Article history:
Received 01 May 2025
Revised 29 July 2025
Accepted 07 August 2025
Published online 12 September 2025

Journal of Resource Management and Decision Engineering

Volume 4, Issue 3, pp 1-14

Application of Sandelowski and Barroso Technique in Identifying the Components of the Reliability Model of Green Value Chain Management in Manufacturing Industries

Arash. Rafati[1], Hasan. Mehrmanesh [1*], Ahmadreza. Kasraee[1]

[1] Management Department, CT.C., Islamic Azad University, Tehran, Iran

*** Corresponding author email address**: h_mehrmanesh@iau.ac.ir

A r t i c l e   I n f o

Article type:
Original Research

How to cite this article:
Rafati, A., Mehrmanesh, H., & Kasraee, A. (2025). Application of Sandelowski and Barroso Technique in Identifying the Components of the Reliability Model of Green Value Chain Management in Manufacturing Industries. *Journal of Resource Management and Decision Engineering, 4*(3), 1-14.
https://doi.org/10.61838/kman.jrmde.134

A B S T R A C T

The aim of this research is to apply the Sandelowski and Barroso technique in identifying the components of the reliability model of green value chain management in manufacturing industries. The researcher employed a systematic review and meta-synthesis approach to analyze the results and findings of previous scholars. By implementing the seven steps of Sandelowski and Barroso's method, the study identified influencing factors. Out of 282 articles, 36 were selected based on the CASP method. The validity of the analysis was confirmed with a Kappa coefficient of 0.747. To measure reliability and ensure quality control, the transcription method was used, which indicated an excellent level of agreement for the identified indicators. Data analysis was conducted using MAXQDA software, leading to the identification of 40 primary concepts based on 40 indicators grouped into 10 categories. Based on the meta-synthesis technique, 10 dimensions were categorized from these concepts. In addition, 10 concepts and 40 indicators were identified. The 10 dimensions are: environmental sustainability, operational efficiency, social and ethical responsibility, green innovation management, traceability and transparency, environmental risk management, awareness-raising and education, policymaking and regulatory compliance, utilization of advanced technologies, and economic viability of green activities. These models must be designed in such a way that they simultaneously address environmental, social, and economic needs. By focusing on these dimensions, manufacturing industries can not only enhance the reliability of their value chain but also contribute to achieving sustainable development goals through the creation of sustainable value. Thus, the use of these models can play a key role in increasing the resilience of manufacturing industries against environmental and economic challenges.

Keywords: *Reliability, Value Chain Management, Green Supply Chain, Manufacturing Industries.*

1. Introduction

In recent decades, global industries have been under increasing pressure to integrate sustainability principles into their operations and supply chain systems. Environmental degradation, resource scarcity, and evolving social expectations have reshaped the way firms approach production, logistics, and value creation. One of the emerging paradigms in this context is green value chain management, which seeks to balance operational efficiency with ecological and social responsibility. The complexities of integrating environmental objectives with supply chain reliability are further intensified by economic uncertainties, technological disruptions, and changing regulatory frameworks (Yu et al., 2024). As such, the need to design and assess models that enhance the reliability of green supply chains in manufacturing industries has become a critical field of inquiry (Ningrum et al., 2024).

The development of closed-loop supply chains (CLSCs) has played a central role in this transformation. CLSCs focus not only on forward flows of goods but also on the return, recycling, and remanufacturing of products, thereby contributing to sustainability and resilience (Kazancoglu et al., 2022). However, managing these systems under uncertainty—such as demand fluctuations, disruptions, and quality variations—requires robust optimization approaches and advanced modeling techniques (Zadeh et al., 2023). Mathematical and simulation-based models have been introduced to design multi-echelon networks capable of withstanding disruptions, especially in critical nodes such as distribution centers (Ramezani et al., 2022). These models serve as foundational tools to evaluate trade-offs between sustainability goals and operational reliability, enabling firms to mitigate risks and create added value across the supply chain.

Risk assessment is another vital component of reliable green supply chain management. By considering stochastic conditions and uncertain parameters, multi-objective frameworks allow researchers and practitioners to optimize cost, service level, and environmental performance simultaneously (Jafari Eskandari & Emami Salout, 2022). Approaches such as Conditional Value-at-Risk (CVaR) have been applied to capture the financial and operational consequences of risk, providing decision-makers with quantifiable measures to enhance supply chain resilience (Saadi et al., 2022). The integration of risk evaluation models has become particularly significant in the face of recent global crises, which exposed vulnerabilities in conventional supply chains and highlighted the necessity for more agile, sustainable, and adaptive systems (Rachid et al., 2024).

Technological advancements have emerged as powerful enablers in reinforcing supply chain sustainability and reliability. The application of Industry 4.0 technologies, including blockchain, artificial intelligence (AI), and the Internet of Things (IoT), has created unprecedented opportunities for real-time monitoring, transparency, and predictive analytics (Almeida et al., 2022). These tools help organizations reduce inefficiencies, optimize energy consumption, and improve coordination across diverse stakeholders (Liao et al., 2024). For instance, blockchain has been employed to enhance traceability and trust in supply chain operations, mitigating risks of fraud and ensuring compliance with environmental standards (Dang et al., 2022). Similarly, AI-based models have been applied to evaluate risks in supply chain finance, particularly for small and medium-sized enterprises (SMEs) that face significant challenges in accessing capital (Piao & Xiao, 2023). This integration of finance and digital technology represents a critical pathway for supporting sustainable supply chain development, especially in emerging economies (Judijanto et al., 2024).

