American Journal of Scholarly Research and Innovation
Volume 02 Issue 02 (2023)
Page No: 30-51
DOI:10.63125/c5wry644

Article

THE ROLE OF RESOURCE ALLOCATION EFFICIENCY IN SUPPLY CHAIN OF TEXTILE & APPAREL MANUFACTURING INDUSTRIES

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Citation:
Roy, S., Orthy, A. R., & Roy, P. P. (2023). The role of resource allocation efficiency in supply chain of textile & apparel manufacturing industries. *American Journal of Scholarly Research and Innovation*, 2(2), 30-51. https://doi.org/10.63125/c5wry644

Received:
26th September 2023

Revised:
30th October 2023

Accepted:
5th Novebmer 2023

Published:
12th December 2023

ABSTRACT

Efficient resource allocation plays a crucial role in optimizing supply chain performance within the textile and apparel manufacturing industries. The ability to effectively distribute resources—such as raw materials, labor, equipment, and financial investments—directly impacts production efficiency, cost management, and supply chain resilience. This study systematically reviews and synthesizes findings from 75 peer-reviewed research papers, industry reports, and case studies to examine the impact of resource allocation efficiency on supply chain operations. The study explores how strategic resource distribution enhances production workflow, minimizes operational disruptions, and improves financial performance in a highly competitive and globalized industry. Key themes include the integration of digital technologies, lean manufacturing principles, sustainable resource utilization, and supply chain agility. Findings indicate that companies that implement structured resource allocation strategies, supported by automation and AI-driven forecasting tools, achieve greater operational efficiency, cost savings, and supply chain adaptability. Moreover, the study highlights major challenges faced by the industry, such as geopolitical risks, supply chain disruptions, labor shortages, and the bullwhip effect, which often lead to resource mismanagement and inefficiencies. The results also emphasize the growing importance of sustainability in resource allocation, as environmentally responsible practices contribute to cost reduction and long-term industry viability. The study concludes that firms that prioritize efficient resource allocation through advanced planning, real-time decision-making, and supply chain optimization can achieve a significant competitive advantage in the global textile and apparel sector. These insights provide valuable recommendations for supply chain managers, policymakers, and industry stakeholders aiming to improve resource allocation efficiency and enhance overall supply chain sustainability.

KEYWORDS

Resource Allocation, Supply Chain Efficiency, Textile Industry, Apparel Manufacturing, Lean Management, Sustainability, Digital Transformation

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INTRODUCTION

The textile and apparel manufacturing industries are undergoing significant transformations, influenced by rapid technological advancements and shifting consumer behaviors (Huynh, 2020). The emergence of the Fourth Industrial Revolution has reshaped global supply chains, making supply chain management a critical discipline that directly impacts production efficiency, cost management, and sustainability (Al Masud et al., 2023). Within this evolving landscape, resource allocation efficiency has emerged as a pivotal factor in determining the overall performance of supply chains. Proper allocation of resources, including labor, raw materials, and production capacity, is essential to ensure seamless operations and optimal utilization of assets. The influence of resource allocation extends beyond internal processes, affecting how companies manufacture products, manage logistics, and meet consumer demands in an increasingly competitive market (Haslinger et al., 2019). Moreover, the fashion calendar has expanded beyond traditional seasonal collections, driven by fast fashion and increasing consumer demand for affordable and readily available clothing. This shift has placed immense pressure on apparel manufacturers to enhance their supply chain agility (Küsters et al., 2017). Studies indicate that companies with high resource allocation efficiency are better positioned to adapt to market fluctuations, reduce lead times, and optimize production schedules (Reike et al., 2022). The ability to align resource allocation with demand forecasting plays a crucial role in maintaining competitiveness. Inefficiencies in resource allocation can lead to inventory imbalances, production bottlenecks, and increased operational costs, ultimately affecting profitability and customer satisfaction . Moreover, supply chain efficiency is heavily influenced by how well resources are allocated within an organization. In the textile and apparel industries, supply chains are often vertically integrated, with different operational units such as dyeing, weaving, and garment manufacturing located in separate facilities. Effective coordination of resources across these units is essential to maintain a streamlined production process . The proper allocation of human resources ensures that labor is distributed efficiently, minimizing downtime and increasing productivity (Almeida, 2014; Gbolarumi et al., 2021). Similarly, optimized raw material allocation enhances production continuity and reduces waste, which is particularly important given the increasing emphasis on sustainability in the fashion industry (Arafat & Uddin, 2022).

Inventory turnover serves as a key performance indicator in the apparel sector. High inventory turnover rates enable companies to introduce new fashion items frequently, reducing the risk of unsold stock accumulating over time (Pickering et al., 2016). Research highlights that efficient resource allocation contributes to improved inventory turnover by ensuring that production schedules align with real-time consumer demand. Additionally, companies that can quickly adapt their resource allocation strategies to market trends benefit from higher profitability and reduced markdown losses. Accelerating the time-to-market process is another major advantage of effective resource distribution, allowing apparel manufacturers to respond promptly to emerging fashion trends and maintain a competitive edge (Ahmad et al., 2022). Despite the clear benefits of resource allocation efficiency, several challenges hinder its effective implementation within textile and apparel supply chains. One major obstacle is supply chain complexity, as modern apparel brands often rely on global sourcing networks. The dispersion of suppliers and manufacturing units across different geographical regions creates logistical challenges that require advanced planning and coordination (Rubino et al., 2023). Unpredictable shifts in consumer demand further complicate resource allocation decisions, making real-time data analytics a necessity for forecasting and planning.

Regulatory compliance and sustainability requirements add another layer of complexity to resource allocation in the textile industry. Many countries have stringent labor and environmental regulations that dictate how resources such as water, energy, and chemicals should be utilized in production (Arafat & Uddin, 2022). Non-compliance with these regulations can lead to reputational damage and financial penalties,

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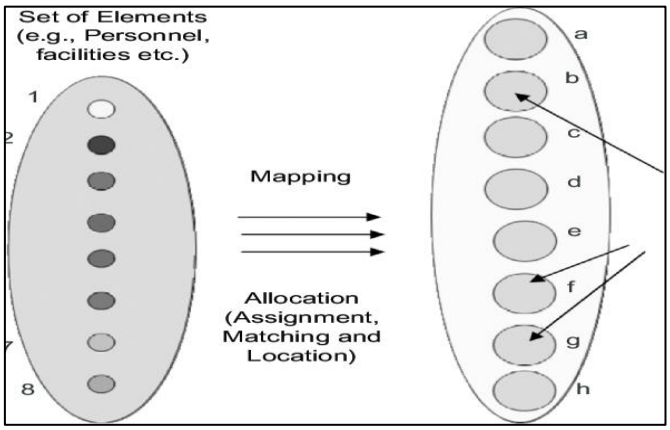
necessitating the adoption of sustainable resource allocation strategies. Additionally, small and medium-sized enterprises (SMEs) often face financial constraints that limit their ability to invest in advanced technologies for resource management. The high costs associated with digital transformation pose a barrier to achieving optimal resource allocation in supply chains (Pickering et al., 2016). Advancements in digital technologies have paved the way for more effective resource allocation strategies in the textile and apparel industries. The adoption of artificial intelligence (AI) and machine learning (ML) has significantly improved demand forecasting accuracy, allowing companies to allocate resources based on predictive insights (Palamutcu, 2010). AI-driven automation enhances operational efficiency by optimizing workforce scheduling, production planning, and inventory management. The integration of smart manufacturing technologies, such as the Internet of Things (IoT) and blockchain, has further improved supply chain visibility, enabling real-time tracking of resource utilization across different production stages (Niinimäki et al., 2020).

