Impact of Warehouse Resources Optimization on Sustainable Performance: Unveiling the Moderating Influence of Seasonality

Dr. Adeel Shah
Assistant Professor, Department of Supply Chain Management Institute of Business Management, Karachi, Pakistan

Dr. Ahras Rashid
Lecturer at the Institute of Business Management Sciences University of Agriculture, Faisalabad.
ahras.rashid@uaf.edu.pk

Qurratulain Lodhi
Research Associate, Department of Supply Chain Management Institute of Business Management, Karachi, Pakistan

Dr. Sherbaz Khan
Associate Professor, Department of Business Administration, Jinnah University for Women, Karachi, Pakistan

Abstract

A warehouse is considered an integral part of supply chain operations. It plays a key role in receiving, storing, packaging, and distributing products from the suppliers to the end customers. However, warehouse management suffers from various challenges due to inappropriate infrastructure, space shortage, data entry errors, and outdated manual procedures. Integrating advanced technology can optimize operations by reducing costs and enhancing overall work efficiency. The current study aims to identify the impact of warehouse resources, i.e., human capital (HC), technology integration (TI), supply chain communication network (SCCN), and warehouse optimization (WO) on the sustainable warehouse performance (SWP) of warehouses. Additionally, the research seeks to uncover the moderating effect of seasonality on warehouse processes. A convenience sampling technique was used to gather data from 116 professional employees working in different manufacturing companies. Based on the analysis of data through Partial Least Squares techniques, results indicate that there is no direct impact of human capital, technology integration, and supply chain communication network on sustainable warehouse performance. However, a significant indirect relationship exists in the presence of optimized warehouse processes. Furthermore, the study also demonstrates the role of seasonality in moderating the relationship between human capital and warehouse sustainable performance. Hence, the findings of this study provide guidelines for companies to manage gaps in their warehouse activities and help them develop strategies to meet global standards. Future research can be performed by incorporating data from other interdisciplinary fields to address the issue of sustainability in warehousing effectively.

Keywords: *Human capital, Technology integration, Supply chain communication network and Warehouse optimization, Seasonality, and Sustainable warehouse performance.*

Introduction

The prime objective of warehouse management is to save costs, create space, manage resources, and handle inventory issues. Qiang Ren and Yaoyao Ku stated that several obstacles created hurdles in smooth warehouse operations. Inventory discrepancies are among the major issues often caused due to ineffective storage systems. Companies sometimes accept orders without accurate knowledge of product availability in the warehouse, resulting in delays in the delivery of the right product to the customer. This situation increases dissatisfaction among customers and damages the company's image in the market (Balakrishnan et al., 2023)

Warehouse management is a crucial component of the supply chain. An inefficient inventory management process often results in improper tracking of goods and leads to errors. The manual handling of large inventories increases the likelihood of human error (Jermsittiparsert et al., 2019). Additionally, the lack of consistent information flow and the absence of supporting technology complicate the company's ability to handle its inventory properly(Ren et al., 2023) This situation reflects weak organizational management, contributing to increased incidents of loss of goods and monetary losses, which pose a serious threat to the firm's existence (Parashar & Singh, 2024)

A research study conducted by the Institute of Transportation and Logistics in Indonesia emphasized that the supply chain network should be strong and coherent, particularly between procurement and warehouse departments. An Inefficient flow path of goods significantly disrupts the supply chain and distribution network (Živicnjak et al., 2022). Moreover, another significant issue in inventory management is the lack of proper records of obsolete items. The accumulation of obsolete material not only increases overhead costs but also reduces space for new products (Shah et al., 2024). Inefficient space utilization for different stock items also disrupts the supply chain network. Additionally, an improper warehouse layout can hinder effective operational performance by causing inappropriate item placement, making unnecessary goods difficult to trace and manage (Helmold & Terry, 2021a).

Large enterprises typically maintain sustainability in warehouse performance by utilizing a high level of automation technology and workflow channels to enhance effective inventory management. Warehouse management extends beyond simple commodity storage and manages the complex flow of information about the inbound and outbound goods in the warehouse (Putrevu, 2022). Similarly, a large warehouse requires a high level of consistent real-time monitoring of the commodity environment to preserve the goods in their required standard conditions. Automation in warehouses makes it easier to deal with inbound, outbound, stocktaking, weighing, and other processes effectively and also facilitates the collection of information about the product in real time (Arif et al., 2023).

In an era of innovative technologies, time management for tracking commodities and stocks is becoming more efficient every day (Duchin & Levine, 2019). Although barcode labels are less consistent, they can still be implemented in the warehouse for better tracking. RFID technology is becoming more famous, particularly in dealing with large warehouses, due to its reliability and longing efficiency. Additionally, the integration of IOT is having a huge impact on efficient warehouse management. A wide range of new sensors and devices has been established and developed across industries to support the evolution of warehouse management systems.

Furthermore, extensive and keen exploration is underway to understand the choice of electronic systems that improve the quality of warehouse operations (Khan et al., 2022).

The implementation of new integrated technologies and storage methods enhances the sustainability of warehouse performance (Shah et al., 2023). Over the past decades, innovative technologies and methods have significantly improved warehouse operations by optimizing warehouse layouts (Mohamud et al., 2023). Similarly, a robust supply chain network between procurement, warehouse, and logistics departments effectively manages huge inventory and avoids delays in production targets. (Sugiarto & Suprayitno, 2023). The experience and familiarity of the working staff with the warehouse layout are important factors in accelerating warehouse operations. An effective layout design maximizes space utilization and facilitates the stock identification process, which ultimately leads to proper channeling of warehouse operations (Kim et al., 2023).

Sustainability has become a critical aspect of warehouse performance, but it is compromised in many firms due to the lack of an inventory management system. This situation causes orders to be delayed, inventory to expire, and demand forecasting to be inaccurately calculated. Additionally, the absence of floor marking is also an area of concern in the warehouse, which raises confusion about storing the finished product according to different analyses and methods. Furthermore, the lack of a synchronized system, technological unawareness, and unskilled staff are some serious issues that directly affect the sustainable performance of the warehouse. To address these issues and meet the requirements of the procurement department, manufacturing department, and customers' demands, the firms need to build a sustainable warehouse management solution that will increase production efficiency, improve the supply chain network, order fulfillment, inventory accuracy, and foster the development of a skilled workforce.