Green supply chain practices also depend on managerial and strategic alignment with corporate sustainability goals. Organizations increasingly adopt sustainable development strategies to enhance firm performance within the digital transformation era (Nayal et al., 2022). Such strategies not only reinforce environmental accountability but also strengthen competitiveness by reducing costs and improving stakeholder trust (Yu et al., 2024). Research has demonstrated that companies embracing big data analytics and AI for green supply chain management are more likely to achieve long-term sustainable performance, even in resource-constrained contexts (Rashid et al., 2024). The adoption of smart green supply chain management, supported by digital transformation, has shown configurational effects that enable firms to balance multiple objectives and create synergistic outcomes (Lerman et al., 2022).

The dynamic nature of consumer markets and globalization has further complicated the implementation of green supply chain models. For instance, closed-loop designs must account for competition between manufacturers and retailers in collecting returned products, while ensuring that processes remain environmentally friendly and efficient (Shahriari & Gholami, 2022). The introduction of multi-objective sustainable closed-loop designs considering multiple products and varying quality levels has been another advancement that aligns ecological concerns with economic viability (Soon et al., 2022). These efforts highlight the interplay between innovation, competition, and sustainability in supply chain management.

Resilience is another fundamental dimension of green supply chains, particularly in sectors such as construction and manufacturing where environmental and operational risks are pronounced. Studies on green building supply chains reveal how capabilities and risks interact to influence resilience, emphasizing the importance of integrating risk management frameworks into sustainability-driven networks (Jiang et al., 2024). In this regard, new models for resilient-sustainable closed-loop supply chains provide actionable insights for policymakers and practitioners aiming to safeguard supply chain continuity under uncertainty (Ramezani et al., 2022). Such frameworks address not only technical and operational resilience but also broader socio-economic implications, such as ensuring fair labor conditions and community engagement (Seyed Nejad Fahim, 2024).

In parallel, environmental imperatives such as carbon reduction have directed significant attention toward green supply chain design. Automotive industries, among others, have adopted methods to minimize carbon emissions across the supply chain, demonstrating how environmental performance can be integrated into traditional operational metrics (Zhang, 2024). Similarly, models addressing manufacturing and remanufacturing decisions under carbon emission constraints reveal how firms can achieve efficiency while reducing environmental impact (Kumar et al., 2022). Such dual objectives highlight the evolving role of supply chains as not merely logistical mechanisms but as key instruments for achieving sustainability and climate goals.

The role of financial structures in supporting green supply chain initiatives has also gained traction. Supply chain finance mechanisms are increasingly being evaluated to facilitate the adoption of environmentally friendly practices, with blockchain and other digital solutions offering transparency and efficiency in transactions (Dang et al., 2022; Judijanto et al., 2024). However, SMEs often face barriers in securing financing, which underscores the need for innovative financial models that address risk, liquidity, and sustainability simultaneously (Piao & Xiao, 2023). Green supply chain finance thus emerges as a critical enabler for bridging the gap between sustainability objectives and financial feasibility (Hu & Tresirichod, 2024).

Furthermore, cultural and organizational shifts are required for the effective integration of sustainability in supply chains. Studies demonstrate that adopting a green entrepreneurial orientation can positively influence sustainable performance, particularly when mediated by green intellectual capital and supply chain management practices (Hu & Tresirichod, 2024). Organizational learning, employee training, and stakeholder engagement all play vital roles in embedding sustainability principles into business culture (Ningrum et al., 2024). These elements foster long-term commitment and innovation, ensuring that green practices are not only implemented but also sustained over time.

In addition to operational and environmental objectives, policy frameworks and regulatory compliance shape the adoption of green supply chain models. Governments and international organizations increasingly enforce stricter environmental standards, compelling industries to align with sustainability objectives (Yu et al., 2024). This institutional pressure, combined with incentive-based policies, accelerates the adoption of green technologies and practices (Rachid et al., 2024). At the same time, firms must develop internal policies and governance mechanisms that integrate environmental responsibility with strategic decision-making (Seyed Nejad Fahim, 2024).

Despite the advancements in theory and practice, challenges remain in fully operationalizing reliable green supply chain models. Many firms struggle with the trade-offs between economic viability and environmental performance (Almeida et al., 2022). Others face barriers related to technological adoption, lack of financial resources, or insufficient stakeholder cooperation (Bagheri & Javadian, 2022). These issues underscore the importance of integrated frameworks that combine optimization models, risk assessment tools, financial mechanisms, and cultural enablers. Only through such holistic approaches can industries achieve the dual objectives of reliability and sustainability in their supply chains.

