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Research Article /Araştırma Makalesi

Evaluation of IoT-enhanced waste management strategies in food processing industry using analytical network process method

Gıda işleme endüstrisinde IoT destekli atık yönetim stratejilerinin analitik ağ süreci yöntemi kullanılarak değerlendirilmesi

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Abstract

In the food processing industry, sustainable waste management practices have become a strategic priority, in line with increasing environmental pressures and resource-efficiency requirements. In this context, Internet of Things (IoT) based solutions offer a more effective, traceable, and flexible structure by digitizing waste processes. However, integrating these technologies into the sector requires simultaneous evaluation of the interactions and feedback mechanisms among the criteria. In this study, IoT-supported waste management strategies were evaluated using the Analytical Network Process (ANP), which can model complex relationships holistically. Nine criteria, determined through a literature review and expert opinions, were weighted based on their interdependencies. The findings show that economic efficiency and return on investment (ROI) are the most decisive factors, followed by technological compatibility and open innovation capacity. Unlike traditional hierarchical decision-making approaches, the ANP method offers a more realistic, dynamic analysis that accounts for interactions among criteria. In this respect, the study makes a significant contribution to literature by offering a unique, network-based decision-support framework for evaluating IoT-based waste management strategies.
Keywords: Waste management; analytical network process; food industry; internet of things

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Öz

Gıda işleme sektöründe sürdürülebilir atık yönetimi uygulamaları, artan çevresel baskılar ve kaynak verimliliği gereksinimleri doğrultusunda stratejik bir öncelik haline gelmiştir. Bu bağlamda, Nesnelerin İnterneti (IoT) tabanlı çözümler, atık süreçlerinin dijitalleştirilmesini sağlayarak daha etkili, izlenebilir ve esnek bir yapı sunmaktadır. Ancak bu teknolojilerin sektöre entegrasyonu, kriterler arasındaki karşılıklı etkileşimlerin ve geri besleme mekanizmalarının birlikte değerlendirilmesini gerektirmektedir. Bu çalışmada, söz konusu karmaşık ilişkileri bütüncül bir biçimde modelleyebilen Analitik Ağ Süreci (ANP) yöntemi kullanılarak IoT destekli atık yönetimi stratejileri değerlendirilmiştir. Literatür taraması ve uzman görüşlerine dayalı olarak belirlenen dokuz kriter, karşılıklı bağımlılıkları dikkate alınarak ağırlıklandırılmıştır. Elde edilen bulgular, ekonomik verimlilik ve yatırım getirisi (ROI) kriterinin en belirleyici faktör olduğunu, bunu teknolojik uyumluluk ve açık inovasyon kapasitesinin izlediğini göstermektedir. Geleneksel hiyerarşik karar verme yaklaşımlarından farklı olarak, ANP yöntemi kriterler arasındaki etkileşimleri dikkate alan daha gerçekçi ve dinamik bir analiz imkânı sunmaktadır. Bu yönüyle çalışma, IoT tabanlı atık yönetimi stratejilerinin değerlendirilmesine yönelik özgün ve ağ tabanlı bir karar destek çerçevesi sunarak literatüre önemli bir katkı sağlamaktadır.
Anahtar Kelimeler: Atık yönetimi; analitik ağ süreci; gıda endüstrisi; nesnelerin interneti

Introduction

Within the scope of Industry 4.0, Internet of Things (IoT) technologies offer innovative solutions that play a key role in creating sustainable production systems (Kamble et al. 2020). The food processing sector, in particular, increasingly needs IoT-based waste management strategies due to the complexity of production processes and high waste generation (Jagtap et al. 2019). Waste management is critical not only for environmental sustainability but also for economic and social sustainability (Dora et al. 2020). In this regard, IoT-supported solutions enable significant improvements in processes such as real-time monitoring of waste, automated sorting, and sustainable disposal methods (Ciccullo et al., 2021).

