

یکپارچه سازی مدل زنجیره تامین لارج و رویکرد پویایی سیستم: مروری بر ادبیات

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چکیده

هدف این بررسی ادبیات، بررسی و تحلیل کاربرد رویکرد سیستم دینامیک در مدل زنجیره تامین موثر لارج است. مدل زنجیره تامین موثر لارج یک چارچوب جامع است که عوامل مختلف موثر بر عملکرد زنجیره تامین را ادغام می کند. این مقاله مروری بر اصول مدیریت زنجیره تامین ناب، چابک، تاب آوری و سبز را ارائه می دهد. اصول ناب بر حذف ضایعات و بهبود کارایی در فرآیندها تمرکز دارد، در حالی که اصول چابک بر انعطاف پذیری و پاسخگویی به تقاضاهای در حال تغییر بازار تاکید دارد. هدف اصول تاب آوری، ایجاد استحکام و سازگاری در زنجیره تامین برای مقاومت در برابر اختلالات است. مدیریت زنجیره تامین سبز بر کاهش اثرات زیست محیطی از طریق شیوه های پایدار تمرکز دارد. همچنین، این تحقیق به بررسی چگونگی یکپارچگی این اصول در یک چارچوب منسجم برای مدیریت زنجیره تامین پایدار می پردازد. نویسندگان استراتژی های مختلفی را برای یکپارچه سازی شیوه های ناب، چابک، تاب آوری و سبز، مانند استفاده از ابزارهای ناب برای شناسایی ضایعات در فرآیندها و اجرای استراتژی های چابک برای پاسخ سریع به تغییرات در تقاضای مشتری، مورد بحث قرار می دهند. همچنین، این مقاله نقش رویکرد سیستم دینامیک را در مدل سازی و تحلیل تعاملات پیچیده در زنجیره تامین پایدار بررسی می کند. سیستم دینامیک ابزاری قدرتمند برای درک چگونگی تعامل متغیرهای مختلف در یک سیستم با یکدیگر در طول زمان است. با استفاده از مدل های سیستم دینامیک، محققان می توانند سناریوهای مختلف را شبیه سازی کنند و استراتژی های مختلف را برای بهبود پایداری در زنجیره های تامین آزمایش کنند. با بررسی مطالعات مرتبط، این مقاله به دنبال شناسایی مزایا، محدودیت ها و زمینه های بالقوه برای بهبود در استفاده از سیستم دینامیک در این مدل است. یافته های این مقاله به درک بهتری از اینکه چگونه سیستم دینامیک می تواند شیوه های مدیریت زنجیره تامین را بهبود دهد، کمک می کند.

کلمات کلیدی: زنجیره تامین لارج پویایی سیستم ناب چابک تاب آور سبز

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Integration of LARG Supply Chain Model and System Dynamics Approach: A Literature Review

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ABSTRACT

This systematic literature review aims to explore and analyze the application of the system dynamics approach in the LARG-Effective Supply Chain Model. The LARG-Effective Supply Chain Model is a comprehensive framework that integrates various factors affecting supply chain performance. This paper overviews lean, agile, resilient, and green supply chain management principles. Lean principles focus on eliminating waste and improving efficiency in processes, while agile principles emphasize flexibility and responsiveness to changing market demands. Resilience principles aim to build robustness and adaptability in supply chains to withstand disruptions. Green supply chain management focuses on reducing environmental impact through sustainable practices. Also, this research explores how these principles can be integrated into a cohesive framework for managing sustainable supply chains. The authors discuss various strategies for integrating lean, agile, resilience, and green practices, such as using lean tools to identify waste in processes and implementing agile strategies to respond quickly to changes in customer demand. Moreover, the paper examines the role of the system dynamics approach in modeling and analyzing complex interactions within sustainable supply chains. System dynamics is a powerful tool for understanding how different variables within a system interact with each other over time. By using system dynamics models, researchers can simulate various scenarios and test different strategies for improving sustainability in supply chains. By examining relevant studies, this review seeks to identify the benefits, limitations, and potential areas for improvement in utilizing system dynamics within this model. The findings of this review will contribute to a better understanding of how system dynamics can enhance supply chain management practices.

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1. Introduction

The LARG Supply Chain Model is a comprehensive framework that aims to enhance supply chain performance by integrating various factors such as logistics, agility, resilience, and green practices [1].

In today's highly competitive business environment, organizations are constantly seeking ways to improve their supply chain performance. The LARG-Effective Supply Chain Model, developed using a System Dynamics approach, has gained significant attention as an effective tool for optimizing supply chain operations. The effective management of supply chains is crucial for organizations to achieve their goals and maintain a competitive edge in today's dynamic business environment. To address the complexities and uncertainties inherent in supply chain management, researchers have explored various approaches and models. One such approach is the system dynamics approach, which offers a holistic perspective on the interconnectedness of different components within a supply chain system. This systematic literature review aims to provide an overview of the existing research on the application of system dynamics in the LARG-Effective Supply Chain Model. By synthesizing and analyzing relevant studies, this review not only identifies key findings and gaps in knowledge but also opens up exciting potential areas for future research in this field.

2.1 Background

2.1.1 LARG supply chain model

The LARG-Effective Supply Chain Model emphasizes four main components: Logistics, Agility, Resilience, and Green practices. Logistics refers to the efficient movement of goods and information throughout the supply chain. Agility focuses on responding quickly to changing market demands and customer needs. Resilience involves building robustness in supply chains to withstand disruptions and uncertainties. Green practices emphasize environmentally sustainable operations [2].

Several studies have highlighted the importance of integrating these components within supply chain management. For instance, a study by Christopher [3] argues that combining logistics with agility enables companies to achieve faster response times while maintaining cost efficiency. Similarly, resilience is crucial in managing risks associated with disruptions in global supply chains [4]. Furthermore, incorporating green practices into supply chain operations can save costs and improve environmental performance [4].

Research has shown that implementing the LARG-Effective Supply Chain Model positively impacts supply chain performance. For example, Li et al. [5] found that companies adopting this model experienced improved customer satisfaction due to enhanced responsiveness and reduced lead times. Additionally, organizations prioritizing green practices have been shown to gain competitive advantages through increased brand reputation and customer loyalty [6].

