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-RESEARCH ARTICLE-

THE IMPACT OF LOGISTICS 4.0 ON SMART WAREHOUSE MANAGEMENT: EXAMPLES FROM COMPANIES IN TÜRKİYE AND A BIBLIOMETRIC ANALYSIS FOR FUTURE TRENDS[*]

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Abstract

This study examines the implementation of smart warehouse management systems in Türkiye from the perspective of Logistics 4.0 and explores the benefits these technologies provide to businesses. The digitalization and automation processes driven by Industry 4.0 enable more efficient and cost-effective management of warehouse operations in the logistics sector. In this context, the research investigates how leading Turkish companies such as Arçelik, Yemek Sepeti, and Borusan Logistics have integrated smart warehouse management systems into their operations and analyzes the impact of this integration on operational efficiency, cost optimization, and customer satisfaction.

The study was conducted using two methods: multiple case analysis and bibliometric analysis. The case analysis method details how these companies have improved their operational processes by utilizing smart warehouse technologies, revealing their unique strategies and the tangible successes achieved. Additionally, the bibliometric analysis, conducted using the keyword "smart warehouse" in the Web of Science database, identifies current research trends and gaps in literature.

The findings indicate that smart warehouse systems significantly enhance operational efficiency, reduce costs, and improve customer satisfaction. Moreover, the bibliometric analysis reveals a growing academic interest in smart warehouse management, with a substantial increase in the number of publications on this topic in recent years. These technologies play a critical role in the digital transformation of Türkiye's logistics sector and provide a significant competitive advantage to businesses. This study offers strategic recommendations for the digitalization of the logistics sector and establishes a solid foundation for future research in this area.

Keywords: *Logistics 4.0, smart warehouse systems, digitalization, industry 4.0.*

JEL Codes: *O14, O33, M11*

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LOJİSTİK 4.0'IN AKILLI DEPO YÖNETİMİNE ETKİSİ: TÜRKİYE'DEKİ ŞİRKETLERDEN ÖRNEKLER VE GELECEKTEKİ EĞİLİMLER İÇİN BİBLİYOMETRİK ANALİZ[2]

Öz

Bu çalışma, Türkiye'deki akıllı depo yönetim sistemlerinin Lojistik 4.0 bağlamında nasıl uygulandığını ve bu teknolojilerin işletmelere sağladığı faydaları incelemektedir. Endüstri 4.0 ile gelen dijitalleşme ve otomasyon süreçleri, lojistik sektöründe depo operasyonlarının daha verimli ve maliyet açısından avantajlı bir şekilde yönetilmesine olanak sağlamaktadır. Bu kapsamda araştırma, Arçelik, Yemek Sepeti ve Borusan Lojistik gibi önde gelen Türk şirketlerinin akıllı depo yönetim sistemlerini operasyonlarına nasıl entegre ettiklerini incelemiş, bu entegrasyonun operasyonel verimlilik, maliyet optimizasyonu ve müşteri memnuniyeti üzerindeki etkilerini analiz etmiştir.

Çalışma iki yöntem kullanılarak gerçekleştirilmiştir: Çoklu vaka analizi ve bibliyometrik analiz. Vaka analizi yöntemi, bu şirketlerin akıllı depo teknolojilerini kullanarak operasyonel süreçlerini nasıl iyileştirdiklerini detaylandırmış, her bir şirketin benzersiz stratejileri ve elde ettikleri somut başarılar ortaya konulmuştur. Ayrıca, bibliyometrik analiz, "akıllı depo" anahtar kelimesi kullanılarak Web of Science veri tabanında yapılmış, bu alandaki mevcut araştırma eğilimleri ve literatürdeki boşluklar belirlenmiştir.

Elde edilen bulgular, akıllı depo sistemlerinin operasyonel verimliliği artırdığı, maliyetleri düşürdüğü ve müşteri memnuniyetini önemli ölçüde artırdığı yönündedir. Ayrıca, bibliyometrik analiz sonucunda, akıllı depo yönetimi ile ilgili akademik araştırmalara olan ilginin hızla arttığı ve son yıllarda bu konuda yapılan yayın sayısının önemli bir artış gösterdiği ortaya çıkmıştır. Bu teknolojilerin Türkiye'nin lojistik sektöründe rekabet avantajı sağladığı ve dijital dönüşüm sürecinde kritik bir rol oynadığı vurgulanmaktadır. Çalışma, lojistik sektörünün dijitalleşmesi için stratejik öneriler sunarken, gelecekteki araştırmalar için sağlam bir temel oluşturmayı amaçlamaktadır.

Anahtar Kelimeler: *Lojistik 4.0, Akıllı Depo Sistemleri, Dijitalleşme, Endüstri 4.0.*

JEL Kodları: *O14, O33, M11.*

"This study has been prepared in accordance with Research and Publication Ethics."

1. INTRODUCTION

Logistics 4.0, as part of Industry 4.0, represents a major leap in the digitalization and automation of logistics processes. Technologies such as the Internet of Things (IoT), big data analytics, artificial intelligence, robotic systems, and cloud computing have revolutionized the logistics industry (Glistau and Coello Machado, 2018). Integrating

[2] Genişletilmiş Türkçe Özet, makalenin sonunda yer almaktadır.

these technologies has enhanced the efficiency of logistics operations by making supply chain management more flexible, efficient, and customer-oriented.

One of the key challenges in logistics is optimizing warehouse operations to meet increasing demands for speed, accuracy, and cost-efficiency. Traditional warehouse management systems struggle to adapt to this rapidly evolving environment. The problem this study addresses is the extent to which logistics companies in Türkiye have adopted smart warehouse management systems (SWMS) and how these systems impact operational efficiency, costs, and customer satisfaction. Understanding these impacts is critical for businesses aiming to remain competitive in the logistics sector.

Numerous studies have highlighted the benefits of Logistics 4.0 and smart warehouse management systems. For instance, research has shown that SWMS enhance operational efficiency, reduce labor and operational costs, and improve customer satisfaction by optimizing warehouse operations (Lee et al., 2018; Barreto et al., 2017). Globally, companies that have adopted smart technologies in their logistics operations report significant improvements in flexibility, real-time monitoring, and decision-making (Halawa et al., 2020). However, while the adoption of these technologies has been widely studied in more developed economies, there is limited research on how SWMS are being implemented in Türkiye, especially in the context of small and medium-sized enterprises (SMEs).