After analyzing the gaps and challenges in warehouse operations in Pakistani industries, this research aims to develop a strategy for improving sustainable supply chain performance by optimizing warehouse operations. Additionally, the study seeks to determine the impact of technological integration, human capital, and communication on sustainable warehouse performance. Therefore, the research aims to answer the following questions:

- How does technology integration affect sustainable warehouse performance in Pakistan?
- How do new storage methods and staffing levels affect warehouse performance?
- How does the supply chain network improve the visibility of warehouse operations?
- How does warehouse layout enhance the supply chain operations, and what benefits does it provide in fulfilling the day-to-day activities in a timely manner?
- How does the integration of technology and storage methods help in overcoming seasonal trends of demand and supply more effectively?

Based on the above questions, the research has the following objectives.

- To improve sustainable warehouse performance by optimizing warehouse layout.
- Enhance the supply chain network to better track lost inventory within the warehouse.

- To evaluate the current existing technology system and identify any gaps or areas that require improvement.
- To establish and integrate data, improving real-time data synchronization and visibility.
- Optimize storage facilities by properly placing staffing levels for better utilization of space.

Literature Review

Theoretical Background

The current study is based on two theoretical frameworks: Triple Bottom Theory (TBT) and contingency theory (CT). These theories offer a conceptual perspective for firms to identify the role of warehouse resources in SWP. An effective utilization of these resources can help a company improve its operational performance. According to Farooq et al. (2021), TBT emphasizes the significance of preserving resources across societal, economic, and surrounding facets. It asserts that sustainability in business can be achieved by stabilizing the economic interest while ensuring that social and environmental aspects are not compromised.

Contingency theory highlights the contingent nature of warehouse management on a firm's supply chain performance. It suggests that an organization's behavior and performance depend on both internal and external elements, which are significantly affected by the operating surroundings (Sadowski et al., 2022). These elements serve as either motivators or constraints for attaining sustainable performance. A key aspect of these theories is ensuring alignment between managerial actions and organizational objectives for meaningful incrimination. Therefore, any sustainable practices incorporated into a warehouse operation must line up with the organization's sustainability goals. Managing the unpredictability elements of socio-economic and surrounding factors, along with organizational complexity, is essential for ideal sustainable performance (Moşteanu, 2024).

Past research indicates that to increase warehouse sustainability performance, various elements need to be accounted for, such as emerging technologies, market competitiveness, governmental regulations, supply chain disruptions, raw material costs, and resource scarcity (Aravindaraj & Rajan Chinna, 2022). Additionally, green initiatives should also be integrated with each contingency factor based on its intensity. Studies show that recent policies addressing climate change, waste management, and carbon reduction have underlined the significance of logistics actions, which are recognized as key contributors to neighborhood pollution in supply chains, including warehousing (Sadowski et al., 2022).

Several authors have discussed the positive impact of green practices in supply chains, highlighting context-specific consequences. Given that warehousing remarkably contributes to logistics costs, implementing green waste management and recycling practices within warehouses could lower operational costs and intensify performance at regional levels (Oloruntobi et al., 2023a). Moreover, conserving natural resources through lower material inventory, lower energy utilization, and decreased emission of hazardous materials encourages sustainable organizational growth (Perrotte & Colicchia, 2023).

Based on TBT and CT theory, a firm can better understand sustainability confrontations in logistics, particularly related to problems like carbon footprints or energy intensity. Previous

research has mainly focused on transportation rather than warehousing. This study wanted to fill this gap by describing a set of best practices or guidelines for various warehouse elements. These endorsed practices offer a blueprint for logistics firms and managers seeking to elevate the sustainability performance of their warehouses.

In the ever-evolving world of contemporary supply chain management, these two theoretical reviews develop a basic framework to understand various warehouse resources and their interplay. This includes factors such as human capital, technology integration, supply chain communication, storage methods, and warehouse optimization to achieve sustainable warehouse performance.

Formulation of Hypothesis

Human Capital and Sustainable Warehouse Performance:

Studies suggest that Human Capital exerts an important influence on warehouse execution. During peak seasons, an increase in order volumes often requires a larger workforce to fulfill the demands (Helmold & Terry, 2021b). Several research works underline the important role of humans in warehouse operations, linking a high number of laborers to sustainable order fulfillment, reduced lead times, and intensified customer satisfaction. Moreover, training and expertise play a major role in optimizing resource utilization, thereby affecting the feasible, unceasing warehouse operations (Gutelius & Theodore, 2019)

While Supply chain (SC) planning often orders addressing sustainability concerns like carbon footprints and energy efficiency in transportation, warehousing tends to receive less attention from both researchers and practitioners. Despite being labeled as 'green warehousing' or 'eco-warehousing,' practical practices to fulfill these objectives remain difficult to find(Yang et al., 2024). Sustainable warehouse practices encompass energy efficiency, waste reduction, and conscious operations. Existing literature recommends that sustainable warehouse performance notably contributes to SC's comprehensive sustainability (Mardani et al., 2020). The ultimate result of sustainable warehouse performance is directly intertwined with Human Capital. Therefore, enhancing human skills can strengthen border sustainability efforts within an organization.

H_1: HC has a significant impact on SWP.

Warehouse Optimization as Mediator between Human Capital and Sustainable Warehouse Performance

The individuals who make up the warehouse workforce hold an important place in warehouse operations. Even in highly automated systems, human involvement in overseeing and managing operations remains crucial (Mohsen, 2023). As emphasized by Andiyappillai (2020), resourcing within warehouses significantly affects warehouse activities. The formation of human resources, including operational resources, material handlers, and system operators, has a substantial effect on warehouse efficiency. Overburdened human resources tend to yield subpar operational outcomes, resulting in issues such as inefficiency, increased costs, and frequent order rescheduling.

Warehousing is typically considered an additional cost to the company. Order picking, the most labor-intensive process, is a significant contributor to warehouse expenses (Oloruntobi et al., 2023b). Organizations always want to reduce this cost to improve their returns. In this context, research showed various strategies used by warehouse professionals, such as mathematical models and lean management tools, to advance and optimize the picking process, ultimately aiming to improve productivity. (Pinto et al., 2023). Additionally, studies have demonstrated the use of innovative techniques such as AR, AI, and robotics to optimize warehouse operations and reduce errors with little human involvement. Therefore, we can hypothesize that WO helps the warehouse team achieve sustainable warehouse performance.

H_2: WO mediates the relationship between HC and SWP

Technology Integration and Sustainable Warehouse Performance:

The advancement of technology has brought about significant changes in how organizations manage their supply chains. Recent technologies like IoT, blockchain, Artificial intelligence, and Advanced data analytics are prominent in streamlining supply chain operations(Mohsen, 2023). Research indicates that adept integration of technology-enhanced visibility, traceability, and responsiveness across the supply chain. Furthermore, technology aids in refining inventory management, curbing wastage, and maximizing resource utilization in warehouses, which ultimately strengthens sustainable practices(Yang et al., 2024).