While the LARG-Effective Supply Chain Model offers numerous benefits, it has challenges. One key challenge is the need for effective collaboration and coordination among supply chain partners to fully realize this model's potential [3]. Additionally, implementing green practices may require significant investments in technology and infrastructure, which can be a barrier for some organizations [7].

2.1.2 System dynamics

The system dynamics approach is a powerful methodology for understanding and analyzing complex systems. It provides a holistic perspective by considering a system's interdependencies and feedback loops. Jay W. Forrester first introduced the system dynamics approach [8] as a tool for studying industrial processes. Over time, it has evolved into a comprehensive framework for modeling and analyzing dynamic systems, encompassing diverse disciplines such as engineering, economics, management, public policy, and environmental sciences.

Key concepts of system dynamics are as follows [9]:

- a) Feedback Loops: System dynamics emphasizes the role of feedback loops in shaping system behavior. Positive feedback loops amplify changes within a system, while negative feedback loops stabilize it.
- b) Stocks and Flows: The approach focuses on stocks (accumulations) and flows (rates of change) within a system. Stocks represent quantities that accumulate or deplete over time, while flows describe the movement between stocks.
- c) Causal Loop Diagrams (CLDs): CLDs are graphical representations used to depict causal relationships among variables in a system. They help identify reinforcing and balancing feedback loops.

Also, applications of system dynamics are as follows [10]:

- a) Business Management: System dynamics has been widely applied in business management to model complex organizational structures, supply chains, market dynamics, and decision-making processes.
- b) Public Policy: The approach has proven valuable in analyzing policy interventions related to healthcare systems, transportation networks, energy transitions, climate change mitigation strategies, and urban planning.
- c) Environmental Sciences: System dynamics models have been employed to study ecological systems, natural resource management, biodiversity conservation efforts, and climate change impacts on ecosystems.

The benefits of system dynamics consist of

- a) Holistic Understanding [11]: The system dynamics approach enables researchers to capture the complexity of real-world systems, considering the interplay of multiple variables and feedback loops.
- b) Policy Insights [12]: System dynamics models provide policymakers with valuable insights into the long-term consequences of policy decisions, helping them design effective interventions and avoid unintended consequences.
- c) Decision Support [13]: The approach offers decision-makers a tool to simulate different scenarios, test policies, and evaluate the potential outcomes before implementation.
- d) Stakeholder Engagement [13]: System dynamics models can facilitate stakeholder engagement by providing a shared platform for discussions, fostering collaboration, and enhancing understanding among diverse stakeholders.

The system dynamics approach has become a powerful tool for understanding and analyzing complex systems in various fields. Its emphasis on feedback loops, stocks, flows, and causal relationships enables researchers to gain a holistic understanding of system behavior. The applications of system dynamics range from business management to public policy and environmental sciences. The benefits include improved decision-making, policy insights, and stakeholder engagement. As systems continue to grow in complexity, the system dynamics approach will remain a valuable tool for addressing real-world challenges.

2.1.3 Integration of LARG supply chain and System dynamics

The LARG-Effective Supply Chain Model is a comprehensive framework that aims to optimize supply chain performance by considering various factors such as logistics, agility, resilience, and green practices. To effectively analyze and improve this complex system, researchers have increasingly turned to the system dynamics approach [14].

System dynamics, a practical and widely used modeling methodology, focuses on understanding complex systems by analyzing their feedback loops, time delays, and nonlinear relationships. It allows researchers to simulate dynamic behavior over time and gain insights into how different variables interact within a system [15]. System dynamics has been widely used in supply chain management to study various aspects such as inventory management, demand forecasting, production planning, and distribution strategies. By incorporating feedback

loops and time delays into models, system dynamics enables a more accurate representation of real-world supply chain dynamics [16]. The LARG-Effective Supply Chain Model incorporates these principles to capture the dynamic nature of supply chain operations, providing a holistic view of supply chain effectiveness [17].

2.2 Research questions

The purpose of this study is to comprehend the integration of system dynamics and LARG supply chain research fields over time in order to identify areas that have not been explored and suggest future research directions. This study addresses four research questions: 1) How can system dynamics research be located within the context of the supply chain domain? This involves understanding which types of research articles should be chosen for the study. 2) What is the main research focus in supply chains using system dynamics? This entails examining which industries or sectors have been targeted in literature and which tools and techniques have been predominantly used. 3) What are the current relationship trends between system dynamics and the LARG supply chain? 4) What are the benefits of using system dynamics in the LARG supply chain? 5) What are the limitations of using system dynamics in the LARG supply chain? Based on these findings, what potential future research avenues can be proposed in this subject domain?

2.3 Summary

Integrating the LARG (Lean, Agile, Resilient, and Green) supply chain model with system dynamics presents a significant innovation in supply chain management literature. Traditional supply chain models often focus on isolated aspects, such as efficiency or responsiveness, without adequately addressing modern supply chains' complex interdependencies and dynamic behaviors. By synthesizing the principles of LARG with system dynamics, researchers can better capture the multifaceted nature of supply chains, allowing for a more holistic understanding of how various factors—such as demand fluctuations, resource constraints, and environmental considerations—interact over time.

This innovative approach enables practitioners to simulate different scenarios and assess the impact of strategic decisions on supply chain performance. The combination of LARG's focus on sustainability and adaptability with system dynamics' capacity for modeling feedback loops and time delays equips organizations to navigate the challenges posed by global disruptions, regulatory changes, and shifting consumer preferences. Furthermore, this integration fosters a proactive rather than reactive mindset in supply chain management, encouraging continuous improvement and resilience.

The literature review highlights the transformative potential of integrating the LARG supply chain model with system dynamics. This approach not only enhances our understanding of complex supply chain interactions but also equips decision-makers with the tools necessary to develop robust strategies that balance efficiency, agility, resilience, and sustainability. As organizations face increasing uncertainties in the global market, adopting this integrated framework can lead to more informed decision-making and improved overall performance. Future research should focus on empirical validations of this integration, exploring case studies that demonstrate its practical applications and benefits in real-world scenarios. By bridging theoretical insights with practical implementations, this innovative framework has the potential to not just improve, but to redefine best practices in supply chain management for years to come.