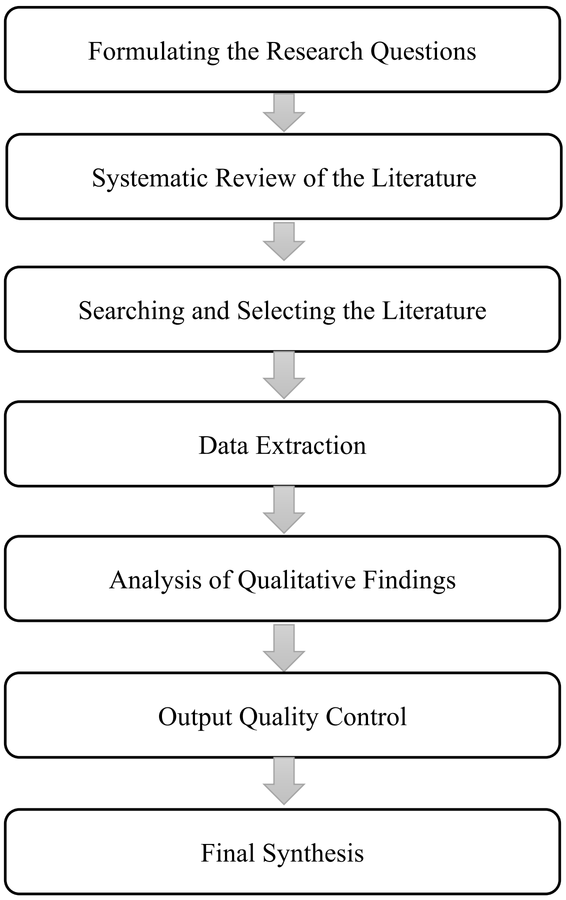
In summary, the literature demonstrates that the reliability of green supply chain management in manufacturing industries is contingent upon a complex interplay of risk management, technological innovation, financial mechanisms, policy frameworks, and organizational culture. Models based on closed-loop designs, digital transformation, and sustainability strategies provide promising pathways for achieving resilience and environmental performance (Soon et al., 2022; Zadeh et al., 2023). At the same time, incorporating cultural, financial, and regulatory perspectives ensures that these models address the diverse challenges faced by modern industries (Hu & Tresirichod, 2024; Rashid et al., 2024; Seyed Nejad Fahim, 2024). The ongoing evolution of global markets, environmental challenges, and technological opportunities underscores the urgency for further research and innovation in this domain (Liao et al., 2024; Zhang, 2024). Therefore, this study aims to to apply the Sandelowski and Barroso technique in identifying the components of the reliability model of green value chain management in manufacturing industries.

2. Methods and Materials

The present research, in seeking to identify the components of the reliability model of green value chain management in manufacturing industries based on a meta-synthesis approach, is a qualitative study conducted through a library-based research method using the meta-synthesis technique in the field of business agility. Meta-synthesis is one of the subcategories of meta-study, which, through the systematic review of sources, is used to extract, evaluate, synthesize, and, when necessary, statistically summarize research that has previously been conducted on a particular subject area. In fact, meta-synthesis involves examining and analyzing the information and findings extracted from other related and similar studies. In this regard, the data collected from these studies are qualitative rather than quantitative. Therefore, the sample for meta-synthesis is selected based on its relevance to the research question. Meta-synthesis is not merely an integrated review of qualitative principles or the analysis of secondary and primary data from selected studies, but rather the analysis of the findings of these studies. In other words, meta-synthesis is the synthesis of the interpretations of primary data from selected studies. For the analysis, MAXQDA software was used. The main stages of meta-synthesis according to Sandelowski and Barroso are as follows:

Figure 1

Meta-synthesis process



3. Findings and Results

As mentioned, meta-synthesis analysis consists of seven steps. In this section, the results corresponding to each step of this analysis are presented separately.

Step 1: Formulating the Fundamental Research Questions

The first step in the Sandelowski and Barroso method is to formulate the research questions. These questions are generally structured based on four parameters: what, who, when, and how. Once the research questions are formulated according to the purpose of the study, the process of systematically reviewing the literature begins. Table 1 presents the answers to these fundamental questions regarding the meta-synthesis method:

Table 1

Research Questions

Parameter	Research Question
What	Identification of the components of the reliability model of green value chain management in manufacturing industries
Who	Various works including books, articles, and reports related to the components of the reliability model of green value chain management in manufacturing industries
When	Encompassing all works published between 2000 and 2025
How	Thematic review, identification and note-taking, key points, concept analysis

Table 2

Introduction of Appropriate Keywords for Step Two of the Meta-synthesis Method

Persian Equivalent of Key Concepts	English Keywords Used for Search
مدیریت زنجیره ارزش سبز صنایع تولیدی	Green value chain management of manufacturing industries
قابلیت اطمینان مدیریت زنجیره ارزش سبز	Reliability of green value chain management
قابلیت اطمینان مدیریت زنجیره ارزش سبز صنایع تولیدی	Reliability of green value chain management of manufacturing industries

Step 2: Systematic Review of the Literature

To collect the research data, secondary data in the form of past documents and records were used. As previously mentioned, the targeted research databases included two major platforms, Scopus and Web of Science. In addition, regarding Persian-language articles, the Iranian Scientific Information Database (SID) and Magiran were also considered.