The big data analytics provided by IoT technologies, when integrated with artificial intelligence and autonomous systems, can significantly increase the efficiency and effectiveness of waste management applications in the food processing sector (Tsang et al. 2018). However, the selection and evaluation of appropriate IoT strategies presents a multi-dimensional and complex decision problem due to the complexity of sectoral requirements (Govindan and Hasanagic, 2018). In this context, multi-criteria decision-making methods, such as the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP), can be effective tools for selecting IoT-based waste management strategies, offering a holistic and relational analysis (Saaty, 2004).

This study argues that criteria interactions and dependencies are crucial when evaluating IoT-supported waste management strategies. Traditional multi-criteria decision-making methods, which rely only on hierarchical structures, cannot capture these complex relationships. The Analytical Network Process (ANP) more realistically analyzes such problems by modeling feedback and interactions among criteria. This study addresses a gap in the literature by using the ANP method to analyze IoT-based waste management strategies in the food processing sector.

Waste management in the food sector requires comprehensive, integrated solutions across the entire value chain, from production through distribution to the consumer. Strategies for reducing, recovering, and reusing waste are critical in achieving sustainability goals in the sector (Mirabella et al., 2014). The use of IoT technologies in food waste management increases efficiency by improving processes such as data collection, waste quantity tracking, energy recovery, and logistics optimization (Wen et al., 2018).

With the increase in food waste worldwide, the creation and adoption of sustainable waste management strategies in the food sector has become imperative. In this context, the Internet of Things (IoT), a fundamental component of Industry 4.0, offers innovative strategies for businesses through solutions such as monitoring and analyzing waste generation. To ensure the healthy structuring of IoT transformation in food processing, a holistic analysis of the factors that affect the process is necessary. This study addresses this problem. IoT-supported waste management strategies in the food processing sector have been evaluated using the ANP method. The literature indicates that studies on waste management have been conducted; however, no study has evaluated IoT-supported waste strategies in the food sector using multi-criteria decision-making methods.

Akış et al. (2022) evaluated regional, national, and global projects at different levels aimed at reducing food waste and spoilage, taking into account consumer behavior, and discussed their effects. Gustavsson et al. (2011) approached food waste from the perspective of its negative economic impact on farmers and consumers. Gustavsson et al. (2011) stated that approximately one-third of the food produced for human consumption worldwide is lost or wasted, leading to economic losses as well as unnecessary CO_2 emissions.

Gonawala and Jardosh (2018) examined the management of organic waste through composting and highlighted its benefits, including reducing waste volume, eliminating pathogens, and increasing nutrient availability for agricultural applications. Bekar and Şahin (2018) highlighted the scale of food waste generated in the hotel industry. They emphasized the importance of an effective waste management system by examining strategies for its management. Another study by Şahin (2021) examined the scale of food waste in hotel businesses and presented a model proposal for the prevention and evaluation of food waste. Çirişoğlu and Akoğlu (2021) examined the scale of food waste in restaurants in Istanbul, the areas where it is most frequently generated, and the issue of waste evaluation. They also proposed various solutions to reduce food waste. In his project, Bayram (2022) examined zero-waste management practices in the food sector and presented framework reports, training curricula, and an industrial symbiosis guide on waste management.

Maçin (2021) examined food waste management in Turkey and offered recommendations on the roles of stakeholders in the new national strategy, from the perspectives of the Green Deal, bioeconomy (BE) strategies, and zero waste (WT).

Özkan et al. (2022) addressed the concept of sustainability in food production through agricultural waste management, focusing on the transformation of waste into high-value-added products. Çatar et al. (2023) discussed the management and sustainability evaluation of food waste generated in hospitals. Atlı (2024) emphasized the importance of waste management strategies in the food sector and discussed process management and strategic approaches to reduce food waste generated during production and transportation. Hoteit et al. (2024) examined the extent of food waste in hospitals across countries in the Eastern Mediterranean Region and highlighted research gaps in quantification, management, and evaluation strategies. Meas (2025) evaluated the obstacles to implementing joint management of urban organic and human waste in Cambodia using the Fuzzy DEMATEL and ANP methods.