Despite the growing global interest in smart warehouse systems, there is a lack of detailed studies exploring their adoption and implementation in Türkiye's logistics sector. Previous research has focused primarily on larger economies, and little is known about how SWMS function within Türkiye's unique economic and industrial conditions. This study aims to fill this gap by examining the prevalence of SWMS in Türkiye's logistics sector, assessing their impact on operational performance, and identifying challenges faced by local companies in implementing these technologies.

The primary aim of this study is to investigate the adoption of smart warehouse management systems in Türkiye's logistics industry and their impact on operational efficiency, costs, and customer satisfaction. Specifically, the study seeks to determine how advanced technologies such as SWMS are used in Türkiye's logistics operations and to analyze the benefits and challenges of implementing these systems. The research also aims to provide recommendations for overcoming barriers to technology adoption.

This study is significant as it contributes to the understanding of the digital transformation process in Türkiye's logistics sector. By examining the impacts of SWMS on key performance indicators such as efficiency, costs, and customer satisfaction, this research will provide valuable insights for logistics companies aiming to enhance their competitiveness. Furthermore, the findings will help guide future strategies for adopting Logistics 4.0 technologies, ultimately contributing to the broader field of digital transformation in logistics.

2. BENEFITS OF SMART WAREHOUSE MANAGEMENT

Smart warehouse management has become a vital aspect of Logistics 4.0, offering advanced functions such as automation of warehouse operations, optimization of inventory management, and real-time decision support through data analytics (Tubis and Rohman, 2023). Various studies have demonstrated the effectiveness of these systems in increasing operational efficiency, reducing costs, and improving customer satisfaction (Buntak et al., 2019).

Globally, smart warehouse management systems are increasingly being adopted across various industries due to their proven impact on optimizing supply chain and logistics processes. According to Jones et al. (2020), the integration of IoT-based systems and robotics has significantly enhanced the accuracy and speed of warehouse operations in North American and European logistics firms. Similarly, Zhong et al. (2017) highlighted that Chinese manufacturer adopting smart warehouse systems experienced a 25% reduction in labor costs and a 30% improvement in inventory accuracy.

However, while much of the research has focused on developed countries, there is limited data on the adoption and impact of these systems in emerging economies like Türkiye. This gap underscores the need for localized studies that examine how smart warehouse systems are being implemented in Türkiye's logistics sector and their specific benefits and challenges.

Several studies have shown that smart warehouse management systems improve operational efficiency by automating critical warehouse tasks. For instance, Chen et al. (2021) found that automation reduced processing times in large distribution centers by over 40%, while Li and Chen (2019) demonstrated that robotic systems could decrease human error by as much as 60%. Robotic systems are particularly effective in transporting, storing, and packaging products accurately and efficiently (Halawa et al., 2020). By eliminating manual bottlenecks, companies can significantly accelerate their warehouse processes and optimize workflow.

The potential for cost reduction is a key driver for companies adopting smart warehouse systems. Automation reduces the reliance on manual labor, cutting down labor costs and improving overall efficiency (Žunić et al., 2018). According to Smith and Brown (2020), companies that integrated automated warehouse management systems reported an average 20% decrease in labor costs and a 15% reduction in operational costs due to optimized space utilization. This aligns with Žunić et al. (2018), who noted that efficient utilization of warehouse space further reduces storage costs, contributing to overall profitability.

One of the key advantages of smart warehouse management is real-time monitoring, enabled by IoT and RFID technologies. Bai et al. (2018) found that real-time monitoring in warehouses improved stock accuracy by 35%, reducing stockouts and overstocking situations. These technologies allow logistics managers to make informed decisions by providing continuous insights into stock levels and warehouse movements (Yılmaz and Kuvat, 2021). In Türkiye, however, the implementation of

such advanced technologies remains limited to a few pioneering companies, suggesting a significant opportunity for growth.

Smart warehouse management systems significantly contribute to customer satisfaction by ensuring faster and more accurate order fulfillment. Studies by Jarašūnienė et al. (2023) and Wang et al. (2021) show that companies utilizing these systems have reduced delivery times and improved accuracy in their deliveries, leading to higher customer retention and satisfaction rates. Proper inventory management prevents stockouts, allowing companies to meet customer demands promptly. This is particularly crucial in e-commerce and fast-moving consumer goods (FMCG) sectors, where delivery speed is critical.

While smart warehouse systems are widely adopted in advanced economies, their implementation in Türkiye's logistics sector remains in its early stages. Existing studies, such as those by Karakoç and Akpınar (2022), have noted that large companies like Arçelik and Borusan have started integrating these systems, but widespread adoption among small and medium-sized enterprises (SMEs) is still limited due to high costs and a lack of technological expertise. This study aims to fill this gap by providing a detailed analysis of how smart warehouse management systems are currently used in Türkiye and what barriers prevent broader adoption.

By analyzing the advantages and challenges of smart warehouse management in Türkiye, this study contributes to a growing body of literature aimed at understanding the digital transformation of logistics in emerging economies.

3. METHOD

This study employs a multiple case study combined with a bibliometric analysis to provide a comprehensive assessment of the adoption and impact of smart warehouse management systems in Türkiye. The multiple case study method offers an in-depth understanding of how key companies in the sector have integrated these systems into their logistics operations, while the bibliometric analysis helps to identify the overall research trends and gaps in the academic literature.

The integration of both multiple case analysis and bibliometric analysis offers a comprehensive evaluation of the research subject from both practical and theoretical perspectives. The multiple case analysis allows for an in-depth exploration of real-world applications of smart warehouse management systems in Türkiye's logistics sector, examining how leading companies implement and benefit from these systems. Meanwhile, bibliometric analysis provides an academic perspective by identifying research trends, gaps, and future directions within the literature on smart warehouse management. By combining these two methodologies, the study ensures a robust analysis of both the practical implementation and academic understanding of smart warehouse systems, thus enhancing the validity and comprehensiveness of the findings.

By combining these two methods, the study achieves a dual objective:

- First, it allows for a detailed evaluation of real-world applications and challenges through case studies of prominent companies.
- Second, the bibliometric analysis provides a broader view of the academic landscape, highlighting the areas where further research is needed to advance the field of smart warehouse management. This mixed-method approach ensures a more holistic understanding of both practical and theoretical aspects of smart warehouse management systems in Türkiye.

3.1. Multiple Case Study

The multiple case study method was used to evaluate how leading logistics companies in Türkiye (Arçelik, Yemek Sepeti, Borusan Lojistik, LC Waikiki, and Migros) have integrated smart warehouse management systems and the effects of these systems on operational efficiency, costs, and customer satisfaction. This method allowed for an in-depth analysis of how these companies implemented smart warehouse technologies and the benefits they achieved.