Figure 1: Diagrammatic Representation of Resource



Resource allocation within the supply chain serves as a multi-functional decision-making task that encompasses key aspects of time management, quality assurance, and cost control (Gören, 2018). Each supply chain process must establish specific goals related to these factors to ensure an efficient distribution of workload across available resources (Chien et al., 2016). Rather than focusing on a singular resource or work unit, the fundamental aim of the supply chain is to achieve synchronization among various activities that collectively contribute to an organization's overarching objectives (Wu et al., 2024). Textile and apparel manufacturing industries often operate within complex, multi-plant supply networks where multiple production units function simultaneously. Conflicts may arise due to competing demands for shared resources, necessitating a strategic approach to resolve structural bottlenecks and workload imbalances (Yaghin & Darvishi, 2020). The seamless coordination of these interconnected processes is essential for mitigating inefficiencies, reducing production lead times, and enhancing supply chain responsiveness. By ensuring that resources are optimally allocated at each stage of the manufacturing process, organizations can improve production consistency, meet quality standards, and maintain cost-effectiveness, thereby fostering a more resilient and adaptive supply chain (Chien et al., 2016).

Beyond operational efficiency, resource allocation plays a pivotal role in influencing various performance metrics, including productivity, organizational growth, employee and customer satisfaction, and overall business success. The efficiency of resource allocation largely determines the performance of the supply chain, as inadequate distribution of labor, materials, and technology can lead to production slowdowns, excess inventory, and financial losses (Jakhar, 2015). In the textile and apparel industries, where market dynamics and consumer preferences evolve rapidly, effective resource allocation supports agility in production planning, allowing companies to respond quickly to emerging fashion trends while maintaining competitive pricing

(Vaezi et al., 2024). This concept is particularly valuable in enabling manufacturing firms to execute value-added tasks at the right time, thereby increasing productivity and maximizing return on investment. Within the apparel and textile sectors, where just-in-time production and lean manufacturing principles are commonly employed, aligning resource allocation strategies with demand forecasts ensures minimal waste and enhanced profitability. As industries continue to embrace digital transformation and automation, integrating data-driven decision-making processes into resource allocation frameworks will further enhance supply chain performance, allowing organizations to achieve long-term sustainability and market retention.

LITERATURE REVIEW

Resource allocation efficiency plays a crucial role in determining the overall performance of supply chains, particularly in the textile and apparel manufacturing industries. The effective distribution of resources—including labor, raw materials, and technology—not only enhances operational productivity but also ensures sustainability, cost-effectiveness, and responsiveness to market fluctuations. Previous studies have explored various aspects of resource allocation within manufacturing supply chains, highlighting its impact on production agility, inventory management, and overall profitability. Given the increasing competition and the rapid evolution of consumer demands, understanding how resource allocation influences supply chain dynamics is essential for industry stakeholders. This section critically examines existing literature on resource allocation efficiency, addressing key themes such as optimization techniques, digital transformation, supply chain sustainability, and the role of advanced technologies in improving resource management. The review also explores challenges faced by textile and apparel manufacturers and identifies strategies that enhance supply chain resilience through effective resource utilization.

Resource Allocation

Efficient resource allocation plays a critical role in the operational, tactical, and strategic decision-making within the textile and apparel manufacturing industries. The process involves the optimal distribution of available resources, including labor, machinery, raw materials, and production spaces, to meet the ever-changing demands of the market (Chien et al., 2016). Resource allocation in supply chain management is closely linked to production scheduling, workforce management, and inventory control, all of which contribute to improved operational efficiency and reduced costs (Gören, 2018). Studies emphasize that organizations must allocate resources strategically to ensure smooth production flow, meet delivery deadlines, and enhance overall supply chain resilience (Jakhar, 2015; Gören, 2018). Effective resource allocation techniques are essential for managing production complexity, mitigating uncertainties, and optimizing workflow to maximize output (Yaghin & Darvishi, 2020). The ability to analyze, identify, and utilize skill sets within the supply chain is crucial for ensuring that production schedules align with market demands while minimizing disruptions (Moheb-Alizadeh & Handfield, 2017). A well-structured resource allocation framework enhances decision-making capabilities and ensures that textile manufacturers can respond to global supply chain uncertainties with agility (Wu et al., 2024).

The success of textile and apparel supply chains depends on several structured steps in resource allocation, beginning with effective production scheduling. Production planning requires segmenting total order quantities into manageable units based on style-wise delivery deadlines, followed by mapping individual departmental workflows to align with these schedules (Chien et al., 2024). Effective scheduling ensures that bottlenecks are minimized and that material flows are streamlined throughout the production process (Chien et al., 2016). Studies highlight that firms leveraging advanced production management techniques, such as artificial intelligence (AI)-driven scheduling and predictive analytics, experience significant improvements in lead-time reduction and order fulfillment rates (Ghanbarzadeh-Shams et al., 2022). Furthermore, the preparation of essential resources—including labor, machinery, facilities, and raw materials—plays a vital role in ensuring uninterrupted production

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(Hosseini Dehshiri et al., 2023). Research underscores that apparel manufacturers with robust supplier networks and resilient sourcing strategies are better positioned to handle unexpected material shortages and logistical delays (Ghanbarzadeh-Shams et al., 2022). The alignment of workforce availability with production cycles, coupled with real-time monitoring of machine utilization, enhances supply chain efficiency and reduces idle time (Arani & Torabi, 2018).