During peak seasons, technology integration provides great support in sustaining warehouse operations. Sophisticated technologies such as automated order processing and inventory management systems play a crucial role in enhancing efficiency and minimizing environmental impact during periods of heightened demand (Javaid et al., 2024). The incorporation of advanced technologies, like RFID systems and warehouse management software, has demonstrated a direct positive influence on promoting sustainable warehouse performance (Aravindaraj & Rajan Chinna, 2022).

H_3: TI has a significant impact on SWP.

Warehouse Optimization as Mediator between Technology Integration and Sustainable Warehouse Performance

Incorporating technology into warehouse operations brings forth advanced systems and tools that streamline processes, significantly impacting warehouse optimization (Adeniran, 2024). This improved setup plays a mediating role, influencing the warehouse's sustainable performance through heightened efficiency, waste reduction, and sustainability resource management. The integration of technology begins with warehouse optimization, which is crucial to enhancing sustainable performance within the warehouse (Ali & Kaur, 2022).

Several technologies stepped into the current marketplace to optimize warehouse operations, like RFID technology, automation, robotics, Cloud computing, JIT (just in time) systems, cross-docking, etc. (Aravindaraj & Rajan Chinna, 2022). These modifications elevate warehouse management to new levels, enabling faster-paced operations. The primary advantage is the time saved, which can be redirected towards a more beneficial purpose(Enoch Oluwademilade Sodiya et al., 2024).

A real-time location system (RLTLS) is another emerging technological approach that can improve the tracking of forklifts and other equipment in warehouses. The incorporation of RLTS has a significant impact on warehouse safety and operational performance (Halawa et al., 2020). Studies showed that optimizing warehouse processes requires speed and accuracy as crucial elements. Typically, warehouses are facing issues like the need for fast access to pick the items from their respective shelves, making an efficient ground area in the warehouse especially important. Automated warehouse systems (AWS) provide a suitable solution to this problem. The application of AWS technology, like IoT and smart devices, has played a significant role in adapting technology in warehouse operations, contributing to improved business sustainable performance (Hao et al., 2020). Therefore, in light of the above research, it is hypothesized that warehouse optimization (WO) mediates the relationship between technology integration and warehouse sustainable performance.

H_4: WO mediates the relationship between TI and SWP

Supply Chain Communication Networks and Sustainable Warehouse Performance:

Efficient communication within the supply chain is a critical factor for sustainable performance, which has varying impacts on seasonal demand.(Javaid et al., 2024). During peak periods, collaborative networks play an especially crucial role in handling heightened demand and minimizing wastage. Existing literature highlights that a well-established communication network not only improves visibility but also reduces delays and strengthens real-time information exchange. Such effective communication significantly facilitates the easy movement of goods within the supply chain and, as a result, within the warehouse (Mohsen, 2023).

Leveraging technology, such as electronic data interchange (EDI) and unified information systems, can transfer information impeccably across the supply chain network (Fellah et al., 2024). These systems allow for building effective communication among the warehouse, suppliers, and various partners. Establishing strong communication channels with customers, providing order updates, delivery information, and efficient customer service is of paramount importance in ensuring customer satisfaction (Rane et al., 2023).

Blockchain technology is another emerging technology capable of enhancing transparency in Supply chain communication networks. It helps in the smooth tracking of product information from its sourcing to delivery to the end customer, thereby improving SC operational efficiency. A centralized communication system often faces issues like data handling and the risk of single-point failure (Sunny et al., 2020). In this context, the incorporation of blockchain can keep decentralized databases in a more secure manner that leads to enhanced, sustainable warehouse performance. Hence, we hypothesized that,

H_5: SCCN has a significant impact on SWP.

Warehouse Optimization as Mediator between Supply Chain Communication Networks and Sustainable Warehouse Performance

Supply chain Communication encourages a conducive working environment and ensures accident prevention by disseminating pertinent information regarding company policies and

ongoing operations. In the context of SCCN, communication and information flow are critical drivers of efficiency in warehouse operations. They enable resource acquisition, reduce costs, and maximize profits (Zaman et al., 2024). Notably, an effective communication network is crucial to transferring real-time data among the warehouse team, other departments, and external stakeholders, which contributes to sustainable operational performance. An Optimized SCCN reduces misunderstandings, enables better cooperation, and strengthens overall efficiency. Studies show that strong communication expertise is instrumental in tasks like inventory cooperation, shipment tracking, and collaborative problem-solving endeavors.(Ngo et al., 2024)

With globalization, the need for global communication channels has increased, for smoothly transferring information among stakeholders. Today, the advancement of technology makes it possible to trade various types of commodities through various channels. Studies show that recent technologies like Blockchain, IoT, and smart devices are doing a marvelous job in improving these channels (Oteri et al., 2023). The efficient communication system aids in transporting the goods manufactured in a specific area to transfer to other boundaries (Hassija et al., 2020). In short, warehouse optimization boosts connectivity across different supply chain operations. Therefore, we hypothesized that warehouse optimization (WO) supports the supply chain communication network (SCCN) in achieving sustainable warehouse performance.

H_6: WO mediates the relationship between SCCN and SWP

Warehouse Optimization and Sustainable Warehouse Performance:

An efficient warehouse management system proved a critical component in building a company's growth strategy and enhancing its productivity. Historically, businesses struggled with confrontations in warehouse optimization, influenced by multiple external factors such as supplier partnerships, relationships with logistic providers, usage of technology, and global economic situations. The modernization of economies, particularly the shift towards digital platforms, has introduced new hurdles in warehouse management (Benzidia et al., 2024). The advent of e-commerce and the introduction of multichannel and Omni distribution channels in the market transformed warehouse management standards.

Nowadays, the emergence of new technologies in supply chain processes, like autonomous mobile robots in warehouses and the development of micro fulfillment centers, has created a demand for same-day or next-day delivery services. These dynamic changes have forced businesses to shift their warehouse operations practices to fulfill customer demands (Delikurt & Corum, 2023). Warehouse optimization now enables companies to get returns within a shorter period. Automation aids in reducing overhead expenses and enhances the overall efficiency of operations (Kakolu & Faheem, 2024).