Table 3

Frequency of Studies Found in Each Database

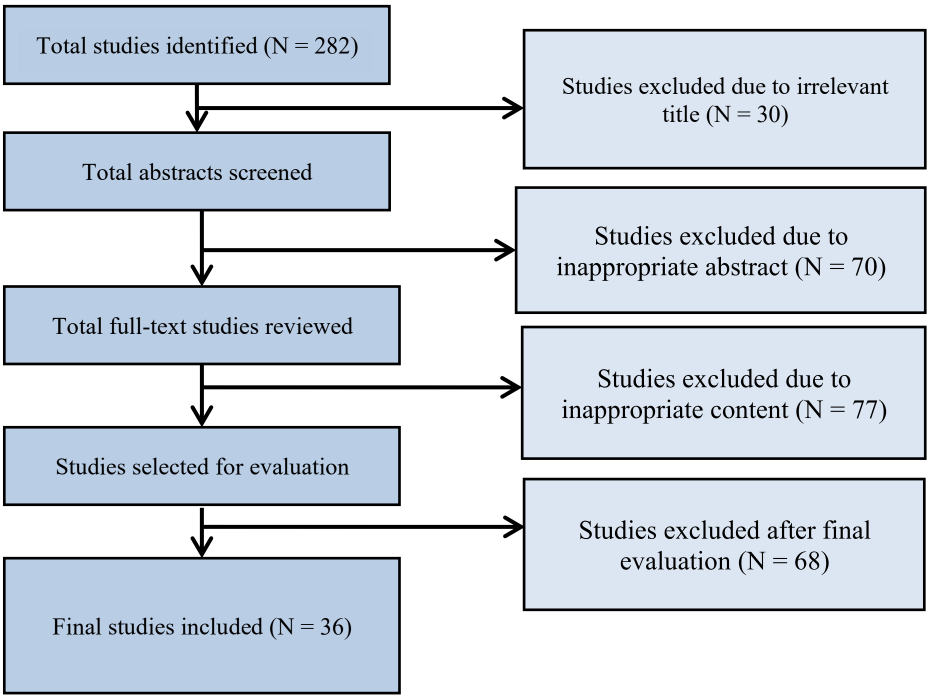
Database	Number of Studies Found
Scopus	47
ScienceDirect	106
ProQuest	60
Magiran	38
SID (Scientific Information Database)	31
Total	282

Step 3: Searching and Selecting the Literature

Table 3 illustrates the steps taken to refine the extracted articles. Based on this table, four stages were carried out to refine the articles obtained from the literature, with the final stage relying on the opinions of five expert reviewers in this study. These experts assessed the final quality of the articles based on the evaluation approach introduced below. Articles that received a score lower than the defined threshold were eliminated from the process.

Figure 2

Review and Selection Process



Accordingly, 282 articles were evaluated and assessed based on ten criteria, and the results of structural and content analysis confirmed 36 articles. Ultimately, after four filtering stages, out of 282 studies, 240 were excluded, and 42 studies were selected for data analysis. After removing studies inconsistent with the research objectives and questions, the researcher had to evaluate the methodological quality of the studies. The purpose of this step was to exclude research in which the researcher could not trust the presented findings. The tool commonly used for assessing the quality of primary qualitative research is the "Critical Appraisal Skills Programme (CASP)," which, through ten guiding questions, helps determine the accuracy, validity, and significance of qualitative studies. These questions focus on the following aspects:

1. Research objectives
2. Rationale for the methodology
3. Research design
4. Sampling method
5. Data collection
6. Reflexivity (referring to the relationship between the researcher and the participants)
7. Ethical considerations
8. Accuracy of data analysis
9. Clear and explicit reporting of findings
10. Value of the research

Table 4

Selected Articles

Article Code	Title	CASP
C01	A Green Dual-Channel Closed-Loop Supply Chain Network Design Model	38
C02	Optimization of Green Closed-Loop Supply Chain with Emphasis on Remanufacturing Policies and Energy Management under Uncertainty	39
C03	Remanufactured products in closed-loop supply chains for consumer goods	37
C04	A systematic literature review of reverse logistics of end-of-life vehicles: bibliometric analysis and research trend	40
C05	How to assess investments in Industry 4.0 technologies? A multiple-criteria framework for economic, financial, and sociotechnical factors	39
C06	A Model for Multi-level Closed-Loop Supply Chain Network Optimization	44