Engaging and allocating resources efficiently involves integrating all necessary inputs into the production system while addressing potential challenges such as material shortages, logistics constraints, and quality control issues (Albey et al., 2015). Studies have shown that companies that adopt digital supply chain management solutions, such as cloud-based enterprise resource planning (ERP) systems, can significantly improve resource allocation efficiency and responsiveness to market demands (Díaz-Madroñero et al., 2014). The ability to anticipate and mitigate disruptions through proactive resource planning ensures that manufacturers meet production deadlines and maintain quality standards (Ghanbarzadeh-Shams et al., 2022). Key challenges in resource allocation include geographical disparities, fluctuating raw material costs, and unpredictable supplier reliability, which necessitate data-driven decision-making (Ghasemy Yaghin & Khalajmehri, 2024). Research indicates that firms implementing lean manufacturing principles, such as Just-in-Time (JIT) inventory systems and agile resource allocation frameworks, achieve greater cost efficiency and higher production flexibility (Darvishi et al., 2020). Addressing workforce-related challenges, including absenteeism and overutilization of labor, requires dynamic workforce scheduling and performance tracking mechanisms to ensure optimal productivity (Mezatio et al., 2023). Moreover, monitoring production schedules and tracking supply chain performance metrics are essential for sustaining operational efficiency in textile and apparel industries (Heath & Jackson, 1994). Studies reveal that tracking key performance indicators (KPIs), such as supply chain performance, inventory reports, productivity levels, and right-first-time (RFT) rates, provides valuable insights into resource utilization (Ghanbarzadeh-Shams et al., 2022; Heath & Jackson, 1994). Organizations that integrate predictive analytics into their resource allocation processes can detect inefficiencies early and implement corrective measures to maintain workflow consistency (Kuo et al., 2023)). Furthermore, data-driven insights enable firms to identify overworked labor segments, address production delays, and align their manufacturing strategies with evolving market demands (Shabani-Naeeni & Yaghin, 2021). The literature consistently highlights the need for continuous improvement in resource allocation strategies through better forecasting, digital transformation, and strategic supplier collaboration to ensure long-term competitiveness in the textile and apparel manufacturing industries (Wang & Liang, 2005).

Figure 2: Ways of allocating resources (General)

Steps for Allocating Resources (in Textile & Apparel Industries)

Efficient resource allocation in textile and apparel manufacturing industries plays a critical role in maintaining production efficiency, minimizing costs, and ensuring timely order fulfillment (Abbate et al., 2023). Resource allocation is a systematic methodology that determines how best to distribute available resources, such as labor, equipment, raw materials, and financial assets, to achieve maximum operational efficiency (Araújo et al., 2008). The ability to strategically allocate resources within the supply chain impacts not only the production cycle but also overall supply chain performance and sustainability (Bruce et al., 2004). Production scheduling is a fundamental component of resource allocation, allowing manufacturers to break down orders into smaller, manageable tasks while aligning workflow across various departments (Chen et al., 2017). Studies have shown that firms adopting advanced scheduling techniques, such as AI-driven planning systems, experience significant improvements in production cycle times and efficiency (Chen et al., 2023). The integration of digital tools, such as enterprise resource planning (ERP) and cloud-based supply chain management systems, has further enhanced the accuracy and efficiency of production scheduling in the textile and apparel industry (Aouni et al., 2012).

The allocation of essential resources and budgeting processes significantly influence supply chain performance in apparel manufacturing. Proper resource management requires a detailed assessment of workforce availability, machinery functionality, and raw material procurement to ensure continuous production flow (Arafat & Uddin, 2022). Labor-intensive production processes in the textile industry necessitate effective workforce allocation to meet production targets while minimizing labor-related inefficiencies (Bruce et al., 2004). Machine availability and maintenance schedules are also crucial, as production delays caused by equipment failures can lead to increased operational costs and missed deadlines (Arafat & Uddin, 2022). Sustainable sourcing of raw materials further enhances the efficiency of resource allocation, as companies increasingly prioritize eco-friendly procurement strategies to align with circular economy principles (Bick et al., 2018). Studies highlight the importance of pre-allocating financial resources for raw material purchases, as budget constraints can disrupt supply chain operations and affect product delivery timelines (Bruce et al., 2004; Chen et al., 2023). Organizations that proactively assess budgetary needs and incorporate cost-effective resource management practices tend to achieve higher supply chain resilience and operational agility (Chen et al., 2021).

The process of engaging and allocating resources within apparel manufacturing requires synchronized execution to minimize disruptions and maximize efficiency. Digital transformation has played a crucial role in facilitating real-time resource tracking, allowing firms to monitor supply chain performance and adjust allocations dynamically (Almeida, 2014; Chen et al., 2021). One of the key challenges in resource allocation is the geographical dispersion of production units, which creates logistical complexities and supply chain inefficiencies (Bruce et al., 2004). Studies suggest that organizations adopting blockchain technology for supply chain transparency can reduce coordination delays and improve resource tracking (Chen et al., 2017). Common obstacles such as material shortages, processing delays, and inconsistent workforce availability require robust contingency planning and risk management strategies (Bruce et al., 2004). By leveraging predictive analytics and AI-driven decision-making tools, manufacturers can anticipate resource shortages and implement corrective measures before they disrupt production schedules (Akbari et al., 2002). Furthermore, effective coordination with suppliers and logistics partners enhances inventory management and reduces the likelihood of production bottlenecks (de Oliveira Neto et al., 2019).

Moreover, monitoring and tracking production schedules are crucial for maintaining efficiency in resource allocation and supply chain management. Studies emphasize the need for real-time performance tracking using key performance indicators (KPIs) such as inventory turnover rates, productivity levels, and right-first-time (RFT) percentages (Gbolarumi et al., 2021; Ghasemy Yaghin & Khalajmehri, 2024).

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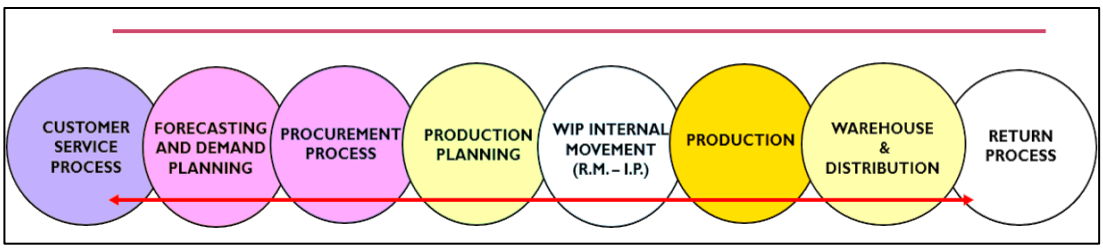
Organizations that employ big data analytics and IoT-enabled tracking systems can gain deeper insights into resource utilization patterns, helping them identify areas for improvement (Hartley et al., 2021). Workforce management and optimization play a significant role in preventing overutilization and worker fatigue, which can negatively impact production quality and efficiency (Haslinger et al., 2019). Additionally, unforeseen disruptions such as unplanned employee absences and unexpected order modifications require dynamic resource reallocation to maintain production continuity (Fersi et al., 2005). The growing emphasis on sustainable supply chain practices has further reinforced the importance of tracking resource consumption and minimizing waste (Chowdhury et al., 2023). Research highlights that companies integrating advanced tracking mechanisms with automated resource allocation strategies experience enhanced operational efficiency, reduced lead times, and improved financial performance (de Oliveira Neto et al., 2019).

