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Lean, Agile, Resilient, Green, and Sustainable Healthcare Supply Chains: A Qualitative Framework for the Medical Equipment Sector

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ABSTRACT

Objective: This study develops a qualitative framework for evaluating healthcare supply chain performance in the medical equipment sector. It distinguishes the core Lean, Agile, Resilient, Green, and Sustainable (LARGS) performance dimensions from the contextual conditions that facilitate or constrain their implementation.

Methodology: Semi-structured interviews were conducted with 18 managers and logistics experts from Iranian medical equipment firms. Participants were selected purposively and had at least five years of relevant experience. Data saturation was reached after 15 interviews, followed by three additional interviews to confirm theme stability. The data were analyzed in MAXQDA using a mixed deductive–inductive thematic approach based on Braun and Clarke's six-phase framework.

Results: The analysis identified 13 themes organized into two levels. The performance level comprised lean, agility, resilience, green, and sustainability. The contextual level included product and service quality, digital technology and infrastructure, information integration and operational coordination, risk and crisis management, human resources and capacity development, leadership and senior management commitment, organizational culture, and government policies and regulations. The findings indicate that quality operates as a control and feedback mechanism, while technology, information integration, leadership, culture, and workforce capabilities support the combined implementation of LARGS dimensions. Institutional conditions, including sanctions, pricing policies, administrative procedures, and budget allocation, can restrict organizational action.

Conclusion: The framework separates performance outcomes from their enabling and constraining conditions and provides an initial set of sector-specific indicators. It can support performance diagnosis, indicator selection, and improvement planning in medical equipment companies and healthcare organizations.

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Introduction

The adoption of supply chain management approaches tailored to organizational needs has become essential for improving operational efficiency, reducing costs, and enhancing service quality. Owing to its human-centered nature, the wide range of services it provides, its time-sensitive operations, and its strong dependence on pharmaceuticals and medical equipment, the healthcare system is considered one of the most complex supply chains worldwide. Recent developments, particularly the COVID-19 pandemic, have further exposed the fragility and vulnerability of healthcare supply chains (Alavi et al., 2026; Barari, 2017; Kafoe, 2025). In recent years, growing demand for healthcare services, rapid advances and increasing diversity in diagnostic and therapeutic technologies, the expansion of pandemics, and continued pressure to reduce costs have imposed substantial challenges on healthcare supply chains. These conditions have increased the need for effective performance evaluation systems capable of identifying operational weaknesses and supporting continuous improvement (Izanlou et al., 2019; Atefi et al., 2021).

A hospital supply chain consists of a network that operates both within and across organizations, through which physical items, data, and financial resources move among suppliers, producers, distributors, and healthcare providers. How well these flows are managed directly affects the quality of care delivered, the expenses incurred, and the level of patient satisfaction reported (Barari, 2017; Akbarzadeh, 2021). In this context, supply chain performance is closely tied to organizational goals, long-term viability, and financial health. For these reasons, implementing a thorough system for evaluating supply chain performance is a strategic requirement for spotting shortcomings, tracking progress, and directing efforts toward improvement (Izanlou et al., 2019; Atefi et al., 2021).

Over the past two decades, four major paradigms, lean, agile, resilient, and green, have been introduced in the supply chain management literature as complementary approaches for improving operational efficiency, responsiveness, resilience, and environmental performance (Mohamadi Zanjiran et al., 2019; Akbarzadeh et al., 2019; Carvalho et al., 2011). The lean paradigm emphasizes waste elimination, inventory reduction, and productivity improvement. The agile approach focuses on reacting swiftly to demand shifts and unpredictable conditions. The resilient perspective concentrates on preserving operational effectiveness when faced with disturbances, while the green orientation aims to lessen the ecological footprint left by supply chain operations (Azevedo et al., 2011; Rasidi et al., 2019). Nevertheless, relying on any one of these perspectives by itself does not offer enough to deal with the complexity and conflicting pressures that characterize today's supply chains. For this reason, bringing them together has been suggested as a way to gain an enduring edge over competitors (Alqudah et al., 2020).

In response to this need, the LARG supply chain concept, integrating the lean, agile, resilient, and green paradigms, was introduced and subsequently extended to the Lean, agile, resilient, green, and sustainable (LARGS) framework through the addition of the sustainability dimension (Carvalho et al., 2010; Aboei-Mehrizi & Shahbazi, 2019). As a multidimensional and complex system, the LARGS supply chain seeks to combine the complementary strengths of the lean, agile, resilient, green, and sustainable paradigms while balancing the potential limitations and incompatibilities among them, thereby enabling higher levels of competitiveness and long-term sustainability (Aboei-Mehrizi & Shahbazi, 2019). Recent review studies indicate that integrating these paradigms across different industries can simultaneously improve the operational, economic, and environmental performance of supply chains (Etemad et al., 2026; Nazari-Shirkouhi & Zarei Babaarabi, 2025; Anvari, 2021).

Literature review

A review of the existing literature indicates that the research gap extends beyond the limited number of studies on the LARG or LARGS paradigms. Much of the available research has been conducted in manufacturing industries, and the proposed performance criteria are not necessarily applicable to the specific characteristics of medical equipment supply chains (Eftekhari et al., 2021; Anvari, 2021). Within the healthcare sector, recent studies, including performance evaluations of hospital departments and quantitative frameworks based on the LARG/LARGS paradigm, have made important progress toward integrated performance assessment (Nazari-Shirkouhi & Samadi, 2025; Nazari-Shirkouhi & Zarei Babaarabi, 2025). Nevertheless, most of these investigations rely on pre-established performance indicators and assessment standards, offering only a limited understanding of the organizational, technical, and regulatory prerequisites necessary to implement these aspects simultaneously. In addition, considerations such as product quality and safety, traceability, handling shortages and interruptions, regulatory requirements, and supply limitations have seldom been treated as separate contextual elements in existing frameworks intended for broad application.

Accordingly, the research gap addressed in this study was defined at three levels. First, there is a contextual gap arising from the lack of performance indicators derived from the experience of practitioners operating within medical equipment supply chains and reflecting the specific characteristics of this sector. Second, there is a structural gap concerning the unclear distinction between the core performance dimensions and the factors that facilitate or constrain their implementation. Third, there is a methodological gap resulting from the limited use of qualitative approaches that allow performance indicators and implementation-related factors to emerge from empirical field data rather than imposing a predetermined set of evaluation criteria.

These points directly shaped the way the current research was designed. The five aspects of the LARGS model were used as guiding ideas to shape the initial structure of the interview guide. Still, the questions were kept open so that performance measures and contextual elements could come from what the participants shared based on their own experience. As a result, the final conceptual model includes two connected levels: one concerned with performance, which covers the main LARGS aspects, and another concerned with context, which covers the conditions that affect how these aspects are put into practice.

Research Objectives, Research Questions, and Contributions

Based on the preceding synthesis, the central research question is: What are the LARGS dimensions and the associated critical success factors within medical equipment supply chains, and how can they be organized into a coherent framework for performance evaluation? The objective of this study is not to develop a final scoring instrument but rather to establish a conceptual framework and an initial set of performance indicators that can subsequently be validated with the participation of relevant stakeholders and developed into a comprehensive measurement tool.

The contribution of this study can be described at three levels. First, instead of proposing another list of LARGS evaluation criteria, it distinguishes the five core performance dimensions from eight critical success factors. Second, the framework puts forward a set of indicators including product quality and safety, traceability, readiness for supply shortfalls, information integration, and regulatory constraints drawn from the hands-on knowledge of managers working in medical equipment firms. Third, by showing that implementing the LARGS paradigm in practice depends not only on better internal operations but also on leadership, organizational culture, digital infrastructure, and government policies, the framework connects the organizational tier with the broader institutional setting. This way of looking at the subject offers a clearer basis for forming research hypotheses and creating measurement tools in subsequent investigations.

Materials and Methods

A qualitative approach with thematic analysis was adopted for this investigation. Since the five LARGS dimensions had already been established through the literature review as preliminary conceptual groupings, and because the research also aimed to uncover performance indicators and implementation conditions specific to the medical equipment field, a combined deductive-inductive method of analysis was used. The analytical process followed the six-phase framework set out by Braun and Clarke, which covers becoming acquainted with the data, producing initial codes, generating themes, checking those themes, defining and labeling them, and writing up the final account.