C07	A systematic review of sustainable supply chain management in global supply chains	30
C08	Data-driven secure, resilient and sustainable supply chains: gaps, opportunities, and a new generalised data sharing and data monetisation framework	32
C09	A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective	32
C10	Green closed-loop supply chain network design considering cost control and CO2 emission	37
C11	Lean, green practices and process innovation: A model for green supply chain performance	39
C12	Bi-objective design of fresh food supply chain networks with reusable and disposable packaging containers	33
C13	A Two-Stage Stochastic Model for Multi-Product Periodic Green Closed-Loop Supply Chain Network Design and Analysis of Interactive Objective Functions	32
C14	Green Closed-Loop Supply Chain Design for Olive Production under Risk Conditions	39
C15	Integrated Operational Model of Green Closed-Loop Supply Chain	38
C16	Viable supply chain model: Integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic	39
C17	Analyzing the Effectiveness of Finance in Supply Chain in Solving the Financing Difficulties of SMEs Based on Grey Theory Model	37
C18	Green and sustainable closed-loop supply chain network design under uncertainty	41
C19	Optimal strategy of social responsibility and quality effort in service supply chain with quality preference	40
C20	Designing a multi-echelon closed-loop supply chain with disruption in the distribution centers under uncertainty	29
C21	Carbon footprint adaptation on green supply chain and logistics of papaya in Yasothon Province using geographic information system	37
C22	Manufacturing/remanufacturing based supply chain management under advertisements and carbon emissions Process	39
C23	Multi-Objective Optimization Model for Risk Assessment in Sustainable Closed-Loop Supply Chain under Parameter Uncertainty: Using Conditional Value-at-Risk (CVaR) Approach	45
C24	Evaluating and forecasting the risks of small to medium-sized enterprises in the supply chain finance market using blockchain technology and deep learning model	39
C25	Multi-Objective Sustainable Closed-Loop Supply Chain Network Design Considering Multiple Products with Different Quality Levels	39
C26	Supply chain and logistics issues of bio-energy production	34
C27	Green supply chain management in Chinese firms: innovative measures and the moderating role of quick response technology	39
C28	Competition in the Collection of Returned Products between Manufacturer and Retailer under Greening and Product Quality Improvement in Closed-Loop Supply Chain	41
C29	Smart green supply chain management: a configurational approach to enhance green performance through digital transformation	42
C30	A New Model for Designing an Antifragile-Sustainable Closed-Loop Supply Chain Network	39
C31	Blockchain technology in supply chain operations: Applications, challenges and research opportunities	43
C32	Adoption of blockchain in supply chain: An analysis of influencing factors	42
C33	Optimization decision of cooperative emission reduction of clothing supply chain based on the carbon tax	39
C34	Mathematical Model Design for Multi-Objective Closed-Loop Supply Chain with Supplier Selection and Discount Consideration	36
C35	A multi-criteria optimization approach to manage environmental issues in closed-loop supply chain network design	38
C36	Impact of Industry 4.0 on supply chain performance	37

Step Four: Data Extraction

This step involves reviewing the remaining articles and extracting texts for coding in the subsequent stage. This step is focused on distinguishing the results, outputs, and interpretations of these outputs, along with the final discussions and conclusions of the researchers.

In this stage, 36 articles were imported into MAXQDA software. For preliminary examination, selective and dispersed portions of the articles were reviewed, and random and scattered codings were conducted in order to familiarize the researcher with the existing data. In this way, the researcher became acquainted with the general framework of the discussion and the dominant context surrounding it.

Step Five: Analysis of Qualitative Findings

During the analysis, the researcher searches for themes that have emerged among the existing studies included in the meta-synthesis. This process is known as thematic analysis. Once the themes are identified and clarified, the reviewer forms classifications and places similar and related classifications within a theme that best describes them. The themes provide the foundation for generating explanations, patterns, and theories or hypotheses. In this research, all the extracted factors from the studies were first considered as codes, and then, by taking into account the meaning of each, the codes were defined within similar concepts. Subsequently, the similar concepts were grouped into explanatory categories so that, in this way, the explanatory dimensions of the research indicators could be identified in the form of the primary and secondary components of the study. In Table 5, under the "Source" column, each article is identified with the letter C and its article number.

Table 5

Main Categories and Corresponding Codes

Dimension	Component	Indicator	Source
Environmental Sustainability	Resource Consumption Management	Reducing energy, water, and raw material consumption	C1-C2-C5-C7
	Pollution Reduction	Managing greenhouse gas emissions, reducing waste and industrial effluents	C3-C8-C18
	Recycling and Reuse	Utilizing recycled materials in production processes	C20-C21-C3
	Green Product Design	Using eco-friendly materials and designing recyclable products	C2-C27-C28-C31
	Biodiversity Protection	Considering the effects of production on local ecosystems	C1-C4-C7-C27
Operational Efficiency	Green Quality Control	Reducing production errors and defective products	C5-C9-C10-C21
	Green Inventory Management	Optimizing the supply chain to reduce storage and transportation costs	C7-C9-C11-C18-C19-C27
	Logistics Optimization	Employing low-carbon transportation methods and reducing transportation costs	C1-C19-C23-C25-C26-C28-C29-C30
	Energy Efficiency in Production	Reducing energy consumption in production processes	C6-C7-C19-C36
Social and Ethical Responsibility	Commitment to Social Issues	Addressing community needs and increasing environmental awareness	C1-C2-C8-C27-C28
	Workers' Rights	Safe, fair working conditions, and compliance with human rights standards	C1-C2-C3-C7-C15-C19-C21-C29
	Information Transparency	Providing accurate information on environmental activities to stakeholders	C5-C27-C28
	Ethics in the Supply Chain	Ensuring ethical principles are respected throughout the supply chain	C13-C16-C19-C27-C31
Green Innovation Management	Green Research and Development	Investing in green and environmentally friendly technologies	C27-C28-C33
	Process Innovation	Designing more efficient and environmentally less costly production processes	C17-C19-C20-C34
	Product Innovation	Developing green and energy-efficient products	C11-C19
	Logistics Innovation	Designing innovative green transportation methods	C20-C21-C27-C28-C29-C30-C31-C32
Traceability and Transparency	Information Systems	Using information management systems to trace materials and products	C12-C18-C23-C26
	Supply Chain Transparency	Providing clear information to consumers and shareholders	C1-C27-C28
	Data Integration	Coordinating and integrating information across the entire value chain	C1-C2-C3-C7-C9-C27-C28-C30-C32-C35
Environmental Risk Management	Risk Prediction	Identifying risks related to climate change and environmental issues	C27-C28-C34
	Crisis Response Programs	Developing contingency plans to address environmental crises	C27-C28-C35
	Supplier Risk Management	Evaluating and monitoring the environmental performance of suppliers	C13-C14-C17
	Reducing Dependency on Non-Renewable Resources	Diversifying input resources	C20-C25-C27-C28-C29-C31-C33
Awareness and Education	Employee Training	Training employees in green production methods	C1-C2-C3-C7-C9-C27-C28-C30-C32-C35
	Green Organizational Culture	Promoting a green culture within the organization	C20-C21-C27-C28-C29-C30-C31-C32
	Public Participation	Involving stakeholders in environmental decision-making processes	C12-C18-C23-C26

