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# Identifying the Dimensions and Components of the Sustainability Evaluation Model for LARG Supply Chains Using the Grounded Theory Approach

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A B S T R A C T

The objective of this study was to identify and conceptualize the dimensions and components of a sustainability evaluation model for LARG (Lean, Agile, Resilient, Green) supply chains using the grounded theory approach. This qualitative study employed an article-based grounded theory methodology. First, a systematic review of academic literature, including peer-reviewed articles, books, and reports, was conducted to extract key indicators relevant to LARG supply chain sustainability. These indicators served as the initial open codes. The data were then analyzed using Strauss and Corbin's coding paradigm through open, axial, and selective coding stages. MAXQDA software facilitated the categorization, integration, and validation of codes. The analysis led to the identification of six main categories: production management (causal condition), market management (central phenomenon), customer relationship management (intervening condition), lean and agile performance (context), resilience (strategy), and green performance (outcome). The grounded theory model revealed a processual and interactive relationship among these dimensions, highlighting resilience as a central strategic axis that bridges operational capabilities and sustainability outcomes in LARG supply chains. The study offers a comprehensive and empirically grounded model for evaluating sustainability in LARG supply chains by integrating key dimensions from lean, agile, resilient, and green paradigms. The findings underscore the importance of systemic integration rather than isolated application of LARG strategies, providing a practical and theoretical foundation for designing sustainable, responsive, and adaptive supply chain systems.

***Keywords:*** *LARG supply chain; sustainability evaluation; grounded theory; resilience strategy; supply chain performance*

## 1. Introduction

In today's volatile, uncertain, complex, and ambiguous (VUCA) environment, the sustainability of supply chains has become a strategic necessity rather than a competitive advantage. Among various paradigms proposed to address this complexity, the LARG paradigm—integrating Lean, Agile, Resilient, and Green principles—has emerged as a comprehensive framework for managing modern supply chains, particularly under conditions of uncertainty and environmental pressure. The convergence of these four strategies provides a multidimensional lens through which organizations can not only enhance operational efficiency but also achieve long-term ecological and economic sustainability (Anvari, 2021; Jamali et al., 2024; Sousa et al., 2020). However, despite the growing interest in LARG supply chain (SC) practices, the literature reveals a lack of consensus regarding the integrated evaluation of their sustainability dimensions.

The need to develop a holistic and adaptive sustainability evaluation model for LARG SCs arises from the increasing complexity of globalized supply chains, technological disruptions, and policy shifts favoring carbon neutrality and circular economy goals (Abdel-Basset & Mohamed, 2020; Chowdhury & Quaddus, 2015). The COVID-19 pandemic further underscored the vulnerabilities of conventional supply chains and accelerated the shift toward adaptive and resilient paradigms (Cohen & Rodgers, 2020; Liu et al., 2023). In this context, organizations seek to align their lean initiatives (focused on waste reduction), agile capacities (focused on responsiveness), resilience (focused on disruption recovery), and green strategies (focused on environmental performance) to build future-proof SCs (Jamali & Karimi Asl, 2018; Vafaei-Zadeh et al., 2020). Nevertheless, despite the maturity of each component individually, a unified, operationalizable model that captures the full spectrum of LARG sustainability dimensions remains underdeveloped (Mehri Babadi et al., 2022).

Lean supply chains emphasize minimizing waste and maximizing value through continuous improvement and process optimization (Sadeghi & Ghassemi, 2021). This strategy supports cost efficiency and reduces environmental burden by optimizing resource consumption. Agile supply chains, by contrast, are built around responsiveness and flexibility, enabling firms to quickly adjust to market changes and customer demands (Ngo et al., 2022). Resilient supply chains focus on risk management, robustness, and recovery capabilities in the face of disruptions (Honarvar & Rezaee, 2019; Liu et al., 2023). Finally, green supply chains integrate environmental concerns into all stages of the supply chain, aiming to reduce ecological footprints through practices like green procurement, reverse logistics, and eco-friendly packaging (Jamali & Karimi Asl, 2018; Sousa et al., 2020).