Case Selection Criteria

The companies selected for this study are recognized as industry leaders in Türkiye's logistics and warehouse management sectors. The selection was based on the following criteria:

- Integration of smart warehouse technologies: Companies were chosen based on their demonstrated use of advanced technologies such as automation, Internet of Things (IoT), and data analytics in warehouse management.
- Sectoral diversity: To provide a broader perspective, companies from different industries were selected, including white goods manufacturing (Arçelik), e-commerce (Yemek Sepeti), logistics services (Borusan Lojistik), retail (LC Waikiki), and grocery retail (Migros). This variety offers insights into how different sectors implement smart warehouse systems and allows for comparison of sector-specific challenges and benefits.
- Market leadership and innovation: The selected companies are pioneers in logistics innovation and have a substantial impact on the market. Their adoption of smart warehouse management systems demonstrates their leadership in the sector and ability to invest in and adapt to digital transformation.

Analysis Process:

The operational processes of these companies were analyzed through a combination of document analysis, sectoral reports, and company-provided data. Specifically:

- Data Collection: Company reports, industry publications, and interviews with key personnel were reviewed to gather information on the specific technologies used, the integration process, and the challenges encountered.

- Evaluation Criteria: Each case was evaluated based on the technologies used (e.g., automation, robotics, IoT), operational benefits (e.g., efficiency gains, cost reductions), and challenges (e.g., financial investment, training needs).
- Cross-Case Analysis: After individual case analysis, a cross-case comparison was conducted to identify common trends, differences across sectors, and the overall impact of smart warehouse systems on Türkiye's logistics sector. This approach allowed for a comprehensive understanding of how smart warehouse technologies are adopted and used in different industries and highlighted sector-specific challenges and best practices.

The integration of smart warehouse management systems represents not only a technological advancement but also a strategic shift requiring significant investment and expertise. Understanding the prevalence of these systems across various industries in Türkiye is essential to assess the logistics sector's readiness for digital transformation.

Prevalence of Smart Warehouse Management Systems

Most logistics companies in Türkiye utilize digital technologies in their logistics processes. However, the extent to which smart warehouse management systems are widely used and adopted in the sector has yet to be determined. Under this sub-heading, the use of smart warehouse management systems by logistics companies in Türkiye has been evaluated, and the level of prevalence in the sector has been revealed.

- Arçelik: As a Türkiye-based white goods manufacturer, Arçelik optimizes its warehouse operations by using smart warehouse management systems in its production facilities and logistics centers. These systems allow Arçelik to make its warehouse management processes more efficient and manage the logistics chain from production to consumer (arcelikglobal.com: 2023). Arçelik-LG used AxionBlade® WMS software in 2009 to perfect the spare parts warehouse inventory management at the Gebze plant. The project, which started in the first quarter of the year, was implemented in the spare parts warehouse in the factory after a detailed analysis. The system, integrated with SAP, manages the spare parts warehouse's goods acceptance, storage, and exit operations (vecsoft.com).

- Yemek Sepeti: Operating in e-commerce and food delivery, Yemek Sepeti optimizes logistics operations and supports fast delivery processes using smart technologies in warehouse management (kurumsal.yemeksepeti.com/inovasyon/, 2024). Yemek Sepeti's smart warehouse systems enable restaurants to track their orders quickly. This system includes menu request management, and restaurants can communicate with customers and receive reports. Moreover, Yemek Sepeti's multi-restaurant system automatically drops restaurants' orders to the takeaway screen and supports fast delivery processes (prestaturk.com).

- Borusan Lojistik: Borusan Lojistik provides freight transportation, warehousing, supply chain management, project logistics, and international transportation services in Türkiye. It provides warehousing, unique distribution,

partial transportation, complete road, auto, and pre-dispatch vehicle inspection (PDI) services with a daily distribution capacity of 8 thousand points, 450 thousand square meters of indoor and outdoor storage area, and 28 transfer centers. Borusan Lojistik, which also developed the digital logistics platform called eTA, provides services worldwide in its sector. As a logistics services provider, Borusan Lojistik optimizes supply chain processes using smart warehouse management technologies. This approach helps the company increase operational efficiency and ensure customer satisfaction (borusanlojistik.com: 2023

- LC Waikiki: LC Waikiki, which operates in the clothing and textile retail sector, improves its inventory tracking and logistics processes using smart warehouse systems in warehouse management and provides fast and accurate products to its stores (lojistikhatti.com: 2024). LC Waikiki's smart warehouse systems optimize inventory management and logistics processes. These systems automate inventory tracking, order management, and product distribution. For example, when products arrive at the warehouse, barcodes identify them and determine their location. Orders are automatically processed, and products are shipped to stores quickly and accurately. This increases customer satisfaction and operational efficiency (lcw.com).

As one of Türkiye's leading retail chains like Trendyol and Getir, Migros has integrated smart warehouse systems in its logistics centers. These systems help them optimize inventory management and make distribution processes more efficient.

Impact on Operational Efficiency

Integrating smart warehouse management systems into logistics operations significantly increases operational efficiency. The various components of these systems aim to increase workforce productivity by automating and optimizing in-warehouse processes.

As a Türkiye-based white goods manufacturer, Arçelik optimizes its warehouse operations using smart warehouse management systems in its production facilities and logistics centers. Arçelik-LG uses WMS software to manage flawless spare parts warehouse inventory at its Gebze plant. This SAP-integrated system manages the goods receiving, storage, and output operations of the spare parts warehouse in the plant. This automation system increases operational efficiency by accelerating warehouse processes and reducing error rates.

As an e-commerce and food delivery company, Yemek Sepeti optimizes its logistics operations by using smart technologies in warehouse management. Yemek Sepeti's smart warehouse systems enable restaurants to track their orders quickly. This system, which includes demand management in menus, enables restaurants to communicate effectively with customers and speed up ordering processes. Yemek Sepeti's multi-restaurant system supports fast delivery processes by automatically enabling orders to appear on the takeaway screen. This way, logistics operations become more efficient, increasing customer satisfaction.

Borusan Lojistik optimizes supply chain processes by using smart technologies in warehouse management. The automation systems used in the company's warehouse

operations speed up receiving, placing, picking, and shipping processes. These systems allow Borusan Lojistik to increase its operational efficiency and maximize workforce productivity. At the same time, the digital logistics platform eTA makes supply chain management more effective and efficient. This enables the company to accelerate its operations and respond quickly to customer demands.

LC Waikiki, which operates in the apparel and textile retail sector, improves its inventory tracking and logistics processes using smart warehouse systems for warehouse management. LC Waikiki's smart warehouse systems automate inventory tracking, order management, and product distribution. When products arrive at the warehouse, they are identified by barcodes, and their location within the warehouse is determined. Orders are automatically processed, and products are shipped to stores quickly and accurately. These processes increase operational efficiency and ensure customer satisfaction.