	Encouraging Green Behavior	Providing incentives and rewards for green performance by employees and partners	C1-C2-C4-C5-C7-C27
Policy-Making and Legal Compliance	Compliance with Regulations	Adhering to national and international environmental laws	C1-C3-C8-C19-C20-C27-C28
	Internal Green Policies	Developing internal policies for sustainability management	C17-C8-C27
	Engagement with Regulatory Bodies	Cooperating with government and environmental organizations	C12-C17-C19-C20-C21-C22-C27-C28-C33-C32
	Incentive Policies	Providing financial incentives to consumers and partners for green activities	C12-C17-C19-C20-C21-C22-C27-C28
Advanced Technology Utilization	Blockchain in Supply Chain	Ensuring transparency and traceability	C12-C17-C21-C22-C27-C28
	Artificial Intelligence in Management	Data analysis for process optimization	C12-C17-C19-C20-C21-C22-C27-C28-C33-C36
	Internet of Things (IoT)	Monitoring energy consumption and tracing raw materials	C25-C27
	Cloud Systems	Managing information and sharing data across the value chain	C30-C33-C27-C28
Economic Feasibility of Green Activities	Economic Value of Green Products	Providing high-quality, high value-added products	C27-C28
	Cost Reduction	Reducing production and logistics costs through green methods	C11-C15-C16-C18-C27-C28-C30
	Return on Investment in Green Innovation	Analyzing the profitability of green projects	C12-C17-C19-C20-C21-C22-C27-C28-C33-C32
	Resource Productivity Improvement	Optimizing the use of resources to reduce waste	C27-C28

Step Six: Output Quality Control

In this research, to ensure the validity of the extracted concepts from the reviewed studies, the researchers compared their interpretations with those of another expert. For this purpose, a 40-item questionnaire consisting of the identified indicators was designed. The data obtained were then analyzed using SPSS software version 23 and the replication index. The results of the calculations, presented below, show that the obtained Kappa index was 0.82, which indicates a reliable level of agreement.

Table 6

Agreement Measurement Values

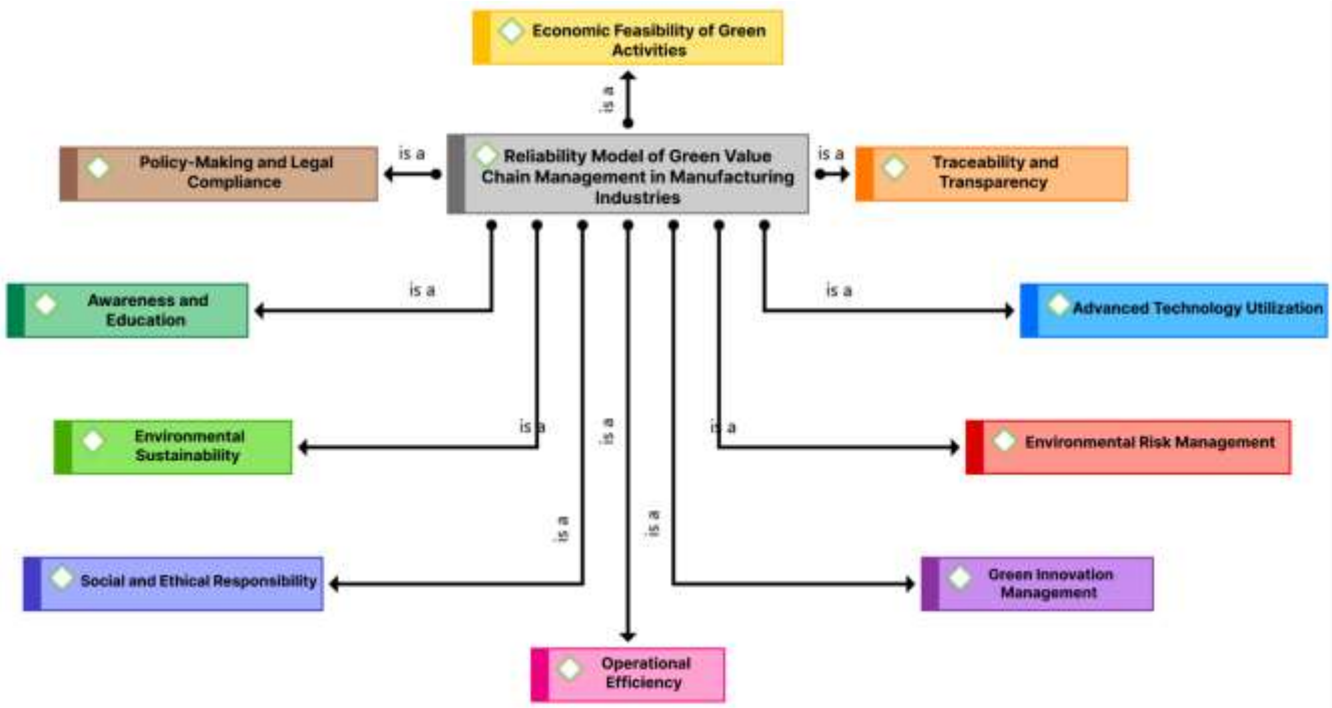
Measure	Value	Significance Level
Kappa Agreement Index	0.82	0.001
Number of Cases	40	

