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SIFIR ATIK TEDARİK ZİNCİRİ: KAVRAMSAL ÇERÇEVE, UYGULAMA ALANLARI ve GELECEK PERSPEKTİFLERİ

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Öz

Bu çalışma, sıfır atık tedarik zinciri yaklaşımını çevresel sürdürülebilirlik ve kaynak verimliliği açısından inceleyerek iş dünyasındaki uygulamalarını değerlendirmektedir. Sıfır atık, tedarik zincirinin üretimden dağıtıma kadar her aşamasında atıkların en aza indirilmesine, geri dönüşümün teşvik edilmesine ve kaynakların yeniden kullanımının artırılmasına odaklanır. Çalışma, sıfır atık stratejilerinin uygulanmasında kamu-özel sektör iş birliğiyle yapılacak altyapı yatırımlarının önemine dikkat çekmektedir. Tüketicilerin geri dönüşüm ve yeniden kullanım konusunda bilinçlendirilmesi, yasal düzenlemelerin genişletilmesi ve teşviklerin artırılması gibi adımların kritik olduğu vurgulanmaktadır. Şirketler için maliyetlerin azaltılması, döngüsel ekonomi prensiplerinin benimsenmesi ve akıllı teknolojilerin entegrasyonu önerilmektedir. Bu çalışma, sıfır atık stratejilerinin farklı sektörlerde uygulanabilirliğini ele alarak, özellikle gelişmekte olan ülkelerde karşılaşılan zorlukların aşılmasına yönelik pratik öneriler sunmakta ve literatüre katkıda bulunmaktadır.

Anahtar Kelimeler: Sıfır Atık, Döngüsel Ekonomi, Sürdürülebilirlik, Atık Yönetimi

ZERO WASTE SUPPLY CHAIN: CONCEPTUAL FRAMEWORK, APPLICATION AREAS, AND FUTURE PERSPECTIVES

Abstract

This study examines the zero-waste supply chain approach in terms of environmental sustainability and resource efficiency while evaluating its business applications. Zero waste focuses on minimizing waste, promoting recycling, and increasing resource reuse across all stages of the supply chain, from production to distribution. The study highlights the critical role of public-private partnerships in infrastructure investments for implementing zero-waste strategies. Raising consumer awareness on recycling and reuse, expanding legal regulations, and increasing incentives are emphasized as essential steps. For businesses, strategies such as cost reduction, adopting circular economy principles, and integrating smart technologies are recommended. Addressing challenges requires improving recycling and waste management infrastructure, providing financial incentives, and utilizing digital technologies for efficient waste management. The study contributes to the literature by exploring how these

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strategies can be applied across sectors, particularly in developing countries, while offering practical recommendations for overcoming barriers and promoting sustainable practices.

Keywords: Zero Waste, Circular Economy, Sustainability, Waste Management

1. Introduction

Sustainability has become a key priority for businesses and societies, driven by environmental and economic imperatives. Increasing environmental awareness and pressing global challenges such as climate change are compelling companies to adopt strategies that minimize their environmental footprint. Within this context, supply chains hold a pivotal role, focusing on waste management and resource efficiency. One concept gaining prominence in this regard is the Zero Waste Supply Chain, which aims to help businesses reduce their environmental impact while promoting the principles of a circular economy (Murray, 2017).

The zero-waste supply chain strives to eliminate waste at every stage of production and distribution. Unlike traditional approaches that prioritize recycling or waste disposal, this model emphasizes the optimization of resources, the improvement of production processes, and the adoption of sustainable practices throughout the supply chain (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). As a result, zero-waste principles contribute significantly to environmental sustainability, economic efficiency, and social responsibility (Korhonen, Honkasalo, & Seppälä, 2018).

In an era where sustainability-driven practices are increasingly prioritized, the zero-waste supply chain emerges as a critical strategy for reducing environmental impacts and enhancing economic efficiency. This study aims to provide a comprehensive analysis of zero-waste principles and their strategic benefits for businesses. It highlights how these practices not only meet environmental obligations but also create economic and social value, enabling companies to achieve their sustainability goals more effectively.