Smart warehouse management systems significantly increase the operational efficiency of logistics companies in Türkiye. Integrating technologies such as automation, robotics, big data analytics, and artificial intelligence optimizes in-warehouse processes, increasing workforce productivity and making logistics operations faster, more reliable, and more efficient. The proliferation of these technologies in Türkiye's logistics sector offers significant advantages in terms of cost savings and customer satisfaction, as well as increases in operational efficiency.

Impact on Costs

Smart warehouse management systems aim to increase financial efficiency by significantly reducing the operational costs of logistics companies. These systems provide savings in various areas, from labor costs to energy consumption.

Arçelik optimizes warehouse operations and reduces costs by using smart warehouse management systems. The WMS software used at Arçelik-LG's Gebze plant automates warehouse processes, reducing labor requirements and minimizing errors. This results in a significant reduction in labor costs and an increase in operational efficiency. In addition, integrated with SAP, the system reduces inventory costs by making inventory management more effective.

Thanks to smart warehouse management systems, Yemek Sepeti reduces costs by optimizing logistics operations. The multi-restaurant system ensures that orders are automatically processed and dropped on the takeaway screen, which reduces labor costs. In addition, the acceleration of in-warehouse processes and the reduction of errors saves operational costs. Yemek Sepeti's smart warehouse systems also reduce energy costs by optimizing energy consumption.

Borusan Lojistik reduces its costs by using smart technologies in warehouse management. The automation systems used by the company reduce the need for labor by speeding up in-warehouse processes. These systems require less labor in goods receiving, placement, picking, and shipment processes, significantly reducing labor costs. Furthermore, the digital logistics platform eTA reduces logistics costs by optimizing supply chain management. Efficient inventory management and real-time

monitoring reduce inventory costs and minimize fuel consumption by optimizing transportation processes.

LC Waikiki optimizes inventory tracking and logistics processes and reduces costs by using smart warehouse systems. Identifying products with barcodes and determining their location within the warehouse makes inventory management more efficient and reduces inventory costs. Automated processing of orders and fast and accurate shipment of products to stores reduces labor costs. In addition, optimizing energy consumption reduces energy costs.

Smart warehouse management systems significantly reduce the operational costs of logistics companies. These systems provide savings in various areas, from labor costs to energy consumption, making logistics operations more efficient and cost-effective. The proliferation of these technologies in Türkiye's logistics sector offers excellent advantages in terms of cost savings and increases companies' competitiveness.

Impact on Customer Satisfaction

Customer satisfaction in the logistics industry is directly related to fast and accurate delivery of orders. Smart warehouse management systems aim to increase customer satisfaction by optimizing order preparation and delivery processes. Under this subtitle, we will examine the impact of smart warehouse management systems on the customer satisfaction of leading logistics companies in Türkiye.

Arçelik increases customer satisfaction by making warehouse operations more efficient through smart warehouse management systems. WMS software optimizes inventory management, ensuring accurate and fast storage and shipment of products. This system allows Arçelik to manage the logistics chain from production to the consumer more effectively, which ensures that products reach customers on time and accurately. Thus, customer expectations are met, and satisfaction is increased.

Yemek Sepeti optimizes order preparation and delivery processes using smart warehouse systems. The system enables restaurants to track and process their orders quickly and easily. The multi-restaurant system shortens delivery times by ensuring that orders automatically appear on the takeaway screen. This ensures fast and accurate deliveries to customers and increases customer satisfaction. In addition, the reporting and communication features offered by the system help resolve customer complaints quickly, which increases overall satisfaction.

Borusan Lojistik increases customer satisfaction by using smart warehouse technologies. Automation systems speed up goods receiving, storage, and shipment processes, ensuring accurate and timely delivery of orders. Real-time monitoring and data analytics enable customers to be instantly informed about the status of their orders. Furthermore, the eTA digital logistics platform optimizes transportation processes, shortening delivery times and increasing customer satisfaction.

Thanks to smart warehouse management systems, LC Waikiki increases customer satisfaction by improving inventory tracking and logistics processes. Identifying products with barcodes and determining their location in the warehouse makes

inventory management more efficient and minimizes stock errors. Automated processing of orders and fast and accurate shipment of products to stores increases customer satisfaction. Delivering the right products to customers on time contributes to LC Waikiki's high customer satisfaction.

Smart warehouse management systems significantly increase logistics companies' customer satisfaction. Accurate and timely delivery of orders is critical in meeting customer expectations and increasing overall satisfaction. The proliferation of these technologies in the logistics sector in Türkiye offers excellent advantages in terms of customer satisfaction and increases companies' competitiveness.

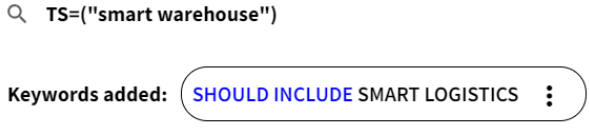
3.2. Bibliometric Analysis

The second method employed in this study is a bibliometric analysis, used to identify research trends in the literature. The Web of Science database was searched using the keyword "smart warehouse," and the resulting data were subjected to bibliometric analysis.

Steps:

- Data Collection: Documents published between 2000 and 2024 were analyzed. A total of 503 documents were included in the analysis, with an annual growth rate of 15.68%. The average age of the documents was 3.72 years, and the average number of citations per document was 13.58.
- Keyword Analysis: 558 different keywords (Keywords Plus and Author's Keywords) and 1,633 unique authors were identified.

The literature searches were conducted in the Web of Science database using the query:



https://www.webofscience.com/wos/woscc/summary/87bb336c-bf1c-48fa-9866-aedf14040a8f-f8ed83e4/relevance/1

Methodology: The steps of the bibliometric analysis included preparing the dataset, conducting citation analysis, keyword co-occurrence analysis, and trend analysis. The results highlight research trends and developments in smart warehouse systems in Türkiye.

Searches encompassed article titles, abstracts, and keywords, and relevant studies were selected based on their relevance to the topic. Citation information was utilized to export data, and bibliometric analysis was performed using the Bibliometrix software (RStudio). This analysis aimed to identify various aspects and trends of existing research, pinpoint gaps in the literature concerning sustainability and the furniture industry, and clarify the context of this study. This literature review elucidates the knowledge base and research methods underpinning the study and

provides the framework for the analyses and findings presented in subsequent sections.

