Research Article

Exploring Key Performance Indicators for Strengthening Supply Chain Resilience: A Systematic Review for Strategic Insights

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ARTICLE INFO	ABSTRACT
	Introduction: Key performance indicators (KPIs) play a pivotal role in building supply chain resilience, helping organizations monitor and adapt to disruptions effectively. **Objectives**: This paper explores the effect of KPIs in fostering supply chain resilience (SCRes), specifically examining how operational KPIs contribute to resilience before, during, and after disruptions. **Methods**: By leading a systematic literature review this study classifies key KPIs such as processing time, delivery reliability, delivery performance, and consumer satisfaction, which are found to have a significant impact on building resilience. **Results**: These findings offer a fresh perspective on the role of KPIs, moving beyond traditional financial metrics to emphasize their operational relevance in enhancing supply chain adaptability and response to disruptions. **Conclusions**: This study subsidizes the theoretical consideration of SCR by connecting operational KPIs to resilience-building elements and providing practical insights for managers looking to monitor and improve their supply chain operations. By identifying specific KPIs linked to resilience, the study offers actionable guidance for supply chain practitioners aiming to improve their organizations' capability to withstand and improve from disruptions **Keywords**: Supply Chain Resilience (SCRes), Key performance indicators (KPIs), product efficiency, reliability, consumer satisfaction.

1. INTRODUCTION

A supply chain (SC) is a structure that connects specialists from the supplier to the end purchaser through service and manufacturing to maintain the flow of goods and information (Singh et al., 2019 [1]). It is now essential for a business to be able to withstand stress and thrive in changing circumstances. The idea of SC resilience gives businesses the ability to anticipate and react to unforeseen circumstances. It is a tactic that enables businesses to successfully and efficiently manage their SC while they adjust to market shifts (Patidar et al., 2023 [2]). The resilience of a SC is increasingly recognized as a strategic asset for organizations aiming to thrive in a dynamic, often unpredictable global market (Khan, 2024 [3]). Supply chain resilience is now a vital resource that helps businesses not only survive but also grow and adapt when faced with shocks, such as natural catastrophes, economic disruptions, or sudden shifts in demand (Hynes et al., 2020 [4]). At its most basic level, resilience describes an SC's ability to bounce back from setbacks, continue to function normally, and perform well even in challenging circumstances. Organizations that cultivate resilience build strong systems that can overcome obstacles and come out stronger (Vakilzadeh & Haase, 2021 [5]). SCs must combine flexibility and redundancy to increase resilience. Flexibility, or the capacity to adjust operating plans, enables SCs to react quickly to changes in supply or demand by redistributing

resources, changing routes, or adjusting output levels (Rahman, 2023 [6]). Contrarily, redundancy entails the purposeful addition of buffer stocks, extra suppliers, or backup systems to guarantee continuation if primary resources are damaged. Redundancy and flexibility are essential components of a robust SC and need to be carefully balanced (Mackay et al., 2020 [7]). Inadequate adaptability exposes the SC to disruption, while excessive redundancy can lead to inefficiencies and higher expenses. By making the most of both, businesses improve their flexibility without going over budget. A significant component of SCRes is its focus on non-financial KPIs, which offer a more complex perspective on resilience (Siegrink et al., 2022 [8]). Although cost and revenue are crucial financial KPIs for assessing profitability, non-financial KPIs provide information about operational health, customer happiness, quality control, and environmental impact—all of which are important components of a robust supply chain. Through proactive monitoring of factors including lead times, inventory accuracy, and supplier dependability, these KPIs enable SC managers to strengthen an organization's capacity to endure and swiftly recover from interruptions. By analyzing these KPIs, businesses can spot possible weaknesses in their networks and modify their plans, like switching to different modes of transportation or diversifying their supplier base (Kohl et al., 2022 [9]). Similar to this, SC managers may evaluate how regularly items match customer expectations by looking at data like product quality and return rates. This has a direct impact on customer loyalty and brand reputation. In particular, data analytics and artificial intelligence (AI) tools that facilitate real-time monitoring, decision-making, and predictive analytics, have made technology a potent enabler of SCRes (Zong & Guan, 2024 [10]). Businesses may better predict demand, foresee any disruptions, and modify their inventory by utilizing AI-driven forecasting models. Real-time data collection and analysis enable SCs to track the program of goods, manage inventory, and respond quickly to sudden shifts in supply or demand.