When preparing the interview guide, the five LARGS dimensions lean, agile, resilient, green, and sustainable were used as general topics to give shape to the conversations. Still, each area was investigated with open-ended questions and probes that followed up on what participants said. In this way, the literature review set the initial direction for the interviews, but the list of performance indicators was not fixed ahead of time. Those taking part were asked to bring up other elements and to point out features particular to medical equipment supply chains that had not been thought of beforehand.

Study Population and Sampling

The people chosen for this study were experts and senior managers who had worked for a long time in the fields of healthcare and medical equipment supply chains. Their jobs included managing production, sales, supply chain activities, and quality control, as well as logistics roles at medical equipment companies. All participants had at least five years of relevant professional experience.

Purposive sampling was employed because participant selection was based on the objectives of the study and the nature of the research. In qualitative interview studies, the required sample size cannot be determined in advance, as data collection continues until the phenomenon of interest has been sufficiently explored. Ideally, interviews are conducted until data saturation is achieved, that is, when newly collected data no longer generate substantially new information compared with the existing dataset. Accordingly, purposive sampling was used to recruit experienced experts and managers from the healthcare and medical equipment supply chain sector. The final sample consisted of 18 participants. Data saturation was reached after the fifteenth interview; however, three additional interviews were conducted to confirm the stability and consistency of the identified themes.

The study included 18 participants holding managerial, supervisory, and specialist positions in medical equipment companies. Their professional experience ranged from 5 to 25 years. The participants represented different functional areas, including production, supply chain management, procurement, logistics, sales, quality control, research and development, and information technology. Table 1 presents their professional characteristics, including job titles, years of experience, educational qualifications, and gender. Participant codes (P1-P18) are used instead of names, and the identities of their organizations are not disclosed.

Table 1. Professional profiles of interview participants

Participant	Job title	Experience (years)	Participant	Job title	Experience (years)
P1	Factory Manager	25	P10	Sales Manager	11
P2	Production Manager	9	P11	Supply Chain Manager	16
P3	Technical Supervisor	5	P12	Quality Control Specialist	5
P4	Supply Chain Manager	6	P13	Information Technology Manager	16
P5	Factory Manager	6	P14	Logistics Manager	11
P6	Production Manager	6	P15	Procurement and Supply Manager	16
P7	Sales Specialist	7	P16	Purchasing Manager	10
P8	Sales Assurance Manager	9	P17	Sales Manager	15
P9	Research and Development Specialist	8	P18	Supply Chain Manager	10

Data Collection Instrument

The information for this study came from exploratory interviews that followed a semi-structured format. This approach was chosen because it allowed for detailed and specialized knowledge to be obtained from the experts taking part. The questions asked during these interviews were arranged within a formal guide, which set out the main subjects to be covered and the general path that the information gathering was meant to take. The data collection process was carried out in an organized manner, using both the theoretical ideas that supported the research and the results from the initial exploratory interviews.

Although the interview questions were prepared in advance, participants were encouraged to respond freely to open-ended questions and discuss issues relevant to their professional experience. Data were collected through individual, face-to-face, semi-structured interviews conducted between June 2025 and February 2026. Each interview lasted approximately 45–60 minutes, and all interviews were conducted in Persian. With the participants' consent, some interviews were audio-recorded. When audio recording was not permitted, detailed notes were taken during the interview. The recorded interviews were transcribed verbatim, while written accounts of the unrecorded interviews were prepared from the notes taken during each session. The transcripts and written accounts were subsequently reviewed against the available audio recordings and original notes, respectively, to check their accuracy and completeness. Selected quotations were translated from Persian into English for inclusion in the manuscript.

Data Analysis

The data obtained from the semi-structured interviews with managers, supply chain specialists, production managers, and quality assurance managers in medical equipment companies were analyzed using thematic analysis. Owing to its systematic yet flexible structure, thematic analysis is one of the most widely used and well-established approaches for analyzing qualitative data (Gibbs, 2007; Braun & Clarke, 2006). It focuses on identifying and interpreting meaningful and recurring patterns within qualitative data. It is commonly applied to semi-structured interviews, focus group discussions, open-ended questionnaire responses, and textual documents (Brandau & Rebello, 2021; Ryan-Vig et al., 2019).

The analysis proceeded through two complementary analytical paths. In the deductive phase, data related to the five LARGS dimensions were examined using the predefined conceptual categories. In the inductive phase, subthemes, performance indicators, and contextual or enabling factors were derived directly from the interview transcripts and written interview accounts. Accordingly, the LARGS framework guided the analytical process without functioning as a rigid classification scheme.

Following Braun and Clarke's six-phase model (Braun & Clarke, 2006), the thematic analysis consisted of the following stages:

Familiarization with the data: Repeated reading of the interview transcripts, listening to the audio recordings, and documenting initial ideas and key concepts.

Generating initial codes: Identifying and labeling meaningful segments of text and extracting codes relevant to the research objectives.

Searching for themes: Organizing related codes into conceptual categories and developing preliminary themes.

Reviewing themes: Examining the identified themes in relation to the complete dataset and refining, merging, or reorganizing them according to their conceptual relationships.

Defining and naming themes: Determining the content and title of each theme based on its meaning and contribution to addressing the research questions.

Producing the report: Describing and interpreting the final themes using representative excerpts from the interview data and explaining their role in understanding the phenomenon under investigation.

For the analytical process, verbatim transcripts of the audio-recorded interviews and detailed written accounts of the unrecorded interviews were used as the primary sources of qualitative data. The thematic analysis was conducted using MAXQDA. Following the initial coding stage, conceptually similar codes were grouped into broader conceptual categories. These categories were subsequently integrated into subthemes and overarching themes, resulting in the development of the final thematic map representing the conceptual structure of healthcare supply chain performance.

The initial coding was conducted by the first author using MAXQDA, following Braun and Clarke's six-phase thematic analysis framework. A second researcher reviewed the codes and themes to assess their consistency and interpretation. Differences in coding or theme interpretation were discussed between the researchers and resolved through consensus, with revisions made where necessary. To strengthen the credibility of the findings, the codes and themes were repeatedly compared with the original interview transcripts and written interview accounts to assess their consistency with participants' perspectives. The coding process, theme development, and subsequent revisions were documented to maintain an audit trail of the analytical decisions made throughout the study.

Results

The thematic analysis of the interview data resulted in the identification of thirteen overarching themes, which were organized into two levels: five LARGS dimensions and eight contextual or enabling themes.

The first level comprises the core LARGS dimensions within the healthcare supply chain, namely lean, agile, resilient, green, and sustainable performance. A summary of the themes, subthemes, and their corresponding conceptual indicators is presented in Table 2.

Table 2. Summary of the LARGS Themes and Extracted Concepts in the Healthcare Supply Chain

Main Theme	Subtheme	Conceptual Indicators
Lean	Waste and error reduction	Reduction in the frequency of pharmaceutical and medical equipment waste, reduction in expired products, reduction in recurring logistics errors, reduction in the proportion of unused consumable materials
	Inventory and resource management	Inventory turnover, alignment of inventory levels with actual demand, reduction in average storage time and incomplete orders
	Process improvement and optimization	Average time from order placement to delivery, percentage of on-time delivery of medical equipment, reduction in patient waiting time
	Cost control and productivity	Ratio of logistics costs to the total budget, reduction in packaging, transportation, and storage costs, improvement in workforce productivity