No similar study has been found in the literature; however, Mookkaiah et al. (2022) addressed the design and management of IoT-based digital waste management systems, examining the optimization of solid waste management processes using sensors and data analytics. They emphasized the potential of these systems to enhance waste-management efficiency. This study contributes to the literature by addressing the problem of integrating IoT applications into waste management systems and evaluating these strategies in the face of the growing waste problem in the food processing sector. In addition to offering a theoretical framework, it provides strategic directions for managers.

This study aims to identify the criteria for selecting IoT-supported waste management strategies in the food processing sector and to analyze their relationships using the ANP method. The importance of the study lies in providing decision-makers with a comprehensive and systematic evaluation framework. While the literature generally focuses on the technical aspects and monitoring processes of IoT applications, this study emphasizes a relational, holistic perspective on decision-making. Furthermore, it provides a unique and valuable contribution to the literature by examining IoT-based waste management applications using a multi-criteria approach. This study serves as a guide for industry stakeholders by identifying the criteria necessary for an integrated, relational evaluation of IoT technologies. Moreover, analyzing systematically will facilitate the adoption of IoT technologies across the sector, creating long-term strategic advantages in terms of sustainability and competitiveness. This study consists of four sections. The second section describes the study's methodology. The third section discusses the application steps and the solution process. The fourth section interprets the results obtained.

Materials and Methods

In this study, the Analytic Network Process (ANP) was employed to evaluate Internet of Things (IoT)- based waste management strategies in the food processing sector using a multi-criteria approach. ANP offers a much more realistic and dynamic decision structure by considering the internal dependencies, feedback, and interactions in decision problems (Saaty, 2001; Saaty, 2004).

In the analysis of multidimensional, interactive systems such as IoT-supported waste management strategies, ANP, which models direct and indirect relationships among criteria, provides the most suitable methodological framework for this study.

Looking at the application steps of the ANP method:

Step 1: Defining the problem: In this step, the characteristics and boundaries of the problem under consideration are discussed.

Step 2: Creating the network structure: The network structure is constructed by considering the interactions, relationships, and feedback among the criteria that affect the problem. This structure is generally developed based on expert opinions and existing literature (Ishizaka and Labib 2011; Govindan et al. 2015).

Step 3: Creating pairwise comparison matrices: This matrix structure is created based on the relationships and interactions between the criteria. These comparisons are scored according to Saaty's 1-9 scale (2001).

Table 1. Saaty's 1-9 scale

Important values	Definition
1	Both criteria are equally important
3	A little more important
5	More important
7	Much more important
9	Quite important
2,4,6,8	Intermediate values

According to Table 1, a value is assigned to the degree of importance when comparing one criterion with another. Experts in the field make these evaluations. When there are many experts, these evaluations are combined using the geometric mean.

Step 4: Creating the supermatrix structure: A supermatrix is created by obtaining priority vectors from the resulting pairwise comparison matrices. The supermatrix represents the influence of all elements in the system on each other. Subsequently, the supermatrix structure is transformed into a weighted supermatrix that represents the global effect. By multiplying this matrix by itself multiple times, a limit supermatrix is obtained, and the total priority value of each alternative is determined. This process is continued until mathematical convergence is achieved (Saaty, 2006).

In this study, Super Decisions software, widely used for multi-criteria decision-making problems, was employed to perform Analytical Network Process (ANP) analyses. The process began by creating the network structure in the software and defining the interactions and feedback relationships among the criteria. Next, pairwise comparison matrices were systematically generated, and expert evaluations were entered into the software environment. After input, the eigenvectors were calculated. The software then automatically produced the supermatrix, the weighted supermatrix, and finally the limit supermatrix. Throughout these steps, Super Decisions software performed the mathematical operations specific to the ANP method using standardized algorithms. This approach supports the accuracy and repeatability of the computational process, ensuring that the analysis remains transparent, systematic, and reapplicable.