Resilience in risk management refers to the proactive detection and reduction of possible hazards. Adopting risk management techniques like scenario planning, frequent supplier audits, and stress testing is necessary to create a resilient culture inside an SC. By imagining different disruption scenarios and creating reaction plans, scenario planning enables businesses to "train" the SC to deal with unforeseen circumstances. Contrarily, supplier audits evaluate the dependability, soundness, and ability of suppliers to manage demand swings (Uye, 2023 [11]). Stress testing, which is frequently employed in the financial industry, simulates various risk scenarios to assess the SC's readiness and pinpoint areas that require improvement. For firms to adapt and succeed in unpredictable marketplaces, SC resilience is essential. It entails constant improvement, evaluating plans to match risks and market demands, and investigating novel technologies and methodologies. Because SCs frequently span several nations in the modern, worldwide economy, they are susceptible to both geopolitical and regulatory problems. To handle regulatory changes, resilient SCs need strong risk assessment frameworks and backup strategies. Strategies for near-shoring can enhance supply network management and lessen dependency on far-off suppliers. For efficient coordination, the exchange of important information, and the distribution of resources, cooperation throughout the SC network is crucial. By keeping lines of communication open with distributors and sharing inventory data with suppliers, manufacturing and delivery plans may be promptly adjusted, avoiding stockouts and guaranteeing steady supply levels. Examining how non-financial KPIs contribute to SCRes is the goal of this article. Since supply chain KPIs cover a wide range of metrics from various management domains, this study gives non-financial KPIs priority because disruptions primarily impact an organization's operational elements. Supply chain resilience frequently depends significantly on non-financial measures, even though financial KPIs are crucial to organizational health. Thus, non-financial KPIs are the main emphasis of this study since they contribute to resilience and, in the end, lay the groundwork for efficient supply chain performance. By combining disparate perspectives on resilience and non-financial KPIs, this study contributes to theoretical knowledge by providing a coherent framework that emphasizes how these factors interact to create SCRes. In practice, this study offers managers a strategic perspective on KPIs that can improve resilience and facilitate well-informed choices in unpredictable situations.

The article is divided into five sections. The introduction explains the goal of investigating SCRes using non-financial KPIs and places the study topic in context. A theoretical framework for comprehending resilience and KPIs in supply networks is given in the second section. The methodology for this study's systematic literature review (SLR) is described in depth in the third part. The fourth section picks important KPIs and resilience-building components from the literature and examines how they interact and how they might affect SCRes. In the conclusion, the results are summed up, study limitations are deliberated, and future research instructions are recommended.

2. THEORETICAL REVIEW

2.1. Key Performance Indicators

Organizational goals are essential to any continuous organization and the success or sustainability of any business, and KPIs assist in defining and measuring them (Asih et al., 2020 [12]). KPIs have the power to alter behavior and provide a wide range of results that enhance operational performance and business outcomes. KPIs also aid in the ongoing implementation of performance measurements, which improves organizational management (Aithal, 2023 [13]). KPIs are used by entities in this framework to monitor these kinds of operations. For businesses to succeed, they need to monitor and control KPIs, which are measurable measures (Riofrio et al., 2023 [14]). To facilitate process evaluation and oversight, KPIs that can display the condition of an organization and its supply chain ought to be created.

Every organization creates and defines its KPIs by the operational context, roles, and goals to collect pertinent data that guide needs and procedures. Choosing the right KPIs within the supply chain paradigm requires integrating goals from different levels, which gives the business a more comprehensive picture (Cruz Villazón et al., 2020 [15]).

2.2. Resilience in the Supply Chain

SCR is the natural ability of a supply chain to predict, adequately prepare for, respond to, and ultimately recover from a range of disruptions, guaranteeing a steady flow of operations and the capacity to regain stability and functionality following adverse events (Gu, 2024 [16]). This idea has become a key component of global supply chain management in the modern era, especially as businesses face a growing number of unforeseen difficulties, such as natural disasters, economic ups and downs, supply shortages, and unprecedented global crises like pandemics, all of which can have a significant effect on their operations (Helo & Hao, 2022 [17]). SCRs are much better able to handle crises, recover quickly, and adjust to the constantly changing dynamics of the global landscape by prioritizing visibility, flexibility, collaboration, risk management, and the use of data-driven insights. This eventually strengthens their competitive advantage and improves customer satisfaction over the long run (Patel, 2023 [18]). A thorough and methodical review was carried out to gain a thorough understanding of supply chain resilience, covering all of the core ideas that have been expressed in the body of literature already available on the subject. Consequently, a concept mapping framework was developed to classify and coordinate the various characteristics associated with resilience. In addition to offering clarity, this approach makes it easier to comprehend how various facets of resilience interact and support supply chains' overall robustness.

