Relationship Between Lean, Agile, Resilient, and Green Paradigm and Sustainable Supply Chain Performance: An Empirical Investigation

Abstract

Purpose

The purpose of this study is to empirically examine the relationship between the Lean, Agile, Resilient, and Green (LARG) paradigm, Critical Success Factors (CSFs), and Sustainable Supply Chain Performance (SSCP) in a manufacturing context by suggesting a new measurement scale based on the literature review. Grounded in the Resource-Based View (RBV) and Dynamic Capabilities (DC) perspectives, it seeks to answer four research questions: the effect of the LARG paradigm on SSCP, the identification and impact of CSFs on SSCP, the direct effect of CSFs on LARG paradigm, and the mediating role of the LARG paradigm between CSFs and SSCP.

Design/methodology/approach

A second-order hierarchical framework integrates LARG and CSFs. A literature review and expert interviews informed a measurement model validated via a survey of 112 Iranian manufacturing supply chain managers. Partial Least Squares Structural Equation Modelling (PLS-SEM) tested hypotheses, with non-response bias and common method bias ensuring robustness.

Findings

The analyses revealed significant relationships between LARG paradigm, CSFs, and SSCP. The LARG paradigm also acted as a partial mediator in the relationship between CSFs and SSCP. The findings highlight the combined effect of the LARG paradigm and CSFs in enhancing economic, environmental, and social performance in supply chains.

Originality/value

This study contributes by proposing a novel integrative approach to SSCP, offering a comprehensive measurement model, and empirically demonstrating LARG's partially mediating role between CSFs and SSCP. It provides the first empirical assessment of these constructs in the manufacturing sector, introduces a validated measurement tool for future research and industry managers, and bridges theoretical frameworks with practical applications for aligning supply chain strategies with sustainability goals. It informs organizations to adopt introduced practices to strengthen sustainable supply chain outcomes and assess their sustainable performance.

Keywords: Lean, Agile, Resilient, Green, Critical success factors, Sustainable supply chain management

1. Introduction

In emerging economies, sustainability in Supply Chain Management (SCM) has become crucial for firms trying to stay competitive (Karmaker et al., 2023). According to Gartner Inc. (2024), more than half of consumers prefer to do business with companies that consider environmental and social sustainability standards. The COVID-19 pandemic further highlighted the importance of sustainability and demonstrated that businesses must integrate sustainability into their Supply Chains (SC) to navigate disruptions effectively (Karmaker et al., 2021) and survive by keeping ahead of competition over a sustainable period of time (El Nemar et al., 2025). Simultaneously, the growing climate crisis requires immediate attention and major investments in sustainability initiatives (Gartner Inc., 2025). As a result, supply chains are under growing pressure to adopt sustainable practices due to strict regulations, rising stakeholder expectations, and consumer demands (Seuring and Müller, 2008; Brandenburg et al., 2019; Foundation, 2022). These pressures raise important questions about what practices should be used to positively increase the Sustainable Supply Chain Performance (SSCP) and from which way the industry leaders can measure their sustainable performance, track it, and get aligned with long-term sustainability, especially in the manufacturing sector, which is central to both economic development and environmental degradation.

In recent years, the Lean, Agile, Resilient, and Green (LARG) paradigm has been increasingly gaining attention as an important strategy in SCM by promoting efficiency, adaptability, resilience, and environmental responsibility (Azevedo et al., 2011; Ciccullo et al., 2018; Karmaker et al., 2021; Nazari-Shirkouhi and Zarei Babaarabi, 2025). Lean improves operational efficiency by eliminating waste in the supply chain (Ruiz-Benitez et al., 2019). Agile enhances market responsiveness by quickly adapting to unpredictable customer demands (Sharma et al., 2021). Resilience strengthens a supply chain's ability to recover from disruptions or return to a more desirable state (Sharma et al., 2021). Green initiatives enhance the firm's profit and market share by reducing negative ecological impacts (Ruiz-Benitez et al., 2019). Numerous investigations into the individual contributions of the LARG paradigm to increase Supply Chain Performance (SCP) have been carried out. For instance, Sahu et al. (2025) investigated how lean-green practices and green human resources affect SCP. Ghaderi et al. (2024) examined the impact of green supply chain management (GSCM) on environmental costs and SCP by considering the mediating effects of agility and resilience in the hotel industry. Yadav and Kumar (2023) proposed lean-agile-green practices to improve the operational, economic, and environmental efficiency of the vaccinate supply chain. However, in the field of the LARG paradigm and sustainability performance, comprehensive research studies that investigate an integrated effect of LARG paradigm on all dimensions of sustainability are still rare.

Alongside LARG, Critical Success Factors (CSFs) are widely recognized as essential drivers for implementing Sustainable Supply Chain Management (SSCM). CSFs represent organizational practices and enablers that motivate firms to adopt sustainability (Alzubi and Akkerman, 2022). These factors are often context-specific and have not been studied in interaction with the integrated LARG paradigm and sustainability performance. In particular, the mediating role of the LARG paradigm on the relationship between CSFs and SSCP remains unexplored. Additionally, existing studies have emphasized the scarcity of empirical investigations in this area

(Ramirez-Peña et al., 2020; Anvari, 2021; Sharma et al., 2021; Yadav and Kumar, 2023). Moreover, a validated and integrated tool that enables the measurement of these constructs in theory and practice is largely absent.

Thus, the motivation of this study stems from the lack of comprehensive empirical research that examines the combined effects of CSFs and the LARG paradigm on SSCP in the manufacturing sector, particularly in emerging economies. The main objective is to develop a new measurement model based on a thorough literature review to accurately capture these relationships. To the best of our knowledge, this is the first empirical study to simultaneously include and assess all these constructs together in this context. By these, the study seeks to answer the following questions:

Q1. What is the effect of the LARG paradigm on SSCP?
Q2. What are the CSFs of manufacturing firms, and how do they affect SSCP?
Q3. What is the direct effect of CSFs on LARG paradigm?
Q4. How does the LARG paradigm mediate the relationship between CSFs and SSCP?

In response to these questions, this study introduces a conceptual framework that integrates the LARG paradigm and CSFs to enhance SSCP. Existing theories provide strong support for such integration. The Resource-Based View (RBV) argues that firms gain sustained competitive advantages by the interaction of valuable, rare, inimitable, and non-substitutable resources into distinctive capabilities (Barney, 1991). Within SSCM, RBV highlights the strategic use of resources to advance triple bottom line objectives (Laosirihongthong et al., 2020). To address the complexity and turbulence of modern supply chains, the study also draws on Dynamic Capabilities Theory (DCT), which emphasizes the ability of firms to reconfigure and adapt resources in turbulent environments (Altay et al., 2018). Given this, it can be argued that this study is primarily grounded in the RBV and DCT.

This study makes several important contributions. The theoretical contributions of this research are fourfold: First, the research is pioneering in developing a second-order hierarchical component model that examines how the LARG paradigm and CSFs together influence sustainable performance, providing new insights into their combined effects on SSCP. Second, it provides novel empirical evidence from Iran's manufacturing sector, an underexplored context that extends existing theory to emerging economies. Third, it develops and validates a new measurement tool for SSCM practices. This tool will provide a reliable way to collect data and is expected to be very useful for future research in this area. Fourth, it empirically investigates the mediating role of the LARG between CSFs and SSCP, an area that has not been previously studied. Practical contributions are equally significant. The proposed framework is validated through real-world empirical research; by bridging theoretical frameworks with real-world applications, the study offers actionable insights for managers and policymakers. Specifically, it identifies which CSFs should be prioritized and demonstrates how adopting LARG paradigm can enhance economic, environmental, and social performance simultaneously. The validated measurement tool also equips managers with a systematic approach to assess SSCM maturity, enabling them to design more resilient and sustainable supply chains with an evidence-based decision-making tool.

The remainder of the paper is organized as follows: Section 2 presents the existing literature review on the LARG paradigm, CSFs, and SSCP to formulate hypotheses and describe the conceptual model. Section 3 discusses the empirical research methodology and data analysis approach. Section 4 provides the data analysis and results. Section 5 discusses the findings, while Section 6 examines their implications for theory and management practices. Finally, Section 7 concludes the paper with the conclusions, highlights research limitations, and suggests areas for future research studies.

2. Literature review and hypotheses development

This section is structured into four main parts. The first part provides a comprehensive review of the LARG paradigm, explaining each paradigm individually and discussing their integration. The second part examines the literature on SSCM, followed by the third part, which focuses on CSFs in SSCM. Within these sections, the study's hypotheses are introduced and developed. Finally, the research framework is presented to visually illustrate the relationships between the constructs and provide a clearer representation of the research hypotheses.

2.1. LARG paradigm

According to a review of the numerous supply chain paradigms in the literature, lean, agile, resilient, and green practices is the most practical paradigm in the context of SCM, which together form the LARG paradigm (Carvalho et al., 2011). The LARG paradigm seeks to make supply chains more efficient, responsive, resilient, and environmentally sustainable. Building on RBV, the LARG paradigm facilitates the development of strategic capabilities that enable firms to leverage unique and valuable resources, thereby sustaining their competitive advantage in a volatile market environment. Within this framework, lean and green practices enhance efficiency and waste reduction (Prajogo et al., 2016; Karmaker et al., 2023), while, based on DCT, agile and resilient practices emphasize responsiveness and recovery capabilities (Altay et al., 2018; Tavana et al., 2022). Therefore, the proposed relationships between LARG paradigm, CSFs, and SSCP are theoretically grounded in RBV and DCT, as these paradigms represent capabilities that enable alignment of CSFs with sustainability objectives. Despite the extensive use of RBV and DCT in previous studies, the literature still lacks an integrated framework that combines resource requirements such as LARG paradigm and CSFs to explain their joint impact on SSCP. This study addresses this gap by developing a theory-driven model that integrates RBV and DCT to explain how LARG paradigm and CSFs collectively contribute to SSCP in emerging economy manufacturing contexts. Next, we will discuss each of the dimensions of this paradigm individually and then highlight the importance of integrating them. Table 1 compares the LARG paradigm based on their definitions, primary goals, practices, and urgency.

2.1.1. Lean

The "Lean" paradigm, which emerged from the Toyota Production System following World War II in the 1990s, was established on the principles of cost reduction and adaptability (Saraji et al., 2023; Doğan and Derici, 2025). Nowadays, this paradigm has become more important because customers are seeking the best prices, and companies need to reduce their price to satisfy end-user requirements. This cost reduction must be passed on to the whole supply chain, from raw materials to sales and from customer orders to delivery (Manzouri et al., 2013). Therefore, supply chain managers can go forward with implementing the lean paradigm to optimize material and energy efficiency, reduce the final price, enhance performance, and acquire more competitive advantages (Saraji et al., 2023). From RBV perspective, implementing lean practices such as JIT and TQC is challenging, which makes them difficult to imitate. When combined, these practices generate complex and distinctive organizational routines and lead to sustainable competitive performance (Prajogo et al., 2016).