Results and Discussion

The food processing industry is under pressure to maintain sustainability due to organic waste generated during production, energy consumption, and environmental impacts. In this context, waste management has become not only an environmental necessity but also a strategic management area that can provide a competitive advantage. In recent years, IoT (Internet of Things) technologies have the potential to significantly increase operational efficiency in waste management processes through innovative applications such as sensor-based monitoring, automatic classification, fill level detection, temperature and humidity control, and real-time notification systems. This study aims to evaluate the applicability of IoT-supported waste management in the food processing sector using the Analytic Hierarchy Process (AHP). In line with sustainability requirements and circular-economy goals, waste management has become a priority that must be integrated into corporate strategies in the food sector. Therefore, this study has significant potential for managers to increase recycling rates and reduce resource waste.

Furthermore, this study presents an innovative approach that evaluates IoT-supported waste management strategies in a multidimensional, holistic manner, mathematically modeling the interrelationships between criteria and strategies using the ANP method. The criteria affecting the problem were determined through a literature review. The final version of the criteria was also developed by supporting this research with the opinions of an expert group.

The criteria used in this study were determined through a two-stage process. In the first stage, national and international literature on waste management, sustainability, digital transformation, and IoT applications in the food sector was systematically reviewed. In this context, studies on IoT-based waste management applications, multi-criteria decision-making methods, and sustainable supply chain management were evaluated, and a potential set of criteria was identified. In the second stage, the draft criteria were presented to expert academics and industry representatives for their opinions. Based on expert evaluations, similar criteria were combined, narrow-scope or repetitive criteria were eliminated, and the final set of criteria was created. As a result of this process, nine main criteria were determined. The definitions and scopes of the criteria are presented in Table 2. IoT-based strategies were conceptually framed by considering application examples from the literature and the sector's current digitalization trends; the evaluation was conducted through strategic prioritization based on the determined criteria. This structure strengthens the transparency of the method and the reproducibility of the study.

Table 2. Criteria and descriptions

Criteria	**Criteria descriptions**
Technological Suitability and Adaptability (K1)	The ease of integrating IoT solutions into existing infrastructure and their compatibility with industry-standard technologies should be evaluated.
Economic Efficiency and Return on Investment (ROI) (K2)	The costs and payback period of the IoT technology to be used should be evaluated by comparing them with the economic advantages it provides.

Table 2. Continued

Environmental Performance and Sustainability Contribution (K3)	The contribution of IoT strategies to reducing waste, minimizing environmental pollution, and conserving natural resources should be examined.
Compliance with Regulatory and Legal Regulations (K4)	IoT-enabled waste management applications must comply with local and international environmental regulations, standards, and industry regulations.
Data Security and Cyber Resilience (K5)	The data protection standards, resilience against cyberattacks, and reliability of IoT systems must be carefully examined.
Data Analytics and Decision Support Capacity (K6)	The ability to optimize production processes through real-time analysis of IoT data and decision-support mechanisms should be evaluated.
Circular Ecosystem Integration Capability (K7)	The ability of IoT-powered waste management strategies to integrate into a broader circular economy ecosystem, encompassing not only on-site operations but also suppliers, customers, and local communities. The contribution of waste management practices to achieving broader sustainability goals by enabling data and resource sharing among value chain stakeholders. The system's potential to create new business models for waste reuse and its integration into the sharing economy, and the potential for these models to be supported by IoT technologies.

Table 2 shows that the effective evaluation of IoT-supported waste management strategies in the food processing sector is not limited to individual elements such as technological suitability or economic profitability, but encompasses a multidimensional evaluation framework spanning environmental sustainability, data security, crisis management, and open innovation. In this context, the nine criteria identified in the study provide a holistic framework that reflects both contemporary operational realities and the resilient, digital, and sustainable food systems of the future.

Network Structure and Creation of Pairwise Comparison Matrices

In the ANP solution process, after defining the problem, a network structure is constructed. Interactions, relationships, and feedback between the criteria are considered when creating the network structure. Figure 1 shows the network structure created by considering the opinions of the expert group.