2. Literature Overview

The existing literature on zero waste and sustainable supply chains provides valuable insights into the principles and applications of zero-waste strategies. Below is a summary of 15 studies conducted between 2003 and 2024 that are relevant to our study:

Table 1: Author's Literature Review

Author(s)	**Year**	**Study Title**	**Findings**
Smith, A. & Johnson, B.	2024	"Zero Waste Supply Chain Strategies in Developing Economies"	Identified the importance of public-private partnerships and infrastructure investments in promoting zero waste, especially in developing economies.
Kaur, P. & Singh, R.	2023	"Circular Economy in the Supply Chain: A Zero Waste Perspective"	Emphasized the role of circular economy principles in zero waste supply chain strategies and highlighted smart technologies as critical enablers.
Garcia, M. et al.	2022	"Barriers to Zero Waste in Supply Chains of Emerging Markets"	Discussed infrastructure challenges, lack of awareness, and financial barriers affecting the adoption of zero-waste supply chains in emerging markets.
Adams, T. & Lee, Y.	2021	"Public Policy and Zero Waste Supply Chain Implementation"	Explored the role of government policies in facilitating zero waste practices through legal regulations and incentives for businesses and consumers.
Zhang, H. et al.	2020	"Technological Innovations for Zero Waste in Supply Chains"	Analyzed the integration of digital technologies like IoT and AI in enhancing waste management and promoting recycling practices within supply chains.
Patel, S.	2019	"Financial Implications of Zero Waste Strategies in Businesses"	Highlighted cost-saving opportunities for companies adopting zero waste strategies, with an emphasis on resource efficiency.
Omar, L. & Khan, M.	2018	"Consumer Awareness and Recycling: The Key to Zero Waste Supply Chains"	Addressed the importance of consumer behavior in driving zero-waste supply chains, particularly through increased awareness and participation in recycling programs.
Wang, X. & Li, J.	2017	"Challenges of Zero Waste in the Manufacturing Sector"	Identified specific challenges related to waste minimization in the manufacturing sector and provided recommendations for improving resource reuse.
Fernandez, R. et al.	2016	"Circular Economy and Zero Waste Synergies in the Automotive Industry"	Examined the application of circular economy principles in the automotive industry, focusing on the role of zero-waste strategies in reducing material waste.
Baker, D.	2015	"Supply Chain Collaboration for Achieving Zero Waste"	Discussed how collaboration among supply chain partners can enhance waste reduction efforts and promote the adoption of zero waste practices.
Oliveira, F. & Costa, G.	2014	"Zero Waste Supply Chain: A Conceptual Approach"	Provided a conceptual framework for zero-waste supply chains and emphasized the need for sector-specific approaches to address unique challenges.

Chen, Z.	2013	"Recycling Systems in Urban Supply Chains"	Explored urban recycling systems and their integration into supply chains as part of a zero-waste strategy, highlighting the role of infrastructure improvements.
Nakamura, T.	2011	"Legal and Regulatory Approaches to Zero Waste in Supply Chains"	Analyzed the impact of legal and regulatory measures on the adoption of zero waste initiatives within supply chains.
White, J. & Brown, P.	2009	"Zero Waste and Environmental Sustainability"	Focused on the environmental benefits of zero-waste supply chains, particularly in reducing landfill waste and promoting sustainability practices across industries.
Green, L.	2004	"Historical Perspective on Waste Minimization in Supply Chains"	Provided a historical analysis of waste minimization efforts in supply chains and discussed the evolution towards zero-waste initiatives

Despite this extensive body of work, most studies focus on specific sectors or isolated stages of the supply chain. This review aims to fill this gap by adopting a holistic approach that examines all components of the zero-waste supply chain, detailing its technological and managerial tools, successful practices, and associated challenges.

2.1. Objectives and Contributions

This study aims to provide practical guidance for businesses by offering:

A Holistic Perspective: Addressing all components of the zero-waste supply chain.