Agility	Rapid response and flexibility	Average response time to emergency orders, percentage of fulfilled emergency orders, system responsiveness to sudden changes
	Supplier dynamism	Diversity of alternative suppliers, percentage of rapid supplier substitution, supplier participation in process improvement
	Service innovation	Number of new products and services, speed of adoption of emerging technologies, level of technology acceptance among employees
	Interaction and collaboration	Percentage of real-time information exchange, stakeholder satisfaction with collaboration, quality of interdepartmental communication, number of coordination meetings
Resilience	Crisis management and recovery	Average time to restore operational performance, percentage of service continuity during crises, number of crisis management plans and training programs, effectiveness of crisis simulation exercises
	Resource diversification and risk reduction	Number of alternative supply sources, percentage reduction in dependence on a single source, overall risk assessment, flexibility in resource substitution
	Workforce preparedness	Risk management training and retraining frequency, operational readiness, employees' level of knowledge and awareness
	Organizational learning and continuous improvement	Number of post-crisis analytical reports, percentage of implemented corrective actions, employee satisfaction, continuous review and improvement programs
Green	Resource consumption reduction	Reduction in the use of single-use plastics, energy conservation and reduced energy consumption, proportion of renewable energy use
	Waste management	Medical waste recycling rate, reduction in waste volume, waste segregation management, use of recyclable equipment
	Environmental responsibility	Achievement of environmental objectives, employee training and awareness, transparent reporting, compliance with environmental regulations, acquisition of required environmental permits
	Regulatory compliance	Compliance with local and international standards and regulations, acquisition of environmental permits, reduction in environmental violations, continuous cooperation with relevant regulatory authorities
Sustainability	Financial and economic sustainability	Long-term cost savings, growth in financial productivity, improvement in cost management, effective return on investment
	Social sustainability	Satisfaction of hospitals and patients, retention of skilled personnel, corporate social responsibility, positive contribution to community health
	Human resource development	Investment in employee training and development, alignment of workforce competencies with organizational needs, promotion of innovation and knowledge transfer
	Balance across sustainability dimensions	Alignment of economic, social, and environmental objectives, effectiveness of cross-functional collaboration, accurate reporting and implementation of sustainability policies

Critical Healthcare Supply Chain Factors and Contextual Enablers for LARGS Implementation

Service and product quality, digital technology and infrastructure, information integration and operational coordination, risk and crisis management, human resources and capacity development, leadership and senior management, organizational culture, and government policies and

regulations. A summary of the themes, sub-themes, and their corresponding conceptual indicators is presented in Table 3.

Table 3. Summary of the Themes and Extracted Concepts of Critical Success Factors in the Healthcare Supply Chain

Main Theme	Sub-theme	Concepts / Indicators
Service and Product Quality	Compliance with quality standards	Percentage of products and services complying with national and international standards; quality error rate; product rejection rate.
	Hospital and patient satisfaction	Satisfaction with product quality and delivery time; responsiveness to complaints; number of repeat visits; satisfaction of relevant staff
	Complaint management and corrective actions	Number of complaints received; percentage of complaints resolved on time; rate of implementation of corrective actions; documentation of complaints
	Process quality control	Number of quality inspections; percentage of compliant cases; process defects; evaluation of packaging and transportation
Digital Technology and Infrastructure	Process automation	Percentage of automated ordering and inventory operations; reduction in manual processing time; reduction in human errors
	Systems integration	Degree of system connectivity and interoperability; percentage of data sharing; reduction in communication delays
	Traceability and transparency	Percentage of traceable products; transparency in order status reporting; reduction in theft and logistics errors; faster response to operational problems
Information Integration and Operational Coordination	Comprehensive and timely information exchange	Continuous flow of information; data accuracy and reliability; rapid data updates; data standardization
	Coordination of operational processes	Alignment of schedules; integration of intra- and inter-organizational processes; optimized inventory management; reduction in operational delays and errors
	Trust and interdepartmental relationship management	Mutual trust; sustained collaboration and long-term commitment; conflict resolution mechanisms; participation in joint projects
	Use of information technologies	Implementation of ERP systems and supply chain management software; tracking and monitoring tools for product and information flows; data security and confidentiality infrastructure; training members in the use of emerging technologies
Risk and Crisis Management	Risk identification and assessment	Identification and prioritization of risks; risk coverage; reduction of operational risks; regular risk updates
	Crisis preparedness and training	Crisis management training programs; professional certifications; effectiveness of operational capabilities; employee satisfaction
	Prevention and response planning	Use of predictive scenarios; response speed; prevention of service disruption; effectiveness of response measures
Human Resources and Capacity Development	Workforce capacity development and training	Professional competency framework; hours of specialized training; regular training programs; access to development opportunities
	Recruitment, retention, and employee motivation	Recruitment and retention rates; job satisfaction; incentive programs; professional advancement
	Human resource management and organizational structure	Policies for recruitment and retention; strategic workforce planning; job descriptions; organizational structure

	Team interaction and collaboration	Mutual support and cooperation; participation in decision-making; development of communication skills
	Professionalization and specialization of SCM	Membership in professional organizations and associations; development of professional standards; continuing education programs
Leadership and Senior Management Commitment	Commitment and active support of senior management	Management commitment to lean, agile, and continuous improvement philosophies; budget allocation; policy formulation
	Transparency and integrity in internal communication	Employee satisfaction; formal communication meetings; accountability; regular communication programs
	Ability to inspire and motivate	Awareness campaigns; positive attitude change; participation in innovation; development of soft skills
	Consistency and persistence in pursuing objectives	Achievement of strategic goals; alignment with organizational policies; periodic reporting; maintenance of strategic priorities
	Managerial participation in decision-making	Specialized meetings; participatory decision-making; management-supported projects; departmental satisfaction
	Transformational leadership and change management	Change management programs; employee acceptance of change; success of transformation projects; transformational leadership training
Organizational Culture	Learning and continuous improvement culture	Encouragement of error reporting; educational programs and workshops; policies supporting constructive learning from mistakes
	Cross-functional collaboration culture	Degree of collaboration; conflict resolution; joint meetings; constructive competition
	Individual and collective accountability culture	Acceptance of responsibility; transparent reporting; performance evaluation criteria
	Resistance to change	Level of resistance to change; causes of resistance; success of change management initiatives
	Organizational health	Quality of internal communication; healthy work environment; stress management; team cohesion
Government Policies and Regulations	Impact of sanctions on the supply chain	Restricted access to supplies; procurement delays; dependence on domestic resources
	Administrative laws and regulations	Bureaucratic regulations; licensing procedures; impact of regulations on organizational agility
	Pricing policies for pharmaceuticals and medical equipment	Price stability; alignment of prices with costs; impact on accessibility
	Government budget priorities in the health sector	Share of the national budget allocated to health; percentage of funding allocated to different healthcare supply chain sectors (pharmaceuticals, medical equipment, technology, and human resources); allocation of resources to preventive programs and logistics infrastructure development; budgetary changes and their alignment with the actual needs of the healthcare supply chain

Main LARGS dimensions in the healthcare supply chain

Lean. The theme of lean emphasizes minimizing waste while maximizing resource efficiency. It comprises four subthemes: waste and error reduction, inventory and resource management, process improvement and optimization, and cost control and productivity. Participants identified several

operational indicators through which lean performance could be assessed. These included reductions in pharmaceutical and medical equipment waste, fewer expired products, improved inventory turnover, closer alignment between stock levels and actual consumption, shorter order-to-delivery times, and lower warehousing and freight expenses as a share of total expenditure. In participants' accounts, waste reduction, accurate inventory management, and workforce efficiency were associated with lower operating expenses. Participants also described the potential to allocate the resulting savings to priority areas of patient care. Selected statements from the interviews are presented below.

"One of the primary concerns in the healthcare supply chain is reducing the frequency of pharmaceutical and medical equipment waste. Better planning and continuous monitoring should always be applied to prevent medicines from expiring, thereby reducing unnecessary costs and ensuring that they are used on time." (P1)

"Reducing storage and warehousing costs through accurate inventory control and waste reduction has enabled our budget to be used more effectively and has created opportunities to invest in more critical areas." (P2)

Agility. Agility refers to the ability to respond rapidly to environmental changes and the evolving demands of the healthcare sector, making it essential for improving healthcare service quality. This theme includes four subthemes: rapid response and flexibility, supplier dynamism, service innovation, and interaction and collaboration. Several metrics offer a clear view of organizational agility, including the mean handling time for urgent orders, the rate at which such orders are completed, the capacity to change vendors quickly in emergency scenarios, the pace at which new technologies are embraced, and the level of real-time data sharing among partners in the supply chain. Active involvement of suppliers in continuous improvement efforts and the periodic holding of collaborative planning sessions were likewise recognized as significant factors contributing to agility. The following remarks from participants illustrate these points.

