	Geometric Mean
Standardization	C1	0.197	0.197
Data Quality and Volume	C2	0.054	0.065
Security and Privacy	C3	0.129	0.129
Interoperability and Integration	C4	0.135	0.134
Usability	C5	0.072	0.072
Scalability	C6	0.094	0.094
Network Performance and Service Quality	C7	0.141	0.140
Modeling and Simulation	C8	0.108	0.105
Management and Configuration	C9	0.059	0.058

Table 5. Direct-Relation Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0.00	1.00	2.00	3.00	1.00	2.00	3.00	1.00	2.00
C2	4.00	0.00	2.00	3.00	1.00	2.00	3.00	1.00	1.00
C3	4.00	1.00	0.00	3.00	2.00	2.00	3.00	2.00	1.00
C4	4.00	3.00	3.00	0.00	2.00	2.00	3.00	3.00	2.00
C5	3.00	1.00	2.00	2.00	0.00	1.00	4.00	2.00	2.00
C6	3.00	1.00	2.00	2.00	2.00	0.00	2.00	1.00	1.00
C7	4.00	4.00	3.00	3.00	3.00	3.00	0.00	3.00	3.00
C8	4.00	2.00	2.00	2.00	1.00	1.00	2.00	0.00	1.00
C9	4.00	2.00	2.00	3.00	1.00	1.00	4.00	1.00	0.00

The scoring presented in Table 5 was used to construct the Direct-Relation Matrix. In light of the evaluations, the arithmetic mean of the assigned scores was calculated, and the Direct-Relation Matrix was established. Subsequently, the remaining steps of the DEMATEL method were carried out, and the Normalized Direct-Relation Matrix was obtained. This stage corresponds to the second step of the method.

Table 6. Determination of the Row Sums, Column Sums, and the Maximum Value of the Direct-Relation Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	TOTAL
C1	0.00	3.00	3.67	3.11	3.33	2.56	2.22	2.44	3.08	23.42
C2	3.00	0.00	3.22	2.89	3.22	2.89	2.44	4.00	3.70	25.37
C3	3.78	3.22	0.00	3.33	3.22	2.11	3.89	3.67	3.37	26.60
C4	3.00	2.89	3.22	0.00	3.78	3.00	3.33	3.89	3.51	26.62
C5	3.33	3.33	3.11	3.78	0.00	2.33	3.89	2.89	2.49	25.15
C6	2.67	2.89	2.11	3.00	2.33	0.00	2.00	2.44	1.48	18.93
C7	2.22	2.44	3.67	3.44	3.89	2.11	0.00	2.89	1.95	22.62
C8	2.56	3.89	3.56	3.89	2.89	2.44	3.00	0.00	1.35	23.57
C9	3.16	3.67	3.23	3.52	2.50	1.56	1.96	1.31	1.14	22.05
TOTAL	23.71	25.33	25.79	26.96	25.17	19.00	22.74	23.54	22.08	214.32

Table 7. Total-Relation Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0.000	0.104	0.132	0.114	0.117	0.069	0.070	0.079	0.097
C2	0.105	0.000	0.121	0.111	0.119	0.084	0.082	0.144	0.126
C3	0.141	0.124	0.000	0.136	0.125	0.062	0.142	0.137	0.118
C4	0.109	0.110	0.126	0.000	0.148	0.091	0.119	0.145	0.123
C5	0.118	0.124	0.117	0.149	0.000	0.067	0.136	0.101	0.081
C6	0.073	0.084	0.061	0.092	0.066	0.000	0.052	0.067	0.037
C7	0.070	0.081	0.129	0.125	0.136	0.055	0.000	0.093	0.058
C8	0.084	0.140	0.129	0.147	0.101	0.067	0.098	0.000	0.040
C9	0.101	0.124	0.110	0.125	0.082	0.039	0.058	0.039	0.074
TOTAL	0.801	0.892	0.926	0.998	0.894	0.534	0.757	0.806	0.755

Based on the Normalized Direct-Relation Matrix, the Total-Relation Matrix and the groups of influencing and influenced factors were obtained. At this stage (Step 4), a relation diagram showing the interactions among the factors is drawn. The sum of the obtained vectors ($V+Y$) constitutes the horizontal-axis vector, indicating the degree of importance of the criteria. Similarly, the difference between the vectors yields the vertical-axis vector ($V-Y$). A positive value of this vector indicates that the criterion belongs to the cause group, whereas a negative value indicates that it belongs to the effect group. The $V+Y$ and $V-Y$ data sets are used to construct the relation diagram. In the final stage of the method, the coefficients of the

obtained criterion weights are normalized. Thus, the weight of each criterion, that is, the w values, is calculated.