Findings

This chapter presents the current research trends and areas of interest in smart storage systems based on bibliometric data from the Web of Science database. The study was conducted on 503 documents between 2000 and 2024. The annual growth rate of the data was 15.68%, and the documents' average age was 3.72 years. The average number of citations per document was 13.58, totaling 17,440 references. In our study, 558 keywords were identified, including Keywords Plus and Author's Keywords, and 1,633 authors were identified. Document types included 262 articles, 184 papers, 27 reviews, and other types (table 1.).

Table 1. Main Information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2000:2024
Sources (Journals, Books, etc)	349
Documents	503
Annual Growth Rate %	15,68
Document Average Age	3,72
Average citations per doc	13,58
References	17440
DOCUMENT CONTENTS	
Keywords Plus (ID)	558
Author's Keywords (DE)	1633
AUTHORS	
Authors	1593
Authors of single-authored docs	44
AUTHORS COLLABORATION	
Single-authored docs	44
Co-Authors per Doc	3,98
International co-authorships %	29,62
DOCUMENT TYPES	
article	262
article; book chapter	1
article; early access	13

article; proceedings paper	2
article; retracted publication	5
book	1
editorial material	2
editorial material; book chapter	2
meeting abstract	3
proceedings paper	184
retraction	1
review	0

The findings will help us understand the overall distribution of research on smart warehouse systems, prominent topics and future research trends.

Source Analysis

The table below shows the sources where the most articles on "smart storage" were published and the number of articles in these sources.

Table 2. Most Relavant Sources

Sources	Articles
IEEE ACCESS	19
SUSTAINABILITY	18
APPLIED SCIENCES-BASEL	10
IEEE INTERNET OF THINGS JOURNAL	10
SENSORS	7
IFAC PAPERSONLINE	6
INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	6
LOGISTICS-BASEL	5
MACHINES	5
BENCHMARKING-AN INTERNATIONAL JOURNAL	4

Table 2. shows the sources where most of the "smart storage" articles have been published. Most articles were published in IEEE ACCESS and SUSTAINABILITY, with 19 and 18 articles, respectively. This shows that these journals are important in the literature on the topic. In addition, other journals such as APPLIED SCIENCES-BASEL and IEEE INTERNET OF THINGS JOURNAL also stand out as essential sources, contributing ten papers each. These journals are the center of research on smart warehouse systems and intensify research activities in this field.

Keywords Analysis

In the analysis, the frequency analysis of the terms frequently mentioned in the literature was examined (Figure 1.).

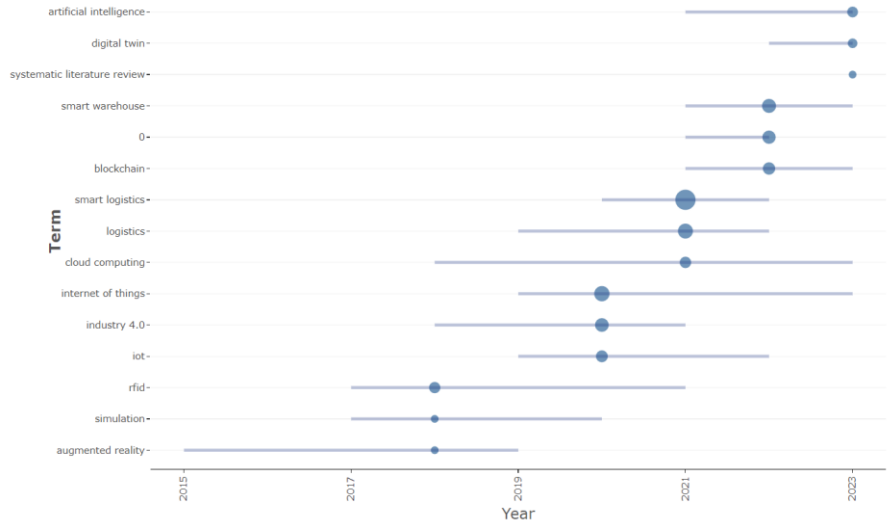
Fig. 1. Word Cloud Analysis

According to the results of the analysis, we see that terms such as "smart logistics," "internet of things," and "industry 4.0" are the most prominent keywords in smart warehouse systems research. These terms are frequently used in studies emphasizing integrating smart warehouse technologies into logistics operations, the development of industrial automation, and digital transformation processes in warehouse management. In addition, new technologies such as 'blockchain' are attracting increasing attention in smart warehouse systems research. The frequency of these terms can guide future research and contribute to identifying new directions for developing smart warehouse systems.

Trend Topics Analysis

This trend analysis reveals changes in the popularity and research focus of specific terms in the academic literature over time. For example, "smart logistics" and "smart warehouse" have significantly increased in recent years, reflecting the emphasis on digitalization and automation in the logistics sector. On the other hand, although the term "industry 4.0" was used with the highest frequency in 2018, the level of interest has decreased over time, indicating that the priorities of this term in the literature have changed. Again, the popularity of new technologies such as "blockchain" and "cloud computing" has increased in recent years, indicating that research in these areas has intensified and interest in emerging technologies has increased. This analysis provides an important guide for academic researchers in understanding current trends and shaping their future work (graph 1.).

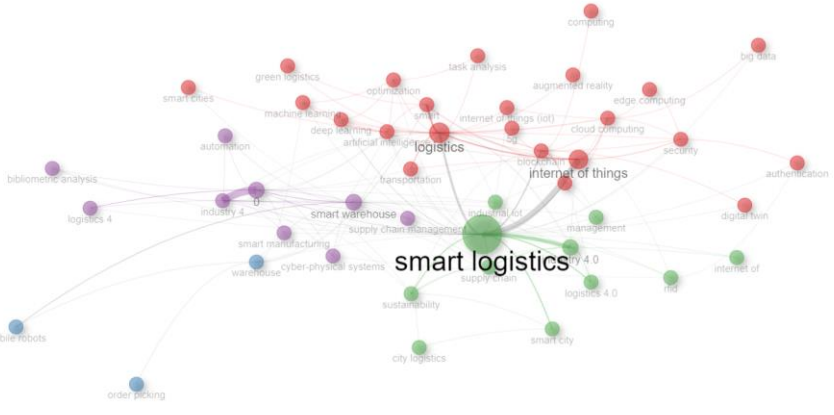
Graph 1. Trend Topics Analysis



Following the trend analysis, a transition was made to co-occurrence network analysis to examine the relationships between the terms in depth.

Smart warehouse management and logistics technologies constitute essential components of digital transformation in the logistics sector today. These technologies significantly contribute to optimizing warehouse operations, increasing efficiency, and ensuring customer satisfaction. In order to understand this, it is necessary to evaluate the results of co-occurrence network analysis in detail (Fig 2.).