The automation of functional processes significantly reduces labor, equipment maintenance, and management costs. Automation also minimizes manual data entry, reduces the burden on human resources, and lowers the likelihood of errors. As a result, automation supports warehouse optimization by diminishing ongoing operational costs like energy utilization, required storage space, and expenses related to safety concerns, leading to substantial material cost savings (Yarlagadda, 2024). Additionally, warehouse optimization not only streamlines

inventory and warehouse operations but also minimizes lost goods, shrinkage, and misplacement, contributing to an accurate inventory system within companies. Efficient inventory management leads to fewer fulfillment and shipping errors. Furthermore, automation solutions such as mobile devices and barcode scanners aid in the smooth movement of items in the warehouse. It also helps increase storage spaces, avoid handling issues, and streamline warehouse activities (Deepali et al., 2024)

Therefore, it is hypothesized that warehouse optimization plays a critical role as an intermediary factor among Human Capital, technology integration, supply chain communication networks, storage methods, and sustainable warehouse performance. A well-optimized warehouse enhances workflow, diminishes unnecessary movements, and maximizes space utilization, which directly contributes to the sustainability of warehouse operations. Studies suggest that a thoughtfully designed and optimized warehouse facilitates smooth goods flow, minimizes operational bottlenecks, and bolsters comprehensive efficiency (Aldin & Bafghi, 2024).

H_7: WO has a significant impact on SWP

Seasonality as Moderator between Human Capital Management and Sustainable Warehouse Performance

Seasonality has a significant impact on demand fluctuation that may influence a firm's sustainable performance (Rajani et al., 2022). Human capital typically marks the number of personnel engaged in managing operations within the warehouse. Sufficient human resourcing during high-demand periods could positively affect sustainability by ensuring efficient handling of high orders while maintaining sustainable practices. Conversely, during off-time seasons, excessive resourcing might lead to inefficiencies and contradict sustainable practices, potentially affecting the extensive sustainable warehouse performance (Agarwal et al., 2022). Therefore, grasping and adjusting human capital to seasonal variations becomes important for sustaining efficiency and powering surrounding responsible warehouse operations.

Globally, labor sourcing and training are critical aspects of warehouse management planning and forecasting. Studies indicate that labor costs account for almost 30% of warehouse expenses. Managing the labor force for seasonal demand is always an area of concern for warehouse managers (Falkenberg & Spinler, 2023). Accurate forecasting of seasonal demands enables warehouse managers to align staff to the expected volume of orders in a specific period. This correct alignment to seasonal demand helps reduce unnecessary labor costs, leads to more stabilized processes, and hence improves company performance.

Additionally, many studies related to workforce planning point out another challenge: ignoring the factor of labor heterogeneity. Every human being has to possess different capacities and skills to perform the task (Falkenberg & Spinler, 2023). Hence, the right selection of employees with relevant skills is crucial for effective work performance. Furthermore, the study suggests that during the planning phase, management should also account for any uncertainties in seasonal conditions that may affect the warehouse process. Therefore, we hypothesized that seasonality has a strong influence on workforce requirements to achieve sustainable warehouse performance.

H_8: Seasonality moderates the relationship between HC and SWP

Research Framework

Figure 1

Conceptual Framework

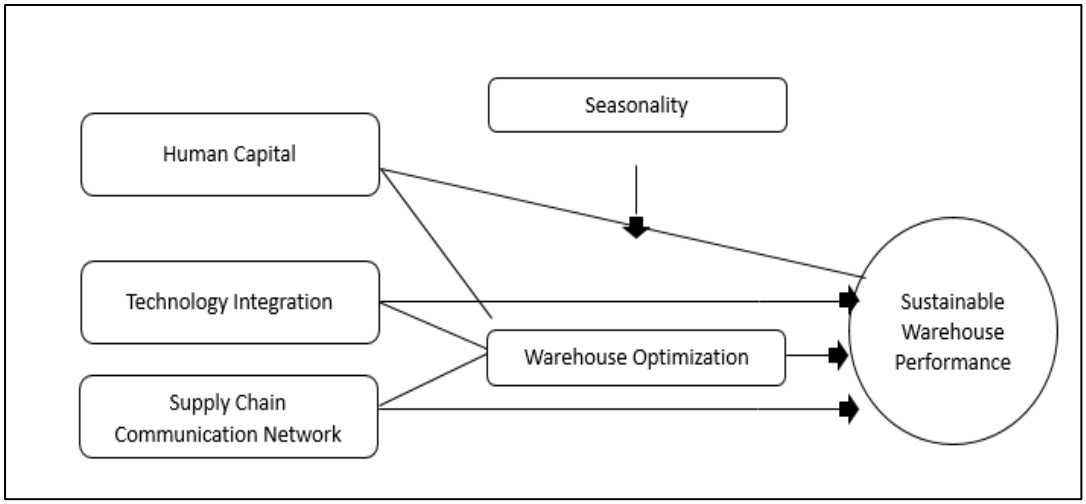

Table 1

Theoretical Model Construct with Definition

Constructs	Definition	Source
Human capital	It is skills possessed by an individual human being, considered as an asset for a firm. Investment in staff education, training, and health programs helps to increase human capital.	(Goldin, 2024)
Technology Integration	Incorporating information technology into daily business operations aids in the development of advanced enterprise systems that improve efficiency.	(Manuel Maqueira et al., 2019)
Supply Chain Communication Network	A large supply chain network involves multiple stakeholders that are associated with each other through specific information technology.	(Ben-Daya et al., 2019)
Seasonality	It is defined as repeated patterns and variabilities in demand and supply that take place at a specific time.	(Tadayonrad & Ndiaye, 2023)
Warehouse Optimization	The process of improving the major functional areas of the warehouse by incorporating technological approaches	(Živicnjak et al., 2022)
Sustainable Warehouse Performance	Considering the social, economic, and environmental dimensions in achieving the long-term warehouse goals.	(Kusrini et al., 2019)

Research Methodology

Methodology & Sampling Technique

This research focused on investigating the impact of warehouse resources on sustainable performance. An explanatory research strategy has used to determine how factors such as human capital, technology integration, supply chain communication network, and warehouse optimization influence sustainable warehouse performance. Additionally, this study also examines the role of seasonality in moderating the relationship between human capital and its impacts on improving warehouse performance.

A nonprobability convenience sampling method was used to collect data from 116 respondents associated with or doing a job in warehouse-related operations in any manufacturing firm. Data were collected by distributing the Google form via social media platforms such as WhatsApp, Facebook, and LinkedIn. The survey utilized closed-ended questionnaires adopted from the previous studies, measured on a five-point Likert scale. The questionnaires were divided into two sections; the first deals with the basic demographic information of respondents, while the second part comprises questions related to warehouse resources to judge the respondents' review of sustainable warehouse practices. Finally, to analyze the results, PLS Smart version 4 was used to identify the reliability, validity, and correlation between constructs.