3. Methodology

The SLR method is useful for comprehending existing knowledge, identifying gaps, and guiding future research. According to Thome, Scavarda, and Scavarda [18], it helps position the direction for future research. Rafi-UI-Shan et al. [19] define the SLR method as an evidence-based approach with four key principles that enhance its robustness: heuristic nature, transparency, explanatory nature, and inclusivity. GarzaReyes [20] states that the SLR method brings transparency and rigor to the literature review process. Additionally, Rafi-UI-Shan et al. [20] and

Carter and Liane Easton [21] argue that it reduces researcher biases and improves the reliability of research. Table 1 outlines the SLR methodology, which will be discussed in the following section.

Table 1. methodology of the study based on [20]

Steps	Descriptions
1	Determining research goal
2	Investigating relevant studies which consists of, choosing electronic databases, forward and backward search, and determining inclusion and exclusion criteria
3	Investigating papers in order to reach final chosen papers
4	Outcome and final analysis of research

The SLR methodology was used to conduct a literature review in this field. Initially, Google Scholar was used to search for publications. Then, the Scopus search engine was used with an electronics database, Science Direct. Other databases, such as Springer, Taylor, and Francis, were also utilized during the snowballing technique. Inclusion and exclusion criteria were established to ensure the reliability of the SLR process, which is shown in Table 2. The keywords used in the search engine consist of “Lean,” “Agile,” “Resilient,” “Green,” “Supply chain management,” AND “Dynamic systems”.

The snowballing technique, also known as the forward and backward approach, was used to find the most relevant literature based on the papers mentioned by Webster and Watson [22] and Levy and Ellis [23]. Articles were gathered from various sources such as Google Scholar, Science Direct. Levy and Ellis [22] emphasized the importance of these approaches and recommended continuing the search until the main themes or concepts of the study started to repeat. The search for research articles resulted in a total of 59 papers deemed most relevant. However, after individual analysis, 21 research articles were excluded due to repetition or irrelevance to this study. Therefore, a final selection of 38 articles was made for this review. It is acknowledged that numerous research articles have been published on the same topic that could not all be reviewed.

Table 2. Inclusion and exclusion criteria of the study

Criteria	Descriptions
Type of articles	All published articles in electronic databases
Language of articles	English
Investigated concepts in the articles	Integration of system dynamics and LARG supply chain
Search engine	Google scholar
Electronic databases	Science direct and Scopus
Exclusion criteria	Peer reviewed papers and books
Number of final papers	38

3.1 Data extraction and analysis

In this section, we discussed the detailed process of analyzing and synthesizing 39 selected articles from 2000 to 2023. We used a structured categorization scheme, with some modifications, to classify all the published articles.

To address research questions, we classified the research articles based on research type, geographical location, tools/techniques used, industry/sector of application, and focus.

The selected articles in the research were divided into four groups based on their type. The first group, the literature review, consisted of articles that examined previous studies and proposed theoretical frameworks or future research propositions. The second group, the survey, included articles that presented the results of online surveys and utilized statistical tools. The third group, case study, focused on specific issues or cases involving one or multiple companies and used analytical tools. The fourth group, miscellaneous, included all other articles that did not fit into the previous categories.

The articles were also classified based on their geographical location, including individual countries, multiple countries, and cases where the country was not specified. Additionally, they were classified based on their area of application/industry, such as manufacturing, food/agribusiness, service industry, or multiple industries.

Furthermore, the articles were categorized based on the tools and techniques used in the research, such as statistical methods, analytical techniques, mathematical modeling, and simulation. Another classification was based on the concepts or paradigms explored in the supply chain domain.

These classifications were further divided into subcategories for a more detailed discussion in the outcome section of the research. Also, based on the Science Direct database, the most used keywords in the investigated field in this study are shown in Figure 1.



Figure 1. The most used keywords in the investigated field in this study

3.2 Thematic and gap analysis

Thematic and gap analysis serves as a critical framework for synthesizing the existing body of knowledge regarding the integration of the LARG (Lean, Agile, Resilient, and Green) supply chain model with system dynamics approaches. As the complexity of global supply chains continues to escalate, understanding how these methodologies can be effectively combined is essential for enhancing operational efficiency, sustainability, and resilience. This section delineates the thematic analysis undertaken in this systematic literature review, followed by an exploration of identified gaps that warrant further investigation.

3.2.1 Thematic analysis

The thematic analysis involved systematically categorizing and interpreting the literature to extract core themes that characterize the intersection of the LARG supply chain model and system dynamics. The review revealed several prominent themes:

1. Principles of LARG Supply Chain: A significant portion of the literature emphasizes the fundamental principles underpinning each component of the LARG model. Studies highlighted how Lean practices aim to eliminate waste, Agile strategies facilitate responsiveness, Resilient frameworks enhance adaptability to disruptions, and Green methodologies promote sustainability. Collectively, these principles provide a holistic approach to supply chain management that addresses both operational efficiency and environmental concerns.

2. Application of System Dynamics in Supply Chains: Another prevalent theme is the application of system dynamics as a modeling tool to understand and simulate complex supply chain behaviors. Researchers have employed system dynamics to analyze feedback loops, time delays, and non-linear relationships within supply chains, providing insights into how various factors influence performance outcomes. This body of work underscores the importance of dynamic modeling in capturing the intricate interactions inherent in supply chain systems.
3. Synergies Between LARG and System Dynamics: The literature also reveals emerging synergies between LARG principles and system dynamics methodologies. Several studies propose that integrating these frameworks can lead to enhanced decision-making capabilities, improved forecasting accuracy, and more robust risk management strategies. By leveraging system dynamics to model LARG principles, organizations can better visualize the implications of their strategic choices and operational adjustments.
4. Case Studies and Empirical Evidence: A noteworthy theme is the reliance on case studies and empirical evidence to validate theoretical propositions regarding LARG and system dynamics integration. Many researchers have documented real-world applications, illustrating how organizations have successfully implemented these combined approaches to achieve tangible benefits in performance metrics such as lead time reduction, cost savings, and improved customer satisfaction.
5. Challenges and Limitations: The literature also addresses various challenges associated with integrating LARG supply chain models with system dynamics approaches. Issues such as data availability, model complexity, and stakeholder engagement are frequently cited as barriers to effective implementation. Understanding these challenges is crucial for practitioners aiming to adopt these methodologies in their operations.