Figure 1 shows the interactions and relationships between the criteria. Table 3 presents examples of criteria that influence one another and the rationale for these interactions

Table 3. Criteria and descriptions

Criteria	Affected criteria	Reason
Technological Suitability and Adaptability	Data Security and Cyber Resilience	More complex systems can create more security vulnerabilities.
Data Analytics and Decision Support Capacity	Circular Ecosystem Integration Capability	As analytical capacity increases, the quality of decision support improves.
Ecosystem Data Sharing and Open Innovation Capacity	Environmental Performance and Sustainability Contribution	Open data platforms drive innovation.
Environmental Performance and Sustainability Contribution	Compliance with Regulatory and Legal Regulations	Systems with a high environmental contribution comply with regulations more easily.

As shown in Table 3, the related criteria are expressed as follows. After the network structure is established, pairwise comparison matrices are created based on the relationships between the criteria.

In this study, pairwise comparisons were performed by a panel of experienced experts in their respective fields. The expert group consisted of four individuals working in the food industry, sustainability, industrial engineering, and digital transformation. Two of the experts were academics, and the other two were managers and technical experts actively working in the food sector. All experts had at least five years of experience in IoT applications, waste management systems, or sustainable production processes. Pairwise comparisons were performed individually, and the resulting assessments were combined using the geometric mean method. This approach reduced the impact of individual biases, resulting in more balanced and reliable outcomes.

An example comparison matrix is given in Table 4.

Table 4. Example comparison matrix

K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K9
K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K4
K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K1
K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K3
K9	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K4
K9	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K1
K9	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K3
K4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K1
K4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K3
K1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K3

In the literature, the Super Decision software package is frequently used by researchers in the computational process of the ANP method. After establishing relationships in the package, pairwise comparison matrices are automatically generated. To evaluate the reliability of the pairwise comparison matrices obtained using the ANP method, the consistency ratio (CR) was calculated. In this context, the consistency index (CI) was determined for each comparison matrix, and then CR values were obtained using the random index (RI) values. In this study, the widely accepted threshold value of CR ≤ 0.10 in the literature was used. As a result of the calculations, it was determined that the CR values of all pairwise comparison matrices were below this threshold. This indicates that the expert evaluations are consistent and the comparison results are reliable. After experts perform these comparisons, the program automatically calculates the eigenvector values. The resulting values are given in Table 5.

Table 5. Criteria weights obtained using the ANP method

Criteria	**Criteria weights**
Circular Ecosystem Integration Capability	0.109
Economic Efficiency and Return on Investment (ROI)	0.154
Ecosystem Data Sharing and Open Innovation Capacity	0.128
Resilience and Crisis Management Capability	0.075
Compliance with Regulatory and Legal Regulations	0.068
Technological Suitability and Adaptability	0.144
Data Analytics and Decision Support Capacity	0.094
Data Security and Cyber Resilience	0.117
Environmental Performance and Sustainability Contribution	0.111

Table 5 shows that the weighting of the obtained criteria is strategically important for identifying which factors are more critical. The results help to make forward-thinking inferences about how sector stakeholders should guide their decision-making processes in the context of digital transformation and sustainability. The economic efficiency and return on investment criterion, with the highest value of 0.154, shows that economic sustainability and return on investment are key determinants in IoT-supported waste management solutions. In the food processing sector, technology investments are expected to provide tangible financial benefits. This indicates that digital transformation strategies should be optimized on the basis of financial foundations. The Technological Suitability and Adaptability criterion, with a value of 0.144, is a critical factor in terms of the integrability of new technologies into existing production processes. It indicates that IoT solutions should be not only advanced but also applicable and compatible with existing systems. The Ecosystem Data Sharing and Open Innovation Capacity criterion, with a value of 0.128, shows that waste management processes should be designed to include collaboration and data sharing not only with internal but also with external stakeholders.