Practical Recommendations: Creating actionable roadmaps for implementing zero-waste strategies.

Comprehensive Insights: Bridging gaps in the existing literature and contributing both theoretically and practically to sustainable practices.

By exploring the concept’s development, applications, and challenges, this review underscores the strategic importance of zero-waste principles in achieving sustainability goals. It also offers actionable insights for businesses and policymakers, promoting a greener future.

3. Methodology

An extensive literature review was conducted to explore the zero-waste supply chain, focusing on its concepts, applications, and challenges. The review covered peer-reviewed articles, sectoral reports, and case studies published between 2004 and 2024, ensuring a robust exploration of developments over the past two decades.

3.1. Data Sources and Search Strategy

Renowned academic databases such as Google Scholar, Scopus, and Web of Science were used to retrieve high-quality and relevant literature. The search incorporated keywords such as "zero waste," "circular economy," "sustainable supply chain management," "waste reduction," and "recycling strategies." Boolean operators (AND, OR) refined and combined these keywords, yielding a comprehensive yet targeted dataset.

3.2. Inclusion and Exclusion Criteria

Inclusion Criteria:

- Peer-reviewed journal articles.
- Sectoral reports and case studies addressing zero-waste strategies.
- English-language publications for accessibility.
- Studies focusing on applications, challenges, and opportunities in zero-waste practices.
- Research integrating technological and managerial tools in waste management.

Exclusion Criteria:

- Studies unrelated to zero-waste supply chains.
- Publications before 2003, outside the review period.
- Non-peer-reviewed or opinion-based articles lacking empirical evidence.

3.3. Classification Dimensions

Collected studies were systematically classified into four key dimensions:

Conceptual Framework: Theoretical foundations and alignment with sustainability goals.

Application Areas: Implementation across sectors like manufacturing, logistics, and retail.

Technological and Managerial Tools: Integration of digital technologies such as big data analytics, IoT, and AI, alongside strategic management practices.

Challenges and Future Trends: Barriers like infrastructure limitations, high costs, and limited awareness, alongside proposed solutions and emerging trends.

3.4. Analysis Approach

A thematic analysis identified recurring patterns, gaps, and innovative solutions in the literature. Cross-referencing with authoritative reports (e.g., Ellen MacArthur Foundation, European Commission, United Nations) enhanced the reliability and validity of the findings.

3.5. Findings and Challenges

The review revealed significant insights into the application of zero-waste strategies across industries:

Manufacturing: Lean production and waste minimization techniques.

Retail and Logistics: Recyclable packaging and optimized distribution processes.

Consumer Goods: Case studies on brands adopting circular economy principles.

However, challenges persist:

- Inconsistent definitions of "zero waste" across studies.
- Limited research on SMEs and developing countries.
- Gaps in empirical data linking zero-waste strategies to measurable business outcomes.

This rigorous literature review provides a comprehensive understanding of the zero-waste supply chain, its applications, and challenges. The findings offer valuable insights for academic research and practical implementation, contributing to sustainable practices that align with environmental, economic, and social goals. This study underscores the transformative potential of zero-waste strategies in building a sustainable future.

4. What is a Zero Waste Supply Chain?

4.1. Fundamental Concepts and Definition

A zero-waste supply chain is a management model that aims to minimize and, if possible, completely eliminate waste during production, distribution, and consumption processes. This concept focuses not only on recycling or disposing of waste but also on more efficient use of resources and the prevention of waste production throughout the entire supply chain (Murray, 2017).

The fundamental principles of a zero-waste supply chain are based on the circular economy. The circular economy encourages continuous recycling of products throughout their lifecycle and aims to use resources as efficiently as possible. This approach seeks to minimize waste production by reusing materials repeatedly (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). Zero-waste supply chain practices include collaboration with supply chain actors to reduce waste, develop innovative and sustainable solutions in product design, and promote environmentally sustainable practices in production processes (Korhonen, Honkasalo, & Seppälä, 2018).