While scholars have made significant strides in evaluating each of these components separately, integration into a comprehensive sustainability evaluation framework for LARG SCs remains an emerging research priority. Past attempts to integrate these paradigms have focused largely on decision-making methods, such as multi-criteria decision-making (MCDM) techniques, system dynamics modeling, or SWOT-based game theory applications (Amiri et al., 2018; Izadiyar et al., 2020; Laínez & Puigjaner, 2012). Although valuable, these approaches often lack the depth of theory-building required to understand the complex, interrelated nature of sustainability within LARG SCs. This highlights the need for an exploratory, inductive approach such as grounded theory, capable of revealing latent structures and emergent dimensions from data (Ramesh et al., 2010).

In particular, grounded theory offers a robust method for theory development in contexts where variables are not fully defined, and relationships between concepts are ambiguous. Its emphasis on iterative coding and constant comparison allows for the extraction of core categories and theoretical constructs grounded in empirical reality. This is especially important in the context of LARG SCs, where dynamic interactions among lean, agile, resilient, and green elements vary depending on contextual and operational contingencies (Ghasemieh et al., 2015; Jamali et al., 2015). Accordingly, this study adopts a qualitative, article-based grounded theory approach to identify and conceptualize the sustainability dimensions of LARG supply chains. The process involves a multi-stage coding sequence supported by MAXQDA software, beginning with open coding of literature-derived indicators, followed by axial and selective coding to form a conceptual model.

The novelty of this research lies in its attempt to bridge the methodological gap between theory-driven evaluation frameworks and practice-based sustainability assessment in LARG SCs. By synthesizing evidence from scholarly literature and expert evaluation using grounded theory, this study aims to produce a validated and context-sensitive sustainability model that reflects the real-world complexity of integrated supply chains (Sadeghi Moghadam et al., 2019; Shams & Salimi Zaviyeh, 2021). The LARG approach has

proven useful in specific industry contexts, such as cement, automotive, and oil and gas industries, yet most existing models lack generalizability or fail to capture the synergies and trade-offs among LARG components (Jamali et al., 2024; Mehri Babadi et al., 2022). Therefore, developing a sustainability evaluation model that captures the full scope of LARG integration has both academic and practical significance.

Furthermore, the strategic alignment of LARG practices within supply chains is becoming increasingly institutionalized due to regulatory and consumer pressures. ISO 14001 certifications, extended producer responsibility, and stakeholder expectations for environmental transparency are forcing firms to reconsider their operational and strategic approaches to sustainability (Sousa et al., 2020; Van Wassenhove & Pedraza Martinez, 2012). In this regard, green performance cannot be achieved independently of agile responsiveness or resilient infrastructure. For example, a firm that succeeds in implementing green logistics may still face sustainability setbacks if its supply chain lacks flexibility during disruptions or cannot reduce delivery lead times (Jamali & Karimi Asl, 2018). Thus, an integrated perspective is essential for capturing the multiplicity of interactions that shape sustainable performance.

Notably, some scholars have proposed that LARG integration is not a sequential process but a dynamic system in which lean efficiency can enhance agile responsiveness, while resilience and green practices mutually reinforce one another (Anvari, 2021; Chowdhury & Quaddus, 2015). However, empirical validation of these synergies has been limited, particularly in non-Western contexts such as the Iranian industrial ecosystem. This study addresses that gap by grounding its model in context-specific data derived from literature and expert insight, filtered through culturally and operationally relevant lenses (Ghazi Zadeh & Jamal, 2022; Jamali et al., 2024).