2.1.2. Agile

To navigate rapidly changing environments in firms, it is necessary to develop, build, and reconfigure internal and external competencies, which is defined as DCT (Altay et al., 2018). Since client needs are changing all the time, a supply chain must be sufficiently agile to deal with these changes. The agile supply chain, which emerged in the 2000s, is aware of market developments and reacts as promptly as feasible (Ramirez-Peña et al., 2020; Saraji et al., 2023; Doğan and Derici, 2025). It uses DCT to increase the SC's capacity to respond quickly and affordably to unanticipated changes in the market and environmental disturbances both in terms of volume and variety (Cabral et al., 2012; Altay et al., 2018).

2.1.3. Resilient

The resilient paradigm emerged in the mid-to-late 1990s and early 2000s and continues to be utilized today (Doğan and Derici, 2025). In the turbulent and changing environment of today, the causes and outcomes of risk are unpredictable, particularly for extreme events with infrequent but serious effects (Karmaker et al., 2021). A supply chain disruption event may interrupt the flow of goods or services among all firms. Consequently, firms are realizing that disruptions in the supply chain might have adverse effects on their operational market and financial performance. Therefore, they are driven to seek ways to lessen the effects of disruptions and determine the path to normality (Papadopoulos et al., 2017). In such situations resilience has gained popularity, indicating the supply chain's capability to be ready for uncertainties in the business environment, respond rapidly to possible disruptions, recover, and resume its initial condition or a new more preferable state after being disturbed (Cabral et al., 2012; Nazari-Shirkouhi et al., 2023). The DCT also provides a lens to understand the impact of resilience on competitive performance. Dynamic capabilities are simple, experiential, unstable processes that draw on rapidly generated insights, allowing firms to combine, transform, or renew resources and competencies into capabilities that are crucial in uncertain environments (Altay et al., 2018). In line with this view, we have conceptualized resilience as a dynamic capability of manufacturing firms.

2.1.4. Green

Aligned with the RBV, our research views GSCM as a critical driver for achieving sustainable performance (Karmaker et al., 2023). The GSCM has arisen in response to growing community and consumer pressure and expectations for environmental protection on a global scale since the 1990s (Rao and Holt, 2005; Doğan and Derici, 2025). Customers will inquire about the goods they buy, so businesses must prepare for concerns about how environmentally friendly their supply chain and production practices are. As a result, there is an increasing need to incorporate environmentally conscious decisions into SCM research and practices (Saraji et al., 2023). A green supply chain (GSC) requires suppliers to keep in mind both their products and associated environmental management at the same time and ensure that their management processes include environmental protection. A GSC's primary objectives are to develop green products, enhance the image of the firm in the eyes of stakeholders, and increase market competitiveness (Saini et al., 2023). Therefore, the ability to develop a GSC represents a valuable and inimitable resource, consistent with the RBV perspective (Karmaker et al., 2023).

Table 1. A comparison of dimensions of the LARG paradigm

	Lean	**Agile**	**Resilient**	**Green**
Definition	A series of activities to minimize waste and maximize value (Carvalho et al., 2011)	Flexibility and responsiveness to market changes (Cabral et al., 2012)	Ability to withstand and recover from disruptions to its initial state (Saraji et al., 2023)	Environmental sustainability and reducing ecological footprint (Carvalho et al., 2011)
Primary Goal	Reduce costs by eliminating non-value-added activities (Cabral et al., 2012)	Satisfy customers by quickly adapting to changing demands (Sharma et al., 2021)	Ensure continuity with permissible time and cost in the face of unexpected disturbances (Sharma et al., 2021)	Reducing environmental impacts while improving ecological efficiency, and improving company image (Cabral et al., 2012; Saini et al., 2023)
Some of the Practices	Just-In-Time, Value Stream Mapping, Total Quality Management (Azevedo et al., 2010; Sharma et al., 2021)	Utilizing IT to integrate activities, Collaborative relationships, and market sensitivity analysis (Azevedo et al., 2010; Sharma et al., 2021)	Strategic stock, Reducing lead times, Flexible sourcing, Information sharing (Azevedo et al., 2010; Ruiz-Benitez et al., 2019)	Eco-friendly materials, Energy-efficient processes, Recycling (Luthra et al., 2016)
The Urgency	Companies need to reduce their price to satisfy end-user requirements (Manzouri et al., 2013)	Client needs are changing all the time (Ramirez-Peña et al., 2020)	The causes and consequences of risks are increasingly difficult to foresee (Karmaker et al., 2021)	Community and consumer pressure for environmental protection is growing (Rao and Holt, 2005)
Historical Evolution (Doğan and Derici, 2025)	1990s	2000s	The mid-to-late 1990s and early 2000s	1990s
Theory	RBV (Prajogo et al., 2016)	DCT (Altay et al., 2018)	DCT (Altay et al., 2018)	RBV (Karmaker et al., 2023)

2.1.5. The integrated LARG paradigm

The integration of lean, agile, resilient, and green practices into a unified LARG paradigm is motivated by their complementary nature and the need for a holistic approach to SCM. Each paradigm individually addresses a specific dimension; however, in today's complex and turbulent environments, managing them separately can harm SCP in some situations. For example, while lean emphasizes waste elimination and efficiency, during disruptions such as economic crises or natural disasters, this focus can result in insufficient buffer inventory and limited adaptability (Azevedo et al., 2011). By integrating these practices into a single framework, LARG paradigm provides a systemic perspective that captures their synergistic effects among these practices. For example, Nazari-Shirkouhi and Samadi (2025) assessed the role of LARG practices in enhancing healthcare supply chain performance, using integrated methods including Pythagorean Fuzzy DEMATEL, interpretive structural modeling (ISM), and Bayesian network (BN). Moreover, LARG offers both theoretical and practical structure for managers and researchers to evaluate and optimize SCP across multiple dimensions simultaneously. This integration also addresses a notable gap in the literature, where previous studies have examined these practices individually or limited combinations (Sukwadi et al., 2013; Altay et al., 2018; Ruiz-Benitez et al., 2019; Hossain et al., 2023), but rarely in a comprehensive framework that explains their joint impact on SSCP. Therefore, firms should adopt the LARG paradigm to leverage their strengths of each dimension while also hiding their weaknesses (Cabral et al., 2012).

2.2. Sustainable supply chain management

SSCM can be defined as the integration of sustainable development and SCM (Zailani et al., 2012). According to Seuring and Müller (2008), it is a comprehensive approach that manages material, information, and capital flows while emphasizing collaboration across all companies within the chain and incorporates the three pillars of sustainable development, including economic, environmental, and social, based on stakeholder and customer demands (Seuring and Müller, 2008).

When it comes to environmental sustainability, green practices play a crucial role. These strategic actions help reduce the negative impacts of manufacturing while improving economic benefits and ecological efficiency by minimizing environmental risks (Cabral et al., 2012; Luthra et al., 2016). Although environmental aspects often receive the most attention, the social dimension is also critical. It leads to equal opportunities, individual rights, education, legal rights, and the development and training of people (Ruiz-Benitez et al., 2019). In addition, focusing on environmental and social performance can bring financial advantages such as cost savings, increased revenue, and better funding opportunities (Kantabutra, 2024). In fact, the economic performance is not the only focus for organizations anymore; stakeholders now expect more. While improving sales and profits is still very important, companies must also consider environmental and social issues (Yusuf et al., 2020).

According to Alzubi and Akkerman (2022) and Hossain et al. (2023), supply chain sustainability is important because it impacts a company's competitiveness as well as its economic, environmental, and social performance. Sustainability performance is a complex idea and cannot be measured directly; instead, it should be assessed using various indicators. However, despite the substantial information developed by researchers over the past few decades, supply chain managers still require direction to find more effective ways to enhance their environmental and social performance (Kantabutra, 2024). In this research, we will identify and examine these factors.

The LARG paradigm is suggested as the foundation for building a competitive SCM. Several studies have explored how the LARG paradigm affects different aspects of performance. Sukwadi et al. (2013) studied lean–agile operations and supplier–firm partnerships in the Taiwanese garment industry based on Structural Equation Modelling (SEM). Altay et al. (2018) examined the effects of agility and resilience on SCP before and after disasters under the moderating effect of organizational culture. Purba et al. (2024) in a study, indicated that all LARG aspects need improvement in Indonesia’s electric vehicle industry, particularly resilience and greenness. Hossain et al. (2023) analyzed factors to implement green-lean supply chain management (GLSCM). Jakhar et al. (2018) explored the interrelationship between lean and green and identified that leanness positively impacts sustainability in supplier selection and production but negatively affects delivery and logistics sustainability. Ruiz-Benitez et al. (2019) studied the effects of lean and resilient strategies on supply chains across three sustainability dimensions. They showed that while economic and environmental sustainability can be supported by lean and resilient strategies, achieving social sustainability is difficult. Numerous studies have conceptually or theoretically examined different dimensions of the LARG paradigm (Azevedo et al., 2011; Carvalho et al., 2011; Cabral et al., 2012; RASIDI et al., 2017), or integrated LARG paradigm with sustainability (Ramirez-Peña et al., 2020; Anvari, 2021; Sharma et al., 2021) and highlighted the need for further research in this area. Ghazvinian et al. (2024) applied SEM and intuitionistic fuzzy TOPSIS to propose a lean, agile, resilient, green, and sustainable supplier selection approach, which contributes to prioritizing and selecting suppliers to enhance SSCP. To better understand the scope of the existing literature and identify critical research gaps, Table S1 of the supplementary material is provided.

Despite all these efforts, there is still a lack of studies that aggregate all dimensions of the LARG paradigm and examine their combined impact on all sustainability dimensions of the supply chain. Based on these findings, we suggest the following hypothesis to explore the potential positive connections between the LARG paradigm and the economic, environmental, and social performance aspects of the supply chain:

Hypothesis 1. LARG paradigm positively and significantly influences SSCP.