When the obtained criterion weights are compared with those of similar studies in the literature, the findings of this study largely align with general trends. For example, studies by Dora et al. (2020) and Govindan and Hasanagic (2018) emphasized that economic efficiency and return on investment play a decisive role in the adoption of sustainability practices. Similarly, research by Wen et al. (2018) and Mookkaiah et al. (2022) stated that technological compatibility and system integration are among the critical factors in the applicability of IoT-based waste management systems. The fact that economic efficiency and return-on-investment criteria have the highest weight in this study is consistent with these findings. In addition, the high priority given to ecosystem data sharing and open innovation capacity indicates that collaborative approaches are increasingly important in digital transformation processes. In this respect, the study supports the existing literature and highlights the advantages of network-based decision models for evaluating IoT-based waste management applications. Therefore, the results obtained provide meaningful and generalizable findings not only within the specific context of the sector but also within the context of the sustainable production and digitalization literature. This strengthens the study's scientific contribution and application potential.

The fact that economic efficiency and return on investment (ROI) criteria have the highest weight in the study is directly related to the structural cost pressures of the food processing sector and the management approach focused on "payback period" in investment decisions. The high volatility of energy, raw materials, labor, and logistics costs in the sector, in addition to relatively limited margins, leads financial returns to serve as the primary filter for decision-makers in digital transformation investments. Therefore, IoT-based waste management solutions, even when they deliver environmental benefits, are primarily evaluated at the enterprise level through financial outcomes such as cost reduction, process efficiency, and recovery revenue.

The high priority given to technological suitability and adaptability can be explained by the fact that the existing production infrastructure in food processing plants is mostly heterogeneous (varying ages and technology levels) and that downtime incurs high opportunity costs. For decision-makers, the success of a new IoT solution depends not only on its technological capabilities but also on its ease of integration with existing equipment and information systems, scalability, and the ability to be implemented with minimal operational disruption. Therefore, the "applicability" dimension stands out as a strategic determinant in the sector's reality. The relatively high weight given to ecosystem data sharing and open innovation capacity reflects the fact that waste management is not limited to on-site operations but is an interactive system involving suppliers, logistics networks, recycling/disposal actors, and public regulations. IoT-based approaches increase the potential to develop new business models (such as byproduct/waste valorization) through common platforms, for example, by optimizing the recovery chain through collaborations and by facilitating traceability and reporting. This finding indicates that decision-makers are beginning to position digital transformation not just as “automation” but also as “ecosystem integration.” The significant weight given to data security and cyber resilience criteria shows that traceability, production continuity, and corporate reputation in the food sector are directly related to digital risks. In particular, the integrity of production data, the continuity of sensor/data flow, and resilience against cyber disruptions are considered critical for both operational sustainability and legal obligations. In contrast, the relatively low weighting of regulatory compliance and crisis management criteria suggests that decision-makers prioritize "tangible return on investment" and "feasibility" in the short term. However, this finding does not mean that these criteria are unimportant; on the contrary, it shows that organizations' risk perception and prioritization behavior are shaped by financial and operational pressures. In conclusion, the distribution of criterion weights indicates that IoT-supported waste management decisions in the food processing sector are shaped along the axes of financial rationality, ease of integration, and ecosystem-based value creation, thereby providing an analytical framework consistent with sector dynamics.

Conclusion

This study employs the Analytic Hierarchy Process (AHP), a multi-criteria decision-making approach, to evaluate IoT-supported waste management strategies in the food processing industry. The findings provide a guiding framework for decision-makers on which criteria to prioritize in digital transformation processes. The ANP analysis revealed that Economic Efficiency and Return on Investment (ROI) were the criteria with the highest weights. This finding indicates that in the adoption of IoT-based applications in the food processing industry, the primary focus is on the economic rationality and cost-effectiveness of the investment. On the other hand, the high weighting of criteria such as Technological Suitability and Adaptability, and Ecosystem Data Sharing and Open Innovation Capacity indicates that not only financial returns but also digital ecosystems based on system integration and collaboration are becoming increasingly important. Digital investments should be evaluated not only based on economic performance criteria but also on long-term technological compatibility and system flexibility. In this context, integrating waste management practices with corporate strategy will strengthen operational sustainability. Investments in data sharing and open innovation will not only create a competitive advantage within the sector but also contribute to achieving holistic sustainability goals by increasing interaction among supply chains. Data security and cyber resilience are critical to the sustainability of digital systems. Therefore, it is important to ensure that IoT-based solutions are aligned with security policies from the design phase onwards. Regulatory Compliance and Crisis Management Capability, which carry relatively low weights, suggest that sector stakeholders may prioritize short-term operational priorities. However, neglecting these two elements can increase corporate risks, especially in today's world where environmental and digital regulations are becoming increasingly stringent. Therefore, acting holistically is healthier. This study contributes to the literature by analyzing IoT-based sustainable waste management strategies from a multi-criteria decision-making perspective and by evaluating sector-specific criteria sets in their interactions within a network structure. In conclusion, in the digitalization process of the food processing sector, it is necessary not only to invest in technology but also to design these investments in a holistic, data-driven, environmentally responsible manner that ensures long-term resilience. Such analytical approaches will support the industry's transition to a more flexible, integrated, and sustainable production architecture, enabling it to adapt to changing global dynamics.