Fig 2. Co-occurrence Network



Smart logistics is one of the terms with the highest ranking in co-occurrence network analysis. This shows that smart logistics is closely related to other technologies and plays a central role in digital transformation processes in the logistics sector. Smart

logistics is integrated with other technologies, such as the Internet of Things, blockchain, and cloud computing, to optimize logistics operations, increase efficiency, and reduce costs. In this context, the high ranking of smart logistics emphasizes the importance of spreading technology-based innovations in the logistics sector and the combined use of these technologies.

4. DISCUSSION

Smart Warehouse Management Systems (SWMS) are a key component of Logistics 4.0, offering significant advantages in warehouse operations. These systems, through automation and data analytics, enhance operational efficiency, reduce costs, and improve customer satisfaction. Findings reveal that companies like Arçelik and Borusan Lojistik in Türkiye have successfully integrated smart warehouse systems, optimizing their processes and increasing their ability to respond quickly to customer demands. This is consistent with global literature, where companies implementing SWMS report similar improvements in flexibility and responsiveness (Lee et al., 2018). However, our findings show that the level of automation in Türkiye's logistics sector, especially in small and medium-sized enterprises (SMEs), is significantly lower than in more developed economies, such as the United States or Germany (Zhong et al., 2017). This indicates that while large companies benefit from these systems, SMEs face distinct challenges in implementing them.

However, alongside the advantages, several challenges emerge, especially for SMEs. One of the most critical challenges is cost (Lee et al., 2018). The installation, operation, and maintenance of smart warehouse systems require substantial investments, which may act as a deterrent for smaller companies. Our study aligns with findings from previous research (Min, 2023), which indicate that while large companies may have the resources to invest in such systems, SMEs struggle with the initial capital outlay and ongoing costs of system updates and technology upgrades. In Türkiye, this financial burden is even more pronounced, given the currency fluctuations and economic pressures faced by businesses. Similar challenges have been noted in other emerging markets, such as India, where the high cost of technological infrastructure limits adoption (Kumar et al., 2022).

Another significant challenge identified in our findings is the lack of technological expertise. For SWMS to be effectively implemented, logistics personnel need to be trained to operate and manage these systems. The gap in digital skills, especially in traditional sectors of the Turkish logistics industry, hinders the full adoption of SWMS. This finding supports earlier studies (Kumar et al., 2022), which argue that training and human resource development are critical to ensuring the success of technological adoption. Additionally, our research suggests that without adequate investment in employee training programs, the potential of SWMS cannot be fully realized. This challenge mirrors global trends, as found in studies on the implementation of SWMS in Southeast Asia, where the lack of skilled personnel remains a key barrier (Bai et al., 2018).

Data security is another major concern highlighted in our study. As smart warehouses rely on real-time data collection and analysis, protecting this data from cyber threats

is critical. Our findings align with global concerns about cybersecurity in logistics operations (Plakantara et al., 2024). The increasing dependence on interconnected systems and IoT devices increases the vulnerability of logistics operations to cyber-attacks, which can disrupt operations, cause financial losses, and damage corporate reputations. In Türkiye, the increasing number of cyber threats and a lack of comprehensive data protection regulations in some sectors heighten this risk, making data security a key issue for logistics companies adopting SWMS. These concerns are echoed in recent literature focusing on data security in smart logistics systems globally (Smith and Brown, 2020).

Despite these challenges, our study demonstrates that SWMS significantly contribute to operational efficiency and cost reduction. Automation in warehouse operations reduces the need for manual labor, streamlines inventory management, and minimizes errors in order processing. In particular, real-time monitoring and decision-support systems improve the accuracy of inventory forecasts and help companies respond to changes in demand more effectively. This is consistent with the literature, which emphasizes the role of SWMS in increasing operational efficiency and improving supply chain visibility (Wang et al., 2020). However, unlike previous studies that report significant labor cost reductions through automation in large-scale manufacturing settings (Žunić et al., 2018), our findings show more modest cost reductions in the Turkish context, possibly due to lower levels of automation and the high cost of importing advanced technologies.

Furthermore, findings indicate that SWMS positively affect customer satisfaction by improving the speed and accuracy of order fulfillment. Companies that have adopted SWMS can reduce delivery times and provide more reliable services to their customers. This is particularly relevant in Türkiye, where the logistics sector is rapidly growing, and customer expectations for fast and accurate deliveries are rising. The ability of SWMS to meet these expectations is a significant competitive advantage for companies in the sector. Similar improvements in customer satisfaction have been noted in studies on e-commerce logistics in Europe and North America (Jarašūnienė et al., 2023).

While the findings offer valuable insights, there are limitations to this study. First, the multiple case analysis is limited to large companies like Arçelik and Borusan Lojistik, which may not fully reflect the challenges faced by smaller firms. SMEs, which represent a significant portion of Türkiye's logistics sector, may encounter different barriers, such as limited access to capital and technical expertise, that were not fully explored in this study. This limitation suggests that future research should focus on a more diverse sample of companies, including SMEs, to capture a broader perspective of the sector.

Secondly, the geographical focus of this study is restricted to Türkiye. While the findings provide important insights into the adoption of SWMS in an emerging market context, they may not be generalizable to other regions with different economic or technological environments. Future research could expand this scope to include comparative studies between different emerging economies, which would provide a

more nuanced understanding of the global challenges and opportunities associated with SWMS adoption.

Lastly, the data used in the multiple case analysis was largely derived from company-provided reports, which may introduce bias. Although efforts were made to corroborate these reports with external sources, there remains the potential for over-reporting of benefits and under-reporting of challenges. Future studies should incorporate more independent data sources to ensure a balanced evaluation of SWMS implementation.

In summary, while the advantages of SWMS in Türkiye's logistics sector are evident, the challenges related to cost, skills development, and data security must be addressed to ensure the widespread adoption of these systems. Future research should focus on exploring strategies to overcome these challenges, particularly for SMEs. For example, government incentives or public-private partnerships could help reduce the financial burden on smaller companies, while collaborative training programs could bridge the skills gap in the industry.

5. CONCLUSION

This study aimed to examine the adoption status of smart warehouse management systems (SWMS) in the logistics sector in Türkiye and the effects of these systems on operational efficiency, costs, and customer satisfaction. Through a combination of multiple case analysis and bibliometric analysis, we provided a comprehensive understanding of the current landscape of SWMS adoption in Türkiye. Our findings indicate that while large companies such as Arçelik and Borusan Lojistik have successfully integrated SWMS into their operations, the widespread adoption of these systems across the logistics sector, especially among small and medium-sized enterprises (SMEs), remains limited.