"The speed of responding to emergency orders is a critical priority. The shorter the average response time, the greater the positive impact on all areas of healthcare delivery." (P6)

"Real-time information exchange among supply chain members has produced highly positive results. When all departments can communicate quickly and keep their information up to date, decisions become much more accurate and timely." (P11)

Resilience. The concept of resilience pertains to the healthcare supply chain's ability to sustain normal operations and achieve rapid recovery after emergencies and disturbances. This construct consists of four distinct dimensions: crisis management and restoration, supplier base

diversification and risk mitigation, staff readiness, and ongoing organizational learning and refinement. Measurable criteria include the duration needed to regain full functionality following incidents, the maintenance of adequate service levels amid crises, the existence of backup sourcing options, reduced reliance on any single vendor, periodic delivery of risk awareness education, and the compilation of lessons-learned documents after adverse events. According to interview respondents, remedial measures ought to be initiated without delay after each emergency, and each crisis event should serve as a basis for institutional knowledge acquisition and process enhancement. Selected comments from participants appear below. One participant noted that returning to full operational capacity after any interruption remains among the most formidable difficulties confronting the healthcare supply chain.

"Every effort should be made to reduce this average recovery time because every day of delay means a decline in service quality." (P5)

"The important point is that post-crisis corrective actions must be implemented promptly and effectively, demonstrating a genuine commitment to continuous improvement." (P10)

Green. The green dimension addresses the environmental aspects of the healthcare supply chain and includes four subthemes: resource consumption reduction, waste management, environmental responsibility, and regulatory compliance. Indicators identified within this dimension include reducing the use of single-use plastics, improving energy efficiency, increasing the use of renewable energy, expanding the recycling of medical waste, reducing the volume of hazardous waste, complying with environmental standards, and obtaining environmental permits. Participation in environmental initiatives and transparent environmental reporting were also identified as expressions of environmental responsibility. Representative interview statements include:

"Energy conservation should always remain a priority. Through effective management programs, electricity and fuel consumption can be reduced while increasing the share of renewable energy sources." (P7)

"Compliance with local and international regulations and standards is non-negotiable for us, and we have always obtained all required environmental permits legally and on time." (P14)

Sustainability. The theme of sustainability encompasses financial and economic sustainability, social sustainability, workforce development, and balance among the dimensions of sustainability. Financial and economic sustainability focuses on long-term cost savings, improvements in financial productivity, and effective returns on investment. Patient and hospital satisfaction, the ability to retain qualified staff, and meaningful contributions to community health all serve as

indicators of social sustainability. Workforce development further involves financial commitments to education and training initiatives, aligning staff competencies with organizational demands, and the protection of retained institutional knowledge. Balance among the dimensions of sustainability refers to the alignment of economic, social, and environmental objectives and the effectiveness of collaboration across organizational units. Interview participants emphasized that cost management should be accompanied by the preservation of service quality and that a long-term investment perspective is essential for sustaining the economic performance of the healthcare supply chain. Representative interview statements include:

"Maintaining a long-term investment perspective enables the organization to achieve greater economic sustainability and manage many financial challenges more effectively." (P12)

"Alignment among economic, social, and environmental objectives is a fundamental principle, and continuous efforts should be made to preserve this alignment through appropriate policies and actions." (P15)

Critical Success Factors in the Healthcare Supply Chain and Contexts for LARGS Implementation

Service and Product Quality. "Service and product quality" emerged as another theme directly linked to the safety and effectiveness of healthcare delivery. This theme encompasses compliance with quality standards, hospital and patient satisfaction, complaint management, and process-based quality control and correction. The proposed indicators include the share of products and services that conform to national and international standards, the occurrence rate of quality-related defects, the quantity of goods that are refused or sent back, the degree of satisfaction with on-time delivery and product condition, the share of complaints settled within the allowed period, and the total number of quality checks carried out across the supply chain. The practice of conducting routine audits, maintaining ongoing oversight, and keeping structured records of complaints shows that quality management is embedded throughout the entire supply process rather than being applied only at the final checkpoint. The following excerpts from participant interviews illustrate this point.

"One of the primary concerns in the healthcare supply chain is ensuring that goods and services comply with national and international standards, which have been evaluated on multiple occasions, with corrective actions taken accordingly." (P7)

"Quality inspections are conducted regularly throughout the supply chain; these reviews help us identify weaknesses and potential issues before they reach the final stage." (P16)

Digital Technology and Infrastructure. "Digital technology and infrastructure" was identified as a key enabling factor that supports various LARGS dimensions. Its three main subthemes are process automation, system integration, and traceability and transparency. Participants associated process automation, fewer manual entry errors, greater connectivity between information systems, and product traceability with faster and more accurate supply chain operations and greater transparency. They also described advanced information systems as potentially useful for reducing product losses and shortening response times to logistical problems. Selected comments from the interviews are presented below.

"Before adopting new technologies, many processes were performed manually, and human errors were frequent; now, with automation, errors have decreased, and accuracy has improved substantially." (P1)

"Tracing goods from origin to destination is now possible with precision, and this has minimized issues related to theft or loss." (P13)

Information Integration and Operational Coordination. This theme centers on the orderly movement of information and the synchronization of operations throughout the supply chain. It covers the timely sharing of complete information, the alignment of operational workflows, the management of trust and relationships across departments, and the application of information technology. Several measures indicate the degree of integration and coordination achieved, including the accuracy and frequency of data updates, the consistency of activity schedules, the presence of formal procedures for resolving disputes, and the use of ERP systems and supply chain management software. Participants associated unified databases and open communication with more timely decisions and faster responses. The following remarks from participants illustrate these points.

"Integrated databases ensure that all departments are informed of the latest changes and can make better decisions." (P9)

"Inventory management software enables more precise control over equipment and helps prevent shortages. Information security is critical to protect hospital, patient, and medication data." (P18)

Risk and Crisis Management. "Risk and crisis management" was identified as a fundamental prerequisite for healthcare supply chain resilience, encompassing three subthemes: risk identification and assessment, crisis preparedness and training, and prevention and response programs. Systematic processes for identifying and prioritizing risks, conducting training courses and crisis management drills, using crisis scenario planning, and monitoring the effectiveness of

response programs are essential elements of this theme. Participants viewed risk management as a dynamic process that must be continuously updated based on conditions and lessons learned from previous crises. Representative statements include:

"The first step in crisis management is risk identification; we have identified a considerable number of risks and, through careful prioritization, focus our efforts on the most critical threats."(P3).

"Using crisis scenario planning has made our response to disruptions much faster and more targeted, resulting in reduced negative impacts." (P14)

Human Resources and Capacity Development. The theme concerned with human resources and capacity development places emphasis on strengthening workforce capabilities through training, managing the recruitment and retention of staff, ensuring motivation, structuring human resource functions and organizational design, encouraging team-based interaction and cooperation, and advancing the professional standing and specialized knowledge of supply chain management. Important measures in this area consist of defined professional competency standards, the number of hours devoted to specialized instruction, structured career progression routes, well-designed approaches to hiring and retaining personnel, and active involvement in professional bodies. When employees take part in organizational decisions, and a cooperative team environment exists, the conditions for successful LARGS adoption are strengthened. The following statements from participants are representative.