Additionally, technological transformation—through digitalization, AI integration, and big data analytics—has expanded the boundaries of what LARG supply chains can achieve (Ngo et al., 2022). Digital supply chain transformation is becoming a critical enabler for real-time coordination and sustainability tracking across SC partners (Sadeghi & Ghassemi, 2021; Vafaei-Zadeh et al., 2020). Nevertheless, digitization alone cannot deliver sustainability outcomes unless it is embedded within a coherent strategic model such as LARG. This further justifies the need for a conceptual framework that accounts for both structural and strategic dimensions of sustainable performance evaluation.

To conclude, this study is driven by the need to fill a critical gap in supply chain sustainability research by identifying, categorizing, and conceptualizing the core dimensions of sustainable LARG supply chains.

## 2. Methods and Materials

This study employs a qualitative, article-based research design rooted in interpretivist methodology and grounded theory analysis. The aim is to explore and conceptualize the dimensions and components essential for evaluating sustainability in LARG supply chains. The research is exploratory in nature and utilizes a sequential and integrative strategy, beginning with a systematic literature review and progressing toward theory development. The approach is inductive, allowing insights and categories to emerge progressively from the data without pre-imposed theoretical structures.

The study first begins with the selection of relevant scientific sources, focusing on peer-reviewed articles, specialized books, and authoritative reports concerning sustainability, supply chain management, and evaluation models. This review phase is not merely narrative but systematic and thematic. Sources are selected based on relevance, citation impact, and recency, with a specific focus on literature published between 2015 and 2025. The sampling strategy here is purposive, aiming to collect documents that contain empirical, theoretical, or conceptual discussions around sustainability in LARG supply chains. From this corpus, key terms, concepts, and indicators are extracted. These extracted elements serve as the initial open codes in the grounded theory process.

In the second stage, data collection is conceptual rather than empirical. The researcher constructs a comprehensive database of sustainability-related indicators, challenges, strategies, and dimensions relevant to LARG supply chains. These data points, derived from texts, are treated as textual data for qualitative coding. The constant comparative method, as prescribed by grounded theory, is employed at this stage. Open coding is applied to identify the underlying meanings and functional roles of each indicator. During this phase, software-assisted qualitative analysis is used. MAXQDA, a qualitative data analysis software, is utilized to manage, categorize, and trace the evolution of codes. The software facilitates the transition from open coding to axial coding by allowing the researcher to group and relate codes based on thematic commonality and conceptual interdependence.

In the third and more analytical phase, the identified codes are synthesized using two complementary strategies. First, a meta-synthesis approach is employed. In this approach, conceptual similarities among the coded data are systematically compared and integrated, leading to the formation of higher-order categories. These categories represent the key thematic dimensions of the sustainability evaluation model. Examples may include environmental accountability, economic resilience, social responsibility, innovation capacity, and regulatory compliance, although the exact dimensions are determined inductively during analysis. The coding transitions from open to axial, and then to selective coding, in accordance with grounded theory procedures. Selective coding involves the identification of a core category that integrates the other dimensions and captures the central phenomenon of the study — sustainability in LARG supply chains.

Throughout this stage, MAXQDA continues to play a pivotal role, especially in facilitating the triangulation of codes across literature and expert inputs. The software is also used to trace coding density, category saturation, and the interrelationships among theoretical constructs. By employing visual mapping features of MAXQDA, the researcher constructs an integrative model that visualizes the multidimensional structure of supply chain sustainability in LARG contexts.

## 3. Findings and Results

The findings of this qualitative study present a comprehensive framework of the dimensions and subcomponents (main and open codes) that define the sustainability evaluation model for LARG supply chains. These findings emerged through iterative coding processes, including open, axial, and selective coding, following the grounded theory approach and supported by MAXQDA software. The categorization reflects the most salient and recurring themes across the analyzed literature and expert evaluations. Ultimately, six main categories (core themes) were identified, each encompassing multiple subcategories (open codes), which collectively articulate a multidimensional view of sustainable supply chain performance in LARG contexts. The results illustrate the breadth of factors that need to be considered in evaluating sustainability, ranging from market strategies to green practices, agility, and resilience.