The bibliometric analysis conducted on the Web of Science database highlighted the growing academic interest in smart warehouse systems, with a notable increase in publications over the last decade. The results underscore the significance of SWMS as a key component of Logistics 4.0, contributing to the digital transformation of logistics operations. However, our analysis also reveals that Türkiye's logistics sector lags behind more developed economies in terms of SWMS implementation, particularly among SMEs, which face significant financial and technological barriers.

While the adoption of SWMS in Türkiye has been shown to enhance operational efficiency, reduce costs, and improve customer satisfaction, the challenges identified—such as high implementation costs, a lack of technological expertise, and concerns around data security—pose significant obstacles to broader adoption. These findings align with global literature but also highlight the unique challenges faced by emerging markets like Türkiye, where economic and infrastructural limitations exacerbate these issues.

The strengths of this study include the systematic evaluation of real-world applications through multiple case analysis and the identification of research trends and gaps via bibliometric analysis. However, the study is not without limitations. The

multiple case analysis primarily focused on large companies, which may not represent the experiences of SMEs, and the geographical scope was limited to Türkiye. Furthermore, the reliance on the Web of Science database for the bibliometric analysis restricts the breadth of academic literature reviewed, as important studies published in other databases such as Scopus may have been omitted. Future research should aim to include a broader range of companies, especially SMEs, and explore comparative studies between different emerging markets to provide a more global perspective on SWMS adoption.

This study contributes significantly to the academic literature on smart warehouse management systems by offering insights into the specific challenges and opportunities within Türkiye's logistics sector. For practitioners, it provides actionable recommendations for overcoming barriers to technology adoption, such as exploring government incentives and public-private partnerships to support SMEs. For researchers, this study sets the foundation for future work to further explore the digital transformation of logistics in emerging economies, with a particular focus on strategies to enhance technology adoption and address skills gaps.

Genişletilmiş Türkçe Özet

LOJİSTİK 4.0'IN AKILLI DEPO YÖNETİMİNE ETKİSİ: TÜRKİYE'DEKİ ŞİRKETLERDEN ÖRNEKLER VE GELECEKTEKİ EĞİLİMLER İÇİN BİBLİYOMETRİK ANALİZ

Bu çalışma, Türkiye'deki akıllı depo sistemlerinin uygulamalarını Lojistik 4.0 perspektifinden incelemektedir. Endüstri 4.0'ın getirdiği dijitalleşme ve otomasyon gelişmeleri bağlamında, akıllı depo sistemleri depo operasyonlarının optimize edilmesi ve tedarik zinciri yönetiminin geliştirilmesinde önemli bir rol oynamaktadır. Çalışma, Arçelik, Yemek Sepeti ve Borusan Lojistik gibi önde gelen Türk şirketlerinin bu teknolojileri nasıl entegre ettiklerini ayrıntılı bir şekilde ele almakta ve bu entegrasyonun avantajlarını vurgulamaktadır. Akıllı depo sistemlerinin Türkiye'nin lojistik sektöründeki stratejik öneminin altını çizen çalışma, bu teknolojilerin operasyonel verimliliği artırdığını, gerçek zamanlı izleme sağladığını, maliyetleri düşürdüğünü ve müşteri memnuniyetini artırdığını ortaya koymaktadır.

Otomatik Depolama ve Geri Alma Sistemleri (AS/RS), robotik sistemler ve gerçek zamanlı veri analitiği gibi akıllı depo sistemleri, geleneksel depo operasyonlarını daha çevik ve duyarlı ortamlara dönüştürmüştür. Bu teknolojilerin entegrasyonu yalnızca envanter yönetimini kolaylaştırmakla kalmaz, aynı zamanda gelişmiş veri görünürlüğü ve analitiği yoluyla karar verme süreçlerini de destekler. Arçelik ve Borusan Lojistik gibi şirketler, akıllı depo teknolojilerinin operasyonel performans ve müşteri hizmetlerini nasıl önemli ölçüde iyileştirebileceğini göstermektedir.

Akıllı Depo Yönetim Sistemlerine Türkiye'den Örnekler

- Arçelik: Yedek parça envanter yönetiminde AxionBlade® WMS yazılımını kullanarak operasyonel verimliliği ve lojistik süreçlerini artırıyor.

- Yemek Sepeti: Depo yönetiminde akıllı teknolojiler kullanarak lojistik operasyonlarını optimize ediyor ve hızlı teslimat süreçlerini destekliyor.
- Borusan Lojistik: Depo operasyonlarında otomasyon sistemleri kullanarak tedarik zinciri süreçlerini optimize ediyor.

LC Waikiki: Depo yönetiminde akıllı sistemler kullanarak envanter takibini ve lojistik süreçlerini iyileştiriyor.

Operasyonel Verimlilik Üzerindeki Etkisi: Akıllı depo yönetim sistemlerinin entegrasyonu, operasyonel verimliliği önemli ölçüde artırır. Otomasyon ve optimizasyon teknolojileri, depo içi süreçleri hızlandırır ve hata oranlarını azaltır. Bu sistemler, iş gücü verimliliğini artırarak lojistik operasyonlarını daha hızlı ve güvenilir hale getirir.

Maliyetler Üzerindeki Etkisi: Akıllı depo yönetim sistemleri, lojistik şirketlerinin operasyonel maliyetlerini önemli ölçüde azaltır. Otomasyon sistemleri iş gücü ihtiyacını azaltır, enerji tüketimini optimize eder ve envanter yönetimini daha verimli hale getirir. Bu sayede iş gücü maliyetleri düşer ve operasyonel maliyetler minimize edilir.

Müşteri Memnuniyeti Üzerindeki Etkisi: Müşteri memnuniyeti, siparişlerin hızlı ve doğru bir şekilde teslim edilmesi ile doğrudan ilişkilidir. Akıllı depo yönetim sistemleri, sipariş hazırlama ve teslimat süreçlerini optimize ederek müşteri memnuniyetini artırır. Bu teknolojilerin yaygınlaşması, müşteri beklentilerini karşılamak ve genel memnuniyeti artırmak için büyük avantajlar sağlar.