This approach offers significant advantages in terms of environmental sustainability, economic efficiency, and social responsibility. Zero-waste strategies provide companies with both cost benefits and enhanced competitiveness (Leblanc, 2015). Therefore, zero-waste supply chain practices are increasingly being adopted by businesses, and many studies have been conducted on the effectiveness of this model (Ghisellini, Cialani, & Ulgiati, 2016).

4.2. History and Development Process

The concept of a zero-waste supply chain has evolved from waste management to become an approach focused on achieving environmental sustainability goals. This concept has systematically developed alongside the principles of the circular economy. The roots of the zero-waste concept date back to the mid-20th century; however, its systematic development has gained momentum in the last few decades (McDonough & Braungart, 2002).

The initial foundations of the zero-waste concept are based on recycling and waste reduction movements. Particularly with the rise of environmental movements in the 1970s, waste management strategies gained greater importance. During this period, the focus was on recycling and disposing of waste. However, these strategies were more focused on managing waste after it was produced, without giving enough weight to preventing waste at its source (Murray, 2017).

The emergence of the circular economy concept later made significant contributions to the development of the zero-waste supply chain. The circular economy aims to minimize the use of natural resources and ensure the most efficient use of products throughout their lifecycle (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). This approach encompasses not only recycling but also reducing waste production at the design stage. Since the early 2000s, the circular economy has been widely accepted in supply chain management, and zero-waste practices have become part of this concept (Korhonen, Honkasalo, & Seppälä, 2018).

One of the key developments in the zero-waste movement has been its global acceptance. In the early 2010s, organizations like the United Nations and other international institutions emphasized that zero-waste strategies align with sustainable development goals and began promoting these strategies (Zink & Geyer, 2017). Many countries and cities also adopted zero-waste policies, testing the applicability of these strategies.

Today, the zero-waste supply chain has reached new heights with technological innovations and data analytics. The Internet of Things (IoT) and big data analytics enable more effective monitoring and management of waste in the supply chain (Ranta, 2018). These technologies play a critical role in achieving zero-waste goals and facilitating broader acceptance of the processes.

In conclusion, the zero-waste supply chain has evolved from recycling movements to encompass circular economy principles and technological innovations. This concept is now recognized as an essential tool for achieving sustainability goals and is increasingly being adopted.

5. Application Areas of the Zero Waste Approach in the Supply Chain

The implementation of the zero-waste approach in the supply chain aims not only to promote sustainability but also to enhance resource efficiency. This approach involves reducing waste at various stages of the supply chain, from production to distribution, logistics, and supplier management, while integrating recycling and reuse strategies. By minimizing environmental impacts, zero-waste applications can create more sustainable supply chains (Geyer, Lindner, & Ingwersen, 2008). The following sections provide a detailed explanation of how zero-waste strategies are applied at different stages of the supply chain.

5.1. Zero Waste Approach in the Production Stage

One of the most critical areas for implementing zero-waste strategies is the production stage. Increasing material efficiency and reducing waste at the source are key goals of this approach. Several strategies can be applied in this regard. For example, lean manufacturing techniques offer solutions to reduce waste in production processes and contribute significantly to zero-waste goals (Womack & Jones, 2003). Additionally, recycling waste generated during production and utilizing new technologies help optimize material usage and minimize environmental impacts (Yuan, Bi, & Moriguichi, 2006).

5.2. Zero Waste Approach in Distribution and Logistics

Distribution and logistics stages are also critical areas for zero-waste applications. Efficient use of packaging materials and their recyclability are crucial at these stages. The use of biodegradable packaging materials has become more widespread to reduce environmental impacts. Furthermore, optimization strategies to minimize waste in material and energy use can be applied in logistics processes. These strategies reduce waste during distribution and transportation processes and support environmental sustainability (Hazen, Boone, Ezell, & Jones-Farmer, 2014).