**Table 1**

*Main and Subcategories of the Study*

| Main Category (Axial Coding) | Subcategory (Open Coding) |
|---|---|
| Production Management | Product optimization |
| | Increasing product variety |
| | Enhancing profitability |
| | Expanding market share |
| Market Management | Identifying suitable sales channels |
| | Service and sales quality |
| | Organizational goal transparency |
| | Brand perception |
| Customer Relationship Management | Customer collaboration |
| | Proper customer relations |
| | Improving customer service |
| | Enhancing responsiveness to market changes |
| Resilience | Enhancing responsiveness to market changes |
| | Ability to change delivery times |
| | Centralized planning |
| Lean and Agile Performance | Improving productivity |
| | Reducing costs |
| | Reducing waste time |
| | Flexible transportation |
| | Optimizing raw material inventory |
| | Flexible sourcing |
| | Implementing just-in-time production |
| | Executing total quality management processes |
| | Reducing delay time |
| | Reducing setup time |
| | Reducing batch size |

| | |
|---|---|
| | Training human resources |
| | Implementing just-in-time production |
| | Management support |
| Green Performance | Reducing energy consumption |
| | Designing reverse logistics |
| | Eco-friendly packaging |
| | Obtaining ISO 14001 certification |
| | Recycling materials and packaging |
| | Environmental cooperation with suppliers |
| | Reducing pollution |
| | Green-based production criteria |
| | Considering market demand for eco-products |
| | Considering social responsibility |

The extracted findings reveal a highly structured and multidimensional model composed of six axial codes representing the overarching domains of sustainability in LARG supply chains: production management, market management, customer relationship management, resilience, lean and agile performance, and green performance. Each of these core domains encompasses a set of interrelated operational or strategic practices. For instance, production management emphasizes not only optimization and profitability but also diversity and market expansion, while lean and agile performance incorporates 14 separate open codes that detail time, cost, flexibility, inventory, and quality management practices critical to supply chain sustainability. Green performance emerged as another central dimension, highlighting environmental initiatives such as reverse logistics, eco-packaging, ISO standards, and social responsibility. The inclusion of resilience and customer management reflects an awareness of dynamic market demands and the necessity for responsiveness and customer-centric practices. These dimensions collectively provide a robust, evidence-based foundation for constructing a practical sustainability evaluation model suited to the complexities of LARG supply chains.

The grounded theory analysis conducted in this study was structured using the Strauss and Corbin paradigm model, which includes five core components: causal conditions, central phenomenon, contextual and intervening conditions, strategies/actions, and outcomes. Through axial coding and integration of data, the key conceptual relationships were organized into a single comprehensive framework that represents the dynamic process of sustainability in LARG supply chains. The findings are summarized in the following table, combining all relevant paradigmatic components.