3.2.2 Gap Analysis

Despite the richness of themes identified in the literature, several critical gaps warrant attention:

1. Limited Empirical Research on Integration: While numerous studies discuss the theoretical underpinnings of both LARG and system dynamics independently, there is a notable scarcity of empirical research that specifically investigates their integration. Future studies should focus on longitudinal case studies or experimental designs that provide concrete evidence of the benefits and challenges associated with this integration.
2. Lack of Comprehensive Frameworks: The literature lacks comprehensive frameworks that delineate how organizations can systematically integrate LARG principles with system dynamics methodologies. Such frameworks could guide practitioners through the complexities of implementation, offering best practices and actionable insights tailored to different industry contexts.
3. Underexplored Contextual Factors: Current research often overlooks contextual factors that may influence the success of integrating LARG and system dynamics. Variables such as organizational culture, industry characteristics, and regional differences could significantly impact implementation outcomes. Future research should consider these contextual elements to provide a more nuanced understanding of integration processes.
4. Insufficient Focus on Sustainability Metrics: Although sustainability is a core component of the LARG model, there is limited exploration of how system dynamics can quantitatively assess sustainability metrics within integrated supply chains. Future investigations should aim to develop metrics that measure environmental impact alongside traditional performance indicators, facilitating a more holistic evaluation of integrated approaches.
5. Need for Interdisciplinary Approaches: Finally, there is a pressing need for interdisciplinary research that combines insights from operations management, environmental science, and systems thinking. Such collaborative efforts could foster innovative solutions that address the multifaceted challenges facing modern supply chains while promoting sustainability and resilience.

4. Result

The outcome phase examines and combines each article separately, presenting the results based on different categorization schemes discussed in Section 3.1. This section provides answers to the research questions. First, the status of the year of publication of the articles is shown in Figure 2. This figure shows that in recent years the tendency of researchers to use the dynamic system in studies has increased, which shows the capabilities of the dynamic system in the LARG supply chain.

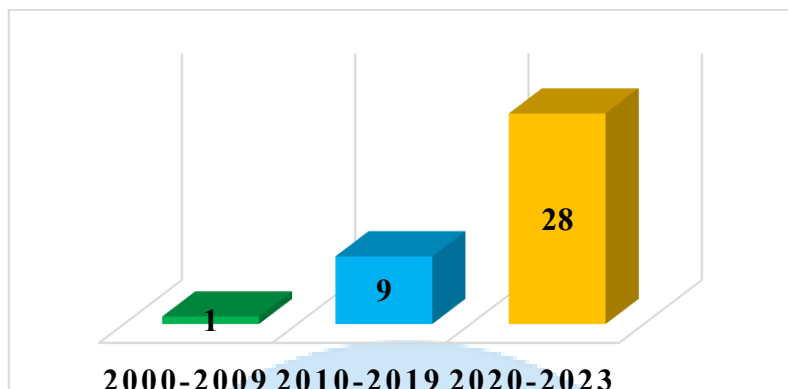


Figure 2. Number of published paper

In terms of research type classification, Figure 3 illustrates the distribution of articles into four groups: literature review, case studies, survey-based studies, and miscellaneous.

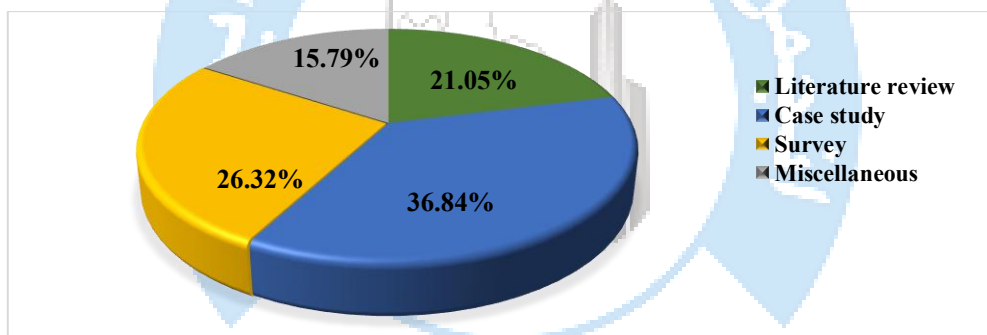


Figure 3. Number of published papers in terms of type

The analysis reveals that 21.05% of the articles are literature review-based, 36.84% are based on case studies, 26.32% are survey-based studies, and 15.79% fall under the miscellaneous category. Geographical location classification is depicted in Figure 4 and mainly includes survey-based and case-based studies.

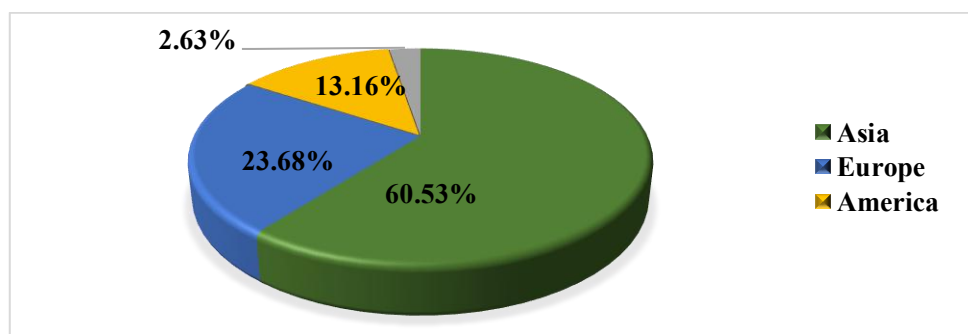


Figure 4. Number of published papers based on geographical location

Out of a total of 38 studies, 60.53% were conducted in Asia, 23.68% in Europe, 13.16% in America and 2.63% in other continents. Further details can be found in Table 3.

Table 3. Inclusion and exclusion criteria of the study

Location	References
Asia	[2][24][25][26][14][27][28][29][30][31][32][33][34][35][36][37][38][39][40][41][42][43][44]
Europe	[45][17][46][47][48][49][50][51][52]
America	[53][54][55][56][57]
Others	[58]

Therefore, a classification system is used based on the industry targeted in the research articles and the tools and techniques utilized. Regarding industry-based classification, most of the research articles (24 out of 38) were either survey-based or case study-based, focusing.