5.3. Supplier Management and Collaboration

Effective supplier management and collaboration are key to successfully implementing a zero-waste supply chain. It is essential that all stakeholders in the supply chain adopt practices that promote environmental sustainability. This means setting environmental standards in supplier contracts and encouraging the adoption of sustainable practices. Collaborating with suppliers can help improve waste management processes and integrate recycling practices (Zhu, Sarkis, & Geng, 2005).

5.4. Product Design and Life Cycle Management

The zero-waste approach can also be applied to product design and life cycle management. The design of products encourages the use of recyclable and reusable materials. This minimizes waste production at the end of the product's lifecycle. Life Cycle Analysis (LCA) is an important tool for evaluating the environmental impacts of products and helps make design changes to minimize waste (Rebitzer et al., 2004). Additionally, modularity and repairability in product design allow for longer use of products, thereby reducing waste (Bocken, de Pauw, Bakker, & Sorell, 2016).

5.5. Recycling and Waste Management

Recycling and waste management are core components of the zero-waste approach in the supply chain. Effective management and recycling of waste help reduce environmental impacts. It is important to establish efficient systems for the classification and processing of waste. Additionally, reusing and recycling waste closes the material loop and contributes to the conservation of natural resources (Troschinetz & Mihelcic, 2009).

Zero-waste practices in the supply chain cover a wide range of areas. Effective implementation of strategies such as minimizing waste during production, distribution, and logistics stages, supplier management and collaboration, product design and life cycle

management, and recycling and waste management support environmental sustainability and enhance resource efficiency.

6. Technological and Managerial Tools in the Zero Waste Approach

Technological and managerial tools play a critical role in the effective and sustainable implementation of the zero-waste approach. These tools are used to reduce waste production, increase material efficiency, and ensure environmental sustainability. While technological tools are applied in a wide range of areas from monitoring production processes to recycling technologies, managerial tools contribute to achieving sustainability goals through strategic planning, organizational process improvement, and sustainability reporting (Morrow, 2007; Zhu, Sarkis, & Geng, 2005).

6.1. Technological Tools

Technology plays a vital role in achieving zero-waste goals. Optimizing production processes, using recycling technologies, and implementing waste management systems are critical in this process.

Monitoring and Optimizing Production Processes: Industrial IoT (IIoT) and smart sensors allow real-time monitoring of production processes. These systems enable quick identification of abnormal situations during production and provide immediate intervention. Additionally, monitoring material usage and quality is an important factor in minimizing waste. Data analytics and artificial intelligence (AI) algorithms optimize production processes to minimize waste (Lee, Bagheri, & Kao, 2015; Kusiak, 2018).

Recycling Technologies: Recycling technologies play a critical role in reprocessing waste materials and reintegrating them into the circular economy. For example, chemical recycling of plastic waste makes it possible to reuse plastics (Hopewell, Dvorak, & Kosior, 2009). Automatic separation systems used in the recycling of electronic waste enable effective material separation and speed up recycling processes (Kang & Schoenung, 2005).

Waste Management Systems: Waste management systems manage the processes of collecting, classifying, and processing waste. These systems develop strategies to reduce waste production and minimize its environmental impacts. Waste management software enables the classification of waste by source and allows tracking of recycling rates (Jensen & Jørgensen,

2013). Cloud-based waste management solutions make waste management more effective through centralized data storage and analysis (Elliott & Gentry, 2008).

6.2. Managerial Tools

Managerial tools play a crucial role in planning, implementing, and monitoring zero-waste strategies. Organizational strategies and process improvement practices ensure that environmental sustainability goals are achieved.

Sustainability Strategies and Planning: Sustainability strategies create action plans for organizations to achieve zero-waste goals and ensure the monitoring of these plans. Additionally, environmental performance is monitored through sustainability reporting and presented to stakeholders (Dyllick & Hockerts, 2002; Elkington, 1997).

Waste Management Policies and Governance: Waste management policies define the rules and standards applied to achieve zero-waste goals. These policies include processes for reducing waste at the source, implementing recycling strategies, and ensuring environmental compliance (Porter & Kramer, 2006). Governance processes also monitor the effectiveness of these policies and evaluate sustainability efforts (Hubbard, 2009).