3. OVERVIEW OF THE LITERATURE REVIEW

Deductive approaches, based on existing literature, are crucial for research advancement. A systematic literature review (SLR) is now preferred in operations management to handle the growing study volume and ensure no significant research is missed. SLRs use a structured, defined process, following established guidelines, promoting transparency, reliability, and reproducibility in findings. The SLR protocol, as detailed in Figure 1, consists of five primary steps.
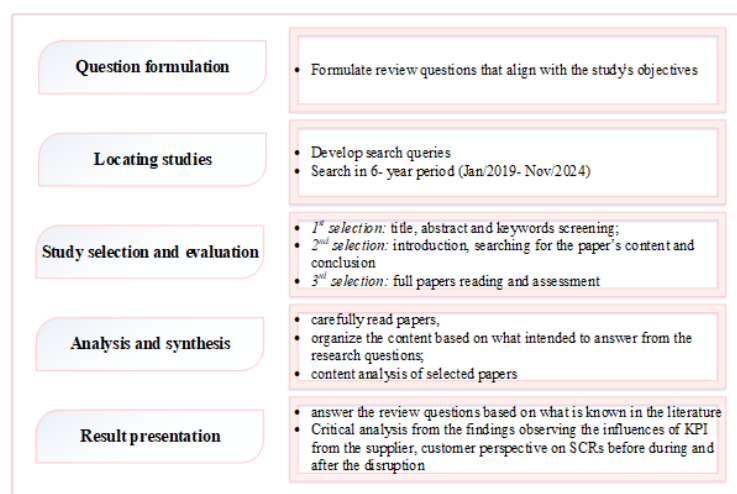

Figure 1. SLR Procedure

3.1. Question formulation

To investigate how non-financial KPIs impact Supply chain resilience creation, three review demands were addressed.

1. What are the KPIs utilized in supply chains?
2. What factors contribute to enhancing resilience within supply chains?
3. In what ways can non-financial KPIs foster SCR management?

Q1 identifies KPIs in supply chains, including non-financial metrics, to provide a comprehensive understanding of KPI usage. Q2 explores elements contributing to building resilience in supply chains, including enablers and capabilities. Q3 focuses on the role of non-financial KPIs in enhancing resilience, addressing the main goal of the study. These insights support Q3's focus on how non-financial KPIs foster a resilient supply chain.

4. FINDINGS

The goal of this thorough discussion is to clarify the important influence that KPIs have on the emergence and improvement of SCRes across the different phases of disruption, including the pre-disruption, during-disruption, and post-disruption phases.

4.1. Pre- disruption phase

Pre-disruption occurs before any possible interruption in the flow of products or services through the supply chain. During this phase, risk management, security, knowledge management, information sharing, visibility, trust, and robustness are the main resilience components.

4.1.1. Security

Effective data security governance enhances the ability to share marketing data securely, which is essential for informed decision-making and improving resilience claims, (Pratama & Fadillah, 2023 [19]). Delivery reliability among the KPIs that, according to the literature, co-occurred with the security factor. By tracking the proportion of orders that are delivered on or before the due date, it evaluates the performance of product delivery. (Sobb et al., 2020 [20]) explored the unique nature of supply chains, highlighting their strengths, weaknesses, dependencies, and fundamental technologies. (Akinsola & Akinde, 2024 [21]) examined tactical ways to defend the software supply chain against risks, emphasizing openness and resilience. The study evaluated the security mechanisms in place and emphasized how crucial it is to maintain security during development. (Hajarath & Vummadi, 2024 [22]) emphasized the importance of proactive tactics in boosting supply chain resilience against interruptions, with importance on natural pandemics, calamities, and geopolitical unrest. By use of scenario planning, risk assessment, proactive steps such as inventory control and diversification optimization, and acceptance of technology. (Kumar et al., 2024 [23]) examined the significance of risk management and supply chain resilience in the face of global disruptions and emphasized the necessity for companies to use proactive measures to withstand and lessen the negative effects of these disruptions. (Fernando & Ikhsan, 2023 [24]) examined the data-driven supply chain focused on marketing data sharing, data security, and digital technology adoption. Delivery performance is an additional indicator that can aid in security development by tracking the dependability of material deliveries and dynamically determining whether a particular supplier is failing to achieve the company's goals.