"A significant number of specialized training hours are conducted annually for supply chain staff, which has enhanced their skills and practical knowledge." (P2)

"Career advancement and professional development opportunities are periodically reviewed and planned to provide a clear and predictable growth path for the workforce." (P1)

Leadership and Senior Management Commitment. "Leadership and senior management commitment" was identified by participants as a contextual factor relevant to healthcare supply chain initiatives. This theme encompasses senior managers' active belief and support, transparency and honesty in communication, the ability to inspire and motivate, persistence and continuity in pursuing objectives, and participation in decision-making and transformational leadership. Budget allocation to supply chain improvement projects, issuance of supportive policies and guidelines, regular informational meetings, and active participation in specialized sessions are examples of this commitment. Participants associated senior management support for Lean, Agile, and continuous improvement with reduced resistance to change and stronger organizational alignment. Representative statements include:

"Our senior managers hold strong beliefs in Lean and Agile philosophies, which they have demonstrated by allocating appropriate budgets to supply chain improvement projects." (P6)

"Specialized management meetings are held with active participation from senior executives, and important decisions are made with their full involvement. Other departments express high satisfaction with managers' participation in cross-functional processes, and these collaborations enhance coordination and synergy." (P17)

Organizational Culture. "Organizational culture" includes a culture of learning and continuous improvement, cross-departmental collaboration, individual and collective accountability, resistance to change, and organizational health. This occurs when staff members feel safe to report mistakes without facing penalties, when errors that yield useful insights are treated as learning opportunities, when workshops focused on ongoing improvement are conducted regularly, and when collaboration between departments is actively encouraged. When disputes are resolved through structured approaches, these elements together point to an organizational culture that supports learning and adapts readily to change. In addition, the provision of a supportive work environment and the availability of programs aimed at reducing stress contribute to the overall health of the organization and strengthen employees' sense of commitment. The interview data suggest that a learning-oriented and collaborative organizational culture may support the sustained implementation of LARGS principles in the healthcare supply chain. The following quotations from the interviews are representative.

"Through change management programs and ongoing communication, we can reduce resistance and gradually help employees develop more positive attitudes toward change." (P1)

"A culture of team cohesion and positive collaboration in the workplace creates a dynamic and encouraging environment that strengthens individual and team commitment and accountability." (P13)

Government Policies and Regulations. Finally, "government policies and regulations" were identified as a macro-level context affecting all dimensions of the supply chain. This theme encompasses the impact of sanctions on the supply chain, administrative laws and regulations, pharmaceutical and medical equipment pricing policies, and government budget priorities in the health sector. Participants pointed to several major problems: limited access to medicines and equipment, delays in supply caused by sanctions, slow and complicated licensing procedures, and a lack of alignment between the budgets assigned and what the supply chain actually needs. Participants identified government policies and institutional support as contextual conditions that

may facilitate or constrain LARGS implementation. The comments below from participants are representative.

"Due to sanctions, the percentage of delays in supplying items has increased considerably, placing substantial pressure on supply chain management." (P1)

"In the areas of prevention and logistics infrastructure improvement, budget allocations sometimes do not align with actual needs, and this is a weakness that requires correction." (P2)

Based on open coding and the extraction and review of themes, a conceptual model was developed in which the main LARGS dimensions (lean, agile, resilient, green, and sustainable), together with the quality of services and products, occupy the central position. The enabling factors, including technology, information integration, risk management, human resources, leadership, organizational culture, and government policies, operate as contextual and supporting mechanisms around these dimensions. The model illustrates the conceptual relationships among the main themes and provides an initial framework for examining healthcare supply chain performance using LARGS indicators. Figure 1 presents the two-level conceptual framework developed from the thematic analysis. The first level comprises the five LARGS dimensions: lean, agile, resilient, green, and sustainable. The second level consists of eight critical success factors: service and product quality, digital technology and infrastructure, information integration and operational coordination, risk and crisis management, human resources and capacity development, leadership and senior management commitment, organizational culture, and government policies and regulations. The connections in the framework indicate the conceptual organization of these themes and their relevance to healthcare supply chain performance evaluation. They do not represent empirically tested causal relationships or establish the direction of influence among the themes. Economic, environmental, and social performance are presented as assessment perspectives rather than additional themes identified through the analysis.

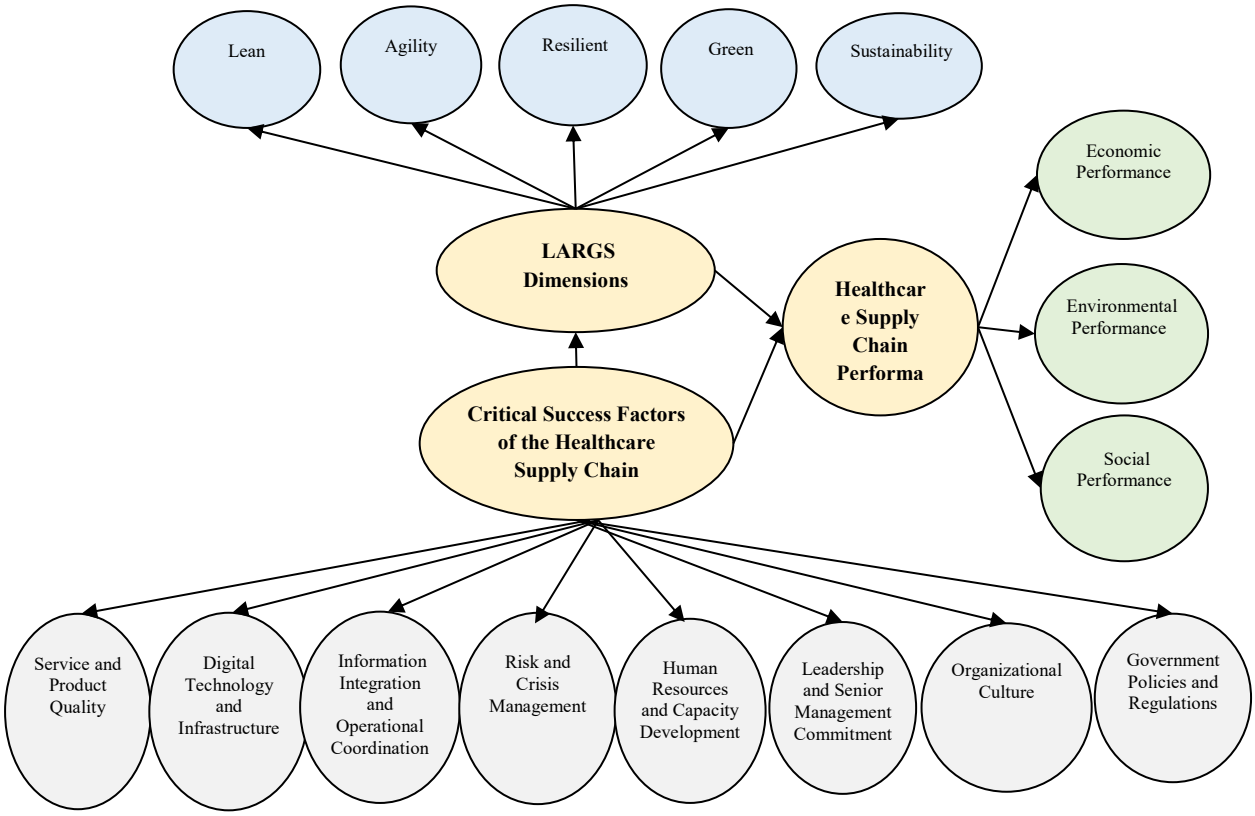


Figure 1. The Proposed Conceptual Framework for Supply Chain Management Performance Evaluation Based on LARGS

Discussion

The thematic analysis conducted in the present study revealed a comprehensive and interconnected framework of healthcare supply chain performance dimensions based on the LARGS paradigm. The findings identified Lean, Agile, Resilient, Green, and Sustainable as the core performance dimensions of the healthcare supply chain. At the same time, a set of critical success factors was found to support their integrated and effective implementation. The interaction among these dimensions indicates that successful implementation of the LARGS approach does not result from isolated initiatives. Rather, it depends on the systematic alignment of process optimization, technological advancement, and human capital development.

Within the Lean dimension, the results show that cutting waste and making better use of resources are central to lowering costs and maintaining operational stability in healthcare settings. Matching stock levels to real consumption patterns, reducing expired products, and increasing inventory turnover all play a direct role in supporting financial soundness and ensuring that essential services continue without interruption. These observations are in line with the work of

Mohammadpur (2023), Sadeghian & Mehdiei Malayeri (2014), Bottani et al. (2024), Sheykhizadeh et al. (2024), de Oliveira-Dias et al. (2023), and Sonar et al. (2022), all of whom have shown that lean thinking enables healthcare organizations to direct resources toward priority areas by removing inefficiencies and raising operational performance.