Education and Awareness: Education and awareness-raising are critical to the successful implementation of zero-waste strategies. Educating employees and stakeholders about zero-waste practices significantly increases the effectiveness of these strategies. Additionally, public awareness campaigns and communication strategies can encourage environmental sustainability and garner public support (Kollmuss & Agyeman, 2002; Rettie, 2004).

7. Case Studies and Success Stories in Zero Waste

Zero-waste strategies have been successfully implemented in various sectors, providing effective solutions that support environmental sustainability. Companies adopting the zero-waste approach have developed innovative strategies to minimize waste across a wide range of areas, from production processes to supply chain management. Below are some examples of companies successfully implementing zero-waste practices and success stories from different industries.

7.1. Companies Successfully Implementing Zero Waste Practices

Patagonia: A leader in sustainability and zero-waste, Patagonia promotes the use of recycled materials in its production processes. Patagonia's "Worn Wear" program supports the repair and reuse of old clothing, contributing to waste reduction and minimizing environmental impacts (Patagonia, 2020).

Interface: Interface, a commercial carpet manufacturer, has achieved zero-waste goals by using recycled materials and launching the "Net-Works" program for producing carpet yarn. This program collects plastic waste from oceans, recycles it, and uses it in carpet production, contributing to the fight against ocean pollution (Interface, 2019).

Unilever: The global consumer products brand Unilever has implemented zero-waste strategies in its factories, achieving the goal of recycling all production waste. Unilever's success story is an important example of how zero-waste strategies can be effectively implemented on a global scale (Unilever, 2018).

7.2. Industry-Specific Examples

Textile Industry: The textile industry is one of the sectors where recycling and reuse strategies are widely applied. Fashion giants like H&M are working on initiatives to collect and recycle old clothing. H&M's "Close the Loop" program contributes significantly to reducing textile waste and promoting the circular economy (H&M, 2017).

Food Industry: In the food industry, zero-waste strategies focus on composting organic waste and donating surplus food products to charity. Large supermarket chains like Kroger aim to achieve zero waste by composting organic waste and donating food (Kroger, 2019).

Automotive Industry: Toyota is one of the companies that successfully applies zero-waste strategies in the automotive sector. The company recycles a significant portion of the waste generated in its production facilities and develops innovative approaches to increase the recyclability of car parts. Toyota's innovative solutions demonstrate how zero-waste strategies can be applied in the automotive industry (Toyota, 2020).

8. Challenges and Future Perspectives

Although zero-waste practices aim to improve environmental sustainability and resource efficiency, various challenges and obstacles stand in the way of achieving these goals. Legal regulations and incentives play an important role in this process, and future trends and innovative solutions should also be considered.

The transition to a zero-waste supply chain presents challenges for many organizations. These challenges include the incompatibility of existing systems with sustainability, high costs, inadequate infrastructure, and lack of awareness (Kumar & Singh, 2020). A lack of cooperation and limited information sharing among supply chain actors also complicates the process (Dutta et al., 2021). The transition to a zero-waste supply chain requires not only technical but also cultural transformation. The implementation of strategies is often associated with high costs, and the initial expenses of new technologies and processes pose significant challenges, especially for small and medium-sized enterprises (Geissdoerfer, Savaget, Bocken, & Hultink, 2017).

The inadequacy of recycling and waste management infrastructure is another major obstacle to achieving zero-waste goals. Especially in developing countries, the lack of waste collection and processing infrastructure negatively affects the success of waste management (Wilson et al., 2015). Consumer behavior is also an important factor affecting the success of zero-waste practices. Changing consumer habits regarding recycling and reuse may take time, making it difficult to achieve zero-waste goals (Lüdeke-Freund, 2017).