4.1.2. Risk management

Risk management practices help organizations prepare for and mitigate potential disruptions, thereby safeguarding business operations. Since several risks cannot be anticipated or prevented, risk management is a component of SCR. It can assist in lowering vulnerabilities by anticipating, tracking, and minimizing hazards. According to (Yadav et al., 2024 [25]) Effective risk management is crucial for supply chain resilience, as it minimizes disruptions from external shocks, cyber threats, and supplier dependencies. Proactive strategies enhance operational efficiency, ensuring compliance and adaptability to changing market conditions, ultimately supporting robust and competitive supply chains. (Kudrenko, 2024 [26]) Explained risk management in supply chain resilience involves creating a shared understanding of risks, promoting a culture of transparency, and employing multi-functional teams. Blockchain technology enhances this resilience by facilitating secure transactions and improving stakeholder trust, ultimately aiding in effective risk management. Further inventory is loaded to prevent a shortage of supplies when there is an unpredictable and inconsistent flow of commodities. Monitoring inventory volume can therefore assist managers in

lowering inventory expenses and mitigating risk. Additionally, risks can be reduced by keeping vigilant on order or dispatch time, which is crucial for customer service as it provides feedback to manage daily operations. Delivery performance is also regarded as a KPI for risk management since it can monitor and detect a drop in supplier performance and the probable disruption in the movement of goods that results.

According to (Dittfeld, 2023 [27]) facilitating efficient risk detection and treatment, contextualizing risk management tactics according to an organization's production features and risk sources, and employing flexible practices to adjust to disturbances and improve overall resilience capabilities. (Barhmi, 2023 [28]) It involves developing capabilities to anticipate, respond to, and mitigate disruptions. It integrates dynamic supply chain risk management (SCRM) with operational capabilities of robustness and resilience, enhancing agility performance during unavoidable risks and disruptions. (Petratos & Faccia, 2023 [29]) highlighted the potential disruptive effects of misleading information on supply chains and suggested that intentional and exogenous disinformation can cause significant disruptions.

4.1.3. Knowledge Management

Knowledge management (KM) is essential for improving supply chain resilience (SCR) because it makes it easier to create, share, and use knowledge, according to (Mukherjee et al., 2024 [30]). Innovation, operational continuity, and disruption adaptation are all made possible by effective knowledge management procedures. A popular non-financial KPI, product efficiency measures how well capacity is employed in service delivery and is crucial in assessing the performance level in a supply chain.

(Sezer et al., 2023 [31]) explained that it supports adaptive capacity, flexibility, and product prioritization, enabling supply chains to respond effectively to disruptions and maintain efficiency in uncertain environments. According to (Sharma et al., 2023 [32]) Knowledge management in supply chain resilience involves practices like knowledge acquisition, sharing, and collaborative learning, enabling organizations to develop operational advantages and enhance resilience against disruptions, ultimately leading to superior business performance in knowledge-based supply chains. (Umar et al., 2021 [33]) explained Knowledge acquisition, sharing, and utilization processes, facilitated by informal socialization and formal training, contribute to the alignment, adaptability, and agility of supply chains in response to disruptions. Additionally, as it influences consumer satisfaction, product reliability is also a crucial indicator. It is possible to determine whether it is time to look for a more dependable or qualified provider by evaluating the delivery performance. According to (Irfan et al., 2022 [34]) Adaptive business strategies, such as focused investments and offshore production, helped the company respond to challenges and create resilience in its supply chain operations.

4.1.4. Visibility

Supply chain visibility (SCV) is important in industries, influencing supply chain resilience, performance, and business performance, based on research by (Huang et al., 2023 [35]). IoT technology improves SCR visibility by facilitating actual data gathering and transfer, claim (Liu et al., 2023 [36]). This feature enables businesses to keep an eye on things, spot irregularities quickly, and become more responsive, all of which help supply chains become more flexible and agile. (Alvarenga et al., 2021 [37]) discussed that it positively correlates with agility, enabling quicker recovery from disruptions and improving overall supply chain performance. Similarly, (McGrath et al., 2021 [38]) emphasized that visibility in supply chains is crucial for resilience, as it enables stakeholders to monitor processes, identify risks, and respond effectively to disruptions, ultimately fostering sustainable practices and enhancing overall supply chain performance.