Of these 38 articles, 5 focused on the energy sector and 5 on the healthcare sector. Four articles were conducted in the food and agriculture sector, 4 in the service sector, 3 in the manufacturing sector, 2 in the construction sector, and 14 in general sectors. This analysis is illustrated in Figure 5.

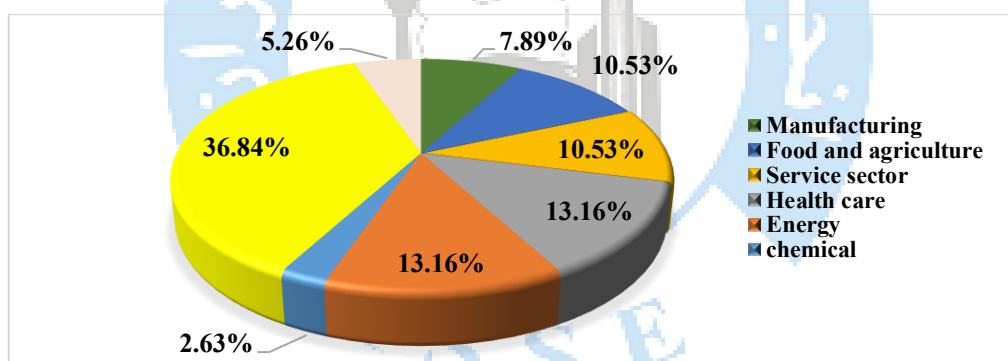


Figure 5. Number of published papers in different fields

4.1. Benefits of the LARG-Effective Supply Chain Model using system dynamics

The LARG-Effective Supply Chain Model has emerged as a promising approach that aims to enhance efficiency, reduce costs, and improve overall performance [59].

1. Improved Decision-Making [50]: The use of system dynamics allows decision-makers to assess the long-term impact of their decisions on various performance metrics within the supply chain.

2. Enhanced Efficiency [60]: One of the primary advantages of adopting the LARG-Effective Supply Chain Model is its ability to streamline operations and improve efficiency throughout the supply chain. Integrating various processes such as procurement, production, and distribution, this model enables organizations to eliminate redundancies and minimize waste. This enhanced efficiency leads to reduced lead times, improved customer satisfaction, and increased competitiveness in the market.

3. Enhanced Understanding [13]: By visualizing complex relationships between different variables, system dynamics helps researchers gain a deeper understanding of how changes in one aspect affect other components within the supply chain.

4. Cost Reduction [25]: Implementing the LARG-Effective Supply Chain Model can significantly contribute to cost reduction for organizations. Through effective demand forecasting and inventory management techniques, this model helps in optimizing inventory levels while minimizing holding costs. Additionally, by leveraging collaborative relationships with suppliers and customers, organizations can negotiate better pricing terms and reduce transportation costs through efficient route planning.

5. Improved Collaboration [60]: The LARG-Effective Supply Chain Model emphasizes collaboration among various stakeholders within the supply chain network. By fostering strong relationships with suppliers, customers, and other partners, organizations can benefit from shared information, resources, and expertise. This collaborative approach enhances communication channels, facilitates joint decision-making processes, reduces information asymmetry, and ultimately leads to improved overall performance.

6. Scenario Analysis [30]: System dynamics enables scenario analysis by simulating different scenarios under varying conditions, helping decision-makers identify potential bottlenecks and vulnerabilities in the supply chain.

7. Increased Flexibility [59]: Flexibility is a crucial aspect of modern supply chains due to dynamic market conditions and changing customer demands. The LARG-Effective Supply Chain Model enables organizations to respond quickly to fluctuations in demand by implementing agile manufacturing practices such as just-in-time (JIT) production or postponement strategies. This flexibility allows companies to adapt their operations efficiently, minimize stockouts, and meet customer expectations promptly.

8. Enhanced Sustainability [26]: Sustainability has become a critical consideration for organizations across industries. The LARG-Effective Supply Chain Model promotes sustainable practices by encouraging the use of environmentally friendly materials, reducing waste generation, and optimizing transportation routes to minimize carbon emissions. By adopting this model, organizations can improve their environmental footprint while also benefiting from cost savings associated with energy efficiency and waste reduction.

The study highlights the numerous benefits associated with implementing the LARG-Effective Supply Chain Model. From enhanced efficiency and cost reduction to improved collaboration and increased flexibility, this model offers organizations a comprehensive framework to optimize their supply chain operations. Moreover, by incorporating sustainable practices, organizations can align their supply chain strategies with environmental goals while reaping economic benefits. Future research should focus on empirical studies to further validate the advantages of this model in different industry contexts.

4.2. Application Areas of the LARG-Effective Supply Chain Model using system dynamics

This study explored the application areas of this model in different industries shown in Figure 6 and highlighted its potential benefits for organizations.

1. Manufacturing Industry [37]: The LARG-Effective Supply Chain Model has been widely applied in the manufacturing sector to enhance operational efficiency and reduce costs. By incorporating agile practices, such as flexible production processes and quick response to customer demands, manufacturers can achieve higher customer satisfaction levels and gain a competitive edge in the market.

2. Retail Industry [42]: In the retail sector, the LARG-Effective Supply Chain Model has proven effective in managing inventory levels, improving order fulfillment processes, and reducing lead times. By adopting green practices within their supply chains, retailers can also enhance their sustainability credentials and meet increasing consumer demands for environmentally friendly products.

3. Healthcare Industry [33]: The healthcare industry faces unique challenges related to supply chain management due to its critical nature and complex regulatory requirements. The LARG-Effective Supply Chain Model offers healthcare organizations a systematic approach to optimize inventory management, reduce waste, improve product traceability, and enhance patient safety.
4. Food Industry [17]: Food companies are increasingly adopting sustainable practices throughout their supply chains to address environmental concerns and meet changing consumer preferences. The LARG-Effective Supply Chain Model provides a holistic framework for integrating green practices into food supply chains while ensuring product quality, safety, and traceability.
5. E-commerce Industry [5]: With the rapid growth of e-commerce platforms, efficient supply chain management has become crucial for online retailers. The LARG-Effective Supply Chain Model enables e-commerce companies to streamline their logistics operations by implementing agile distribution networks, optimizing last-mile delivery processes, and leveraging technology-driven solutions such as automation and data analytics.
6. Automotive Industry [25]: The automotive sector faces challenges related to global supply chain complexities, just-in-time manufacturing, and product customization. The LARG-Effective Supply Chain Model helps automotive manufacturers enhance their supply chain resilience by implementing risk management strategies, improving supplier collaboration, and adopting lean manufacturing principles.
7. Energy Industry [51]: The energy sector, including renewable energy sources, requires efficient supply chain management to ensure the availability of resources and minimize environmental impacts. The LARG-Effective Supply Chain Model assists energy companies in optimizing their logistics operations, reducing carbon emissions through green practices, and enhancing supply chain resilience against disruptions.