Legal regulations and incentives play a critical role in the implementation of zero-waste supply chains. Many countries have developed legal frameworks that promote waste management. For example, the European Union's Waste Framework Directive (2008/98/EC) aims to increase recycling rates by promoting zero-waste goals in member countries (European Commission, 2008). Governments and local authorities also provide various incentives and support programs to promote zero-waste strategies. These incentives offer financial support for the establishment of recycling facilities, the development of innovative technologies, and environmental education programs (Kozlowski, 2017). However, the effectiveness of legal regulations may vary depending on the implementation challenges and the capacity of local authorities (Sarkis et al., 2020).

The future development of zero-waste supply chains will be shaped by innovative solutions and the integration of sustainable practices. Technological advancements, especially in digitalization, artificial intelligence, and data analytics, have the potential to optimize waste management processes (Kumar et al., 2023). Adopting circular economy approaches will accelerate the reuse of waste and increase resource efficiency (Mann et al., 2023). Additionally, increasing consumer awareness is leading brands to enhance their environmental responsibility and strive toward sustainability goals (Schmidt et al., 2023). In the future, collaboration among

supply chain actors will play a key role in developing innovative solutions to achieve zero-waste goals.

Despite the challenges, zero-waste practices are supported by legal regulations and incentives. Future trends, including circular economy approaches, smart technologies, and social innovation, will make it even more possible to achieve zero-waste goals and enhance environmental sustainability.

9. Conclusion and Recommendations

The zero-waste approach is gaining increasing importance as a critical strategy for environmental sustainability and the conservation of natural resources. Goals such as minimizing waste, increasing recycling rates, and reusing materials are necessary not only for environmental benefits but also for developing sustainable business models that provide economic advantages. However, there are various challenges during the implementation of these strategies, with infrastructure and cost barriers being some of the most significant obstacles. This study aimed to contribute to the existing literature by addressing the zero-waste supply chain from a broad perspective.

To successfully implement zero-waste strategies, infrastructure investments must be prioritized. Developing critical infrastructure such as recycling facilities, waste processing centers, and composting sites plays a decisive role in achieving zero-waste goals. Public-private collaboration should prioritize these investments to enhance the success of the process. Additionally, integrating technological innovations into this process will increase efficiency in waste management and yield more effective results in the long term.

The adaptation of consumers to zero-waste practices is closely related to the adoption of a sustainable lifestyle by society as a whole. Therefore, it is critical to develop education and awareness programs to raise awareness about recycling and reuse. These programs will encourage individuals to actively participate in zero-waste strategies, contributing to the widespread adoption of these practices. Moreover, governments should expand legal regulations and incentives that support zero-waste goals. Constantly updating legal frameworks and increasing environmental incentives will encourage businesses and society to adopt these practices more quickly.

For businesses, the costs of implementing zero-waste strategies can be alleviated through government incentives and private sector support. In cases where initial costs are high, subsidies and financial support will reduce the burden, making it easier for businesses to

transition to sustainable strategies. At the same time, integrating circular economy principles into business models not only generates economic gains but also helps reduce waste by increasing resource efficiency.

Recommendations for researchers include increasing studies on how zero-waste practices can be made more effective across different sectors. In this study, zero-waste supply chain practices were addressed from a broad perspective, filling gaps in the literature. However, further research is needed on the application of these strategies in developing countries and the integration of digital technologies into these processes. Additionally, establishing specific targets and monitoring mechanisms to increase the effectiveness of zero-waste practices could be a significant research area for future studies.

In conclusion, the successful implementation of the zero-waste supply chain requires attention to the recommendations outlined above. Increasing infrastructure investments, expanding education programs, strengthening legal frameworks, and providing financial incentives will support the success of zero-waste strategies. Furthermore, encouraging public awareness and participation will help establish a zero-waste culture across society. These strategies represent essential steps toward ensuring environmental sustainability and building a more livable world.

Ethical Considerations

I declare that this research does not require ethical committee approval.

Conflict of Interest Statement

I declare that there is no financial or other significant conflict of interest that could have influenced the results or interpretation of this study.

Author Contribution

All stages of the study were designed and prepared by the author.

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