Bibliyometrik Analiz

Çalışmanın bir diğer önemli yönü, Web of Science veri tabanında "akıllı depo" anahtar kelimeleri kullanılarak yapılan bibliyometrik analizdir. Bu yöntemin amacı, yeni araştırma eğilimlerini ve ilgi alanlarını belirlemek için mevcut bilimsel literatürün sistematik bir incelemesini yapmaktır. Bu analiz, akademik çevrelerdeki mevcut bilgi tabanının derinleştirilmesine önemli ölçüde katkıda bulunmakta ve bu alanda gelecekteki araştırma yönlerini aydınlatmaktadır. Bibliyometrik analiz, akıllı depo sistemlerine olan ilginin arttığını, son yıllarda yayınlarda kayda değer bir artış olduğunu ve bunun da sağlam ve genişleyen bir araştırma alanına işaret ettiğini göstermektedir.

Bulgular

Web of Science veri tabanından elde edilen bibliyometrik veriler ışığında, akıllı depolama sistemleri alanındaki araştırma eğilimlerini ve ilgi alanlarını sunmaktadır. 2000 ve 2024 yılları arasında yayımlanmış 503 doküman üzerinde gerçekleştirilen araştırmanın yıllık büyüme oranı %15.68 olup, dokümanların ortalama yaşı 3.72 yıldır. Her bir belge başına düşen ortalama atıf sayısı 13.58 olup, toplamda 17,440 atıf yapılmıştır. Çalışmamızda, Keywords Plus ve Author's Keywords dahil olmak üzere 558 anahtar kelime ve 1,633 yazar belirlenmiştir. Doküman türleri arasında 262 makale, 184 bildiri, 27 inceleme ve diğer türler bulunmaktadır.

Araştırma bulguları, akıllı depo sistemleri üzerine yapılan çalışmaların genel dağılımını, öne çıkan konuları ve gelecekteki araştırma eğilimlerini anlamamıza yardımcı olacaktır. En çok makale yayımlanan kaynaklar arasında IEEE ACCESS ve SUSTAINABILITY dergileri öne çıkmaktadır. Bu dergiler, konuya ilişkin literatürde önemli bir yer tutmakta olup, akıllı depo sistemleri araştırmalarının merkezi konumundadır.

Anahtar kelime analizi sonucunda "akıllı lojistik," "nesnelerin interneti," ve "endüstri 4.0" gibi terimlerin akıllı depo sistemleri araştırmalarında en öne çıkan anahtar kelimeler olduğu görülmektedir. Bu terimler, akıllı depo teknolojilerinin lojistik operasyonlara entegrasyonunu, endüstriyel otomasyonun gelişimini ve depo yönetiminde dijital dönüşüm süreçlerini vurgulayan çalışmalarda sıkça kullanılmaktadır. Ayrıca, 'blockchain' gibi yeni teknolojiler de akıllı depo sistemleri araştırmalarında giderek daha fazla dikkat çekmektedir.

Trend konular analizi, belirli terimlerin akademik literatürdeki popülerlik ve araştırma odaklarındaki değişiklikleri ortaya koymaktadır. Örneğin, "akıllı lojistik" ve "akıllı depo" terimleri son yıllarda önemli ölçüde artış göstermiştir. Buna karşılık, "endüstri 4.0" teriminin kullanımı 2018'de en yüksek seviyedeyken, zamanla ilginin azaldığı görülmektedir. Bunun yanında, "blockchain" ve "bulut bilişim" gibi yeni teknolojilerin popülerliği son yıllarda artmış olup, bu alanlardaki araştırmalar yoğunlaşmıştır.

Eş-zamanlılık ağ analizi, terimler arasındaki ilişkileri derinlemesine incelememize olanak tanır. Akıllı lojistik, eş-zamanlılık ağ analizinde en yüksek sıralamada yer alan terimlerden biridir. Bu, akıllı lojistiğin diğer teknolojilerle yakından ilişkili olduğunu ve lojistik sektöründeki dijital dönüşüm süreçlerinde merkezi bir rol oynadığını göstermektedir.

Sonuç

Bu çalışmada, Türkiye'deki lojistik sektöründe akıllı depo yönetim sistemlerinin (ADYS) kullanımının etkileri incelenmiştir. Elde edilen bulgular, ADYS'nin operasyonel verimliliği artırdığını, maliyetleri düşürdüğünü ve müşteri memnuniyetini yükselttiğini göstermektedir. Arçelik, Yemek Sepeti, Borusan Lojistik ve LC Waikiki gibi öncü firmaların başarılı uygulamaları, bu sistemlerin potansiyelini ve sektör genelinde benimsenme hızını gözler önüne sermektedir.

ADYS'nin sağladığı faydalar açık olsa da, bu sistemlerin entegrasyonu ve bakımı önemli yatırımlar gerektirmektedir. Özellikle küçük ve orta ölçekli işletmeler için başlangıç maliyetleri ve teknik bilgi eksikliği, bu sistemlerin yaygınlaşmasını engelleyebilir. Ancak, uzun vadede sağlanan verimlilik artışı ve maliyet tasarrufları, bu yatırımların geri dönüşünü hızlandırmaktadır. Ayrıca, ADYS'nin başarılı bir şekilde uygulanabilmesi için personelin eğitimi ve sürekli güncellemelerin yapılması gerekmektedir.

Bibliyometrik Analiz:

Web of Science ve Scopus gibi veri tabanlarından elde edilen bibliyometrik analiz sonuçları, akıllı depo yönetim sistemleri konusundaki akademik ilginin ve araştırma sayısının hızla arttığını göstermektedir. Türkiye'deki araştırmalar, global trendlere paralel olarak artış göstermektedir. Özellikle son beş yılda, ADYS'nin lojistik ve tedarik zinciri yönetimindeki rolünü inceleyen çalışmaların sayısında belirgin bir artış olduğu gözlemlenmiştir. Bu da akademik ve endüstriyel ilginin ADYS'nin potansiyel faydalarını ve uygulama zorluklarını anlamaya yönelik olduğunu göstermektedir.

Bibliyometrik analiz sonuçları, ADYS üzerine yapılan araştırmaların genellikle operasyonel verimlilik, maliyet azaltma ve müşteri memnuniyeti konularına odaklandığını ortaya koymaktadır. Bu bağlamda, Türkiye'deki lojistik sektöründe ADYS'nin benimsenmesi, sektördeki rekabet gücünü artırmak için önemli bir strateji olarak görülmektedir.

Sonuç olarak, Türkiye'deki lojistik firmalarının ADYS'yi benimsemeleri ve bu sistemlerin etkin bir şekilde uygulanması, sektörde önemli faydalar sağlamaktadır. Ancak, sistem entegrasyonu ve bakım maliyetleri, küçük ve orta ölçekli işletmeler için bir engel oluşturabilir. Bu nedenle hem akademik hem de endüstriyel araştırmaların, bu zorlukların üstesinden gelmek için yenilikçi çözümler sunmaya devam etmesi gerekmektedir.

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