On the Agility dimension, the findings suggest that responsiveness to external changes and evolving patient needs is relevant to healthcare service quality. Supplier flexibility, coordination across different functions, and real-time information exchange were all identified as necessary features of a responsive and agile supply chain (Bahadori Jahromi, 2026). The findings suggest that digital infrastructure and communication systems may help healthcare organizations maintain essential operations during periods of disruption. The Resilience dimension appeared as a strategic asset built on organizational learning and adaptation, not simply on crisis reaction. Routine training, assessments carried out after disruptive events, and the use of multiple supply sources were recognized as the main elements of resilience (Marjani et al., 2026; Nazari-Shirkouhi et al., 2023b). These results imply that crisis management in healthcare supply chains ought to move away from a fixed, response-only model and toward a more dynamic and learning-centered approach.

With respect to the Green dimension, the results suggest that environmental responsibility now goes beyond simply meeting legal requirements and has become a meaningful source of institutional credibility and public confidence. Sound waste handling, efficient consumption of energy, and compliance with environmental regulations do more than reduce ecological damage; they also enhance the reputation and social standing of healthcare organizations. Sustainability as defined in this research, includes economic, social, and human components and places importance on the ongoing maintenance of healthcare system functioning over time. Directing resources toward employee training and protecting the knowledge held within the organization leads to greater productivity, higher staff satisfaction, and improved quality of patient care. The results also suggest that real sustainability calls for the concurrent treatment of economic, social, and environmental concerns. These findings can be considered in relation to previous research by Mohammadpur (2023), Sadeghian and Mehdiei Malayeri (2014), Bottani et al. (2024), Sheykhizadeh et al. (2024), Taheri Tafreshi et al. (2021), de Oliveira-Dias et al. (2023), Anvari (2021), and Mohamadi Zanjiran et al. (2019).

Among the critical success factors influencing the healthcare supply chain, service and product quality emerged as a control and feedback mechanism rather than merely an outcome measure (Tavana et al., 2022). Compliance with quality standards, process quality control, and complaint management provide the information required for the continuous improvement of lean, agile, and resilient processes (Alipour et al., 2022). Related studies include Shahriari (2017), Sheykhizadeh et al. (2024), and Divsalar et al. (2022), which have examined supply chain management and

performance evaluation from different perspectives. Related research includes Ghoroghchian et al. (2022), Taheri Tafreshi et al. (2021), Akbarzadeh et al. (2019), Piprani et al. (2024), de Oliveira-Dias et al. (2023), and Arghiani et al. (2026). In the proposed framework, digital technology and infrastructure, together with information integration and operational coordination, are identified as contextual factors associated with the implementation of LARGS dimensions. These practices were identified as potentially relevant to error reduction, transparency, agility, and risk management. Without these capabilities, the practical implementation of many LARGS principles would be difficult or costly (Nazari-Shirkouhi et al., 2023a).

Risk and crisis management, through systematic risk identification, regular training and simulation exercises, and preventive and responsive planning (Esmaeili & Marjani, 2026), is closely linked to the resilience dimension and reduces part of the pressure arising from macro-level conditions such as sanctions and supply disruptions. The findings of Mehri Babadi et al. (2022) and Jamali & Karimi-Asl (2018) indicate that neglecting this area can compromise the performance of the entire supply chain, even when appropriate technological infrastructure and human resources are available.

Within the human resources and capacity development theme, continuous professional training, structured career development pathways, transparent organizational structures, and employee participation in decision-making were identified as prerequisites for the successful implementation of lean, agile, green, and resilient practices. In the proposed framework, human resources function as the connecting element between technology, organizational processes, and organizational culture. Sustainable transformation is therefore unlikely to occur without workforce empowerment. Similar observations have been reported by Mohammadpur (2023) and Nasiri and Morovatisharifabadi (2021), who emphasized the contribution of human resources to healthcare supply chain performance.

Consistent with the findings of Mehri Babadi et al. (2022), Atefi et al. (2021), Nasiri and Morovatisharifabadi (2021), and Jamali & Karimi-Asl (2018), leadership and top management commitment, together with organizational culture, emerged as two intangible yet influential enablers of healthcare supply chain performance. When senior leaders openly back LARGS ideas, when money is put into projects aimed at making things better, when communication stays straightforward and open, and when choices are made with input from various people, pushback against change lessens, and the organization holds together more firmly. In parallel, a work environment that welcomes reports of errors, fosters joint work across units, and gives attention to both psychological health and team unity sets the stage for steady learning and the smooth use of new technologies.

On the broader national level, government rules and policies emerged as background forces affecting every part of the proposed structure. Problems stemming from sanctions, heavy administrative procedures, and gaps between funds set aside and real requirements hold back the supply chain from reaching Agility, resilience, and green goals. So, although the LARGS approach can be used within single organizations, getting its complete value depends on changes to policy, easing of rules, and firmer backing from central authorities.

Theoretical Contributions

The primary theoretical contribution of the findings is that the LARGS paradigm in the medical equipment supply chain cannot be conceptualized simply as the sum of five independent approaches. Instead, the proposed framework introduces a two-layer structure. The first layer comprises the core performance dimensions, whereas the second consists of the contextual conditions that facilitate or constrain the realization of those dimensions. From this perspective, differences in organizational performance cannot be explained solely by the extent to which lean, agile, resilient, green, and sustainable practices are implemented. They also depend on the degree to which these practices are aligned with information infrastructure, human resources, leadership, and the institutional environment.

A second theoretical implication concerns the role of service and product quality. The findings indicate that quality should not be regarded as a sixth LARGS dimension. Rather, it functions as a control and feedback mechanism that reflects the outcomes of the other dimensions and provides the information required for their continuous refinement. Likewise, technology and information integration operate as connecting mechanisms between agility, lean management, and resilience, while risk management links preventive actions with post-disruption recovery capability. This conceptual distinction clarifies the boundaries between the identified themes and reduces potential overlap among indicators in future model development.

A third implication is the identification of government policies and regulations as a contextual condition shaping supply chain performance. The findings suggest that the effectiveness of LARGS approaches in highly regulated supply chains is determined not only by organizational decisions but also by the broader institutional environment. Supply restrictions, licensing procedures, and pricing policies can substantially influence managers' strategic and operational choices. Consequently, the proposed framework offers several propositions for future empirical research. For example, future studies may examine whether information integration and management commitment strengthen the combined effects of the LARGS dimensions, and whether institutional constraints weaken these relationships.

Managerial Implications and Practical Recommendations

The primary application of the proposed framework is to support diagnosis and improvement planning rather than to provide a definitive scoring system for organizations. Managers of medical equipment companies and healthcare organizations can begin by selecting a limited set of indicators from Tables 2 and 3 that best match their organizational mission and then establish baseline performance levels. After that, they can identify which enabling factor lies behind any shortfall in a given performance dimension and then assign responsible staff, set timeframes for action, and specify measurable goals for improvement. Take poor on-time delivery: its causes may include not just vendor performance issues but also insufficient data sharing, slow administrative clearance, or the absence of alternative supply arrangements.

At the operational tier, hospitals and health supply organizations are advised to examine the movement of medicines and equipment across the chain, pinpoint the main areas where waste occurs and where processes slow down, and then launch lean improvement efforts at those specific spots. Setting up teams that bring together staff from different functions, arranging joint sessions with purchasing, pharmacy, finance, and clinical units, and using straightforward yet clear performance measures such as the time from order to receipt, waste rates, and the share of deliveries made on time can make these efforts easier to carry out and keep track of.

On the human resources side, raising the technical and managerial skills of supply chain staff, especially in data analysis, information systems, and risk handling, is a key requirement. Ongoing training, well-defined career tracks, and reward systems that promote cooperation and organizational learning should be put in place. At the same time, senior leaders need to show active support for lean, agile, resilient, and green practices by setting aside adequate funds, joining specialized planning meetings, and including LARGS indicators in supply chain management performance reviews.

At the policy level, healthcare regulators and policymakers should give greater attention to the unintended effects of certain regulations and administrative procedures on supply chain agility and resilience. Streamlining licensing processes, revising pricing policies so that they do not discourage investment in quality improvement and innovation, and allocating a stable and clearly defined proportion of the healthcare budget to logistics infrastructure and information technology are among the measures that could strengthen the practical implementation of the LARGS framework in healthcare supply chain management at the national level.