**Table 2**

*Paradigm Model Components of the Grounded Theory*

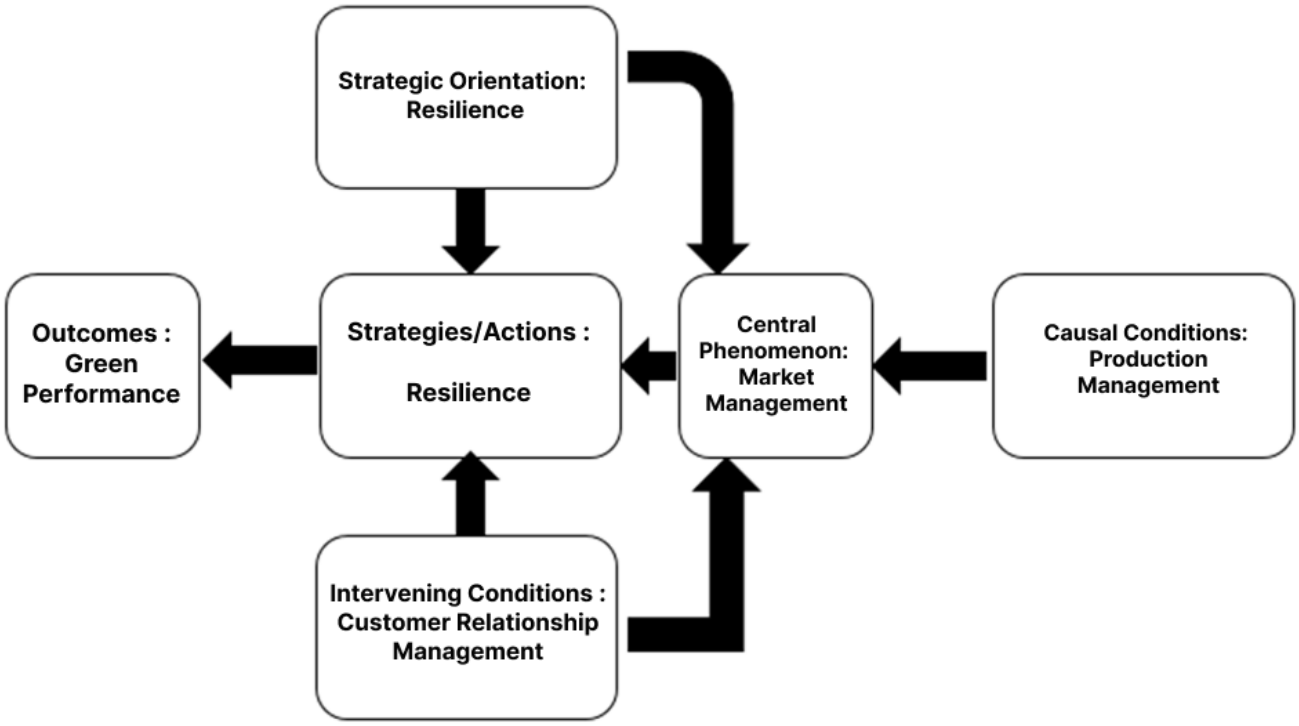
| Paradigm Component | Subcategory (Axial Code) |
|---|---|
| Causal Conditions | Production Management |
| Central Phenomenon | Market Management |
| Strategies/Actions | Resilience |
| Intervening Conditions | Customer Relationship Management |
| Outcomes | Green Performance |
| Strategic Orientation | Resilience |

The grounded theory analysis reveals that production management serves as the primary causal condition, influencing the emergence of the central phenomenon, which is market management. The rationale is that efficient and optimized production processes provide the operational foundation upon which sustainable market strategies can be constructed. The phenomenon of market management, in turn, is shaped and stabilized by resilience-oriented strategies, which act as deliberate responses to sustainability challenges and opportunities. These strategies reflect the organization's capacity to adapt to fluctuations in demand, environmental regulations, and supply chain disruptions. The execution of these strategies is mediated by intervening conditions, specifically customer relationship management, which encompasses collaboration and responsiveness to client needs, ensuring alignment between operational changes and market expectations. The outcome of this interconnected process is green performance, a

multidimensional construct capturing improvements in environmental sustainability, including reduced emissions, efficient resource use, and eco-friendly logistics. Notably, resilience not only appears as a strategic action but also functions as an overarching strategic orientation, reinforcing its pivotal role in navigating uncertainty and driving long-term sustainability in LARG supply chains. This integrated model provides a theoretical framework that encapsulates the cause-effect pathways and dynamic interactions essential for sustainable supply chain governance.