2.3. CSFs in SSCM

In the study of SSCM, it is essential to identify the practices that motivate companies to integrate sustainability into their operations. The CSFs are the essential areas, conditions, or capabilities that an organization must effectively manage to achieve its goals. They highlight the key areas that an organization needs to excel in to achieve superior performance (Prasad et al., 2018). Identifying CSFs can help organizations align their resources and strategies with critical factors that directly impact sustainability (Alzubi and Akkerman, 2022). Many empirical studies show that properly implementing CSFs has a significant positive impact on business performance and sustainability (Alzubi and Akkerman, 2022). For example, Prasad et al. (2018) examined CSFs and their interactions with sustainability performance in the Indian steel industry using quantitative data. According to their findings, external factors do not significantly affect SSCP, whereas among organizational factors, top leadership commitment and support stand out as the key factor that can significantly improve an organization's sustainability performance. Su et al. (2023) identified the CSFs supporting sustainable development in the agricultural food cold chain. Their research indicated that managing stakeholder pressure is the most influential CSF. Chowdhury et al. (2020) presented 12 CSFs for the apparel supply chain in Bangladesh, where collaboration and customer satisfaction were found essential. According to the study, Setino (2020) identified five CSFs for implementing supply chain strategies in state-owned entities, with the development of supply chain policies and procedures ranked highest. Agrawal et al. (2023) identified and ranked the most significant CSFs for sustainable GSCM in the Indian brass manufacturing industry. This literature reveals the developing significance of CSFs, which would boost the chances of having a successful implementation of SSCM.

Managers need to know which measurement metrics are effective for their manufacturing sustainability success. Additionally, having too many metrics is not as important as having a few strong ones with a clearer picture of performance (Carvalho et al., 2011). Based on our review of various studies on CSFs, several CSFs have been identified that might have an impact on how well SSCM methods operate in organizations. We selected and integrated the most frequently mentioned CSFs in SCM to investigate their impacts on SSCP of the manufacturing sector, including:

1. Top leadership commitment and support: Strong leadership is essential to make policy changes and promote a culture of sustainability in the firms (Prasad et al., 2020).
2. Government support: Government policies and procedures play a crucial role in the successful implementation of SCM practices (Chowdhury et al., 2020).
3. Capable human resources: Appropriately motivated and skilled employees are essential for the successful implementation of SCM strategies. According to Setino (2020) the implementation of supply chain strategies will remain impossible without the right people with the right sets of skills for SCM.
4. Trust between partners: Building trust among supply chain partners increases commitment, and collaboration, and improves the implementation of sustainability practices (Wu et al., 2004).
5. Dedicated IT infrastructure: Khan et al. (2018) concluded that investing in IT infrastructure helps to enhance communication and efficiency throughout the supply chain. Better information sharing with supply chain partners and training for employees using this infrastructure can improve performance in SSCM.
6. Social practices for employees and the community: Supporting employee well-being and community engagement contributes to a positive work environment and enhances employee satisfaction (Das, 2018).

In light of these findings, the second hypothesis of this paper is as follows:

Hypothesis 2. Supply chain CSFs positively and significantly influence SSCP.

According to the literature, the relationship between CSFs and each of the LARG indicators has been studied individually. Luthra et al. (2016) examined the role of CSFs in implementing GSCM in India's automobile industry. They found that regulatory factors drive green practices, while internal management and competitiveness are crucial for better sustainable performance outcomes. In another study, Azam et al. (2023) looked at the CSFs that are important for making a resilient supply chain. The paper highlighted eleven vital CSFs related to small and medium-sized enterprises (SMEs). Nozari and Aliahmadi (2022) emphasized quick customer response as a key CSF in lean supply chains. Fekri and Ahmadi (2023) identified eleven CSFs relevant to agile supply chains in service enterprises.

To the best of our knowledge, the effect of CSFs on the integration of all dimensions of the LARG paradigm has not yet been explored. This study aims to examine whether different CSFs significantly relate to the LARG paradigm. Understanding these relationships helps prioritize and strengthen CSFs to optimize implementation of the LARG, which will ultimately improve sustainability outcomes. It also enables tailoring LARG strategies specifically to the manufacturing sector to meet its specific needs. In addition to determining the direct relationships between CSFs and SSCM, we hypothesize that the LARG paradigm plays a significant mediating role in how CSFs impact SSCM. If direct relationships are weak, this analysis would clarify if the LARG paradigm is essential for enabling the full impact of CSFs on sustainability performance. If the direct links are strong, the mediation analysis will still provide insight into how the LARG paradigm enhances or alters CSFs’ effects on SSCM. Consequently, the third and fourth hypotheses are proposed:

Hypothesis 3. Supply chain CSFs positively and significantly influence the LARG paradigm.

Hypothesis 4. The LARG paradigm has a mediating effect on the relationship between CSFs and SSCP.

2.4. Research framework

The proposed framework is developed from an extensive literature review and expert insights. Figure 1 illustrates a conceptual model to explore the relationship between the LARG paradigm and CSFs and their impacts on SSCP. The model also proposes that CSFs have both direct and indirect effects on SSCP, exploring the mediating role of the LARG paradigm.

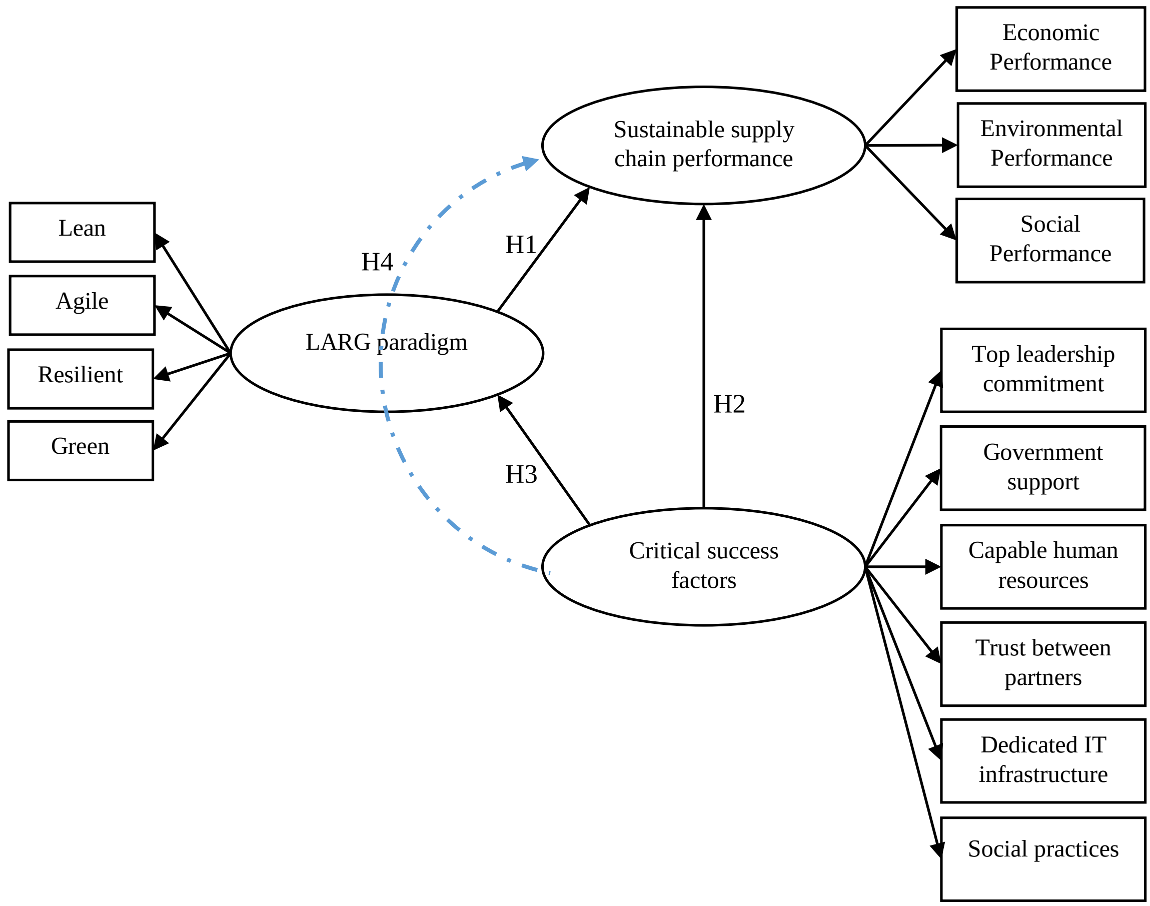

Figure 1. Conceptual model of the research

3. Research methodology

In this section, more information about the context of the research, measurement items, the sample and data collection process, assessment of potential biases, and details of proposed analytical tools can be found.

3.1. Research Context

Manufacturing firms play a significant role in both economic development and environmental challenges. They are major contributors to environmental pollution, primarily due to the excessive use of natural resources and the generation of substantial waste. At the same time, disruptions in this sector create serious vulnerabilities across economies. The COVID-19 pandemic clearly demonstrated this dependence, as manufacturing became essential even for basic necessities such as personal protective equipment (Foundation, 2022). It is therefore not surprising that manufacturing is often referred to as the backbone of the economy (Foundation, 2022). In Iran, this role is particularly significant. In 2023, Iran's manufacturing sector contributed approximately 19.41% to its Gross Domestic Product (GDP). This figure is notably higher than the global average of 12.33% for the same year (TheGlobalEconomy.com, 2023). This comparison underscores the sector’s crucial contribution to Iran’s economic growth and industrial development. Despite its importance, sustainable practices are still limited in Iranian manufacturing. For example, Pourvaziri et al. (2024), in a study on the Iranian construction industry, reported that although green culture has a positive effect on sustainable performance, it is still not widely implemented. These challenges motivate this study to explore the overlooked relationships among the LARG paradigm, CSFs, and SSCP in the context of Iranian manufacturing firms.

3.2. Measurement items

3.2.1. Survey design

In this research, a comprehensive process, incorporating input from research literature, industry professionals, and academic experts, was used to create a well-rounded research questionnaire. The questionnaire consisted of two sections. The first section included six questions designed to gather general and demographic information about the respondents and their firms, and the second section contained the study's main constructs, including the LARG paradigm, factors that are critical to the success of sustainable supply chains (CSFs), and SSCP. To develop measures for dimensions of the LARG paradigm and CSFs, which are not explicitly addressed in the existing research literature, an approach developed by Bienstock et al. (1997) was used. The process started with developing questions based on variables drawn from the literature and insights obtained through interviews with 10 logistics experts from Iran’s manufacturing sector. The profile of these experts is presented in Table 2. Some primary characteristics considered during the selection of experts include direct involvement in logistics and SCM activities, consistent awareness of operational and sustainability-related projects in the manufacturing sector, motivation and willingness to collaborate in research initiatives, Belief in the value of knowledge obtained through collective agreement (Ghasemi and Valmohammadi, 2023). Consulting with these experts helped us refine the questions and ensure that the LARG paradigm and CSFs we included were accurately represented. Following that, academic experts were selected from faculty members in operations and SCM with peer-reviewed publications in the field to evaluate the questions’ clarity, readability, and validity. In the third step, we tested these refined questionnaires through face-to-face interviews with industry experts. This phase aimed to confirm the clarity of the questions based on practical experiences. The feedback we received resulted in additional revisions. This dual profile ensured that the questionnaire items were both theoretically grounded and practically applicable. A detailed list of sources for each structure and item can be found in Table 3, and the survey items are presented in Appendix A, using a five-point Likert scale for all items (with 1 indicating ‘Strongly Disagree’ and 5 indicating ‘Strongly Agree’).