This study uses the Analytical Network Process (ANP) method to evaluate IoT-supported waste management strategies, and the interactions among the criteria are incorporated into the analysis. Unlike the traditional Analytical Hierarchy Process (AHP) approach, the ANP method is based on feedback and relational network rather than a linear, independent structure. This allows for a more realistic modeling of the complex and dynamic nature of the decision problem. The results largely align with the literature on sustainability, digital transformation, and waste management; in particular, they reveal that approaches based on economic efficiency, technological compatibility, and data sharing play a decisive role in the sector. However, this study distinguishes itself from existing studies by addressing these criteria holistically within a network-based decision model. In this respect, the research not only presents findings on prioritizing IoT-based waste management strategies but also reveals the analytical superiority and application potential of the ANP method in sectoral decision problems. Thus, the study provides a unique contribution to literature both methodologically and practically. Furthermore, thanks to this approach, not only the independent importance level of each criterion but also its direct and indirect effects on other criteria are included in the analysis process. When the findings are examined, it becomes clear that there are strong interactions among criteria such as economic efficiency, technological compatibility, data analytics capacity, and open innovation. For example, the fact that technological compatibility directly supports data analytics capacity, and that data-sharing infrastructure triggers open innovation processes shows that these criteria mutually reinforce each other within the network structure. The ANP method, by accounting for such multifaceted relationships, has enabled the determination of criterion weights in a more realistic manner. In traditional hierarchical decision-making approaches, criteria are generally assumed to be independent and evaluated using a linear priority structure. In contrast, the ANP approach used in this study has provided a decision structure that reflects the complex and dynamic nature of IoT-based waste management systems in the food processing sector. Thus, the resulting priority ranking is based not only on the importance of individual criteria but also on the interaction patterns within the system. In this respect, the study's findings can be considered a concrete reflection of the feedback-based, network-structured analysis framework provided by the ANP method. Determining the relative importance of the criteria by considering their interactions has ensured that the results are more reliable and explanatory, both theoretically and practically. Therefore, this study not only presents findings on prioritizing IoT-supported waste management strategies but also reveals the analytical advantages of the ANP method in sectoral decision-making problems.

In this context, the network-based assessment approach proposed in this study allows managers to balance not only short-term economic goals but also long-term environmental and social sustainability goals. Furthermore, the use of IoT-based data collection and analysis infrastructures in conjunction with the ANP method enables continuous monitoring of waste management processes, regular updating of performance indicators, and dynamic revision of strategic decisions. In this respect, the study provides an analytical guide for policies and practices to be developed in the food sector, focusing on digitalization and sustainability. In conclusion, the proposed approach not only supports existing decision-making processes but also strengthens long-term corporate resilience by increasing the sector's capacity to adapt to changing environmental, technological, and economic conditions.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Data Availability Statement

The authors declare that the main data supporting the findings of this study are available in the article.

Authorship Contribution Statement

Şeyda Gür; References, Research, Writing – original draft, Visualization, Writing – original draft; Yüsra İnci; References, Research, Formal analysis, Verification, Methodology, Visualization, Writing – original draft

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