**Figure 1**

*Final Paradigm Model*




## 4. Discussion and Conclusion

The present study aimed to identify and conceptualize the dimensions and components of a sustainability evaluation model for LARG (Lean, Agile, Resilient, Green) supply chains using a grounded theory approach. Through a multi-stage coding process—beginning with open coding based on a literature-driven document analysis and culminating in selective coding—six major categories were extracted: production management, market management, customer relationship management, lean and agile performance, resilience, and green performance. These categories were then positioned within the Strauss and Corbin paradigm framework to form a comprehensive and process-oriented model. The final theoretical model elucidates the causal, contextual, intervening, strategic, and outcome dimensions that drive sustainable performance in LARG SCs. This discussion interprets the findings in light of existing studies and theoretical insights to establish alignment, highlight novelty, and clarify implications.

The results revealed that *production management* functions as the causal condition for enabling sustainable supply chain configurations. This finding aligns with the literature highlighting that sustainable performance begins with optimized production processes, emphasizing waste reduction, flexible manufacturing, and cost-efficiency, core tenets of lean strategy (Ghasemieh et al., 2015; Sadeghi & Ghassemi, 2021). This reflects the lean pillar of the LARG paradigm and supports research indicating that production-level interventions are foundational in achieving broader sustainability goals (Jamali & Karimi Asl, 2018; Sousa et al., 2020). Lean practices such as JIT (Just-In-Time), value stream mapping, and quality control systems contribute significantly to downstream SC efficiency, resilience, and environmental compliance (Maleki et al., 2011).

The *central phenomenon* in the model was identified as market management, emphasizing the significance of market responsiveness, customer perception, and organizational

agility. This resonates with the agile dimension of LARG, which prioritizes adaptability, speed, and customer-centric decision-making (Anvari, 2021; Ngo et al., 2022). Agile SCs are characterized by their ability to respond rapidly to volatile customer demands and shifting environmental conditions—a necessity for competitive survival in uncertain markets (Jamali et al., 2024). As the pandemic demonstrated, agility in market management enabled firms to reroute resources, shift distribution channels, and maintain customer trust during crises (Cohen & Rodgers, 2020; Liu et al., 2023). The identification of market management as the core category thus reflects the convergence of operational flexibility and strategic customer engagement that defines sustainable agile systems.

*Customer relationship management* emerged as the intervening condition in the model. This construct bridges internal processes and external expectations, emphasizing collaboration, responsiveness, and customer service quality. This is strongly supported in the literature where the relational aspect of sustainability is underscored as a key enabler of SC resilience and agility (Ghazi Zadeh & Jamal, 2022; Shams & Salimi Zaviyeh, 2021). In a LARG context, building and maintaining strong relationships with customers enhances both responsiveness and resilience by enabling better demand forecasting, real-time feedback, and more effective supply-demand synchronization (Jamali et al., 2015; Mehri Babadi et al., 2022). The importance of trust, transparency, and communication in customer relationships also supports green performance by encouraging shared sustainability goals across the value chain (Sousa et al., 2020).

The *strategic axis* of the model—*resilience*—is critical in enabling SCs to navigate uncertainty, disruptions, and risk. Its dual appearance in the model, both as a strategy and as a core enabler of sustainability, underlines its pivotal role in modern supply chains. As supported by recent studies, resilience is not merely a defensive mechanism but a strategic orientation that enables proactive disruption management, operational continuity, and structural adaptability (Honarvar & Rezaee, 2019; Liu et al., 2023). The inclusion of capabilities such as adaptive planning, flexible sourcing, and delay mitigation within this category reflects well-established resilience practices (Van Wassenhove & Pedraza Martinez, 2012). This is particularly important in post-COVID supply chain management, where firms are now expected to design systems that can absorb and recover from shocks while maintaining performance standards (Abdel-Basset & Mohamed, 2020; Ngo et al., 2022).