Table 2. Profile of the industry experts

Expert	Position / Role	Years of Experience	Education	Industry Sector	Gender
E1	Logistics Manager	12	PhD	Automobile Industry	Male
E2	Supply Chain Director	18	PhD	Food & Beverage	Male
E3	Operations Manager	15	MSc	Cellulose industry	Male
E4	Procurement Head	10	MSc	Electronics	Male
E5	SCM Planner	11	MSc	Chemical Manufacturing	Female
E6	Distribution & Transport Manager	7	MSc	Food & Beverage	Male
E7	Logistics Manager	14	MSc	Automobile Industry	Male
E8	Head of SCM	16	PhD	Electronics	Male
E9	Logistics Supervisor	9	MSc	Pharmaceutical products industry	Female
E10	Fleet Manager	13	MSc	Food & Beverage	Male

Table 3. Constructs and respective measures

Construct or Latent Variable	Measures or Manifest Variable	Number of questions	Measure code	Adapted from
LARG paradigm	Lean	4	Lean	(Moyano-Fuentes et al., 2019) (Dey et al., 2019)
	Agile	7	Agile	(Altay et al., 2018)
	Resilient	6	Resilient	Golgeci and Y. Ponomarov,) (2013
	Green	6	Green	(Zhu et al., 2008)
CSFs	Top leadership commitment and support	4	Leadership commitment	(Prasad et al., 2018) (Chin et al., 2004) (Grimm et al., 2014) (Khan et al., 2018) (Chowdhury et al., 2020)
	Government support	4	Government support	(Khan et al., 2018) (Chowdhury et al., 2020)
	Capable human resources	4	Capable HR	(Setino, 2020) (Chowdhury et al., 2020)
	Trust between partners	3	Partnership Trust	(Wu et al., 2004)
	Dedicated IT Infrastructure	3	IT Infrastructure	(Khan et al., 2018)
	Social practices for employees and community	4	Social practices	(Das, 2018)
SSCP	Economic performance	3	Economical	(Zailani et al., 2012) (Wang and Dai, 2018)
	Environmental performance	2	Environmental	
	Social performance	2	Social	

3.2.2. Control Variables

We incorporated industry type and firm size as control variables to make sure our hypotheses stayed valid in the empirical analysis, even after considering these factors (Yu et al., 2019). However, none of these variables had a significant effect on SSCP, indicating that they did not meaningfully influence the model's outcomes (see Table 4).

Table 4. Results of control variables performance

Path	T statistics	P-value
Firm Size -> SSCP	1.338	0.181
Industry Type -> SSCP	0.782	0.434

3.3. Sampling and data collection

Data for this research were gathered through an online questionnaire distributed to manufacturing firms in Iran, one of the major emerging economies. The link to the online form was sent to 400 respondents from small-to-large manufacturing firms in Iran. Approximately 18% from small companies, 45% from medium-sized companies, and 37% from large companies. Participants included managers and experts from various sectors such as food (72%), chemicals (11%), pharmaceuticals (7%), automobiles (4%), cellulose (4%), and electronics (2%). All participants had relevant experience and a strong understanding of SSCM, having attended a sustainable development strategies conference. Table 5 provides detailed information about the companies, along with demographic details about the respondents. In this study, 112 filled questionnaires were received with a response rate of 28%. There were no missing or incomplete answers.

The convenience sampling technique was applied to identify potential respondents. This technique, in addition to being useful for confirmatory research surveys, can also reduce the cost and time of the data collection process as one of the non-probability sampling techniques (Alipour et al., 2022). This method can introduce bias, as we will discuss in the following sections.

Table 5. Demographic profile of respondent

Demographic Item	Categories	Total	Percentage
Age of firms	< 5 years	51	45%
	5–10 years	4	4%
	11–20 years	46	41%
	> 20 years	11	10%
The primary activity of firms	food and beverage industry	81	72%
	Chemicals and petrochemicals industry	13	11%
	Pharmaceutical products industry	8	7%
	Automobile Industry	4	4%
	Cellulose industry	4	4%
	Electronics and electrical industry	2	2%
Size of firms (number of employees)	< 50 people	20	18%
	50–100 people	3	3%
	101–200 people	22	20%
	201–300 people	25	22%
	> 300 people	42	37%
Job position	CEO	2	2%

Demographic Item	Categories	Total	Percentage
	Chief	2	2%
	Manager	24	21%
	Senior expert	25	22%
	Expert	59	53%
Years of experience	< 5 Years	27	24%
	5 to 10 Years	46	41%
	11 to 20 Years	31	28%
	21 to 30 Years	5	4%
	> 30 Years	3	3%
Status of work	Planning and production	24	21%
	Engineering and product development	19	17%
	Logistics and purchasing	9	8%
	Marketing and sales	25	22%
	Customer service	2	2%
	Other	33	30%

3.4. Non-response bias test

Non-response bias was evaluated using the method proposed by Armstrong and Overton (1977), comparing early respondents (N=52) with late respondents (N=60) across six demographic variables. The t-test results indicated no significant differences between the two groups (p > 0.05). Additionally, Levene's test indicated equal variances between early and late respondents, indicating that non-response bias does not affect this study (see Table 6).

Table 6. Comparisons of early and late respondents

Variables	Mean early respondents (N = 52)	Mean late respondents (N = 60)	t-value	Sig. (2-tailed)	Leven Sig.
Size of the firm	3.27	3.15	0.42	0.67	0.33
Age of firms	2	1.97	0.17	0.86	0.33
activity of firms	3.98	4.22	-1.09	0.28	0.94
Status of work	3.75	3.37	1.05	0.3	0.23
Job position	4.15	4.32	-0.87	0.39	0.78
Years of experience	2.21	2.2	0.06	0.95	0.65

3.5. Common method bias test

Common Method Bias (CMB) arises as a potential validity concern when the same method is used to collect data across multiple variables. In our study, we collected data from a single source within each firm using a self-report questionnaire, which introduces the potential for CMB. For checking the CMB, prior studies have suggested several approaches (Lindell and Whitney, 2001; Podsakoff et al., 2003), which can be grouped into prior and posterior. In doing the former, as explained before, the measurement items in the study were initially developed using the systematic approach of Bienstock et al. (1997), which emphasizes construct clarity, expert validation, and pre-testing, thereby reducing the likelihood of method-related variance at the scale development stage. Despite these measures, the possibility of the CMB in the data was not ignored. To assess whether our study was affected by this bias, first we conducted Harman's one-factor test (Podsakoff et al., 2003). The results indicate that a single factor accounted for about 48.49% of the total variance, which is below the 50% threshold. This implies that CMB is not a significant concern in our research. However, in line with extant studies (Schwarz et al., 2017), which have criticized Harman's single-factor approach to CMB detection, the marker variable technique proposed by Lindell and Whitney (2001) was also used (see Appendix B). The results of the marker variable test revealed non-significant paths from the marker variable to the main constructs (CSFs, LARG, and SSCP), with P-value exceeding 0.05. These two statistical tests suggest that CMB is not a major concern for the validity of the results.

3.6. Data analysis approach

In this study, Variance-Based Structural Equation Modelling (VB-SEM) was employed using SmartPLS4 software to test the hypotheses. Partial Least Squares Structural Equation Modelling (PLS-SEM) is good at predicting results and developing theories, combining methods such as regression, discriminant analysis, and factor analysis. It works well with small sample sizes and data that are not normally distributed (Alipour et al., 2022; Hair et al., 2021). Unlike Covariance-Based modelling (CB-SEM), which requires normal data and is better for confirming theories, PLS-SEM offers more statistical power and flexibility. This method was a good fit for our study because of the sample size of 112, which meets Cohen's (1992) guideline of at least 110 (with a power of 80%, significance level of 5%, $R^2 < 0.10$, and 2 arrows pointing at a construct). By using PLS-SEM, the study effectively assessed and confirmed the relationships among the LARG paradigm, CSFs, and SSCP, providing reliable results in the context of SSCM research. Therefore, model estimation was conducted in two steps: initially, the measurement model was assessed for validity and reliability, and subsequently, the structural model was analyzed to evaluate the hypotheses. SmartPLS 4.0 software was used for both stages, with parameters estimated through bootstrapping. Figure 2 shows the steps of the proposed methodology.