According to (Kalaiarasan et al., 2023 [39]) visibility is enhanced by improving analytical capabilities and deviation management in inbound logistics, particularly regarding arrival time changes, thereby potentially extending visibility to internal and outbound flows for better overall performance. Moreover, (Chen et al., 2023 [40]) explained stakeholders can access actual information about supply chain operations, which enhances decision-making, responsiveness, and collaboration, ultimately improving the overall resilience of the pharmaceutical supply chain in the post-pandemic era.

4.1.5. Information sharing

Through improved decision-making, increased responsiveness, and the development of partner trust, information sharing is essential to increasing SCR. According to (Gruzauskas et al., 2023 [41]) integrating information-sharing techniques can greatly reduce risks and improve recovery capacities during interruptions. Information-sharing level

improves supply chain resilience by increasing visibility, decreasing uncertainty, and enabling prompt reactions to disturbances, based on (Yang et al. 2022 [42]). It has a beneficial influence on readiness, reactivity, and recovery capacities, which eventually helps manufacturers to successfully handle crises and continue operating. (Hannibal et al., 2022 [43]) state that information sharing increases the SCR by endorsing transparency and effective statements between members. A more robust and flexible supply chain network is achieved by addressing problems including supplier assurance fatigue, improving data quality, and lowering disruption-related risks. Being that this data is required to align client requirements for product/service creation, supply chain KPIs must be connected to consumer satisfaction. Furthermore, keeping an eye on the inventory volume from clients and suppliers is a crucial KPI to prevent or lessen the bullwhip impact.

According to (Madhavika et al., 2023 [44]) Information sharing significantly impacts supply chain resilience by enabling timely and accurate data exchange among stakeholders. This collaboration helps mitigate unexpected disruptions, enhancing overall operational effectiveness. In closed-loop supply chains, improving stakeholder participation and communication is essential, according to (Dominguez et al., 2019 [45]). According to (Collichia et al., 2019 [46]), it enables improved resilience and disruption management in intricate supply chains, which eventually results in higher security and performance.

4.1.6. Trust

By encouraging improved communication and cooperation between partners, trust enhances supply network resilience, (Giannoccaro & Iftikhar, 2022 [47]). Trust in supply chain resilience greatly improves manufacturer readiness, responsiveness, and recovery capacity, claim (Yang et al. 2022 [48]). Facilitating information exchange makes it possible to coordinate quickly and solve problems in an emergency, which eventually promotes stability and sustainable development in industrial processes. KPIs that enhance this component include product reliability and delivery reliability since they boost customers' faith in the business.

(Mathiyazhagan et al., 2023 [49]) state that a robust CSR strategy improves supply chain resilience by establishing credibility and trust, encouraging a common goal among stakeholders, and lessening the detrimental effects of disruptions on communities that are already at risk. According to (Hajarath & Vummadi, 2024 [50]), information exchange and cooperation among partners increase confidence in supply chain resilience, which eventually results in a more resistant and responsive supply chain system by enhancing readiness for disruptions and assisting in recovery effort coordination. Likewise, it promotes openness and communication between suppliers and operators, claims (Wallis & Dorrey, 2023 [51]).

4.1.7. Robustness

In terms of supply chain resilience, robustness is the capacity of supply chains to tolerate disturbances while preserving business operations. Rising global threats like pandemics and geopolitical conflicts have made this idea more well-known. A robust supply chain integrates many tactics to improve resilience and is distinguished by its ability to absorb shocks and recover rapidly. According to (Li et al., 2023 [52]) strongest of the supply chain and the ability to preserve stability and operational continuity in the face of interruptions is referred to as resilience. It enhances resilience, which emphasizes proactive planning and quick reaction, guaranteeing that businesses can successfully manage risks and maintain performance in the face of difficulties. It refers to the capacity to tolerate disturbances and continue to function, claims (Sadeghi et al., 2021 [53]).

According to (Sadrabadi et al., 2021 [54]) Robustness is the ability to withstand and recover from disruptions through strategies like multiple sourcing, lateral transhipment, and facility fortification, enhancing economic viability and reducing costs associated with lost sales and inventory holding. High sensitivity and efficient reaction to disruptive events are necessary for this, and proactive measures like backup plans and early warning systems are necessary to support it, said (Yang et al., 2022 [55]).