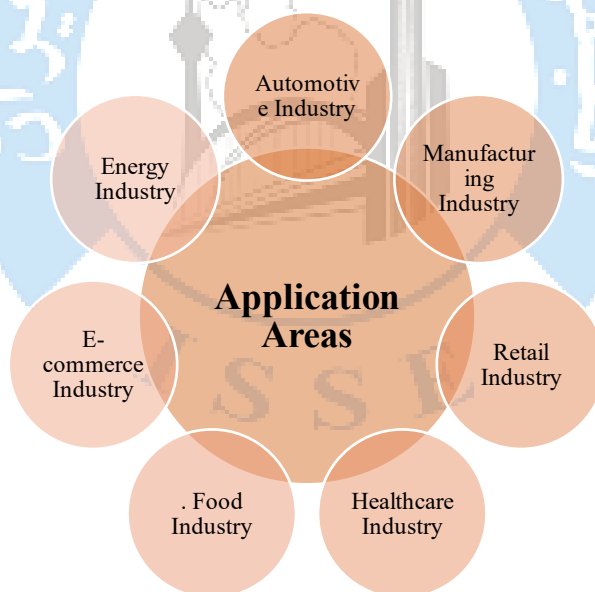


Figure 6. Application Areas of the LARG-Effective Supply Chain Model using system dynamics

The study highlighted the diverse application areas of the LARG-Effective Supply Chain Model across various industries. From manufacturing to healthcare, retail to e-commerce, this model offers organizations a comprehensive framework to optimize their supply chain performance by integrating logistics, agility, resilience, and green practices. By adopting this model, organizations can achieve operational efficiency, reduce costs, improve customer satisfaction levels, enhance sustainability credentials, and mitigate risks associated with supply chain disruptions. Further research is needed to explore the implementation challenges and potential limitations of this model in different industry contexts.

4.3. Limitations and evaluation of System Dynamics in the LARG-Effective Supply Chain Model:

Limitations are as follows:

1. Data Availability [11]: System dynamics models heavily rely on accurate and reliable data. However, obtaining real-time data for all variables within the supply chain can be challenging, limiting the accuracy of model predictions.
2. Complexity [38]: Developing a system dynamics model for the LARG-Effective Supply Chain Model requires a deep understanding of supply chain dynamics and expertise in system dynamics modeling techniques. Supply chains are inherently complex, involving multiple interconnected components, such as suppliers, manufacturers, distributors, and customers. Modeling such complexity accurately requires a comprehensive understanding of all these components and their interactions. However, obtaining accurate data on all these components can be challenging due to limited availability or confidentiality concerns.
3. Simplification [12]: Due to the complexity of supply chains, certain assumptions and simplifications may need to be made when developing system dynamics models, potentially leading to deviations from real-world scenarios. The accuracy of the model heavily relies on the assumptions made during its development. Assumptions regarding consumer behavior, production capacities, lead times, and other variables can significantly impact the model's predictions. Ensuring that these assumptions accurately reflect real-world conditions is a challenge that requires continuous validation and refinement. It is important to note that any model is an abstraction of reality and may not capture all aspects of a complex system accurately. The LARG-Supply Chain Model may overlook certain nuances or interactions within the supply chain that could affect its predictions.

In conclusion, while applying the system dynamics approach in the LARG-Supply Chain Model offers valuable insights into supply chain dynamics, it faces limitations related to complexity, the dynamic nature of supply chains, assumptions made during model development, specialized tools required for implementation, and potential abstraction from reality. Overcoming these challenges requires continuous improvement in data collection, model validation, and expertise in system dynamics modeling techniques.

4.3.1 Evaluation of System Dynamics in the LARG-Effective Supply Chain Model

The integration of the LARG supply chain model with system dynamics offers numerous practical benefits for organizations. Firstly, it enhances decision-making capabilities by providing a visual representation of supply chain dynamics. Managers can simulate various scenarios and assess the potential impact of different strategies on overall performance. For instance, a company might explore how implementing lean practices affects inventory levels and customer satisfaction under varying demand conditions.

Secondly, this integrated approach fosters improved forecasting accuracy. By modeling the feedback loops inherent in supply chains, organizations can better predict the consequences of their actions over time. This predictive capability is particularly valuable in dynamic environments where demand fluctuations are common.

Thirdly, integrating system dynamics with the LARG model enhances risk management strategies. Organizations can simulate potential disruptions—such as supplier failures or natural disasters—and evaluate their resilience in real-time. This proactive approach allows companies to develop contingency plans that minimize risks and ensure continuity of operations.

The benefits of integrating the LARG supply chain model with system dynamics are manifold:

1. Holistic Perspective: The integration encourages a systems-thinking approach that considers the interdependencies among lean, agile, resilient, and green practices.
2. Enhanced Performance Metrics: Organizations can develop comprehensive performance metrics that assess not only financial outcomes but also environmental impact and operational efficiency.

3. Improved Collaboration: By utilizing a shared modeling platform, cross-functional teams can collaborate more effectively, aligning their strategies with organizational goals.
4. Informed Policy Development: The insights gained from simulations can inform policy decisions at both organizational and governmental levels, promoting sustainable practices across industries.
5. Continuous Improvement: The iterative nature of system dynamics modeling supports ongoing learning and adaptation, enabling organizations to refine their strategies over time.