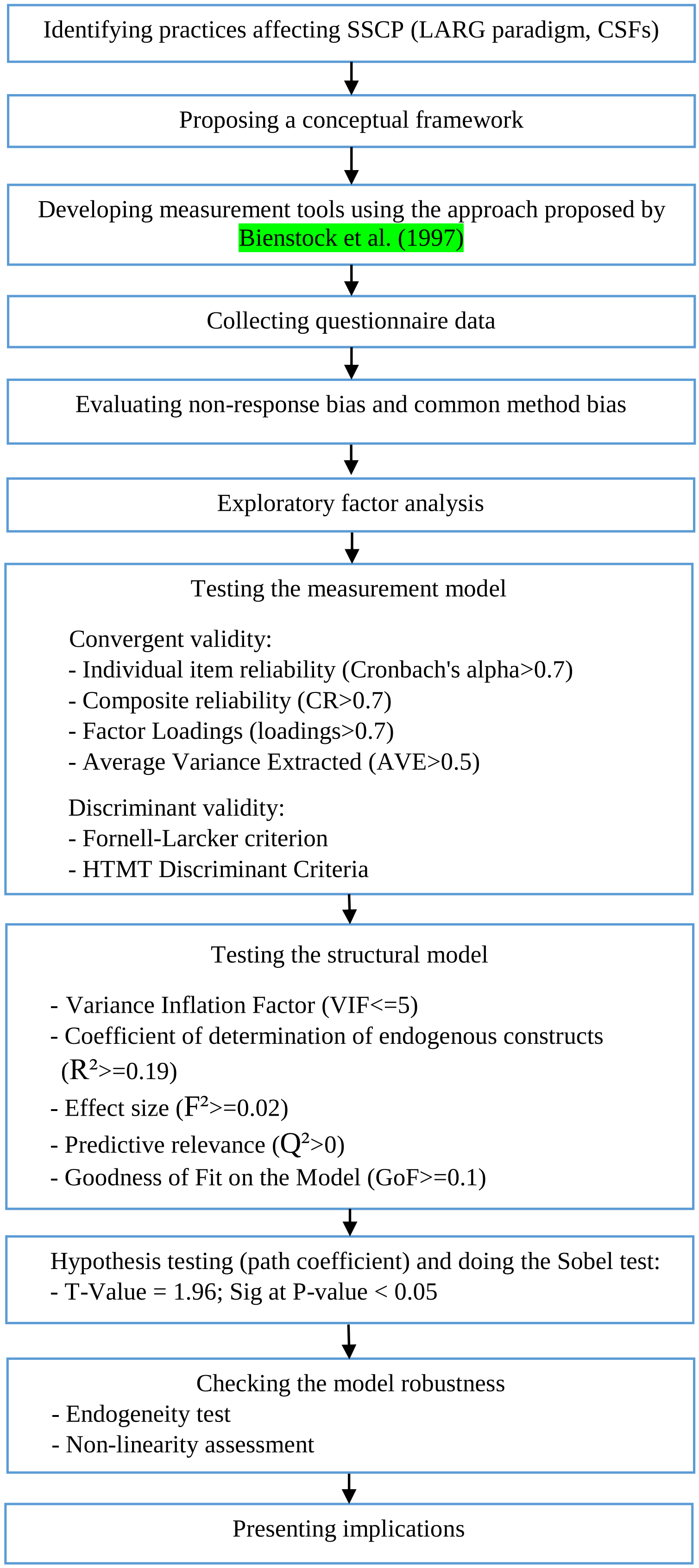

Figure 2. Steps of the proposed methodology

4. Data analysis and findings

The data analysis was conducted in three main phases. First, an Exploratory Factor Analysis (EFA) was applied to examine the underlying structure of the constructs and verify that the items loaded properly on their respective factors. After confirming the dimensionality of the constructs, the analysis proceeded with the PLS-SEM method, which is implemented in two steps: the analysis of the measurement model and the analysis of the structural model. First, the measurement properties of the first-order constructs were assessed because these constructs serve as a foundation for the second-order constructs (LARG paradigm, CSFs, and SSCP). Following this, the structural assessment was conducted. All outputs generated by the SPSS and SmartPLS software are available and can be shared for further reference.

4.1. Exploratory factor analysis

In this study, EFA was conducted to examine the validity of the constructs, given that the variables consisted of several components (Ahmad Amouei et al., 2023). We conducted Principal Component Analysis (PCA) with Varimax rotation in SPSS 27.0 to explore construct dimensions, streamline the number of items, and establish a standard linear and powerful model. Following Kaiser (1974), the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.881, which is well above the recommended minimum threshold of 0.6, indicating that the sample size was sufficient for factor analysis. In addition, Bartlett's Test of Sphericity was significant (χ^2 = 5200.350, df = 1326, $p < 0.001$), providing additional evidence for the suitability of the data for factor analysis. Moreover, all item loadings exceeded the recommended criteria of 0.60 (Bartlett, 1954; Hair et al., 2010). Then the EFA was conducted in two stages. First, first-order EFA was performed on the measurement items to identify the underlying first-order factors for each construct. All item loadings exceeded the recommended threshold of 0.50, so no items were deleted (Hair et al., 2010). On the basis of these first-order results, three factors, including economic, environmental, and social performance, were identified and subsequently combined to form the second-order construct SSCP. Likewise, first-order factors representing LARG were found to load onto the second-order LARG construct, and six dimensions clustered under the second-order CSFs construct. Detailed results of both first- and second-order EFAs are presented in Tables 7–10.

Table 7. KMO and Bartlett's Test

KMO Measure of Sampling Adequacy.		0.881
Bartlett's Test of Sphericity	Approx. Chi-Square	5200.350
	df	1326
	P-Value	0.000***

***P<0.001

Table 8. First- and second-order EFA for SSCP

Item	Principal components (First-order)			Component (Second-order)	
	Economic	Environmental	Social	Variables	SSCP
Q1	0.859			Economic	0.849
Q2	0.848				
Q3	0.880				
Q4		0.905		Environmental	0.845
Q5		0.905			
Q6			0.912	Social	0.856
Q7			0.912		

Table 9. First- and second-order EFA for LARG

Item	Principal components (First-order)				Component (Second-order)	
	Lean	Agile	Resilient	Green	Variables	LARG
Q8	0.863				Lean	0.85
Q9	0.896					
Q10	0.873					
Q11	0.899					
Q12		0.864			Agile	0.886
Q13		0.884				
Q14		0.852				
Q15		0.893				
Q16		0.857				
Q17		0.836				
Q18		0.840				
Q19			0.861		Resilient	0.887
Q20			0.858			
Q21			0.873			
Q22			0.870			
Q23			0.870			
Q24			0.808			
Q25				0.813	Green	0.813
Q26				0.894		
Q27				0.872		
Q28				0.895		
Q29				0.866		
Q30				0.702		

Table 10. First- and second-order EFA for CSFs

Item	Principal components (First-order)						Component (Second-order)	
	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	Variables	CSFs
Q31	0.914						CSF1	0.834
Q32	0.921							
Q33	0.927							
Q34	0.930							
Q35		0.842					CSF2	0.683
Q36		0.840						
Q37		0.863						
Q38		0.867						
Q39			0.840				CSF3	0.816
Q40			0.854					
Q41			0.783					
Q42			0.818					
Q43				0.878			CSF4	0.816
Q44				0.915				
Q45				0.839				
Q46					0.922		CSF5	0.846
Q47					0.932			
Q48					0.904			
Q49						0.874	CSF6	0.856
Q50						0.794		
Q51						0.892		
Q52						0.819		

4.2. Testing the measurement model

PLS analysis begins with establishing the measurement model, commonly referred to as the outer model. In testing the measurement model, construct reliability, construct validity, convergent validity, and discriminant validity were employed.

4.2.1. Reliability analysis

To demonstrate the construct reliability of the variables, we used two tests: Cronbach's alpha and the Composite Reliability (CR) coefficient. According to Hair et al. (2021) the acceptance level of Cronbach's alpha coefficient in assessments is 0.7 or above. All the Cronbach's alpha values for the constructs were over 0.7, indicating good reliability. However, Cronbach's alpha tends to underestimate reliability for Likert-type scales with five levels, so its use is not recommended (Gadermann et al., 2012). Compared to the conventional Cronbach's alpha coefficients, CR assesses the reliability of internal consistency more accurately (Hair et al., 2021). The value of CR ranges from 0.894 to 0.958 and exceeds the 0.70 acceptability threshold. Table 11 shows that all constructs have a high degree of internal consistency reliability.

4.2.2. Convergent validity

To show convergent validity, Average Variance Extracted (AVE) was employed, which is calculated as a mean of each indicator's squared loadings. For each construct, the AVE values ranged from 0.678 to 0.852, higher than the suggested acceptable value of 0.50 (Hair et al., 2021). At the indicator level, all items in this research demonstrated factor loadings greater than 0.708, indicating significant values based on Hair et al. (2021). Consequently, all constructs have satisfactorily met the convergent validity requirement, as illustrated in Table 11.

Table 11. Reliability and convergent validity tests

Variables	Item	Factor Loading (> 0.7)	Cronbach's alpha (> 0.7)	CR (> 0.7)	AVE (> 0.5)
Economic performance	Q1	0.851	0.828	0.897	0.744
	Q2	0.842			
	Q3	0.893			
Environmental performance	Q4	0.908	0.778	0.900	0.818
	Q5	0.901			
Social performance	Q6	0.903	0.798	0.908	0.832
	Q7	0.920			
Lean	Q8	0.864	0.906	0.934	0.779
	Q9	0.899			
	Q10	0.872			
	Q11	0.896			
Agile	Q12	0.864	0.942	0.952	0.741
	Q13	0.881			
	Q14	0.855			
	Q15	0.893			
	Q16	0.857			
	Q17	0.836			
	Q18	0.840			
Resilient	Q19	0.863	0.928	0.943	0.734
	Q20	0.856			
	Q21	0.869			
	Q22	0.870			
	Q23	0.873			
	Q24	0.810			
Green	Q25	0.797	0.917	0.936	0.709
	Q26	0.885			
	Q27	0.851			
	Q28	0.900			
	Q29	0.875			
	Q30	0.731			
Top leadership commitment and support	Q31	0.914	0.942	0.958	0.852
	Q32	0.917			
	Q33	0.928			
	Q34	0.934			
Government Support	Q35	0.843	0.875	0.914	0.727
	Q36	0.862			
	Q37	0.861			
	Q38	0.844			
Capable human resources	Q39	0.825	0.842	0.894	0.678

	Q40	0.833			
	Q41	0.799			
	Q42	0.835			
Trust between partners	Q43	0.880	0.850	0.910	0.770
	Q44	0.912			
	Q45	0.840			
Dedicated IT Infrastructure	Q46	0.918	0.909	0.943	0.845
	Q47	0.929			
	Q48	0.911			
Social practices	Q49	0.881	0.866	0.909	0.715
	Q50	0.786			
	Q51	0.889			
	Q52	0.822			

4.2.3. Discriminant validity

To determine whether we can conclude that this study has discriminant validity, we first used the Fornell-Larcker criterion, which finds out whether the AVE of each construct is greater than the squared correlation coefficient between them (Fornell and Larcker, 1981). However, considering that the Fornell-Larcker criteria cannot accurately identify the absence of discriminant validity, the method is frequently contested. As a result, Heterotrait-Monotrait (HTMT) ratios of correlation were suggested under multitrait-multimethod matrices. The HTMT index, as well as calculating discriminant validity within a construct, is capable of calculating discriminant validity across constructs. Values for the HTMT ratio must be less than 0.85 to comply with discriminant validity (Kline, 2015), all of which are less than 0.85 in this study (see Tables 12 and 13). In addition, all the results of the path analysis are illustrated in Figure 3.