4.2. During- disruption phase

KPIs can also help track the effects and take action after the disruption has occurred. Collaboration, agility, flexibility, and redundancy are the components of resilience in this stage. These elements improve withstanding ability and proactive crisis management, enabling organizations to effectively navigate modern supply chain dynamics.

4.2.1. Collaboration

Collaboration enhances supply chain resilience by fostering stronger supplier relationships, enabling shared resources, and facilitating information exchange. This proactive approach helps organizations mitigate risks, improve operational efficiency, and maintain competitiveness amidst challenges, as highlighted by (Cooper, 2024 [56]). (Ivanov, 2023 [57]) demonstrated that collaborative emergency adaptation significantly mitigates the effect, improving recovery performance in intertwined supply networks compared to non-collaborative approaches. Delivery performance and product reliability are two KPIs that are related in the literature. Since the outcome of this KPI determines consumer satisfaction, cooperation is required to improve product reliability.

(Kim et al., 2024 [58]) suggested that collaboration among stakeholders in the supply chain framework enhances system resilience by promoting synchronized decision-making among retailers. This facilitates operations without compromising competitive advantages by sharing sensitive information. This approach addresses reluctance to share critical data, leading to improved inventory transhipment and operational efficiency. (Akbar & Isfianadewi, 2023 [59]) emphasized the importance of adaptability and strategic re-engineering in achieving superior business performance metrics, highlighting the complexities of the modern market landscape. These factors are crucial in directing the complications of the contemporary market landscape.

4.2.2. Agility

Agility in SCR refers to the ability to quickly reallocate resources and respond to disruptions. Disruptive technologies like IoT enhance agility by allowing real-time data collection and transmission, facilitating rapid decision-making and adaptive responses to risks, claims (Liu et al., 2023 [60]). According to (Abourokbah et al., 2023 [61]) Agility rapidly adapts to unforeseen changes and recovers from significant disruptions, enabling quick detection of environmental changes and efficient responses to digital transformation and emerging opportunities.

Product efficiency is especially crucial during disruptive times since there may be capacity available to meet urgent needs. Moreover, (Akhtar et al., 2022 [62]) explained it is a critical capability for supply chain resilience, enabling firms to respond quickly to market changes and disruptions. The dispatch time is no exception. Therefore, monitoring these KPIs can assist managers in taking action during disruptions and, as a result, in developing SCRes. It enhances by improving flexibility, speed, accuracy, and cost-efficiency, thus supporting effective decision-making and operational processes. Similarly, (Lotfi |& Sodhi, 2024 [63]) highlighted the interplay between agile and resilient practices, enhancing performance objectives like cost, delivery, flexibility, and recovery time. Consumer satisfaction will therefore undoubtedly rise if the company and its supply chain can distribute a produce significantly earlier than its rivals. This is particularly valid during disruptive times.

4.2.3. Flexibility

Flexibility in supply chain resilience is crucial for organizations to adapt to disruptions and maintain operational continuity. According to, (Tootell et al., 2023 [64]) Flexibility in supply chain resilience involves adapting systems to changing circumstances, minimizing disruptions, and enhancing responsiveness. (Jamaludin et al., 2023 [65]) Explained resource flexibility significantly influences supply chain resilience by enhancing an organization's ability to adapt to market changes and achieve operational efficiency. It plays a vital part in both agile and lean supply chains, contributing to overall SCR. Managers can adjust operations to quickly meet consumer needs by keeping focus on product efficiency, delivery reliability, and dispatch time. Additionally, there was an intriguing co-occurrence for flexibility between processing and dispatch times.

Furthermore, according to (Amico et al., 2023 [66]), it facilitates faster reaction to interruptions; yet, it may also raise operational complexity and expenses, requiring a balance between efficiency and flexibility. To navigate market turbulence, seize opportunities, and mitigate risks, including professional misconduct, (Pratono et al., 2023 [67]) investigated how resilience in flexibility adopts dynamic partnerships and strategies, such as funnel-based partnerships, ultimately improving competitive advantage and adaptability in uncertain environments. It is essential for adjusting to interruptions, allowing logistics service providers to respond to demand fluctuation and sustain performance successfully, claim (Zainuddin et al., 2022 [68]). To improve responsiveness and operational efficiency, it entails integrating technologies such as blockchain, IoT, and AI.