Step Seven: Final Synthesis

In this stage of the meta-synthesis method, the findings from the previous steps are presented. Next, the research indicators are identified. From the extracted indicators in the related articles, after eliminating synonymous and repetitive indicators, and finally by categorizing the final indicators, 40 categories and 10 dimensions were obtained. In this stage of coding, the main and sub-categories of the research were specified.

Figure 3

Factors Affecting the Reliability Model of Green Value Chain Management in Manufacturing Industries



4. Discussion and Conclusion

The findings of this study highlight that the reliability of green value chain management in manufacturing industries is grounded in ten interrelated dimensions: environmental sustainability, operational efficiency, social and ethical responsibility, green innovation management, traceability and transparency, environmental risk management, awareness and education, policy-making and compliance, advanced technology utilization, and the economic feasibility of green practices. These results confirm that supply chain reliability cannot be separated from ecological imperatives and stakeholder expectations, and must be supported by a systemic combination of managerial, financial, and technological mechanisms.

The analysis first showed that environmental sustainability plays a foundational role in ensuring reliability. Indicators such as reduced resource consumption, pollution control, recycling, green product design, and biodiversity protection were central in the findings. Previous studies support this conclusion, noting that the incorporation of sustainable practices into supply chains contributes to both resilience and competitiveness (Zhang, 2024). For example, in the automotive industry, methods for carbon reduction through green supply chain management have been demonstrated to lower emissions while enhancing operational continuity (Zhang, 2024). Similarly, closed-loop models that emphasize recycling and reuse have been shown to strengthen sustainability outcomes (Kazancoglu et al., 2022). These findings align with our results by confirming that supply chain models grounded in ecological responsibility simultaneously improve environmental and operational performance.

Operational efficiency emerged as another critical determinant of reliability. The study revealed that green quality control, inventory optimization, low-carbon logistics, and energy efficiency in production are essential components for achieving robust value chains. Prior research shows similar patterns. Studies demonstrate that optimization in closed-loop networks under uncertainty can significantly reduce inefficiencies and maintain service reliability even when disruptions occur (Zadeh et al., 2023). Multi-objective sustainable designs also confirm the value of logistics optimization, showing that green distribution methods can reduce both cost and environmental burden (Soon et al., 2022). At the same time, models focusing on energy consumption in production reveal that efficiency directly strengthens competitiveness while reducing dependency on nonrenewable resources (Ramezani et al., 2022). These converging insights emphasize that operational efficiency, when pursued within a green framework, not only supports cost control but also underpins long-term supply chain resilience.

The results also underscore the importance of social and ethical responsibility. Commitment to social needs, worker rights, information transparency, and ethical supply chain governance were repeatedly identified as reliability-enhancing factors. This finding resonates with studies emphasizing that sustainable development strategies must be holistic, encompassing not only ecological concerns but also social well-being (Nayal et al., 2022). Prior research has shown that firms adopting fair labor practices, transparent communication, and community engagement are more likely to build trust with stakeholders, which in turn enhances the perceived reliability of their supply chains (Seyed Nejad Fahim, 2024). Furthermore, ethical supply chain practices have been recognized as crucial for long-term risk mitigation, as they prevent reputational damage and strengthen institutional legitimacy (Rachid et al., 2024). The results of this study therefore validate the broader body of research that positions social and ethical responsibility as inseparable from sustainable supply chain reliability.

Another key dimension emerging from this study is the role of green innovation. The analysis revealed that green research and development, process and product innovation, and innovative logistics systems are fundamental to building reliable supply chains. These findings align with existing literature that highlights the importance of innovation in promoting sustainability. For example, investing in green R&D has been shown to increase competitiveness and adaptability in volatile environments (Hu & Tresirichod, 2024). Similarly, innovation in production processes has been found to reduce both costs and environmental impacts (Kumar et al., 2022). Our findings are also consistent with those showing that logistics innovation, such as green transportation systems, supports the creation of resilient and sustainable closed-loop networks (Shahriari & Gholami, 2022). Collectively, these studies suggest that green innovation not only drives environmental performance but also enhances the ability of supply chains to respond reliably to uncertainty and change.

Traceability and transparency also emerged as decisive elements of supply chain reliability. Our findings revealed that effective information systems, transparent communication with stakeholders, and data integration across the value chain significantly contribute to reliability. These findings are corroborated by research showing that digital transformation enables organizations to build efficient and transparent supply chain systems (Liao et al., 2024). Blockchain applications, for instance, have been demonstrated to increase traceability and reduce fraud, thereby enhancing trust and reliability (Dang et al., 2022). Similarly, smart green supply chain management supported by digital transformation has been recognized as a powerful enabler of enhanced environmental and operational performance (Lerman et al., 2022). The findings therefore reinforce the growing consensus that transparency and data-driven traceability are not optional but necessary for reliable and sustainable supply chains.