Results and Discussion

Measurement Model

Demographic profile

Table 1 gives the demographic profile of the respondents. It shows that among 116 participants, 58.6% were males, while 41.7% were females. The majority of respondents, 46.6%, are in the age bracket of 31-40, while the second largest group, 31.9%, is in the age bracket of 21-30. As far as the educational level of respondents is concerned, 50.9% hold a master's degree, while 43.1% have completed a bachelor’s degree.

Table 2

Demographic Profile of the Respondents

Characteristics	Frequency	Percentage
Gender		
Male	68	58.6%
Female	47	41.4 %
Age		
Under 20	1	0.9%
21-30	37	31.9%
31-40	54	46.6%
41-50	22	19%
50 above	2	1.7%

Education Level		
Intermediate/A-Levels	1	0.9%
Bachelor	50	43.1%
Masters	59	50.9 %
PhD	1	0.9%
M Phill	5	4.3%

Reliability of the Constructs

The reliability analysis in research and psychometrics is a set of techniques used to assess the ability, consistency, and dependability of the measurements, tests, and instruments. The main goal is to determine whether the data collected through these constructs is reliable and trustworthy. Cronbach's Alpha is a common statistical method used in this study to evaluate the consistency of items within constructs. The use of Cronbach's Alpha during the development and validation of tests and surveys ensures that the items work together cohesively and measure the intended construct's reliability. If the Alpha is low (below the standard value of 0.7), it indicates that items need to be revised and eliminated to improve the scales' reliability.

Table 2 shows that the Cronbach alpha value of all constructs is above 0.7, which confirms that their internal consistency is reliable.

Table 3

Construct Reliability & Validity

Variables	Cronbach's alpha	Composite reliability	Composite reliability	(AVE)
Human Capital	0.881	0.884	0.927	0.808
Seasonality	0.878	0.886	0.908	0.622
Supply Chain Communication Network	0.801	0.810	0.884	0.718
Sustainable Warehouse Performance	0.744	0.765	0.856	0.666
Technology Integration	0.759	0.769	0.860	0.672
Warehouse Optimization	0.770	0.777	0.867	0.685

Validity of Constructs

The average variance extracted (AVE) measures how much variance each construct possesses through its items. Table 2 shows that all constructs' AVE values are above the standard range of 0.5, proving that all constructs fulfill the convergent validity condition. The discriminant validity of constructs is measured through the Fornell-Larcker. Table 3 represents the Fornell-Larcker scale, which shows that the diagonal value of all constructs is greater than the

correlation value of other constructs, representing that each construct is different and measures a unique concept.

Table 4
Discriminant validity (Fornell-Larcker Criteria)

Variables	HC	SE	SCCN	SWP	TI	WO
Human Capital	0.899					
Seasonality	0.783	0.788				
Supply Chain Communication Network	0.686	0.889	0.847			
Sustainable Warehouse Performance	0.618	0.750	0.714	0.816		
Technology Integration	0.868	0.729	0.665	0.660	0.820	
Warehouse Optimization	0.479	0.580	0.601	0.802	0.595	0.828

Correlation

Correlation describes the strength of the relationship between all variables. It is a way to determine whether the association between the constructs is positive or negative based on the numerical values evaluated. The correlation value lies between 0.5 to 0.7 (Hüsser, 2017). shows strong relationships between constructs. However, a value less than 0.5 shows a weak relation with the variable. The zero value shows that no relation exists between the variables (Tabachnick & Fidell, 2019). Moreover, the values from 0.7 to 0.9 show very strong relations. From Table 4, the highest correlation value is for technology integration and human capital, which is 0.868. In contrast, the lowest value exists between warehouse optimization and human capital, which is 0.479, showing the weak relationship between these constructs.

Table 5

Correlation table

Variables	HC	SE	SCCN	SWP	TI	WO
Human Capital	1.000					
Seasonality	0.783	1.000				
Supply Chain Communication Network	0.686	0.889	1.000			
Sustainable Warehouse Performance	0.618	0.750	0.714	1.000		
Technology Integration	0.868	0.729	0.665	0.660	1.000	
Warehouse Optimization	0.479	0.580	0.601	0.802	0.595	1.000

Structural Model and Hypothesis Testing

To test the hypothesis, PLS Smart version 4 was utilized. The results indicate that human capital, technology integration, and supply chain communication networks have no direct impact on sustainable warehouse performance. Thus, hypotheses H_1 ,H_3, and H_5 were rejected. The study also reveals that warehouse optimization has a significant impact on sustainable

warehouse performance. Therefore, hypothesis H_7 is accepted. Moreover, the research shows that warehouse optimization significantly mediates the relationship between human capital, technology integration, and supply chain communication networks to sustainable warehouse performance. This is shown through the acceptance of hypotheses H_2, H_4, and H_6. The results are discussed in Tables 5 and 6.

Table 6

Path Coefficient Hypotheses Testing

H	Path	T statistics	P values	Support
H_1	HC -> SWP	0.815	0.415	NO
H_7	WO -> SWP	13.453	0.000	YES
H_5	SCCN-> SWP	0.050	0.960	NO
H_3	TI -> SWP	0.514	0.607	NO

Table 7

Specific Indirect Effect

H	Path	T statistics	P values	Support
H_2	HC-> WO -> SWP	4.517	0.000	YES
H_6	SCCN-> WO-> SWP	7.463	0.000	YES
H_4	TI-> WO -> SWP	6.395	0.000	YES
H_8	SE × HC -> SWP	7.354	0.000	YES

H_1: Human Capital has no significant impact on Sustainable Warehouse Performance. This result is consistent with (Agyabeng-Mensah & Tang, 2021) shows that green human capital has no significant impact on sustainable performance.

H_2: Warehouse optimization has significantly mediated the relationship between human capital and sustainable warehouse performance, which is consistent with the research (Popović et al., 2021) that discusses how efficient utilization of supply chain resources reduces labor costs and time, leading to sustainable warehouse performance.

H_3: Technology Integration has no significant impact on sustainable warehouse performance. This outcome is consistent with a study performed by (Mahroof, 2019) It demonstrates the

challenges of incorporating AI in warehouse operations due to a shortage of skills and the typical mindset of management.

H_4: Warehouse Optimization has significantly mediated the relationship between technology integration and Sustainable Warehouse Performance. This hypothesis is consistent with a study that showed that optimizing warehouse operations helps encompass innovative technologies that enhance sustainable organizational performance (Maswanganyi et al., 2024).