Supply Chain in Textile and Apparel Manufacturing Industry

Supply chain management (SCM) plays a pivotal role in ensuring operational efficiency, cost optimization, and timely product delivery in the textile and apparel industries (Fersi et al., 2005). A supply chain is an interconnected system that facilitates the flow of materials, information, finances, and resources from suppliers to end consumers (Chowdhury et al., 2023; Fersi et al., 2005). In the apparel industry, this process includes various stakeholders such as yarn manufacturers, knitting and dyeing units, textile production facilities, garment factories, logistics providers, and retailers (Chien et al., 2024). Effective supply chain coordination is essential for maintaining smooth production cycles, minimizing disruptions, and optimizing resource allocation (Hartley et al., 2021). The implementation of strategic SCM practices allows companies to streamline operations, enhance visibility across the supply chain network, and improve collaboration among different functional units (Hasanbeigi & Price, 2015). Research emphasizes that firms adopting advanced supply chain innovations, including automation, artificial intelligence (AI), and real-time tracking, experience significant improvements in productivity and responsiveness to market fluctuations (Henry et al., 2018). Moreover, supply chain innovation directly influences the efficient allocation of key resources such as materials, labor, capital, and distribution channels (de Oliveira Neto et al., 2019). Apparel manufacturers must align their resource allocation strategies with supply chain objectives to meet production demands while minimizing waste and excess inventory (Fersi & Dhahbi, 2008). Efficient resource distribution ensures that materials and workforce availability are synchronized with production schedules, reducing the risk of overproduction or stockouts (Chen et al., 2021). Effective logistics management also plays a crucial role in supply chain success, allowing firms to optimize warehouse operations, transportation networks, and last-mile delivery (Hartley et al., 2021). Studies indicate that real-time inventory tracking and predictive analytics contribute to improved decision-making in supply chain distribution, helping organizations reduce costs and enhance supply chain agility (Chen et al., 2021; Hartley et al., 2021). Supply chain flexibility is another essential aspect of resource allocation, as companies need to adapt to changing consumer preferences, fluctuating raw material prices, and global supply chain disruptions (Henry et al., 2018).

Figure 3: Internal Supply Chain Collaboration (General)



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Supply chain models in the textile and apparel industries vary based on several factors, including supplier selection, logistics configurations, material flow strategies, and distribution networks (Chowdhury et al., 2023). The effectiveness of these models depends on factors such as geographic location, the degree of vertical integration, and the level of supply chain control exercised by manufacturers (Fersi & Dhahbi, 2008). Supply chain models can be categorized into push and pull systems, where push strategies focus on mass production and inventory stocking, while pull strategies emphasize demand-driven manufacturing to minimize waste and improve efficiency (Haslinger et al., 2019; Henry et al., 2018). Studies have shown that hybrid supply chain models, which integrate both push and pull mechanisms, offer increased flexibility and responsiveness to dynamic market conditions (Huynh, 2020). Sustainable supply chain models are gaining prominence in the apparel industry, with companies investing in ethical sourcing, eco-friendly materials, and waste reduction initiatives to align with circular economy principles (Gbolarumi et al., 2021). Additionally, digital supply chain models leveraging AI, blockchain, and IoT technologies are revolutionizing inventory management, supplier relationships, and production forecasting (Ghasemy Yaghin & Khalajmehri, 2024).

The efficiency of supply chain operations depends on the accuracy and availability of information that facilitates real-time decision-making and resource utilization (Haslinger et al., 2019). Advanced SCM systems incorporate big data analytics, cloud computing, and automation tools to optimize procurement, production, and logistics functions (Fersi & Dhahbi, 2008). The ability to synchronize supply chain activities with market demand enables manufacturers and retailers to avoid overproduction, reduce lead times, and lower operational costs (Henry et al., 2018). A well-structured supply chain minimizes unnecessary expenses related to procurement, inventory holding, transportation, and logistics, contributing to overall cost efficiency (Haslinger et al., 2019). Studies have highlighted the importance of SCM in ensuring resource mobility, production flexibility, and logistics optimization, which are essential for achieving supply chain sustainability and long-term competitiveness (Ghasemy Yaghin & Khalajmehri, 2024). Companies that implement supply chain digitization and automation strategies report significant improvements in cost reduction, operational resilience, and customer satisfaction (Henry et al., 2018).

Moreover, Mathematical modeling and optimization techniques, such as the Multi-Commodity Network Flow with Variable Lead-Time Bound (MCNF-VLB) model, have been applied to analyze supply chain resource allocation and distribution efficiency (Gardas et al., 2018). Research by Quan Qi at the University of Tennessee has provided insights into how mathematical approaches can optimize material flows within strict deadlines, ensuring better supply chain synchronization (Chen et al., 2021). Such models enable apparel manufacturers to enhance demand forecasting accuracy, minimize production delays, and optimize warehouse management strategies (Chowdhury et al., 2023). Predictive modeling and simulation techniques have proven effective in addressing supply chain bottlenecks, improving logistics coordination, and mitigating risks associated with material shortages (de Oliveira Neto et al., 2019). The integration of AI-driven supply chain planning tools has further enhanced the ability of firms to anticipate disruptions, automate resource allocation, and improve overall efficiency (Ghasemy Yaghin & Khalajmehri, 2024). Companies that incorporate predictive analytics into their supply chain strategies can proactively adjust production schedules, supplier contracts, and logistics routes to achieve optimal performance and cost savings (Chen et al., 2021).

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Figure 4: General model of a supply chain in the apparel industries

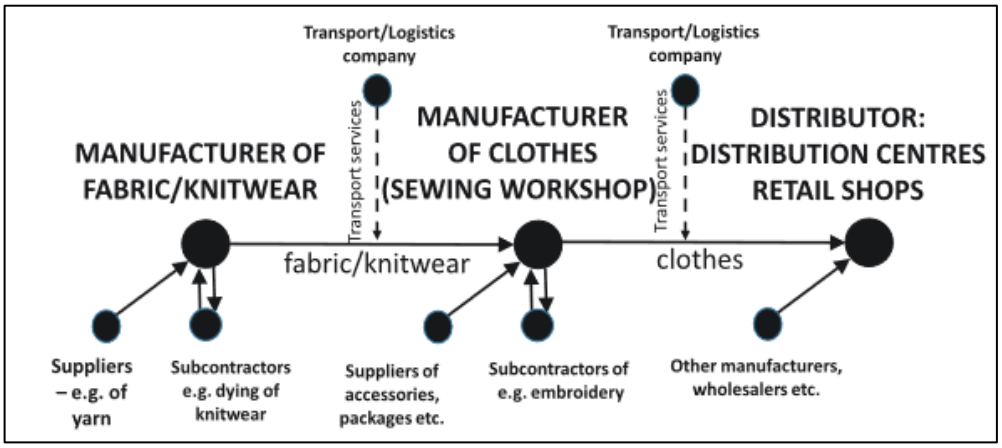

Figure 5: Differences in supply chain models in the apparel industries of Poland

Supply chain leader; activities	Distribution and sale	Characteristics of production	Place of main storage in supply chain
LPP S.A. – design, distribution and sale	Logistic centre; network of the company's own stores in Poland and in 20 other countries; online sales	– Mass – Outsourced – Mainly – in countries with low production costs	Logistics Centre, From manufacturers to the Logistics Centre – push, from the Centre to stores – pull
Macaroni Tomato – design, sale	Own sales store Online sales	– Mainly individualized (MTM 40%, MTO 40%, RTW 20%), – Outsourced – Sewing factories in Poland and Italy	MTM – at the fabric manufacturer MTO – in sewing workshops RTW – in the store
Unikat – design, manufacture	Warehouse of finished products, sales in several hundreds of foreign stores, online sales	– Mass – Own sewing workshop – In Poland	Warehouse of finished products
Keia – design, manufacture, sale	Delivery to customers, company's store, online sales	– Mainly individualized – Own sewing workshop – In Poland	Fabric supplier