4.2.4. Redundancy

In the face of interruptions like pandemics, natural catastrophes, and geopolitical tensions, redundancy is especially important for improving supply chain resilience. Kamalahmadi et al., 2022 [69]) claim that it acts as a buffer that enables supply networks to withstand shocks and preserve operational continuity. According to (Aityassine et al., 2022 [70]), redundancy is the practice of having backup suppliers and keeping emergency supplies on hand to minimize interruptions. It seeks to lower expenses and improve service delivery in times of crisis, guaranteeing that a supply chain can successfully bounce back from unforeseen circumstances. Maintaining excess resources on hand is a crucial tactic used by businesses to get through difficult and limited times brought on by supply interruptions. Managers can see how long the company can continue to operate in the event of a supply disruption by using inventory volume as a KPI.

Furthermore, (Grzybowska & Stachowiak, 2022 [71]) emphasized adding more resources or using different procedures to lessen interruptions, known as redundancy in supply chain resilience. It reduces vulnerability and improves overall operational continuity by offering backup choices that increase the supply chain's resilience to shocks. (Kancs, 2024 [72]) asserted that it explains the deliberate duplication of essential parts or procedures to reduce the risks of unforeseen occurrences like pandemics or natural catastrophes, improving resilience and guaranteeing business continuity during disruptive events.

4.3. Post-disruption phase

After disruptions, KPIs ought to be employed to assess and oversee the recuperation process as well as the insights acquired. The fundamental components of resilience during this stage encompass information sharing, Knowledge management, visibility, and collaboration.

4.3.1. Knowledge management

The level of maturity of the companies and their industry sectors influenced the way they implemented knowledge management strategies, claim (Kolyasnikov & Kelchevskaya, 2020 [73]). According to (Novak et al., 2021 [74]) "The system's ability to return to its original state or move to a new and more desirable state, after being disturbed" is the definition of SCR. Regarding this, approaches to comprehend supply chain behavior before and after disruption and create plans to reach the desired state include monitoring treatment or dispatch time and delivery reliability. Focusing on the dispatch time and delivery reliability of commodities can help you understand supply chain behavior both before and after disruption and develop measures to get to the desired state.

Finally, (Balinado et al., 2021 [75]) explained how consumer satisfaction is measured in the automobile industry. Through after-sales monitoring, the assembly industry performs a diagnosis to determine the critical issues that need to be addressed for future unanticipated scenarios.

4.3.2. Information sharing

Information sharing is the foundation for attaining knowledge management, per the same reasoning as in the earlier stages, claim (Ali & Anwar, 2021 [76]). Effective dissemination of information can significantly mitigate the negative impacts of disruptions, enabling quicker restoration of normal operations.

According to (Li et al., 2022 [77]), Information sharing between manufacturers and suppliers can enhance supply reliability post-disruption. Manufacturers may choose to share demand information, which can lead to improved supply chain resilience. Consequently, the post-disruption period also benefits from the previously mentioned KPIs (inventory volume, and consumer satisfaction).

4.3.3. Visibility

Organizations may better anticipate, react to, and recover from unforeseen occurrences by increasing supply chain visibility. According to (Bowen & Siegler, 2024 [78]), increased visibility enables businesses to locate hidden vital suppliers, which is crucial for efficient risk management during disruptions. The possible trade-offs between local and global supply chain strategies must be considered, even though visibility is vital for resilience. According to (Mubarak et al., 2021 [79]), striking a balance between these strategies can result in a more SCR that can endure a variety of disturbances.

4.3.4. Collaboration

Processing time and delivery reliability should be managed and maximized to attain a higher degree of cooperation claims, (Octora et al., 2023 [80]). According to (Shcherbakov & Silkina, 2021 [81]), a Cooperative supply chain depends on limits, and all chain connections have production and delivery times. Additionally, (Omar et al., 2021 [82]) explained enhancing cooperation among supply chain participants can help lower the Distributor fault rate.

4.4. Critical analysis of the findings

KPIs were divided into pre-, during-, and post-disruption elements as well as performance metrics about the main firm, distributor, and customer. This allows for the observation of crucial characteristics that ensure KPIs have a positive effect on fostering resilience among the main players in a supply chain.