H_5: The supply chain network has no positive significant impact on sustainable warehouse performance. This hypothesis is inconsistent with research demonstrating that the supply chain communication network is the most important factor impacting sustainable business performance (Trivellas et al., 2020). Additionally, another study conducted by (Dehgani & Jafari Navimipour, 2019) Also, discussing efficient supply chain communication networks improves relationships among supply chain partners, thereby improving sustainable performance.

H_6: Warehouse optimization has significantly mediated the relationship between Supply chain communication network and sustainable warehouse performance. The results are consistent with studies performed by (Bhatti & Faisal, 2023) Demonstrating that warehouse optimization boosts sustainable warehouse operation by improving communication throughout the supply chain.

H_7: Warehouse Optimization has a significant impact on Sustainable Warehouse Performance. This hypothesis is consistent with the study conducted by (Nguyen, 2024) shows that optimization of inventory management through the ARIMA model in the aviation sector results in superior warehouse performance

H_8: Seasonality moderates the relationship between Human Capital and sustainable performance. The research supports this hypothesis. (Borucka, 2023) Said that seasonality has a strong influence on product demand. Optimizing inventory planning and forecasting in warehouse operations can help managers efficiently utilize the workforce to attain required targets, enabling firms to achieve sustainable performance.

Conclusion and Discussion

Conclusion

This research provides valuable information related to the impact of different supply chain resources on the sustainable performance of warehouses. The study comprised eight hypotheses, including four direct and four indirect hypotheses. Based on the results, it is concluded that human capital, technological integration, and supply chain communication networks greatly influence the optimization of warehouse procedures. Moreover, it also verifies that warehouse optimization promotes and leads to sustainable warehouse performance. Furthermore, seasonality appears to be a moderating factor that strengthens the relationship between human capital and sustainable warehouse performance.

On the other hand, results also indicate that human capital, technology integration, and supply chain communication networks failed to impact sustainable warehouse performance. These parameters can be tested in future research.

Theoretical and Managerial Implications

This study is helpful in understanding the dynamic nature of different resources in supply chain operations and their effects on emerging field of study. It helps organizations understand the rising innovative technologies like block chain, robotics, AI, IoT, and other emerging techniques in warehouse operations and sustainable performance. Managers can examine how mechanization and autonomous technologies are integrated into warehouses and how this affects efficiency, saving, and green sustainability. They can analyze the role of employee progress and training initiatives in improving staff enthusiasm, happiness, and commitment and sustain long-term warehouse performance.

Additionally, the study provides insights to examine the effects of real-time statements and information-sharing platforms on supply chain networks' sustainability and efficiency. Finding of this research also highlight impact of seasonality in demand fluctuation. Thereby, requires manager to utilize predictive analytics for forecasting, planning and allocation of resources to improve performance throughout seasonal cycle.

Future Research

Future research can provide systematic sustainability indicators, such as water use, waste management, energy use, and carbon footprint, for warehouses. It can also concern the concepts of the smoothed financial system for warehouse operations to reduce waste and supply consumption. Moreover, researchers can explore the flexibility of warehouse systems in the features of disruptions, as well as natural catastrophes, geopolitical crises, and global pandemics. They can evaluate risk-managing techniques to pledge production continuity and improve warehouse sustainability.

Therefore, the current study encourages interdisciplinary research to integrate data from environmental science, social science, operation research, and supply chain organizations to address the issues of sustainable warehouse performance.

References

Adeniran, I. A. (2024). *UK . 3 Nigeria Inter-Bank Settlement System Plc (NIBSS), Nigeria . 4 Optimizing logistics and supply chain management through advanced analytics : Insights from industries*. *September*.

Agarwal, V., Mathiyazhagan, K., Malhotra, S., & Saikouk, T. (2022). Analysis of challenges in sustainable human resource management due to disruptions by Industry 4.0: an emerging economy perspective. *International Journal of Manpower*, *43*(2), 513–541.

Agyabeng-Mensah, Y., & Tang, L. (2021). The relationship among green human capital, green logistics practices, green competitiveness, social performance and financial performance. *Journal of Manufacturing Technology Management*, *32*(7), 1377–1398. https://doi.org/10.1108/JMTM-11-2020-0441

Aldin, H., & Bafghi, F. (2024). *Leveraging Blockchain Technology for Sustainable , Transparent and Efficient Supply Chain Management : An Integrative Exploration from an Engineering Management Perspective*.

Ali, S. S., & Kaur, R. (2022). Exploring the Impact of Technology 4.0 Driven Practice on Warehousing Performance: A Hybrid Approach. *Mathematics*, *10*(8), 1–22. https://doi.org/10.3390/math10081252

Aravindaraj, K., & Rajan Chinna, P. (2022). A systematic literature review of integration of industry 4.0 and warehouse management to achieve Sustainable Development Goals (SDGs). *Cleaner Logistics and Supply Chain*, *5*(June). https://doi.org/10.1016/j.clscn.2022.100072

Arif, M., Shah, A., & Khan, S. (2023). Embracing the Future: Evaluating the Strategic Impact of Digital Supply Chain Integration on Business Performance. *Journal of Asian Development Studies*, *12*(3), 376–393.

Balakrishnan, S., Azman, A. D., Nisar, J., Ejodame, O. E., Cheng, P. S., Kin, T. W., Yi, Y. J., & Das, S. R. (2023). IoT-Enabled Smart Warehousing with AMR Robots and Blockchain: A Comprehensive Approach to Efficiency and Safety. *International Conference on Mathematical Modeling and Computational Science*, 261–270.

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: a literature review. *International Journal of Production Research*, *57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140

Benzidia, S., Bentahar, O., Husson, J., & Makaoui, N. (2024). Big data analytics capability in healthcare operations and supply chain management: the role of green process innovation. *Annals of Operations Research*, *333*(2–3), 1077–1101. https://doi.org/10.1007/s10479-022-05157-6

Bhatti, M. A., & Faisal, K. (2023). *WAREHOUSE OPERATIONAL EFFICIENCY : ROLE OF MATERIAL HANDLING TECHNOLOGY , SKILLS SET , SUPPLY CHAIN COMMUNICATION NETWORK AND STAFFING LEVEL*. *6*(1), 293–311.

Borucka, A. (2023). Seasonal Methods of Demand Forecasting in the Supply Chain as Support for the Company's Sustainable Growth. *Sustainability (Switzerland)*, *15*(9). https://doi.org/10.3390/su15097399

Deepali, C., Monika, P., & Dharmendra, S. (2024). Integrating Barcode Technology into Warehouse Management Systems for Enhanced Efficiency and Inventory Accuracy. *JoCoSiR Journal of Computer Science Research*, *2337*, 8–14. http://doi.org/10.XXXXX/JoCoSiR.v2iss1.pp08-14

Dehgani, R., & Jafari Navimipour, N. (2019). The impact of information technology and communication systems on the agility of supply chain management systems. *Kybernetes*, *48*(10), 2217–2236.