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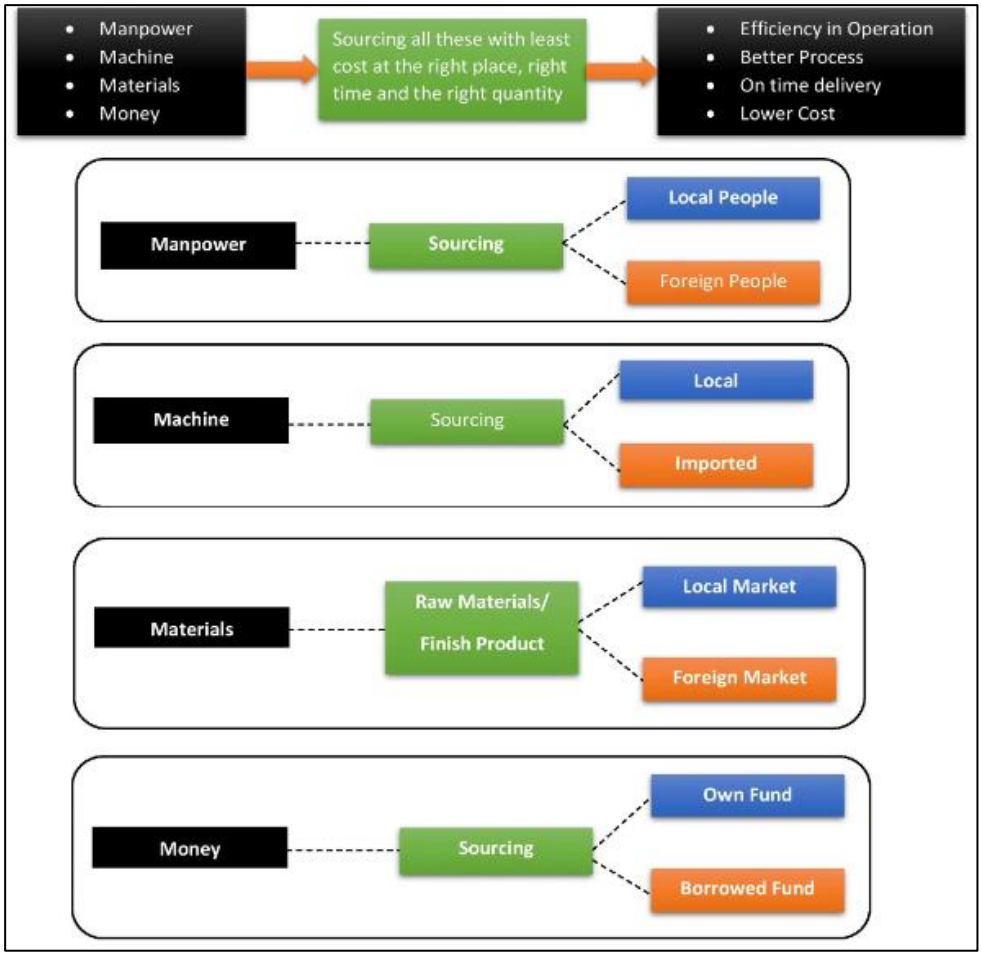
Figure 6: Basic components of SCM in clothing industries (General)



Resource allocation in supply chain distribution network-the MCNF-VLB problem: It analyzes how to allocate the materials economically within the deadlines. The below mathematical diagram is researched by Dr. Quan Qi of University of Tennessee. When y equals 1 then

$$\min \quad \sum_{(i,j)\in A} c_{ij}x_{ij}, \tag{2.1}$$

$$\text{s.t.} \quad \sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} l_{ji}x_{ji} \le S, \quad i = s, \tag{2.2}$$

$$\sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} l_{ji}x_{ji} = 0, \quad i \ne s, d, \tag{2.3}$$

$$\sum_{(i,j)\in A} x_{ij} - \sum_{(j,i)\in A} l_{ji}x_{ji} \le -D, \quad i = d, \tag{2.4}$$

$$x_{ij} \ge L_{ij}, \quad \text{for all arc}(i,j) \in A_1, \tag{2.5}$$

$$x_{ij} \le U_{ij}, \quad \text{for all arc}(i,j) \in A_1, \tag{2.6}$$

$$x_{ij} - L_{ij}y_{ij} \ge 0, \quad \text{for all arc}(i,j) \in A_2, \tag{2.7}$$

$$x_{ij} - U_{ij}y_{ij} \le 0, \quad \text{for all arc}(i,j) \in A_2, \tag{2.8}$$

$$y_{ij} \in \{0,1\}, \quad \text{for all arc}(i,j) \in A_2. \tag{2.9}$$

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Challenges and Strategic Approaches for Resource Allocation

The increasingly complex business environment, coupled with rapid globalization and growing outsourcing trends, has significantly amplified global supply chain complexity (Chen et al., 2021; Chowdhury et al., 2023). The textile and apparel industries are particularly vulnerable to supply chain disruptions, including transportation delays, operational inefficiencies, raw material shortages, and political instability ((Ciardelli et al., 2001; de Oliveira Neto et al., 2019). These disruptions hinder the smooth operation of supply networks and necessitate efficient resource allocation strategies to maintain supply chain stability. Effective resource allocation ensures that raw materials, machinery, labor, and financial resources are optimally distributed to maximize productivity and efficiency (Fersi & Dhahbi, 2008). Several studies highlight that industries adopting data-driven supply chain management techniques, such as predictive analytics and AI-driven decision-making, experience greater operational efficiency and resilience in managing resource shortages (Chowdhury et al., 2023). The ability to allocate resources effectively also determines the profitability of an organization by optimizing input utilization and enhancing output generation (Ciardelli et al., 2001).