Table 8. Mutual Influence Among Factors

Factors	V Vector	Y Vector	V+Y Vector	V-Y Vector	Effect Type	w	W
C1	0.564	0.574	1.138	-0.009	Influenced	1.138	0.099
C2	0.728	0.726	1.454	0.001	Influencing	1.454	0.126
C3	0.923	0.733	1.656	0.190	Influencing	1.667	0.145
C4	0.881	0.998	1.880	-0.117	Influenced	1.883	0.164
C5	0.745	1.246	1.991	-0.501	Influenced	2.053	0.178
C6	0.092	0.091	0.183	0.001	Influencing	0.183	0.016
C7	0.483	0.496	0.979	-0.012	Influenced	0.979	0.085
C8	0.615	0.621	1.236	-0.006	Influenced	1.236	0.107
C9	0.460	0.465	0.925	-0.005	Influenced	0.925	0.080

According to the findings presented in Table 8, Standardization, Interoperability and Integration, Usability, Network Performance and Service Quality, Modeling and Simulation, and Management and Configuration were found to be influenced factors, whereas Data Quality and Volume, Security and Privacy, and Scalability were identified as influencing factors.

Table 9. Factor Weights

Code	Factors	w	Influence Type
C1	Standardization	1.138	Influenced
C2	Data Quality and Volume	1.454	Influencing
C3	Security and Privacy	1.667	Influencing
C4	Interoperability and Integration	1.883	Influenced
C5	Usability	2.053	Influenced
C6	Scalability	0.183	Influencing
C7	Network Performance and Service Quality	0.979	Influenced
C8	Modeling and Simulation	1.236	Influenced
C9	Management and Configuration	0.925	Influenced

CONCLUSION AND RECOMMENDATIONS

In this study, the challenges hindering the use of Internet of Things (IoT) technology, which is among the important technologies of today, were identified and ranked according to their importance by using the SWARA method. Within this scope, the relevant national and international literature was reviewed, and the criteria related to the challenges facing the use of IoT were determined. Among the identified criteria, nine were selected based on expert opinions and included in the analysis. The study aimed to weight the numerous problems encountered in the widespread use of IoT technologies. Through the findings obtained, the most significant and least important challenges encountered in IoT applications were

identified, thereby providing guidance for decision-makers in the measures they may take and the policies they may formulate on the subject.

The results of the SWARA method applied in the study indicate that the most important challenge encountered in Internet of Things applications is standardization. This challenge is followed, respectively, by network performance and service quality, interoperability and integration, and security and privacy. By contrast, the analysis revealed that data quality and volume, management and configuration, usability, and scalability are among the least important challenges encountered in the use of Internet of Things applications. In addition, the DEMATEL method was applied to reveal the mutual effects of factor weights on one another. In this way, the degree to which the factors influence one another was determined. According to the findings, security and privacy is the factor with the highest net causal influence, indicating that it is the main source of the problems arising in the widespread use of IoT technology. In contrast, usability was identified as the criterion most affected by the other problems.

The results obtained are partially consistent with the studies reported in the literature. Koshizuka and Sakamura (2010) stated that infrastructure standardization and system standardization constitute the most important challenge for IoT applications. Cui et al. (2021) concluded that standardization problems are among the three most important challenges hindering the use of the Internet of Things. The same study also reported that data quality is the least important criterion among the challenges encountered in IoT applications. Van der Veer and Wiles (2008) stated that interoperability-related challenges are among the major obstacles to the use of IoT applications.

It is believed that the findings of this study, in which the importance levels of the challenges encountered in the use of Internet of Things (IoT) technology were determined, will increase businesses' awareness of the difficulties they may face in integrating IoT, one of the most important technologies of today, into their processes, and will encourage them to take steps toward developing strategies and implementing necessary measures according to the relative importance of these challenges. In this respect, the findings of the study are important for decision-makers. Increasing the number of criteria and experts, as well as employing other multi-criteria decision-making methods, may produce different results. This may be considered a recommendation for future research.

Conflict of Interest Statement: The authors declare that they have no conflict of interest.

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