The framework ought to be used with attention to possible conflicts between its different dimensions. Cutting inventory too far may reduce the ability to withstand disruptions, bringing in

a larger number of suppliers can push up coordination expenses, and choosing greener procurement options may raise costs in the short term. For these reasons, LARGS measures should be tracked through a well-rounded performance dashboard and examined jointly by the purchasing, quality, finance, and risk units. Also, minimum standards that are not open to negotiation should be set for quality, patient safety, and service continuity. This approach helps ensure that progress in one area does not come at the cost of another.

Conclusion

This study addressed the contextual gap in applying the LARGS paradigm within the medical equipment supply chain by developing a two-layer conceptual framework. The five dimensions of lean, agile, resilient, green, and sustainable performance constitute the core performance layer. At the same time, the remaining eight themes describe the organizational and institutional conditions that enable or constrain their implementation. The contribution of this research extends beyond introducing a new set of performance indicators. The proposed framework suggests that an assessment of supply chain capability should consider service and product quality, digital infrastructure, information integration, risk management, human resources, leadership, organizational culture, and government policies alongside the five LARGS dimensions.

The principal conclusion is that LARGS should be implemented as an integrated management program rather than as a collection of independent initiatives. The proposed framework can support the selection of initial performance indicators, the identification of operational bottlenecks, and the design of improvement plans. However, it should not yet be regarded as a validated measurement scale or a ready-to-use organizational ranking instrument. Moving this qualitative framework toward a workable performance assessment tool will require the development of a structured questionnaire, confirmation of the validity and dependability of the proposed measures, involvement of hospitals, equipment suppliers, and regulatory bodies, and empirical examination of the suggested relationships with larger participant groups.

Limitations and Future Research Directions

As with any empirical work, this study has certain shortcomings. First, the data come from interviews conducted with specialists and experienced managers working within one part of the national health system. Because of this, the results may not apply across all organizations or to every tier of the healthcare supply chain. Accordingly, the findings ought to be understood in light of the particular organizational and environmental conditions in which the participating experts operated.

Second, the study relied on qualitative evidence and the subjective perspectives of experts. Although rigorous coding procedures and repeated reviews were employed to strengthen the internal credibility of the findings, participant perceptions and narratives may still contain inherent sources of bias. Future studies are encouraged to transform the indicators identified in this research into quantitative measurement instruments and evaluate their validity and reliability using larger and more diverse samples.

Third, the present work was mainly concerned with explaining the conceptual links between the LARGS dimensions and contextual factors, rather than empirically testing those links to show their strength and direction. To address this, subsequent studies might adopt methods like structural equation modeling, network analysis, or system dynamics modeling in order to investigate how these relationships operate in causal terms and to assess their relative contributions.

In addition, future research could bring in variables such as national culture, ownership structure, and the features of healthcare markets as moderating elements. Doing so would allow for a fuller picture of how LARGS performance varies across different organizational settings and institutional environments.

Author Contributions

S.S.L.: Conceptualization, methodology, Software, Validation, Formal Analysis, Writing—Original Draft Preparation, Visualization; S.N.S.: Conceptualization, Methodology, Software, Validation, Visualization, Formal Analysis, Writing—Original Draft Preparation; Writing—Review and Editing, Supervision, Project Administration; M.S.: Conceptualization, Validation, Formal Analysis, Writing—Review and Editing.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical considerations

The authors avoided data fabrication, falsification, and plagiarism, and any form of misconduct.

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Conflict of interest

The authors declare no conflict of interest.

Using artificial intelligence chatbots

We used ChatGPT version 6 to check grammar and enhance the academic quality and clarity of the text, which was primarily written by the authors. The final version of the text, after incorporating ChatGPT-assisted improvements, was thoroughly reviewed and approved by the authors.

References

Aboei-Mehrizi, S., & Shahbazi, A. (2019). Evaluation of large supply chain maturity in Saipa Yadak Company using fuzzy inference system (FIS). *Journal of Engineering Sciences Elites, 5*(3), 1–13.

Akbarzadeh, Z. (2021). *Large supply chain: Developing a conceptual framework and measurement tools in dairy industries (case study of Kaleh Dairy Company)* [Doctoral dissertation, University of Mazandaran].

Akbarzadeh, Z., Ghadikolaei, A. S., Madhoushi, M., & Aghajani, H. (2019). A hybrid fuzzy multicriteria decision-making model based on fuzzy DEMATEL with fuzzy analytical network process and interpretative structural model for prioritizing LARG supply chain practices. *International Journal of Engineering, 32*(3), 413–423. https://doi.org/10.5829/ije.2019.32.03c.09

Alavi, S., Mirmohammadsadeghi, S., Kabir, G., & Gunasekaran, A. (2026). Identification, evaluation, and validation of lean, agile, resilience, and green activities in remanufacturing using the IPPA and data mining approaches. *International Journal of Productivity and Performance Management, 75*(4), 1358–1385. https://doi.org/10.1108/IJPPM-06-2025-0565

Alipour, N., Nazari-Shirkouhi, S., Sangari, M. S., & Vandchali, H. R. (2022). Lean, agile, resilient, and green human resource management: The impact on organizational innovation and organizational performance. *Environmental Science and Pollution Research, 29*(55), 82812–82826. https://doi.org/10.1007/s11356-022-21576-1

Alqudah, S., Shrouf, H., Suifan, T., & Alhyari, S. (2020). A moderated mediation model of lean, agile, resilient, and green paradigms in the supply chain. *International Journal of Supply Chain Management, 9*(4), 158–172.

Anvari, A. R. (2021). The integration of LARG supply chain paradigms and supply chain sustainable performance: A case study of Iran. *Production & Manufacturing Research, 9*(1), 157–177. https://doi.org/10.1080/21693277.2021.1963349

Arghiani, M., Rezaeenour, J., Rahnama, A., & Roozbahani, Z. (2026). A systematic review of the process mining literature in the supply chain. Journal of Engineering Management and Soft Computing, 12(3), 111–149. https://doi.org/10.22091/jemsc.2026.15287.1347

Atefi, M. R., Radfar, R., & Asgharizade, E. (2021). A system dynamics model for balanced performance evaluation of a LARG supply chain. *Journal of Industrial Management Perspective, 11*(4), 253–290. https://doi.org/10.52547/jimp.11.4.253

Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. (2011). A proposal of LARG supply chain management practices and a performance measurement system. *International Journal of e-Education, e-Business, e-Management and e-Learning, 1*(1), 7–14. https://doi.org/10.7763/IJEEEE.2011.V1.2

Bahadori Jahromi, H. (2026). From analytics to agility: How smart contract capability and supply chain digitalization strengthen supply chain performance in financial services. Journal of Data Analytics and Intelligent Decision-Making, 2(3), 31–61. https://doi.org/10.22091/jdaid.2026.16727.1094

Barari, A. (2017). *Presenting a comprehensive model for evaluating the healthcare supply chain using multi-criteria decision-making tools* [Master's thesis, University of Science and Culture].