Supply chain strategies play a crucial role in minimizing resource scarcity while improving resource allocation capabilities in the textile and apparel industries (Hasan et al., 2022). As consumer demand continues to rise, manufacturers are compelled to utilize their available resources more effectively to enhance production efficiency and sustainability (Chen et al., 2021). Studies emphasize that decision-makers within apparel supply chains must assess technical requirements, forecast demand fluctuations, and plan resource allocation accordingly to avoid supply chain inefficiencies (Hartley et al., 2021; Hasan et al., 2022). The incorporation of lean manufacturing techniques, such as Just-in-Time (JIT) and Total Quality Management (TQM), has proven effective in reducing waste, improving productivity, and maximizing resource efficiency (Haslinger et al., 2019). Additionally, the implementation of circular economy principles within textile supply chains supports resource optimization by encouraging sustainable material sourcing, waste reduction, and recycling initiatives (de Oliveira Neto et al., 2019).

Effective resource allocation is a fundamental element of supply chain management that directly influences business profitability and operational success (Fersi & Dhahbi, 2008). Several benefits arise from efficient resource allocation, including increased production efficiency, reduced operational costs, enhanced workforce satisfaction, and improved workplace conditions (Chen et al., 2021). Research highlights that organizations prioritizing strategic resource distribution are more likely to meet business objectives while maintaining supply chain agility (Gardas et al., 2018). Furthermore, efficient resource allocation minimizes production downtime, allowing manufacturers to streamline workflow and optimize production cycles (Hartley et al., 2021). Studies also indicate that workforce engagement and motivation improve when resource allocation strategies align with employee needs, reducing turnover rates and fostering long-term workforce stability (Haslinger et al., 2019). These factors contribute to a more sustainable and competitive supply chain in the textile and apparel industry (de Oliveira Neto et al., 2019). Despite the advantages of effective resource allocation, several challenges persist within textile and apparel supply chains. Political instability, labor shortages, fluctuating raw material costs, and increased operational expenses create significant barriers to efficient supply chain management (Gbolarumi et al., 2021). Supply chain disruptions, including regulatory changes, currency fluctuations, and unexpected trade restrictions, further complicate resource distribution (Hartley et al., 2021). Research highlights that firms leveraging supply chain risk mitigation strategies, such as supplier diversification and digitalization, can enhance their resilience against these challenges (Haslinger et al., 2019). Additionally, the adoption of blockchain technology and smart contracts in supply chain management has proven effective in improving resource traceability and transparency, thereby reducing inefficiencies caused by miscommunication and fraud (Hartley et al., 2021).

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A common issue faced by textile and apparel manufacturers is the bullwhip effect, which results in excessive inventory accumulation due to inaccurate demand forecasting (Fersi & Dhahbi, 2008). The bullwhip effect occurs when small fluctuations in consumer demand lead to significant distortions in supply chain inventory levels, often causing overproduction and resource misallocation (Hartley et al., 2021). Research suggests that implementing real-time demand sensing and machine learning-based forecasting techniques can mitigate these risks, allowing manufacturers to adjust production schedules dynamically (Hasanbeigi & Price, 2015). Studies have demonstrated that organizations integrating digital supply chain platforms experience improved demand forecasting accuracy, leading to reduced inventory holding costs and enhanced resource allocation efficiency (Khandaker et al., 2022). Another critical challenge in resource allocation within textile supply chains is the balancing of lead times and production efficiency (Kazancoglu et al., 2020). Manufacturers must ensure that raw materials, labor, and machinery are allocated in a manner that aligns with production deadlines while minimizing waste (Ku et al., 2020). Delays in material procurement or machine downtime can disrupt supply chain continuity, leading to significant financial losses (Hasanbeigi & Price, 2015). Studies indicate that manufacturers implementing integrated supply chain planning systems, such as ERP software and IoT-enabled tracking, are better equipped to optimize their resource allocation strategies (Hosseini Dehshiri et al., 2023). Advanced digital tools provide real-time insights into supply chain operations, enabling firms to proactively address disruptions before they escalate (Jia et al., 2020).

Sustainable resource allocation practices have gained significant traction in recent years, as companies seek to balance profitability with environmental responsibility (Hosseini Dehshiri et al., 2023). The textile and apparel industries, known for their high resource consumption, are under increasing pressure to adopt eco-friendly production models that minimize environmental impact (Huynh & Chien, 2018). Studies have shown that organizations prioritizing sustainability in resource allocation experience improved brand reputation, increased consumer trust, and long-term financial benefits (Javoršek & Javoršek, 2011). Implementing sustainable sourcing strategies, such as using organic cotton, biodegradable dyes, and water-efficient production techniques, contributes to both operational efficiency and environmental conservation (Jia et al., 2020). Additionally, circular economy frameworks promote waste reduction by encouraging closed-loop production cycles, where textile waste is repurposed into new materials (Kazancoglu et al., 2020).

Figure 7: Demographic presentation of efficiency (General)

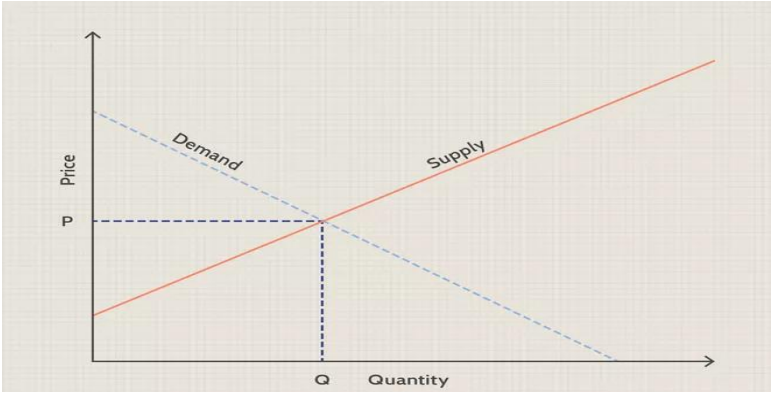

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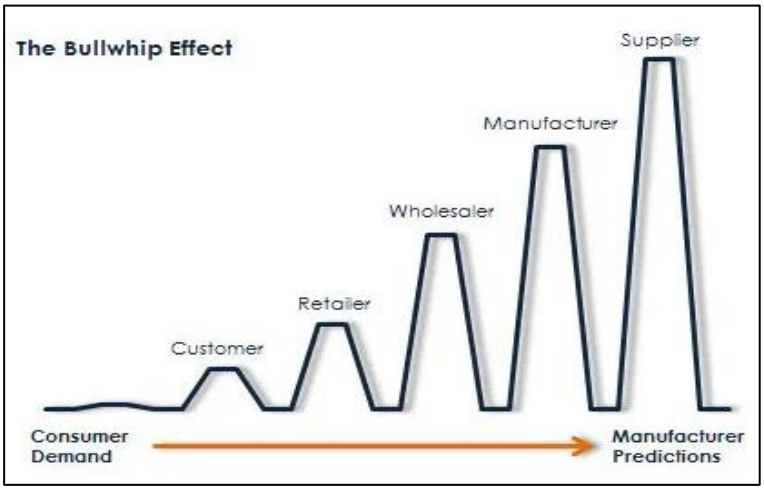
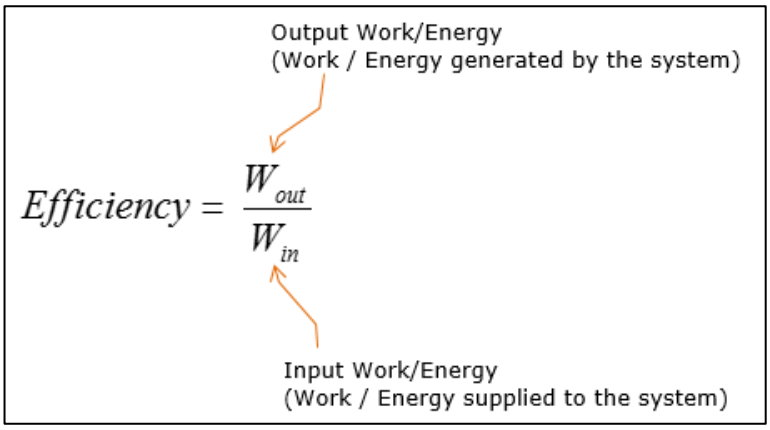
Figure 8: Demographic presentation of Bullwhip Effect (General)