Despite its advantages, integrating the LARG supply chain model with system dynamics is not without challenges:

1. Complexity of Modeling: Developing accurate system dynamics models requires a deep understanding of both the supply chain's operational details and the underlying theoretical principles. This complexity can deter organizations from pursuing integration.
2. Data Availability: Effective modeling relies on high-quality data; however, many organizations struggle with data collection and management, limiting the accuracy of their simulations.
3. Stakeholder Engagement: Engaging stakeholders in the modeling process is crucial for gaining buy-in and ensuring that models reflect real-world conditions. However, achieving this engagement can be challenging due to differing perspectives and priorities.
4. Resistance to Change: Organizational culture may resist adopting new methodologies or changing established practices. Overcoming this resistance is essential for successful integration.
5. Limited Empirical Evidence: While theoretical discussions abound, empirical studies demonstrating the effectiveness of this integration are still limited. This lack of evidence can hinder widespread adoption.

4.4. Application of System Dynamics in the LARG-Effective Supply Chain Model: Case Studies Analysis

This section aims to explore the application of system dynamics in the LARG-Effective Supply Chain Model through a comprehensive analysis of case studies.

Case Study 1: Application in Retail Industry [42]:

A case study conducted in a retail industry context demonstrated the effectiveness of the LARG-Effective Supply Chain Model. By incorporating system dynamics principles into its supply chain operations, the organization achieved significant improvements in inventory turnover rates and reduced stockouts. The model allowed them to simulate different scenarios and identify optimal reorder points and order quantities.

Case Study 2: Application in Manufacturing Industry [61]:

In another case study conducted in a manufacturing industry setting, the LARG-Effective Supply Chain Model was applied to optimize production planning processes. By considering factors such as demand variability, lead times, and production capacity constraints using system dynamics techniques, the organization achieved better synchronization between demand and production levels. This resulted in reduced lead times and improved customer satisfaction.

Case Study 3: Application in Healthcare Industry [33]:

The LARG-Effective Supply Chain Model was also successfully applied in the healthcare industry to improve supply chain performance. By incorporating system dynamics principles, the organization was able to optimize inventory levels of critical medical supplies, reduce stockouts, and enhance patient safety. The model allowed them to simulate different demand scenarios and identify optimal reorder points and order quantities.

4.5. Discussion on integration of System Dynamics into the LARG-Effective Supply Chain Model: Recommendations for Improvement

The integration of System Dynamics into the LARG-Supply Chain Model has proven to be a valuable addition, providing a more comprehensive understanding of the dynamics and complexities within the supply chain. This discussion aims to highlight the strengths and weaknesses of this integration and provide recommendations for improvement.

One of the key strengths of integrating System Dynamics into the LARG-Supply Chain Model is its ability to capture feedback loops and non-linear relationships. The traditional static models used in supply chain analysis often fail to account for these dynamic interactions, leading to inaccurate predictions and suboptimal decision-making. By incorporating System Dynamics, the LARG-Supply Chain Model can better simulate real-world scenarios, considering factors such as delays, inventory accumulation, and demand fluctuations.

Furthermore, System Dynamics allows for a more holistic view of the supply chain by considering both internal and external factors that influence its performance. This includes factors such as market demand, competitor behavior, technological advancements, and government regulations. By incorporating these variables into the model, decision-makers can gain insights into how changes in one part of the supply chain may impact other areas.

However, there are several areas where improvements can be made to enhance the integration of System Dynamics into the LARG-Supply Chain Model. Firstly, there is a need for more accurate data collection and validation. The accuracy of any model heavily relies on the quality of input data. Therefore, efforts should be made to collect reliable data from various sources such as suppliers, customers, and industry reports. Additionally, validation techniques should be employed to ensure that the model's outputs align with real-world observations.

Another area for improvement is enhancing model transparency and interpretability. While System Dynamics models can capture complex relationships within a system, they often lack transparency in terms of how decisions are made or how variables interact with each other. To address this issue, efforts should be made to document the assumptions and equations used in the model clearly. Additionally, visualizations and graphical representations can be employed to aid in understanding the model's behavior and facilitate communication with stakeholders.

Furthermore, the integration of System Dynamics into the LARG-Supply Chain Model should consider incorporating more advanced optimization techniques. While System Dynamics provides valuable insights into the behavior of the supply chain, it may not always provide optimal solutions to complex decision problems. By integrating optimization algorithms, such as genetic algorithms or linear programming, decision-makers can identify optimal strategies that maximize performance metrics such as cost efficiency or customer satisfaction.

Lastly, continuous model updating and refinement should be emphasized. The supply chain environment is dynamic and subject to constant changes. Therefore, the LARG-Supply Chain Model should be regularly updated to reflect these changes and ensure its relevance over time. This includes incorporating new data, refining assumptions, and validating the model against real-world observations.

In conclusion, the integration of System Dynamics into the LARG-Supply Chain Model has proven beneficial in capturing dynamic interactions within the supply chain. However, there is room for improvement in terms of data collection and validation, transparency and interpretability, incorporation of optimization techniques, and continuous model updating. By addressing these areas, decision-makers can leverage the full potential of System Dynamics in enhancing supply chain performance and making informed decisions.

4.6. Application of the LARG Supply Chain Model and System Dynamics Approach in Iranian Projects

This application is particularly pertinent given the unique economic, environmental, and geopolitical challenges faced by the country, including sanctions, resource scarcity, and the need for sustainable development. Iran's supply chain landscape is characterized by a complex interplay of factors, including a diverse range of industries

from oil and gas to agriculture and manufacturing. The LARG model emphasizes four critical dimensions—logistics efficiency, supply chain agility, resilience against disruptions, and environmental sustainability. By employing a system dynamics approach, which focuses on understanding the feedback loops and time delays that influence behavior within complex systems, stakeholders can develop a more nuanced understanding of how these dimensions interact over time.

4.6.1 Enhancing Logistics Efficiency

In the context of Iranian projects, logistics efficiency is paramount due to the country's vast geography and varying infrastructure quality. The LARG model advocates for streamlined logistics operations that minimize costs and transit times. By utilizing system dynamics simulations, project managers can identify bottlenecks in the supply chain and evaluate various logistical strategies under different scenarios. For instance, simulations can reveal how changes in transportation routes or warehousing practices impact overall efficiency, allowing for data-driven decision-making that optimizes resource allocation.