Table 12. Fornell-Larcker criterion results

Factors	Agile	Capable HR	Economical	Environmental	Government support	Green	IT Infrastructure	Leadership commitment	Lean	Partnership Trust	Resilient	Social	Social practices
Agile	**0.86**												
Capable HR	0.66	**0.82**											
Economical	0.64	0.57	**0.86**										
Environmental	0.52	0.53	0.58	**0.90**									
Government support	0.44	0.49	0.40	0.51	**0.85**								
Green	0.61	0.63	0.60	0.57	0.51	**0.84**							
IT Infrastructure	0.65	0.65	0.53	0.43	0.53	0.56	**0.92**						
Leadership commitment	0.76	0.61	0.69	0.64	0.45	0.62	0.61	**0.92**					
Lean	0.70	0.64	0.65	0.62	0.40	0.59	0.56	0.69	**0.88**				
Partnership Trust	0.72	0.59	0.62	0.51	0.41	0.62	0.64	0.73	0.63	**0.88**			
Resilient	0.74	0.64	0.66	0.55	0.46	0.66	0.63	0.67	0.65	0.63	**0.86**		

Social	0.59	0.52	0.60	0.59	0.45	0.59	0.52	0.67	0.64	0.61	0.55	**0.91**	
Social practices	0.63	0.65	0.56	0.54	0.57	0.59	0.69	0.66	0.64	0.59	0.64	0.56	**0.85**

Table 13. HTMT result

Factors	Agile	Capable HR	Economical	Environmental	Government support	Green	IT Infrastructur	Leadership commitment	Lean	Partnership Trust	Resilient	Social	Social practices
Agile													
Capable HR	0.74												
Economical	0.72	0.68											
Environmental	0.60	0.65	0.71										
Government support	0.47	0.56	0.46	0.61									
Green	0.64	0.70	0.68	0.67	0.56								
IT Infrastructure	0.70	0.73	0.61	0.50	0.58	0.61							
Leadership commitment	0.81	0.68	0.77	0.75	0.48	0.65	0.65						
Lean	0.76	0.73	0.75	0.73	0.44	0.63	0.61	0.75					
Partnership Trust	0.81	0.69	0.74	0.62	0.47	0.69	0.72	0.81	0.71				
Resilient	0.79	0.72	0.75	0.65	0.50	0.71	0.69	0.71	0.71	0.71			
Social	0.68	0.63	0.73	0.74	0.52	0.68	0.61	0.78	0.75	0.75	0.64		
Social practices	0.69	0.75	0.65	0.66	0.64	0.65	0.77	0.72	0.71	0.69	0.71	0.68	

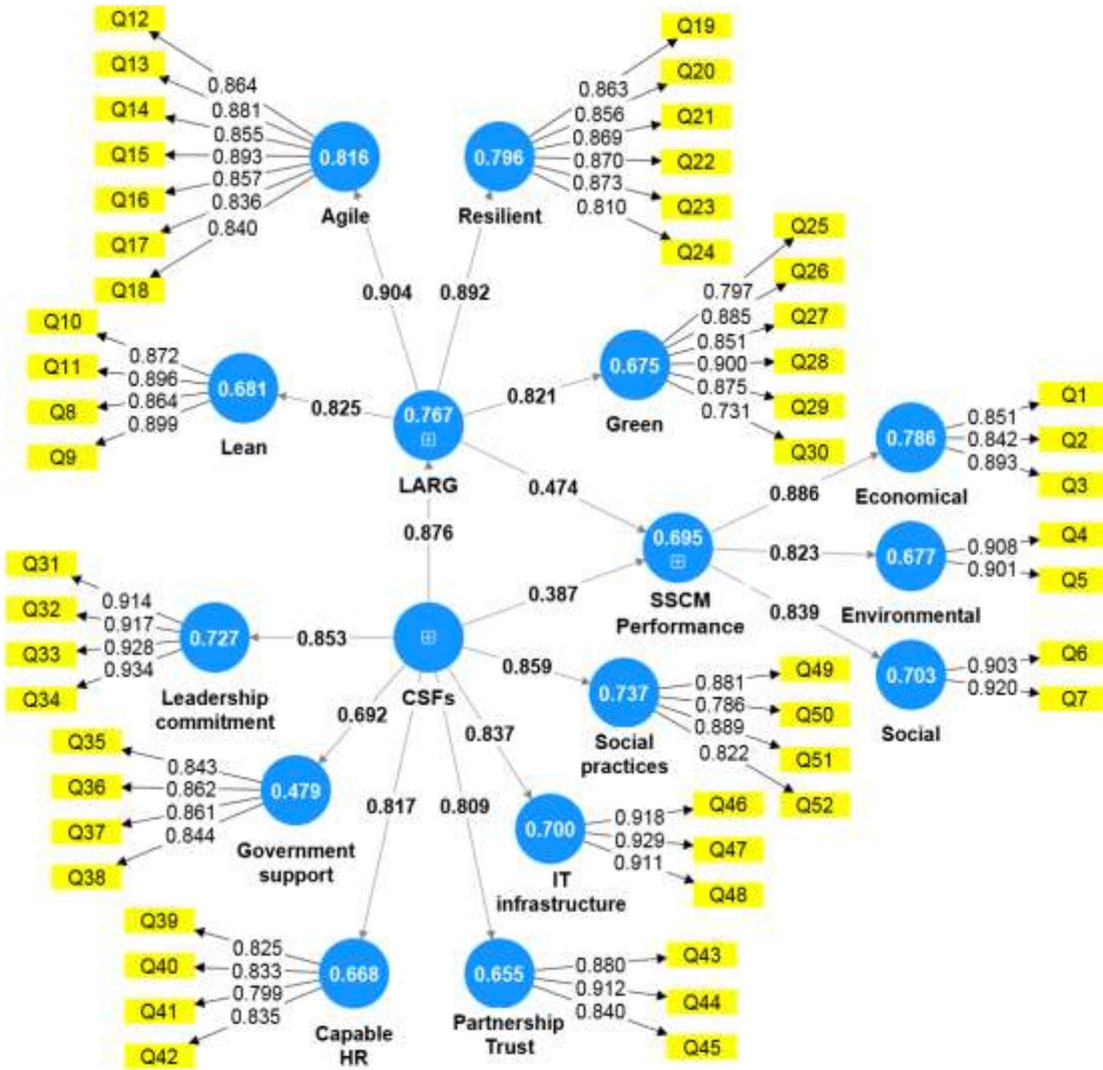

Figure 3. Measurement Model Assessment

4.3. Analysis of the structural model

After assessing the fit of the measurement model and confirming its reliability and validity, the structural research model was looked at. As recommended by Hair et al. (2021) the first step is to measure the level of collinearity between the exogenous constructs and the structural model. For this purpose, the Variance Inflation Factor (VIF) should not exceed 5. The maximum VIF for this model was 4.293, which suggests multicollinearity is not a problem.

The next examined is the coefficient of determination (R^2) of the endogenous constructs. The R^2 represents the model's explanatory power, showing how much of the variance in the endogenous construct is explained by its predictor constructs (Hair et al., 2021). According to Chin (1998) the values of R^2 equal to 0.67, 0.33 and 0.19 can be considered substantial, moderate, and weak. In the suggested model, both LARG and CSFs follow with 0.767 and 0.690, respectively, and can be considered substantial.

The value of effect size (F^2) demonstrates the extent of the effect of the factor when removed from the model (Hair et al., 2021). Cohen (1992) indicates weak, moderate, and substantial effects for the significant independent variables, respectively, with F^2 values of 0.02, 0.15, and 0.35. In this model Table 14 shows that both CSFs and LARG have moderate effects on SSCP ($F^2 = 0.114$ and $F^2 = 0.172$), while the relationship between CSFs and LARG is highly influential ($F^2 = 3.293$).

To evaluate the prediction power of the structural model, the Q^2 value was analyzed. In PLS path models, the Q^2 is obtained to compare the prediction errors with simple mean predictions. To that end, it predicts the holdout sample results based on the mean value of the training sample. When Q^2 is positive, PLS-SEM results have a smaller predictive error than using mean values alone. In that case, the PLS-SEM model would offer better prediction (Shmueli et al., 2019). As seen in Table 14, all Q^2 values are above zero, which indicates a good predictive power at the inner suggested model structural level.

Finally, the Goodness-of-Fit index (GoF) was computed as an overall measure of model fit that accounts for the performance of both the measurement and structural models (Tenenhaus et al., 2004). A weak, medium, and strong value of GoF is introduced as 0.01, 0.25, and 0.36, respectively (Wetzels et al., 2009). The results indicate a GoF value of 0.71 for the model, which implies a strong fit of the model to the data.

Table 14. VIF, F^2, R^2, R^2 Adjusted, and Q^2_predict

Item	SSCP		LARG		R^2	R^2 Adjusted	Q^2_predict
	VIF	F^2	VIF	F^2			
LARG	4.293	0.172	-	-	0.767	0.765	0.764
CSF	4.293	0.114	1.000	3.293	0.695	0.690	0.634

4.4. Hypothesis testing

To put the research model's hypotheses to the test, a bootstrapping technique involving 5,000 bootstraps was conducted (Hair et al., 2017). This technique elaborates the relationship between the studied variables: the LARG paradigm, CSFs, and SSCP. Results from Table 15 and Figure 4 display the significance t-values and standardized path coefficients for each path in the structural model, with all three hypotheses confirmed. We used a Sobel test to evaluate the importance of the LARG paradigm as a mediating variable. The Sobel test, which is a kind of t-test, checks if the mediation effect is significant by measuring how much the influence of the independent variable decreases in the model (Sobel, 1982). The outcomes of this test are reported in Table 16 and support the idea that the LARG paradigm mediates the relationship between CSFs and SSCP. Here are the details of our findings:

1. Results for H1: The data supported the primary research question (H1) (b = 0.474, t = 3.247, p < 0.001), confirming that the LARG paradigm significantly enhances the SSCP.
2. Results for H2: Integrated CSFs showed a positive relationship with sustainability performance, confirming H2 (b = 0.387, t = 2.694, p < 0.007).
3. Results for H3: CSFs had a strong relationship with the LARG paradigm, supporting H3 (b = 0.876, t = 31.396, p < 0.000).
4. Results for H4: The Sobel test produced a significant t-value of 3.229 and p < 0.001, indicating that the LARG paradigm partially mediates the relationship between CSFs and SSCP.