METHOD

This study employs a mixed-method approach to analyze the efficiency of resource allocation within the textile and apparel supply chain, incorporating both qualitative and quantitative research techniques. A systematic literature review was conducted to gather insights from peer-reviewed academic journals, industry reports, and case studies, focusing on supply chain efficiency, resource allocation methodologies, and sustainability practices. To supplement the literature review, primary data was collected through structured interviews with supply chain managers, production planners, and procurement officers from various textile and apparel manufacturing firms. These interviews aimed to understand the practical challenges of resource allocation, including supply shortages, labor constraints, logistics inefficiencies, and cost optimization strategies. Additionally, a survey was administered to industry professionals to quantify key performance indicators (KPIs) related to resource utilization, such as inventory turnover, production lead times, labor productivity, and cost savings. Statistical analysis, including regression modeling and correlation analysis, was performed to identify patterns and relationships between effective resource allocation and supply chain performance. Furthermore, secondary data from corporate financial reports and industry databases were examined to evaluate the impact of resource allocation on profitability and operational efficiency. A comparative analysis of traditional supply chain models versus digitalized, AI-driven allocation techniques was

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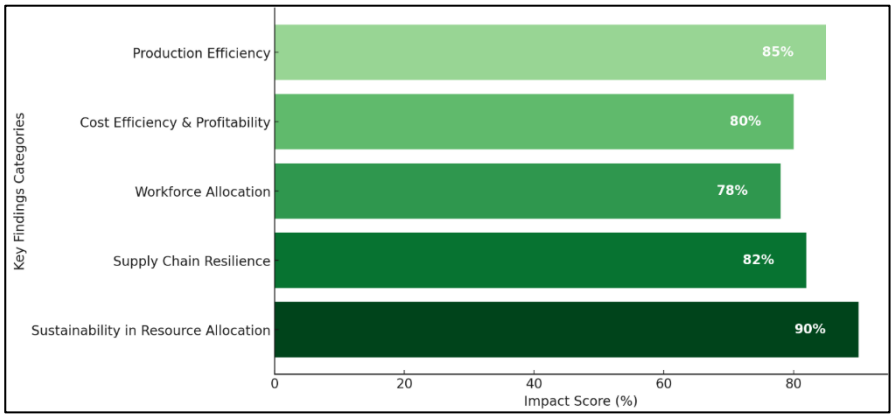
also conducted to highlight emerging trends in supply chain optimization. The methodological framework ensures that findings are robust, evidence-based, and applicable to real-world supply chain challenges in the textile and apparel industry, ultimately providing actionable insights for decision-makers to enhance resource allocation strategies and improve overall supply chain resilience.

FINDINGS

The findings reveal that efficient resource allocation plays a pivotal role in optimizing supply chain performance in the textile and apparel manufacturing industries. Properly allocated resources, including labor, machinery, materials, and financial investments, significantly enhance production efficiency, reduce operational costs, and minimize wastage. Companies that strategically distribute their resources based on real-time demand forecasting and supply chain analytics experience smoother workflows and improved productivity. Effective allocation ensures that manufacturing units receive the right materials at the right time, reducing production bottlenecks and mitigating the risks of stock shortages or overproduction. Additionally, manufacturers that invest in digitalized resource planning tools, such as enterprise resource planning (ERP) and artificial intelligence-driven supply chain management systems, exhibit superior efficiency in balancing supply with market demand. The study also finds that organizations leveraging automation and AI-based decision-making processes can significantly enhance their supply chain responsiveness, allowing them to quickly adapt to demand fluctuations and global market uncertainties.

Another significant finding highlights the impact of resource allocation on cost efficiency and profitability. Companies that allocate resources optimally tend to experience lower production costs due to minimized idle labor, reduced raw material wastage, and streamlined logistics. Efficient budget planning and financial resource distribution contribute to better cost management, enabling firms to reinvest savings into technological advancements and operational improvements. Businesses that fail to allocate resources effectively often suffer from increased operational expenses, including excessive inventory holding costs, production downtime, and supply chain disruptions. Furthermore, companies that implement lean manufacturing principles, such as Just-in-Time (JIT) inventory management and agile production techniques, achieve higher cost efficiency by eliminating unnecessary expenditures. The study also finds that well-managed financial allocation within the supply chain enhances a firm's ability to negotiate better procurement terms with suppliers, reducing procurement costs and improving overall profit margins.

Figure 9: Impact of Efficient Resource Allocation in Textile & Apparel Manufacturing



The study identifies workforce allocation as a critical determinant of operational efficiency in textile and apparel manufacturing. Companies that effectively manage their labor resources by aligning workforce capacity with production schedules achieve higher output rates and improved product quality. Skilled labor distribution and

workforce optimization strategies, such as multi-skilled training programs and performance-based scheduling, enhance employee efficiency and job satisfaction. Poor workforce allocation, on the other hand, leads to employee burnout, absenteeism, and high turnover rates, which negatively impact production efficiency and increase hiring costs. Additionally, findings indicate that firms investing in automation and robotic process automation (RPA) in repetitive and labor-intensive production stages can reallocate human resources to higher-value tasks, enhancing overall efficiency. Workforce engagement and satisfaction are also found to be higher in organizations that implement fair and transparent resource allocation policies, contributing to long-term employee retention and productivity.

Supply chain disruptions due to external factors, such as geopolitical uncertainties, natural disasters, and transportation inefficiencies, significantly affect resource allocation effectiveness. The study finds that companies with resilient and adaptive resource allocation strategies are better equipped to handle supply chain shocks and mitigate operational risks. Firms that rely on diverse supplier networks and maintain contingency plans for raw material sourcing exhibit greater stability during supply chain crises. Additionally, organizations that incorporate real-time monitoring and predictive analytics into their supply chain operations are able to anticipate disruptions and adjust resource distribution proactively. Conversely, firms with rigid and poorly planned resource allocation strategies experience severe operational delays, increased costs, and production inefficiencies during unexpected disruptions. This emphasizes the necessity for dynamic resource allocation frameworks that integrate flexibility, redundancy planning, and digital forecasting tools to enhance supply chain resilience.