Bottani, E., Monferdini, L., Casella, G., & Mora, C. (2024). Evaluating supply chain performance through lean, agile, resilient, and green (LARG) perspectives: A comprehensive framework. In *Proceedings of the 26th International Conference on Harbor, Maritime and Multimodal Logistic Modeling & Simulation (HMS 2024)* (pp. 1–7). https://doi.org/10.46354/i3m.2024.hms.011

Brandau, M., & Rebello, A. (2021). Surviving cyberbullying: A thematic analysis of online videos. *Issues in Mental Health Nursing, 42*(7), 619–627. https://doi.org/10.1080/01612840.2020.1833118

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Carvalho, H., Azevedo, S. G., & Cruz-Machado, V. (2010). Supply chain performance management: Lean and green paradigms. *International Journal of Business Performance and Supply Chain Modelling, 2*(3–4), 304–333. https://doi.org/10.1504/IJBPSCM.2010.036204

Carvalho, H., Duarte, S., & Cruz-Machado, V. (2011). Lean, agile, resilient and green: Divergencies and synergies. *International Journal of Lean Six Sigma, 2*(2), 151–179. https://doi.org/10.1108/20401461111135037

Divsalar, M., Ahmadi, M., & Nemati, Y. (2022). A SCOR-based model to evaluate LARG supply chain performance using a hybrid MADM method. *IEEE Transactions on Engineering Management, 69*(4), 1101–1120. https://doi.org/10.1109/TEM.2020.2974030

Eftekhari, A., Jamali, G., & Shirazi, A. N. M. (2021). A model for designing and evaluating LARG-based supply chain using axiomatic design and the best-worst method in a hesitant fuzzy environment. *International Journal of Management, Accounting & Economics, 8*(8), 561–584. https://doi.org/10.5281/zenodo.5750767

Esmaeili, F., & Marjani, M. R. (2026). The integrated problem of locating, allocating, and routing transportation vehicles in the blood product supply chain during crisis conditions. Journal of Engineering Management and Soft Computing, 12(3), 1–19. https://doi.org/10.22091/jemsc.2026.12252.1254

Etemad, M., Nazari-Shirkouhi, S., Chaharsooghi, S. K., & Govindan, K. (2026). Relationship between lean, agile, resilient and green paradigm and sustainable supply chain performance: An empirical investigation. *Industrial Management & Data Systems, 126*(6), 2046–2081. https://doi.org/10.1108/IMDS-05-2025-0725

Ghoroghchian, M., Adeli, O. A., Safa, M., & Pourfakharan, M. R. (2022). A framework for identifying LARG supply chain risks. *Journal of Environmental Science and Technology, 24*(4), 1–15. https://www.sid.ir/paper/1063712/en

Gibbs, G. R. (2007). Thematic coding and categorizing. In *Analyzing qualitative data* (pp. 38–55). SAGE Publications. https://doi.org/10.4135/9781849208574

Izanlou, Z., Dehghanian, F., & Karimi, H. (2019). Supply chain assessment based on SCOR model case study: Kia Electrode Shargh Company. *Scientific and Promotional Quarterly Journal of Supply Chain Management, 20*(61), 34–46.

Jamali, G., & Karimi-Asl, E. (2018). Evaluation of LARG supply chain competitive strategies based on gap analysis in cement industries. *Production and Operations Management, 9*(1), 29–54. https://doi.org/10.22108/JPOM.2018.92479.0

Kafoe, A. S. (2025). Healthcare supply chain management: Transformation strategies and innovative solutions. *RAIS Journal for Social Sciences, 9*(1), 73–93. https://doi.org/10.5281/zenodo.15428056

Marjani, M. R., Habibi, M., Jabbari, M., & Aghaee, M. (2026). A hybrid approach based on data density analysis for group supplier selection problem considering multi-level risk assessment: A case study. Journal of Data Analytics and Intelligent Decision-Making, 2(3), 1–30. https://doi.org/10.22091/jdaid.2026.16147.1066

Mehri Babadi, E., Iranzadeh, S., & Fathi Hafshejani, K. (2022). Presenting a model for evaluating LARG supply chain performance in oil and gas industries: A study on National Iranian South Oil Company. *Iranian Journal of Management Sciences, 17*(65), 83–121.

Mohamadi Zanjiran, D., Hashemkhani Zolfani, S., & Prentkovskis, O. (2019). LARG supplier selection based on integrating house of quality, Taguchi loss function and MOPA. *Economic Research–Ekonomska Istraživanja, 32*(1), 1944–1964. https://doi.org/10.1080/1331677X.2019.1635036

Mohammadpur, K. (2023). *Designing a large supply chain model using DEMATEL and ANP techniques: Case study of Avan Pipe and Fittings (Avan Kurdistan)* [Master's thesis, Kharazmi University].

Nasiri, E., & Morovatisharifabadi, A. (2021). Providing a model for the key success factor in LARG supply chain using meta-synthesis. *Organizational Resources Management Researches, 11*(2), 165–186. https://dor.isc.ac/dor/20.1001.1.22286977.1400.11.2.7.2

Nazari-Shirkouhi, S., & Samadi, S. (2025). Enhancing healthcare supply chains: A comprehensive evaluation of lean, agile, resilient and green paradigms. *Engineering Applications of Artificial Intelligence, 145*, 110204. https://doi.org/10.1016/j.engappai.2025.110204

Nazari-Shirkouhi, S., & Zarei Babaarabi, R. (2025). Enhancing decision-making in healthcare systems: Lean, agile, resilient, green, and sustainable (LARGS) paradigm for performance evaluation of hospital departments under uncertainty. *Industrial Management Journal, 17*(2), 85–116. https://doi.org/10.22059/imj.2025.386420.1008208

Nazari-Shirkouhi, S., Badizadeh, A., Dashtpeyma, M., & Ghodsi, R. (2023a). A model to improve user acceptance of e-services in healthcare systems based on technology acceptance model: An empirical study. *Journal of Ambient Intelligence and Humanized Computing, 14*(6), 7919–7935. https://doi.org/10.1007/s12652-023-04601-0

Nazari-Shirkouhi, S., Tavakoli, M., Govindan, K., & Mousakhani, S. (2023b). A hybrid approach using Z-number DEA model and artificial neural network for resilient supplier selection. *Expert Systems with Applications, 222*, 119746. https://doi.org/10.1016/j.eswa.2023.119746

Oliveira-Dias, D., Maqueira-Marin, J. M., Moyano-Fuentes, J., & Carvalho, H. (2023). Implications of using Industry 4.0 base technologies for lean and agile supply chains and performance. *International Journal of Production Economics, 262*, 108916. https://doi.org/10.1016/j.ijpe.2023.108916

Piprani, A. Z., Khan, S. A. R., & Yu, Z. (2024). Driving success through digital transformation: Influence of Industry 4.0 on lean, agile, resilient, green supply chain practices. *Journal of Manufacturing Technology Management, 35*(6), 1175–1198. https://doi.org/10.1108/JMTM-05-2023-0179

Rasidi, N. A. S. A., Salleh, N. H. M., & Jeevan, J. (2019). Compatibility analysis of new lean, agile, resilience and green (LARG) paradigm for enhancing seaport supply chain practices. *International Journal of e-Navigation and Maritime Economy, 13*, 70–83.

Ryan-Vig, S., Gavin, J., & Rodham, K. (2019). The presentation of self-harm recovery: A thematic analysis of YouTube videos. *Deviant Behavior, 40*(12), 1596–1608. https://doi.org/10.1080/01639625.2019.1599141

Sadeghian, S. H., & Mehdiei Malayeri, H. (2014). Applying a hybrid model based on fuzzy Delphi, fuzzy KA and fuzzy network analysis process to select suppliers in a large supply chain (case study: Khuzestan Steel Company). In *5th International Conference on Interdisciplinary Studies in Management and Engineering*.

Shahriari, S. (2017). *Evaluation of supply chain management in Parsian Energy Bitumen Company based on the LARG approach* [Master's thesis, Shahid Chamran University of Ahvaz].

Sheykhizadeh, M., Ghasemi, R., Vandchali, H. R., Sepehri, A., & Torabi, S. A. (2024). A hybrid decision-making framework for a supplier selection problem based on lean, agile, resilience, and green criteria: A case study of a pharmaceutical industry. *Environment, Development and Sustainability, 26*(12), 30969–30996. https://doi.org/10.1007/s10668-023-04135-7

Sonar, H., Gunasekaran, A., Agrawal, S., & Roy, M. (2022). Role of lean, agile, resilient, green, and sustainable paradigm in supplier selection. *Cleaner Logistics and Supply Chain, 4*, 100059. https://doi.org/10.1016/j.clscn.2022.100059

Taheri Tafreshi, M., Salari, A., & Mosleh, M. (2021). Identifying and prioritizing factors affecting the establishment of long-term relationships with large supply chain suppliers using the fuzzy AHP technique (medical equipment companies). *Journal of Strategic Industrial Management, 6*(1), 42–57.

Tavana, M., Nazari-Shirkouhi, S., Mashayekhi, A., & Mousakhani, S. (2022). An integrated data mining framework for organizational resilience assessment and quality management optimization in trauma centers. *Operations Research Forum, 3*(1), 17. https://doi.org/10.1007/s43069-022-00132-0