Table 15. Hypothesis result

Hypothesis	Path tested	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P-Values	Findings
H1	LARG -> SSCP	0.474	0.481	0.146	3.247	0.001***	Confirmed
H2	CSF -> SSCP	0.387	0.380	0.144	2.694	0.007**	Confirmed
H3	CSF -> LARG	0.876	0.875	0.028	31.396	0.000***	Confirmed

***P<0.001; **P<0.01

Table 16. Mediating effects through Sobel test

Path tested	A		B		Sobel test	
	t-value	P-value	t-value	P-value	t-value	P-value
CSF -> LARG	31.396	0.000***				
LARG -> SSCP			3.247	0.001***		
CSF -> LARG -> SSCP (H4)					3.229	0.001***

***P<0.001

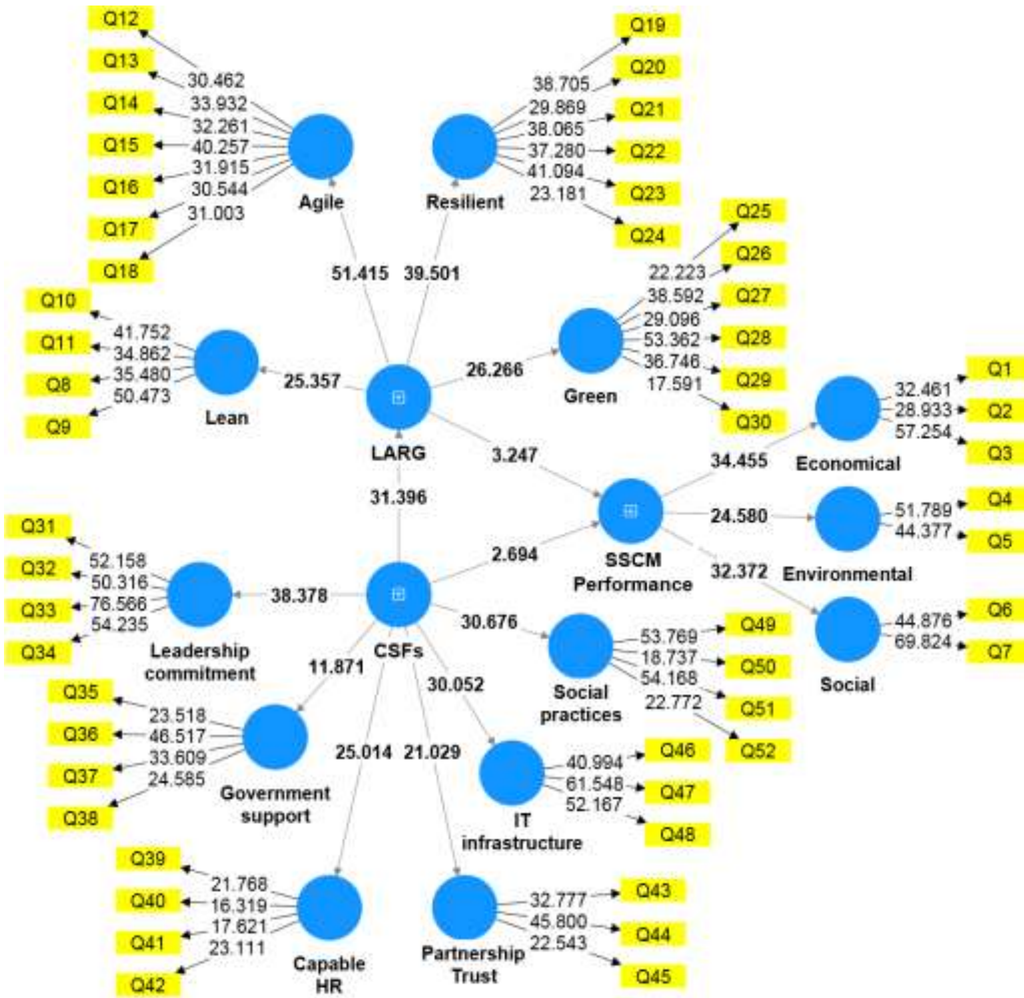

Figure 4. T-values of paths (bootstrapping)

4.5. Model robustness check

4.5.1. Endogeneity test

Endogeneity is a common issue in statistical modelling that arises when a predictor variable is correlated with the error term of the associated dependent variable, potentially resulting in biased and inconsistent parameter estimates. This problem can occur due to omitted variables, measurement errors, or simultaneity between variables (Ntsiful, 2025). In the context of our study, we addressed potential endogeneity by employing the Gaussian copula approach (Park and Gupta, 2012). Table 17 shows the results of the endogeneity assessment, where four models were estimated with the introduction of a copula in each model. The results in bold show that the copula terms were not significant ($p > 0.05$). Accordingly, it can be concluded that endogeneity does not pose a threat in this study and further reinforces the robustness of its structural model.

Table 17. Results of the endogeneity assessment using the Gaussian copula approach

Test	Construct	Coefficient	p-value
Model 1: Gaussian Copula Test (endogenous variable: CSFs; outcome variable: LARG)	CSFs	0.655	0.101
	^{c}CSFs	**0.228**	**0.571**
Model 2: Gaussian Copula Test (endogenous variable: CSFs; outcome variable: SSCP)	CSFs	0.677	0.046
	^{c}CSFs	**-0.067**	**0.367**
Model 3: Gaussian Copula Test (endogenous variable: LARG; outcome variable: SSCP)	LARG	0.199	0.536
	^{c}LARG	**0.063**	**0.364**
Model 4: Gaussian Copula Test (endogenous variable: CSFs, LARG; outcome variable: SSCP)	CSFs	0.606	0.16
	LARG	0.196	0.557
	^{c}CSFs	**-0.247**	**0.552**
	^{c}LARG	**0.311**	**0.344**

c stands for the copula. Models that include the copula are shown in bold.

4.5.2. Non-linearity assessment

To evaluate potential non-linearity, we examined Ramsey's Regression Equation Specification Error Test (RESET) in SPSS. This test assesses whether non-linear combinations of the explanatory variables provide additional explanatory power for the response variable (Ramsey, 1969). The results indicate that the quadratic terms were not statistically significant (Table 18). Therefore, no strong evidence of nonlinear relationships was found, suggesting that linear models remain appropriate for interpreting the associations among the variables.

Table 18. Non-linearity assessment with Ramsey's RESET

Path	P-value
QE (LARG) → SSCP	0.545
QE (CSFs) → LARG	0.137
QE (CSFs) → SSCP	0.750

5. Discussion

This study empirically explains how the LARG paradigm and CSFs affect SSCP. The first hypothesis (H1) revealed a significant impact of the LARG paradigm on SSCP. Some of the previous works support our finding; for example, Ruiz-Benitez et al. (2019) addressed achieving sustainability through lean and resilience in the aerospace supply chain. Govindan et al. (2014) introduces various lean, resilient, and GSC practices in the automotive sector, some with a significant impact on supply chain sustainability and others without. In their study, "ISO 14001 certification" was not found to have a significant impact. However, in our study, it was included as part of green practices.

Findings for the second hypothesis reveal a positive and direct effect of CSFs on SSCP. This finding is crucial because it sets the foundation for understanding the influence of the fourth hypothesis. If this direct relationship had not been significant, the mediating role of the LARG paradigm would have played a more dominant role. However, since the direct relationship is strong, it means that when a firm implements CSFs, it more easily achieves SSCP. In this scenario, the mediation by the LARG paradigm still adds value, but the direct impact of CSFs alone is already significant. These results align with existing literature that explores the association between CSFs and SSCP separately. Studies have shown that factors such as top leadership commitment and support (Chowdhury et al., 2020; Prasad et al., 2020; Agrawal et al., 2023), government support (Khan et al., 2018; Chowdhury et al., 2020), capable human resources (Setino, 2020), trust between partners (Wu et al., 2004), dedicated IT infrastructure (Khan et al., 2018), and social practices for employees and the community (Das, 2018) all contribute to improved sustainability performance. Therefore, our findings are consistent with prior research, further confirming the direct importance of integrated CSFs in achieving sustainability goals in supply chains.

The third hypothesis states the effect on the LARG paradigm caused by CSFs. The findings confirm a positive relationship between the two, which is in line with previous work that individually investigated these relationships, such as CSFs in implementing GSCM in India's automobile industry (Luthra et al., 2016), CSFs for a resilient supply chain (Azam et al., 2023), CSFs in a lean technology-based supply chain (Nozari and Aliahmadi, 2022), and CSFs in an agile supply chain (Fekri and Ahmadi, 2023). The high t-value in this relationship suggests that the CSFs are fundamental to the effective implementation of the LARG paradigm in manufacturing firms. It also indicates that while CSFs directly influence SSCP, this effect is likely mediated by the LARG paradigm, as explored in our final hypothesis.

Our fourth hypothesis assessed the mediating role of the LARG paradigm in the relationship between CSFs and SSCP. Empirical evidence from the Sobel test confirmed a partial mediation effect, indicating that CSFs not only exert a direct influence on SSCP but also enhance outcomes through LARG practices. This result positions LARG as a pivotal mechanism that channels managerial initiatives into stronger sustainability achievements. The finding provides a novel contribution to the literature by demonstrating that, while CSFs independently improve performance, their integration with the LARG paradigm substantially amplifies their impact on supply chain sustainability.

Totally, the findings confirm that the LARG paradigm, when aligned with CSFs, significantly enhance SSCP. This outcome is consistent with the RBV, which posits that competitive advantage arises from deploying valuable and inimitable resources, and with the DCT, which highlights the ability of firms to reconfigure resources in dynamic environments. Importantly, this study fills a gap by showing that, despite the extensive use of these theories, there is still a lack of an integrated framework that combines the resources required for SSCP. Building on this, the study makes several contributions by developing a hierarchical model of LARG and CSFs, providing empirical evidence from an underexplored context, validating a new measurement tool, and examining the mediating role of LARG in enhancing SSCP, all of which are useful for both theory and practice.

6. Implications

6.1. Theoretical implications

The outcomes of this study provide several theoretical implications. With this study, we contribute to the conceptual frameworks discussed in SSCM and its enablers. This research confirmed that the integrated LARG paradigm had a significant positive influence on SSCP. Prior research in this field focused on only a subset of the LARG paradigm or sustainability dimensions. This study incorporates all LARG paradigm and sustainability dimensions comprehensively. Additionally, it explores the incorporation of CSFs into the LARG and SSCP framework for the first time, offering new insights into their combined influence. The proposed research has demonstrated that CSFs significantly and positively impact the LARG paradigm and SSCP. It suggests that CSFs are essential for building effective SSCs.

Additionally, the findings indicate that the LARG paradigm mediates the effect of CSFs on SSCP. To the best of our knowledge, this study is the first to incorporate the LARG paradigm as mediators in SSCP. That means manufacturing firms need to focus on operationalizing CSFs through the LARG paradigm to achieve sustainability goals better. Such mediation represents a novel contribution to the literature. Furthermore, the study offers contextual uniqueness. Our present research is unique in that it examines the interplay between the LARG paradigm, CSFs, and SSCP in the Iranian manufacturing industry.

Moreover, by showing that LARG paradigm strengthen the link between CSFs and sustainability outcomes, this study extends the explanatory power of both RBV and DCT. Specifically, it contributes to theory by integrating two theoretical lenses and demonstrating how a combined resource- and capability-based perspective explains the joint impact of the LARG paradigm and CSFs on sustainability. Thus, the study moves beyond prior research that has examined these practices in isolation and advances theoretical understanding by offering a holistic framework for explaining SSCP in emerging economies.