This study suggests that non-financial KPIs can influence SCRe development over the three disruption stages. Businesses can monitor operations and deploy resources to minimize any disruptions, which ultimately results in actions that enhance organizational or supply chain resilience. Furthermore, these KPIs and the times during and following disruption have a substantial correlation. This occurs because during disruptions, firms usually concentrate on fulfilling orders and deadlines, and stock management is a common strategy to achieve this. The previous discussion is summarized in Table 1.

Table 1: An overview of the resilience components and non-financial KPIs

| Phase | Resilience components | Central firm | | | | | | Distributor | | Consumer | |
		Product Efficiency	Product reliability	Processing time	Dispatch time	Delivery reliability	Inventory volume	Delivery performance	Distribution false rate	Consumer Satisfaction	Defective return rate
Pre-disruption phase	Security					✓		✓			
	Risk Management				✓		✓	✓			
	Knowledge management	✓	✓							✓	
	Visibility										
	Information Sharing						✓			✓	
	Trust		✓			✓					
	Robustness										
During-disruption phase	Collaboration		✓					✓		✓	
	Agility	✓			✓					✓	
	Flexibility	✓			✓	✓					
	Redundancy						✓				
Post-disruption phase	Knowledge management				✓	✓				✓	
	Information Sharing						✓			✓	
	Visibility										
	Collaboration			✓		✓			✓		

The supplier claims that while KPIs had a major influence on the pre-disruption phase, they did not affect the entire or post-disruption phases, which are crucial for resilience to sustain operations and forge solid bonds between

suppliers and customers. The post-disruption phase, which comes after the pre-disruption phase, has significant co-occurring KPIs and features. These results demonstrate that the non-financial KPIs studied in this study had a higher positive influence on resilience during the disruption period compared to the earlier or later phases. KPIs often fail to focus on monitoring specific actions aimed at preparing the supply chain or managing resources to address unexpected events effectively. As it is acknowledged that all knowledge must be recorded for future use to minimize and thrive in any kind of disruption, knowledge management is just as important in the pre-disruption phase as it is during the disruption and post-disruption phases. Thus, developing qualities like visibility, cooperation, and information sharing is equally crucial to advancing knowledge management. Monitoring and managing all supply chain KPIs is a useful way to gather data to improve knowledge management, even though the study does not conclusively show that all KPIs are related to the knowledge management component. Since the knowledge gained may be applied to developing or enhancing other elements like risk management, security, and flexibility, this is especially important in the post-disruption stage. Despite the literature's emphasis on the value of visibility in a business and supply chain, no discernible relationship between visibility and particular KPIs in the three stages of disruption was discovered. However, keeping an eye on several KPIs results in visibility. Since visibility necessitates capital input from suppliers or focus firms, it may be connected to financial KPIs.

5. CONCLUSION

The importance of KPIs in raising SCRes is highlighted in this article, emphasizing non-financial KPIs. The study examined the effects of specific KPIs on the development of resilience in various supply chain components by conducting a comprehensive literature review. The investigation revealed a strong positive correlation between 10 non-financial KPIs and 11 resilience variables. Of the 11 variables, visibility and robustness were the only two that had no significant relationship with the KPIs. However, the metrics most commonly linked to the resilience elements were process and dispatch time, inventory volume, and customer satisfaction. The successful management of other KPIs frequently leads to consumer happiness, which indirectly influences SCRes. This is a significant conclusion. Whether during the pre- or post-disruption stages, knowledge management as an element showed the highest degree of co-occurrence with KPIs, underscoring its function as a knowledge source to support other resilience components. The significance of knowledge exchange and efficient information flow in supply chains for resilience-building is highlighted by this realization.

The study adds to the theoretical body of knowledge by bringing disparate pieces of literature together and establishing a link between resilience components and KPIs. This gives businesses a fresh viewpoint on how to use KPIs to promote SCRes. Practically speaking, supply chain managers may use the useful advice this research offers to select and track KPIs that maximize operational effectiveness and help strengthen resilience to shocks.

The results of our investigation have two implications. To begin with, it gives supply chain managers important information about how to use particular KPIs—particularly non-financial ones—to strengthen and improve supply chain resilience. This knowledge facilitates the identification of vulnerable locations and the use of focused measures to increase resilience. Second, by linking different aspects of resilience with KPIs, the study fills a vacuum in the literature and provides a framework that can direct future resilience-focused initiatives for practitioners and academic researchers.

Future research should build on this work by incorporating financial KPIs or examining the impact of operational KPIs on financial outcomes to better understand how SCRes can be formed utilizing both operational and financial information.

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