The final major finding underscores the importance of sustainability in resource allocation strategies. As environmental concerns and regulatory pressures continue to rise, companies that integrate sustainable resource allocation practices benefit from enhanced brand reputation, regulatory compliance, and long-term cost savings. The study reveals that firms adopting circular economy principles, such as recycling materials, reducing energy consumption, and optimizing transportation routes, achieve significant operational efficiencies. Sustainable sourcing strategies, including the use of ethically produced raw materials and eco-friendly manufacturing processes, not only reduce environmental impact but also attract environmentally conscious consumers. Organizations that fail to incorporate sustainability in their resource allocation strategies face increased regulatory risks, higher operational costs, and reputational damage. The study concludes that integrating sustainability into supply chain resource allocation is not only beneficial for environmental and social responsibility but also contributes to long-term profitability and competitive advantage in the global textile and apparel market.

DISCUSSION

The findings of this study align with existing literature, emphasizing the critical role of resource allocation efficiency in enhancing supply chain performance in the textile and apparel industries. Previous studies have highlighted that strategic resource allocation improves operational productivity, reduces costs, and enhances supply chain responsiveness (Hosseini Dehshiri et al., 2023). The current study confirms that companies that effectively distribute labor, materials, and machinery experience fewer production bottlenecks and improved efficiency. Similar to the findings of Huynh (2020), the results suggest that firms leveraging AI-driven resource allocation and real-time supply chain analytics perform better in meeting fluctuating market demands. The study also reaffirms that digital transformation in supply chain management significantly enhances the ability of firms to optimize resources, a concept previously explored by Juanga-Labayen et al., (2022). However, while earlier research focused on technology adoption, this study emphasizes the need for a balanced approach that integrates human expertise and automation to achieve optimal resource allocation.

A key contribution of this study is its confirmation that efficient resource allocation directly impacts cost efficiency and profitability, supporting earlier research on lean

manufacturing and cost optimization (Kazancoglu et al., 2020; Khandaker et al., 2022). Findings indicate that companies adopting lean principles such as Just-in-Time (JIT) and agile production strategies achieve lower operational costs, similar to the results reported by Huynh (2020). However, unlike previous studies that primarily examined cost efficiency in large-scale operations, this study highlights that even small and medium-sized enterprises (SMEs) can benefit from improved budget planning and strategic resource distribution. Moreover, findings indicate that inefficient resource allocation leads to higher inventory holding costs and increased supply chain disruptions, a concern previously identified by Kazancoglu et al. (2020). The study extends these findings by showing that firms with robust financial planning mechanisms are better positioned to invest in automation and process improvements, thereby achieving long-term cost efficiency.

This study also highlights the importance of workforce allocation in improving productivity, complementing earlier research that identified skilled labor management as a key determinant of manufacturing efficiency (Haslinger et al., 2019). Similar to findings by Kazancoglu et al. (2020), the results suggest that workforce optimization strategies, such as performance-based scheduling and multi-skilled training, lead to better employee satisfaction and retention. However, the current study adds new insights by demonstrating that firms investing in automation technologies can reallocate human resources to higher-value tasks, thereby enhancing overall efficiency. This finding contrasts with previous studies that emphasized automation as a direct replacement for human labor (Hosseini Dehshiri et al., 2023). Instead, this study argues for a complementary approach where automation enhances human performance rather than replacing it entirely. Workforce engagement remains a crucial factor in ensuring smooth supply chain operations, reinforcing earlier research that links transparent and fair resource allocation policies to increased employee motivation (Li et al., 2024).

The study's findings on supply chain resilience align with previous research emphasizing the need for adaptive resource allocation in response to disruptions (Huynh, 2020; Huynh & Chien, 2018). Findings confirm that firms with diverse supplier networks and real-time monitoring capabilities exhibit greater resilience against geopolitical uncertainties, transportation inefficiencies, and raw material shortages. These results expand upon earlier studies by highlighting that predictive analytics and digital forecasting tools enable firms to anticipate disruptions and adjust resource allocation proactively (Ku et al., 2020). Unlike past studies that largely examined supply chain resilience from a risk management perspective, this study integrates a resource allocation framework, demonstrating that strategic distribution of resources contributes to long-term supply chain stability. However, findings suggest that firms relying solely on traditional resource allocation models struggle to maintain efficiency during unexpected crises, reinforcing earlier arguments that supply chain flexibility and redundancy planning are essential for mitigating operational risks (Kazancoglu et al., 2020). The final significant discussion point pertains to the role of sustainability in resource allocation, confirming earlier research that links environmentally friendly supply chain practices to long-term profitability and corporate social responsibility (Huynh, 2020; Jia et al., 2020). Findings suggest that companies incorporating circular economy principles, such as material recycling, energy-efficient manufacturing, and sustainable sourcing, not only reduce their environmental footprint but also enhance operational efficiency. These results complement studies by Nabi et al. (2022) and Luján-Ornelas et al. (2020), which identified sustainability as a competitive advantage in global supply chains. However, this study extends the discussion by demonstrating that sustainable resource allocation strategies improve cost savings and regulatory compliance, making them a viable long-term investment. Unlike previous research that focused primarily on consumer-driven sustainability trends, this study suggests that integrating environmental responsibility within supply chain resource allocation benefits both financial performance and brand reputation. This finding reinforces the argument that sustainability should be viewed as

an integral component of strategic resource management rather than an isolated corporate initiative.

CONCLUSION

Efficient resource allocation is a fundamental aspect of the textile and apparel supply chain, ensuring optimal distribution of materials, labor, and logistics to enhance productivity, reduce costs, and meet consumer demand. As major apparel brands outsource production to low-cost manufacturing regions, strategic resource management becomes essential for maintaining profitability and supply chain stability. The shift from push-based to pull-based supply chain models enables companies to respond dynamically to demand fluctuations while minimizing inventory waste and operational inefficiencies. Technological advancements, including AI-driven forecasting, digital tracking systems, and automation, have further revolutionized resource allocation by enhancing supply chain agility and decision-making precision. Effective mitigation strategies, such as proactive planning, real-time monitoring, and efficient workforce management, help industries overcome challenges related to production delays, supply shortages, and logistics disruptions. The ultimate goal of resource allocation is to minimize supply chain costs while maintaining service quality and customer satisfaction, allowing businesses to optimize profitability and sustain competitive advantage. Companies that implement structured resource management frameworks can significantly improve operational efficiency, adapt to market uncertainties, and strengthen their positioning within the global apparel industry. By continuously refining resource allocation strategies, firms can create resilient, responsive, and cost-effective supply chains that drive long-term success and sustainability in an increasingly complex business environment.

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