Furthermore, this study has responded to the call of authors, who urged empirical studies regarding the impact of the LARG paradigm on the sustainability of supply chains. While systematic literature reviews like Ciccullo et al. (2018) and Sharma et al. (2021) and case studies such as Govindan et al. (2014) and Anvari (2021) have explored the impacts of lean, agile, resilient, or green practices on SCM or SSCM conceptually and qualitatively, they have not empirically validated it. Our study offers crucial empirical evidence that supports the theoretical discussions and extends previous conceptual and case-based research. Additionally, this empirical research has attempted to validate the proposed framework via statistical analyses in the manufacturing industries of Iran, an emerging country context that is not considered in the literature.

Finally, this study introduces a validated measurement model for SSCM practices, which will be a valuable resource for future studies. To our knowledge, there is not a comprehensive measurement tool in the existing literature for these sustainability enablers in manufacturing firms. We believe this tool is straightforward and will assist researchers in advancing studies on SSCM practices.

6.2. Practical implications

This study offers crucial guidance for managers in the manufacturing sector to adopt practices that promote environmental responsibility, social awareness, and economic benefits in the supply chain. Our analysis found a significant impact of the LARG paradigm on SSCP. Therefore, managers in the manufacturing sector should implement integrated LARG practices to achieve better sustainable performance in their supply chains. Additionally, our analysis found a significant impact of CSFs on both the LARG paradigm and SSCP and highlighted the mediating role of the LARG paradigm. This shows that while CSFs are beneficial on their own, the LARG paradigm facilitates the full realization of their benefits. This means that manufacturing managers should implement CSFs alongside the LARG paradigm to achieve optimal sustainability across the supply chain. These factors provide a foundation for enabling the LARG paradigm, which works together to optimize the economic, environmental, and social performance of supply chains.

Moreover, sustainability has multiple dimensions that are difficult to capture in a single system, and improvement efforts are often fragmented. Nevertheless, manufacturing firms are under pressure to consider sustainability dimensions in their operations (Brandenburg et al., 2019), and firms must monitor and evaluate performance across economic, environmental, and social dimensions. This study introduces a unique measurement model that helps managers evaluate the sustainability of their supply chains. By consistently evaluating progress in these dimensions, firms can identify areas for improvement and maintain long-term sustainability.

7. Conclusions

This study explored the combined impact of the LARG paradigm and CSFs on SSCP. A conceptual framework with four hypotheses was developed to empirically analyze these relationships in Iran's manufacturing sector. Data from 112 decision-makers in manufacturing firms were collected using a measurement model developed in the study. A PLS-SEM model was constructed to test the hypotheses, and statistical analyses were conducted to validate the model. Grounded in the RBV and DC perspectives, the findings revealed that the LARG paradigm and CSFs significantly improved SSCP, with CSFs strongly impacting the LARG paradigm. Additionally, the LARG paradigm played a partially mediating role in the association between CSFs and SSCP. Manufacturing firms need to prioritize CSFs along with the LARG paradigm to achieve optimum sustainability performance of their supply chains and effectively navigate the challenges of a vulnerable business environment and evolving market requirements.

This study had certain limitations, which can be transformed into recommendations for further research. First, in this study we examined the mediating role of the LARG indicators. Future research is recommended to explore the moderating effect of the LARG between CSFs and SSCP. Second, SSCP is influenced by various factors beyond CSFs and the LARG paradigm, such as Industry 5.0 practices or viable practices, which were not considered in this study. Future empirical studies could investigate these variables to deepen understanding. Third, CSFs may vary across industries. This study suggested that future research compare their impact across sectors and identify industry-specific CSFs for framework refinement. Fourth, the study was based on a sample of 112 respondents from Iran's manufacturing sector, which limits generalizability. Additionally, as the research was cross-sectional, longitudinal data could better capture long-term relationships between constructs.

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Appendix A: Survey items

Table A1: The survey items for the SSCM, LARG, and SSCM CSFs

During the last two years, how do you evaluate the situation of your organization in the following areas?			
Sustainability performance	Economic performance	Q1: A significant increase in sales and market share was achieved. Q2: Significant savings in waste disposal costs. Q3: A significant improvement in the efficiency of resource management.	(Zailani et al., 2012)
	Environmental performance	Q4: A significant improvement in the organization's compliance with environmental regulations. Q5: A significant reduction in energy consumption and the usage of hazardous/harmful/toxic materials.	(Zailani et al., 2012)
	Social performance	Q6: A significant improvement in product image. Q7: The improvement of employee health and safety at work.	(Zailani et al., 2012; Wang and Dai, 2018)
What is the extent of your agreement with the following?			
Lean	Continuous improvement	Q8: Through value stream mapping we identify and eliminate supply chain waste.	(Moyano-Fuentes et al., 2019)
	Customer relationship	Q9: We use effective customer relationship management practices.	(Dey et al., 2019)
	Supplier relationship	Q10: We are committed to maintaining long-term collaborative relationships with our suppliers.	(Moyano-Fuentes et al., 2019)
	JIT	Q11: In our supply chain we strive to reduce lead time so long as there is no cost increase.	(Moyano-Fuentes et al., 2019)
Agile	Quick detection	Q12: Our organization can detect environmental changes promptly. Q13: Our organization can recognize changes in its surroundings immediately.	(Altay et al., 2018)

	Competency	Q14: It is our organization's policy to collect information continuously from suppliers.	
	Quick response	Q15: In response to changes in the environment, we make quick decisions.	
	Flexibility	Q16: To implement our decisions, we can adjust our supply chain operations as necessary. Q17: Our organization can expand its immediate capacity as necessary. Q18: We can adjust the specification of orders based on the requirements of our partners.	
Resilience	Response	Q19: We have a supply chain that can quickly restore product flow when unexpected disruptions occur.	(Golgeci and Y. Ponomarov, 2013)
	Flexibility	Q20: In the event of a disruption in our supply chain, we can quickly restore the supply chain to its original state.	
	Recovery	Q21: After being disturbed, our organization's supply chain can shift to a new more desired condition.	
	Readiness	Q22: We are prepared to deal with the financial ramifications of disruptions in our supply chain.	
	Efficiency	Q23: We can maintain the desired level of control of our supply chain's structure and function during disruptions.	
	Integration	Q24: From disruptions and unexpected events our organization's supply chain can extract valuable information and learn from them.	
Green	Internal environmental management	Q25: Our organization has/is seeking ISO 14001 certification.	(Zhu et al., 2008)
	Green purchasing	Q26: Our organization cooperates with suppliers for environmental objectives. Q27: Our organization sources its raw materials from suppliers who have ISO 14001 certification.	
	Cooperation with customers	Q28: Our organization cooperates with customers for cleaner production.	
	Eco-design	Q29: Our organization cares about designing products for reuse, recycling, and recovery of materials and parts.	
	Investment recovery	Q30: Our organization sells its scrap and used materials.	
Critical success factors	Top leadership commitment and support	Q31: Improvements in supply chain practices are a priority for top and middle management. Q32: Top managers commit to the company's support. Q33: Top managers need to provide adequate resources for the system to be successful. Q34: Coordinating and collaborating effectively are facilitated by top management.	(Chin et al., 2004; Grimm et al., 2014; Khan et al., 2018)
	Government support	Q35: Reforming taxes and digitalizing business will help develop the IT infrastructure. Q36: Codification and standardization can be effectively accomplished with the positive support of the government. Q37: The government encourages us to use technology by providing budgets, technology training equipment, and tax concessions. Q38: Effective government policies support our organization.	(Khan et al., 2018)
	Establish capable human resources	Q39: In our organization SCM personnel have the necessary skills for the positions in which they are employed. Q40: SCM personnel have relevant qualifications.	(Setino, 2020)

	Q41: To develop our SCM personnel, we invest in training and development. Q42: We have career development plans for SCM personnel in our organization.	
Trust between partners	Q43: We are perceived by our supply chain partners as being entirely honest and truthful. Q44: We are perceived as having a high level of integrity by our supply chain partner. Q45: We would like to keep our supply chain partners updated on the latest developments.	(Wu et al., 2004)
Dedicated IT infrastructure	Q46: Training and learning are supported by our IT infrastructure. Q47: A suitable IT infrastructure is implemented to support traceability in SC environments at our organization. Q48: In our organization the information is produced, processed, stored, and shared with other SC partners.	(Khan et al., 2018)
Social practices for employees and community	Q49: We ensure that our employees work in a positive and healthy environment. Q50: In our organization the employees receive enough compensation and benefits to cover their essential demands. Q51: We provide primary/vocational education facilities to the surrounding people. Q52: The local community can take advantage of our healthcare facilities.	(Das, 2018)

Appendix B: Common Method Bias Tests

A six-item marker variable was employed in this study (Donavan et al., 2004):

Table A2: Marker variable items used in the study

ID	Statement
MKR_MV1	There have been occasions when I took advantage of someone.
MKR_MV2	I sometimes try to get even rather than forgive and forget.
MKR_MV3	At times I have really insisted on having things my own way.
MKR_MV4*	I like to gossip at times.
MKR_MV5*	I have never deliberately said something that hurt someone's feelings.
MKR_MV6*	I am always willing to admit it when I make a mistake.

* *Used in the survey but omitted in the CMB analysis*

Both reliability and EFA supported the selection of three items for the marker variable. Reliability analysis (Cronbach's α) and corrected item-total correlations indicated that items MKR_MV5 and MKR_MV6 lowered overall reliability, while MKR_MV4 had low correlation with the total score. Similarly, EFA communalities showed that MKR_MV1, MKR_MV2, and MKR_MV3 had adequate loadings (>0.55). Therefore, only these three marker variables were retained for the CMB analysis.

Table A3: Selection for the marker variables

Marker Variables	Communalities	Component
MKR_MV1	0.797	0.893

MKR_MV2	0.822	0.907
MKR_MV3	0.559	0.747
MKR_MV4	0.386	0.622
MKR_MV5	0.206	-0.454
MKR_MV6	0.246	-0.496

Extraction Method: PCA.

Table A4: Reliability Statistics of marker variables

Cronbach's Alpha	N of Items
0.862	3

Table A5: Total Statistics marker variables

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
MKR_MV1	5.79	1.516	0.808	0.777
MKR_MV2	6.29	2.116	0.840	0.723
MKR_MV3	6.54	2.611	0.651	0.890

Table A6: CMB test using marker variable

Relations	P values
Marker Variable -> CSFs	0.052
Marker Variable -> LARG	0.813
Marker Variable -> SSCP	0.901

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