Delikurt, O., & Corum, A. (2023). *Importance of Same Day Delivery of Fast-Moving Consumer Goods for E-Commerce Companies*. 1294–1302. https://doi.org/10.46254/eu05.20220263

Duchin, F., & Levine, S. H. (2019). Industrial Ecology. *Encyclopedia of Ecology: Volume 1-4, Second Edition*, *4*, 352–358. https://doi.org/10.1016/B978-0-12-409548-9.09407-0

Enoch Oluwademilade Sodiya, Uchenna Joseph Umoga, Olukunle Oladipupo Amoo, & Akoh

Atadoga. (2024). AI-driven warehouse automation: A comprehensive review of systems. *GSC Advanced Research and Reviews*, *18*(2), 272–282. https://doi.org/10.30574/gscarr.2024.18.2.0063

Falkenberg, S. F., & Spinler, S. (2023). Integrating operational and human factors to predict daily productivity of warehouse employees using extreme gradient boosting. *International Journal of Production Research*, *61*(24), 8654–8673. https://doi.org/10.1080/00207543.2022.2159563

Farooq, Q., Fu, P., Liu, X., & Hao, Y. (2021). Basics of macro to microlevel corporate social responsibility and advancement in triple bottom line theory. *Corporate Social Responsibility and Environmental Management*, *28*(3), 969–979. https://doi.org/10.1002/csr.2069

Fellah, K. El, Azami, I. El, & Makrani, A. El. (2024). A comparative analysis of blockchain and Electronic Data Interchange (EDI) in supply chain: Identifying strengths, weaknesses, and synergies. *Journal of Autonomous Intelligence*, *7*(5), 1481. https://doi.org/10.32629/jai.v7i5.1481

Goldin, C. (2024). Human capital. In *Handbook of cliometrics* (pp. 353–383). Springer.

Gutelius, B., & Theodore, N. (2019). *The Future of Warehouse Work: Technological Change in the U.S. Logistics Industry*. *October*, 1–76. http://laborcenter.berkeley.edu/future-of-warehouse-work/.

Halawa, F., Dauod, H., Lee, I. G., Li, Y., Yoon, S. W., & Chung, S. H. (2020). Introduction of a real time location system to enhance the warehouse safety and operational efficiency. *International Journal of Production Economics*, *224*, 107541.

Hao, J., Shi, H., Shi, V., & Yang, C. (2020). Adoption of automatic warehousing systems in logistics firms: A technology-organization-environment framework. *Sustainability (Switzerland)*, *12*(12). https://doi.org/10.3390/su12125185

Hassija, V., Chamola, V., Gupta, V., Jain, S., & Guizani, N. (2020). A survey on supply chain security: Application areas, security threats, and solution architectures. *IEEE Internet of Things Journal*, *8*(8), 6222–6246.

Helmold, M., & Terry, B. (2021a). *Global Supply Chain and Logistics* (Issue January 2020). https://doi.org/10.1007/978-3-030-68696-3_8

Helmold, M., & Terry, B. (2021b). *Global Supply Chain and Logistics* (Issue August). https://doi.org/10.1007/978-3-030-68696-3_8

Javaid, M., Haleem, A., Singh, R. P., & Gupta, S. (2024). Leveraging lean 4.0 technologies in healthcare: An exploration of its applications. *Advances in Biomarker Sciences and Technology*, *6*(July), 138–151. https://doi.org/10.1016/j.abst.2024.08.001

Jermsittiparsert, K., Sutduean, J., & Sriyakul, T. (2019). Role of warehouse attributes in supply chain warehouse efficiency in Indonesia. *International Journal of Innovation, Creativity and Change*, *5*(2), 786–802.

Kakolu, S., & Faheem, M. A. (2024). *Digitization and automation in mobile applications : A catalyst for operational efficiency and user engagement Digitization and automation in*

mobile applications : A catalyst for operational efficiency and user engagement. *March 2023*.

Khan, M. G., Ul Huda, N., & Uz Zaman, U. K. (2022). Smart Warehouse Management System: Architecture, Real-Time Implementation and Prototype Design. *Machines*, *10*(2), 1–21. https://doi.org/10.3390/machines10020150

Kim, T. Y., Woo, S. H., & Wallace, S. W. (2023). A recipe for an omnichannel warehouse storage system: Improving the storage efficiency by integrating block stacking and racking. *Computers and Industrial Engineering*, *182*. https://doi.org/10.1016/j.cie.2023.109320

Kusrini, E., Ahmad, A., & Murniati, W. (2019). Design Key Performance Indicator for Sustainable Warehouse: A Case Study in a Leather Manufacturer. *IOP Conference Series: Materials Science and Engineering*, *598*(1). https://doi.org/10.1088/1757-899X/598/1/012042

Mahroof, K. (2019). A human-centric perspective exploring the readiness towards smart warehousing: The case of a large retail distribution warehouse. *International Journal of Information Management*, *45*, 176–190.

Manuel Maqueira, J., Moyano-Fuentes, J., & Bruque, S. (2019). Drivers and consequences of an innovative technology assimilation in the supply chain: cloud computing and supply chain integration. *International Journal of Production Research*, *57*(7), 2083–2103. https://doi.org/10.1080/00207543.2018.1530473

Mardani, A., Kannan, D., Hooker, R. E., Ozkul, S., Alrasheedi, M., & Tirkolaee, E. B. (2020). Evaluation of green and sustainable supply chain management using structural equation modelling: A systematic review of the state of the art literature and recommendations for future research. *Journal of Cleaner Production*, *249*. https://doi.org/10.1016/j.jclepro.2019.119383

Maswanganyi, N. G., Fumani, N. M., Khoza, J. K., Thango, B. A., & Matshaka, L. (2024). *Evaluating the Impact of Database and Data Warehouse Technologies on Organizational Performance: A Systematic Review*. https://doi.org/10.20944/preprints202410.0059.v1

Mohamud, I. H., Abdul Kafi, M., Shahron, S. A., Zainuddin, N., & Musa, S. (2023). The Role of Warehouse Layout and Operations in Warehouse Efficiency: A Literature Review. *Journal Europeen Des Systemes Automatises*, *56*(1), 61–68. https://doi.org/10.18280/jesa.560109

Mohsen, B. M. (2023). Developments of Digital Technologies Related to Supply Chain Management. *Procedia Computer Science*, *220*, 788–795. https://doi.org/10.1016/j.procs.2023.03.105

Moşteanu, N. R. (2024). Adapting to the Unpredictable: Building Resilience for Business Continuity in an Ever-Changing Landscape. *European Journal of Theoretical and Applied Sciences*, *2*(1), 444–457. https://doi.org/10.59324/ejtas.2024.2(1).37

Ngo, V. M., Quang, H. T., Hoang, T. G., & Binh, A. D. T. (2024). Sustainability-related supply chain risks and supply chain performances: The moderating effects of dynamic supply chain management practices. *Business Strategy and the Environment*, *33*(2), 839–857. https://doi.org/10.1002/bse.3512

Nguyen, N. (2024). *Utilizing machine learning to enhance optimal inventory management: case: aviation industry spart parts*.