*Lean and agile performance* was categorized as the *context* for strategic decision-making in LARG SCs. This context provides the operational infrastructure—such as waste minimization, time reduction, and responsive transportation—that enables resilience to be implemented effectively. This finding aligns with studies arguing that lean and agile capabilities must be embedded in day-to-day operations to support higher-level strategic objectives (Jamali & Karimi Asl, 2018; Sadeghi & Ghassemi, 2021). Notably, this reflects a shift in the literature from treating lean and agile as independent paradigms to viewing them as foundational layers upon which resilience and green strategies can be built (Izadiyar et al., 2020; Laínez & Puigjaner, 2012).

Finally, the model posits *green performance* as the ultimate *outcome* of a well-orchestrated LARG supply chain. The presence of green performance as the result dimension validates the conceptual integrity of the model by illustrating the cumulative impact of production efficiency, market agility, relational quality, operational resilience, and environmental responsibility. This supports the findings of several researchers who emphasized that green supply chain practices—such as reverse logistics, eco-packaging, emission reduction, and ISO 14001 certification—are no longer optional but are now expected by regulators, customers, and investors alike (Moons et al., 2019; Sousa et al., 2020). Furthermore, the synergistic effects of the LARG components enhance the feasibility and effectiveness of green strategies, confirming recent work that highlighted the mutual reinforcement between agility, resilience, and environmental performance (Amiri et al., 2018; Jamali et al., 2024).

The theoretical model developed in this study thus contributes to a more holistic understanding of sustainability in supply chains by integrating the fragmented paradigms of lean, agile, resilient, and green management. It confirms that sustainability in LARG SCs is not achieved through the isolated implementation of individual practices but rather through their systemic and synergistic integration. This supports calls in the literature for more integrated frameworks that recognize the interdependence of operational and strategic dimensions in sustainable SC performance (Chowdhury & Quaddus, 2015; Sadeghi & Ghassemi, 2021). The grounded theory approach adopted in this study allowed for the emergence of a context-sensitive,

empirically grounded, and conceptually robust framework, thus addressing a critical gap in the literature.

Despite its contributions, this study is not without limitations. First, although the grounded theory approach allows for deep conceptual exploration, its reliance on literature-based data rather than field interviews may limit the richness of contextual understanding. While expert validation through fuzzy Delphi enhances credibility, the absence of real-time organizational data or case observations means that the model remains primarily conceptual and exploratory. Secondly, the qualitative nature of the study restricts generalizability. The findings, though theoretically saturated, may not capture all possible variations across industries or regions. Third, the study's focus on LARG SCs may overlook sector-specific constraints or enablers, such as those found in service-based or highly regulated sectors. Finally, while MAXQDA facilitated rigorous data management, its use may inadvertently introduce coder bias depending on categorization choices during axial coding.

Future research should aim to empirically validate the proposed model using quantitative methods such as structural equation modeling (SEM) or system dynamics simulation. This would enable researchers to test causal relationships and assess the predictive power of the model components. Additionally, sector-specific studies could enhance contextual relevance by focusing on industries such as healthcare, aerospace, or retail, where LARG practices may manifest differently. Comparative cross-national studies could also reveal how cultural, regulatory, or infrastructural differences affect the adoption and effectiveness of LARG strategies. Moreover, integrating digital transformation variables—such as AI-driven supply chain visibility or blockchain traceability—into the model could extend its relevance in digitally mature supply chain ecosystems.

Practitioners seeking to implement sustainable LARG SCs should begin by auditing their current capabilities across the four pillars—lean, agile, resilient, and green—to identify imbalances or gaps. Integrating these strategies requires alignment at both strategic and operational levels, including supplier engagement, internal process redesign, and investment in training and technology. Firms should institutionalize resilience as a core competency rather than a reactive tool, embedding it in planning, sourcing, and logistics. Customer relationship management should be reframed as a strategic function that supports agility and market responsiveness. Finally, sustainability indicators should be incorporated into key performance metrics to monitor progress and compliance with environmental and social expectations.

## Authors' Contributions

Authors contributed equally to this article.

## Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

## Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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## Declaration of Interest

The authors report no conflict of interest.

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## Ethics Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

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