4.6.2 Fostering Agility

Agility in supply chains is essential for responding to market fluctuations and unexpected disruptions. In Iran, where economic conditions can be volatile due to external sanctions and internal policy shifts, the ability to adapt quickly is crucial. The LARG model encourages organizations to develop flexible supply chain strategies that can pivot in response to changing demands. Through system dynamics modeling, stakeholders can simulate various market scenarios to understand how agile responses can mitigate risks and capitalize on emerging opportunities. This proactive approach enables companies to maintain competitiveness in an uncertain environment.

4.6.3 Building Resilience

Resilience is another cornerstone of the LARG model, particularly relevant in Iran's context of geopolitical tensions and natural disasters such as earthquakes. A resilient supply chain can withstand shocks and recover more quickly from disruptions. By applying system dynamics, organizations can map out potential disruption scenarios—such as supplier failures or transportation breakdowns—and assess their impact on the overall supply chain performance. This modeling allows for the identification of critical vulnerabilities and the development of contingency plans that enhance resilience.

4.6.4 Promoting Sustainability

Environmental sustainability is increasingly becoming a priority for businesses globally, and Iran is no exception. The LARG model incorporates green practices that aim to reduce waste and carbon footprints throughout the supply chain. System dynamics can facilitate the modeling of environmental impacts associated with various supply chain strategies, enabling organizations to evaluate trade-offs between economic performance and ecological responsibility. For example, simulations may help assess how shifts toward renewable energy sources or waste reduction initiatives can affect both operational costs and environmental outcomes.

The application of the LARG supply chain model combined with a system dynamics approach holds significant promise for Iranian projects across various sectors. By fostering logistics efficiency, agility, resilience, and sustainability, organizations can navigate the complexities of Iran's economic landscape more effectively. As businesses continue to face challenges posed by both internal and external factors, leveraging these integrated methodologies will be essential for achieving long-term success and sustainability in supply chain operations. Future research should focus on refining these models further and exploring their applicability in diverse contexts within Iran's evolving market landscape.

5. Potential areas for future

One potential area for future research is to investigate the integration of System Dynamics into the LARG-Supply Chain Model to enhance its predictive capabilities and decision-making support. Future research could focus on developing a comprehensive framework that combines the strengths of both approaches, leveraging the dynamic modeling capabilities of System Dynamics and the detailed representation of logistics, operations, and supply chain processes in the LARG model.

Another area for future research could be exploring the impact of incorporating feedback loops and time delays into the integrated model. System Dynamics is well-suited for capturing complex feedback dynamics and time delays, which are inherent in supply chain systems. By incorporating these elements into the LARG-Supply Chain Model, researchers can gain a deeper understanding of how various factors interact over time and how delays in decision-making or information flow can affect overall system performance.

Additionally, future research could focus on integrating real-time data and simulation capabilities into the integrated model. With advancements in technology and data availability, it is now possible to collect real-time data from various sources within a supply chain. By integrating this data into the model, researchers can simulate different scenarios and evaluate their impact on key performance indicators such as cost, lead time, inventory levels, and customer satisfaction. This would enable more accurate predictions and better decision-making in dynamic supply chain environments.

Furthermore, investigating the scalability of the integrated model is another potential area for future research. The LARG-Supply Chain Model may need to handle large-scale supply chain networks with numerous nodes, multiple tiers of suppliers, complex product flows, and diverse demand patterns. Understanding how well the integrated model performs under such conditions and identifying any limitations or bottlenecks would be crucial for its practical implementation in real-world supply chain management.

Overall, these potential areas for future research highlight opportunities to enhance the integration of System Dynamics into the LARG-Supply Chain Model by exploring feedback loops, time delays, real-time data integration, simulation capabilities, scalability considerations, and other relevant factors. By addressing these research areas, researchers can contribute to the development of more robust and effective supply chain models that can support decision-making and improve overall supply chain performance.

While the existing case studies demonstrate the effectiveness of applying system dynamics in the LARG-Effective Supply Chain Model across various industries, further research is needed to explore its applicability in different contexts. Future studies could focus on evaluating the model's performance under different scenarios or comparing it with other supply chain optimization approaches.

6. Conclusion

This research examines and discusses the current state, findings, trends, and future opportunities in using system dynamics in LARG paradigms in supply chain management. Initially, relevant articles were selected from various databases. The backward and forward approach was then used to gather a total of 38 research articles published between 2000 and 2023. Five research questions were raised. The first research question revealed that most studies were case study-based and focused on a single country. In research question 2, it was found that most research was conducted in general. There was limited research reported from the chemical sector despite its potential in various fields such as the service sector, healthcare, energy, and construction.

The application of system dynamics in the LARG-Effective Supply Chain Model offers significant advantages by providing a dynamic perspective on supply chain operations. It enables decision-makers to make informed decisions by considering various performance metrics and simulating different scenarios. However, challenges such as data availability and model complexity need to be addressed to ensure an accurate representation of real-world supply chain dynamics. Future research should focus on refining system dynamics models within the LARG-

Effective Supply Chain Model framework and exploring ways to overcome these limitations for more effective supply chain management.

Utilizing the system dynamics approach in the LARG-Supply Chain Model has demonstrated significant potential in enhancing decision-making processes and improving overall supply chain performance. The reviewed studies consistently reported that incorporating system dynamics principles and methodologies into the model resulted in a more comprehensive understanding of complex supply chain dynamics, enabling better identification and analysis of key variables, feedback loops, and causal relationships. Furthermore, the systematic literature review revealed that applying system dynamics facilitated effective simulation and scenario analysis, allowing for robust testing of various policies and strategies. This enabled decision-makers to gain insights into potential outcomes and make informed decisions to optimize supply chain operations. Additionally, the reviewed studies highlighted that utilizing system dynamics in the LARG-Supply Chain Model contributed to improved coordination among supply chain partners, enhanced responsiveness to demand fluctuations, reduced bullwhip effect, minimized inventory holding costs, and increased customer satisfaction.

However, it is important to note that while the application of system dynamics showed promising results in improving supply chain performance within the LARG-Supply Chain Model, there were limited studies available specifically focused on this context. Therefore, further research is recommended to explore additional aspects, such as scalability and implementation challenges with applying system dynamics in this particular model.

In conclusion, based on the systematic literature review findings, it can be concluded that integrating system dynamics principles into the LARG-Supply Chain Model offers significant decision-making capabilities and overall supply chain performance improvement. This scientific statement provides a foundation for future research endeavors aiming to investigate and validate these findings further.

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