Oloruntobi, O., Mokhtar, K., Mohd Rozar, N., Gohari, A., Asif, S., & Chuah, L. F. (2023a). Effective technologies and practices for reducing pollution in warehouses - A review. *Cleaner Engineering and Technology*, *13*(March), 100622. https://doi.org/10.1016/j.clet.2023.100622

Oloruntobi, O., Mokhtar, K., Mohd Rozar, N., Gohari, A., Asif, S., & Chuah, L. F. (2023b). Effective technologies and practices for reducing pollution in warehouses - A review. *Cleaner Engineering and Technology*, *13*(March), 100622. https://doi.org/10.1016/j.clet.2023.100622

Oteri, O. J., Onukwulu, E. C., Igwe, A. N., Mikki Ewim, C. P.-, Ibeh, A. I., & Sobowale, A. (2023). Cost Optimization in Logistics Product Management: Strategies for Operational Efficiency and Profitability. *International Journal of Multidisciplinary Research and Growth Evaluation*, *4*(1), 852–860. https://doi.org/10.54660/.ijmrge.2023.4.1-852-860

Parashar, A., & Singh, A. (2024). *Streamlining Purchase Requisitions and Orders : A Guide to Effective Goods Receipt Management*. *October*.

Perotti, S., & Colicchia, C. (2023). Greening warehouses through energy efficiency and environmental impact reduction: a conceptual framework based on a systematic literature review. *International Journal of Logistics Management*, *34*(7), 199–234. https://doi.org/10.1108/IJLM-02-2022-0086

Pinto, A. R. F., Nagano, M. S., & Boz, E. (2023). A classification approach to order picking systems and policies: Integrating automation and optimization for future research. *Results in Control and Optimization*, *12*(July). https://doi.org/10.1016/j.rico.2023.100281

Popović, V., Kilibarda, M., Andrejić, M., Jereb, B., & Dragan, D. (2021). A new sustainable warehouse management approach for workforce and activities scheduling. *Sustainability (Switzerland)*, *13*(4), 1–19. https://doi.org/10.3390/su13042021

Putrevu, V. L. P. K. (2022). *Study on the impact of data and information quality on warehouse management of raw materials on the supply chain in an enterprise of the consumer goods branch*.

Rajani, R. L., Heggde, G. S., Kumar, R., & Chauhan, P. (2022). Demand management strategies role in sustainability of service industry and impacts performance of company: Using SEM approach. *Journal of Cleaner Production*, *369*, 133311.

Rane, N., Choudhary, S., & Rane, J. (2023). Metaverse for Enhancing Customer Loyalty: Effective Strategies to Improve Customer Relationship, Service, Engagement, Satisfaction, and Experience. *SSRN Electronic Journal*, *05*, 427–452. https://doi.org/10.2139/ssrn.4624197

Ren, Q., Ku, Y., Wang, Y., & Wu, P. (2023). Research on design and optimization of green warehouse system based on case analysis. *Journal of Cleaner Production*, *388*(December 2022), 135998. https://doi.org/10.1016/j.jclepro.2023.135998

Sadowski, A., Wojciechowski, P., & Engelseth, P. (2022). The contingent nature of warehouse flexibility. *International Journal of Productivity and Performance Management*, *71*(8), 3417–3442. https://doi.org/10.1108/IJPPM-05-2020-0250

Shah, A., Che Mat, C. R., Ibrahim, A., Zhang, Y., & Muzammil, S. (2024). Understanding Digital Supply Chains in the Context of Industrial Ecology. In *Industrial Ecology: A Fusion of Material and Energy in Green Supply Chain Context* (pp. 55–105). Springer.

Shah, A., Soomro, M. A., Zahid Piprani, A., Yu, Z., & Tanveer, M. (2023). Sustainable supply chain practices and blockchain technology in garment industry: An empirical study on sustainability aspect. *Journal of Strategy and Management*.

Sugiarto, M., & Suprayitno, D. (2023). Analysis of Factors Causing Logistics Warehouse Inventory Mismatch at PT Dai Nippon Printing Indonesia. *Sinergi International Journal of Logistics*, *1*(1), 17–31. https://doi.org/10.61194/sijl.v1i1.12

Sunny, J., Undralla, N., & Madhusudanan Pillai, V. (2020). Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers and Industrial Engineering*, *150*. https://doi.org/10.1016/j.cie.2020.106895

Tadayonrad, Y., & Ndiaye, A. B. (2023). A new key performance indicator model for demand forecasting in inventory management considering supply chain reliability and seasonality. *Supply Chain Analytics*, *3*(June), 100026. https://doi.org/10.1016/j.sca.2023.100026

Trivellas, P., Malindretos, G., & Reklitis, P. (2020). Implications of green logistics management on sustainable business and supply chain performance: evidence from a survey in the greek agri-food sector. *Sustainability (Switzerland)*, *12*(24), 1–29. https://doi.org/10.3390/su122410515

Yang, X., Su, M., Zhang, T., & Jia, F. (2024). The integration of sustainability into the service supply chain: towards a research agenda. *International Journal of Logistics Research and Applications*, 1–26. https://doi.org/10.1080/13675567.2024.2391978

Yarlagadda, V. K. (2024). Cutting-edge developments in Robotics for Smart Warehousing and Logistics Optimization. *Robotics Xplore: USA Tech Digest*, *1*(1), 61–79.

Zaman, M., Puryear, N., Abdelwahed, S., & Zohrabi, N. (2024). A Review of IoT-Based Smart City Development and Management. *Smart Cities*, *7*(3), 1462–1501. https://doi.org/10.3390/smartcities7030061

Živicnjak, M., Rogic, K., & Bajor, I. (2022). Case-study analysis of warehouse process optimization. *Transportation Research Procedia*, *64*(C), 215–223. https://doi.org/10.1016/j.trpro.2022.09.026