Environmental risk management was also identified as a core component of reliability. Specifically, risk prediction, crisis response programs, supplier risk evaluation, and the diversification of nonrenewable resource dependencies emerged as crucial mechanisms. This finding is consistent with research highlighting that resilience requires active risk anticipation and crisis preparedness (Jiang et al., 2024). Lean, agile, resilient, and green supply chain models emphasize that organizations must balance efficiency with adaptability in order to respond effectively to disruptions (Rachid et al., 2024). Moreover, multi-objective models addressing risk under parameter uncertainty confirm that integrating environmental risk management into decision-making significantly improves supply chain sustainability (Jafari Eskandari & Emami Salout, 2022). Our findings thus reinforce the importance of integrating risk management practices into green supply chain models to strengthen overall reliability.

Awareness and education were also confirmed as critical dimensions. The results showed that employee training, promoting a green organizational culture, public participation, and incentivizing green behaviors are fundamental to establishing reliable supply chains. Previous research has demonstrated that employee training in sustainable practices leads to long-term organizational learning and innovation (Ningrum et al., 2024). Promoting green culture within firms has also been linked to stronger environmental performance and improved stakeholder engagement (Hu & Tresirichod, 2024). Similarly, active involvement of stakeholders in environmental decision-making processes has been shown to foster legitimacy and accountability (Seyed Nejad Fahim, 2024). These insights confirm that awareness and education are not merely supportive practices but central pillars of supply chain reliability.

The study also identified policy-making and compliance with regulations as necessary for reliable green supply chains. Adherence to environmental laws, the formulation of internal green policies, collaboration with regulatory bodies, and incentive-based policies were found to be crucial elements. This conclusion is consistent with studies emphasizing that institutional pressure and government regulations play an instrumental role in accelerating the adoption of sustainable practices (Yu et al., 2024). Research has also shown that incentive-based policies support firms in balancing short-term costs with long-term environmental benefits (Almeida et al., 2022). Furthermore, collaboration with governmental and environmental institutions has been identified as an effective approach to aligning corporate practices with national and international sustainability goals (Seyed Nejad Fahim, 2024). These findings confirm that compliance and proactive policy engagement strengthen both the reliability and legitimacy of green supply chain management.

Advanced technology utilization was another central theme. The study revealed that blockchain, AI, IoT, and cloud systems are key enablers of reliable green supply chains. Prior research supports this finding by demonstrating that AI-based models enhance decision-making and risk prediction (Piao & Xiao, 2023). Blockchain applications, as noted earlier, provide enhanced traceability and transparency (Dang et al., 2022). IoT systems contribute to real-time monitoring of energy consumption and resource use, thereby reducing inefficiencies (Bagheri & Javadian, 2022). Cloud systems, in turn, support data integration and sharing across the value chain, strengthening coordination and responsiveness (Lerman et al., 2022). These findings are consistent with the broader literature that positions advanced technologies as critical infrastructure for reliable and sustainable supply chains (Liao et al., 2024).

Finally, the economic feasibility of green activities was confirmed as a decisive factor. The findings revealed that the economic value of green products, cost reduction, return on green investments, and improved resource productivity are crucial in sustaining reliability. These findings align with research showing that firms adopting sustainable practices can achieve cost savings and added value simultaneously (Nayal et al., 2022). For example, remanufacturing and recycling processes have been found to reduce costs while enhancing environmental outcomes (Kumar et al., 2022). Similarly, investment in green innovation has been linked to profitability and competitiveness (Hu & Tresirichod, 2024). These converging insights confirm that economic feasibility is not a barrier but an enabler of reliable green supply chain management, provided that firms adopt integrated approaches combining financial, operational, and environmental perspectives (Judijanto et al., 2024).

Overall, the results of this study demonstrate that reliable green supply chain management in manufacturing industries requires a holistic integration of ecological, technological, financial, organizational, and policy-related factors. The ten dimensions identified provide a comprehensive framework that reflects both theoretical advancements and practical necessities. By aligning these results with prior studies, it is evident that the future of supply chain reliability lies in models that simultaneously address environmental, social, and economic imperatives while leveraging technological and institutional enablers.

Despite the robustness of the findings, this study is not without limitations. First, the reliance on secondary data through meta-synthesis means that the analysis depends on the quality, scope, and methodological rigor of the reviewed studies. Although quality assessments were conducted, potential biases in the original studies may still influence the outcomes. Second, the study primarily focused on manufacturing industries, which may limit the generalizability of findings to other sectors such as services or agriculture. Third, while the analysis identified ten key dimensions, the relative importance and dynamic interactions among these dimensions were not quantitatively assessed, leaving room for future empirical validation.

Future research should focus on empirically testing the identified framework in diverse industrial and geographical contexts. Quantitative modeling could be employed to measure the relative impact of each dimension on supply chain reliability. Longitudinal studies are also needed to examine how these dimensions evolve over time under conditions of disruption or regulatory change. Additionally, cross-sectoral comparative studies could provide insights into how supply chain reliability manifests differently in sectors such as services, healthcare, or energy. Finally, integrating stakeholder perspectives—including suppliers, consumers, and regulators—would enrich the understanding of how social and cultural factors interact with technological and economic enablers.

Practitioners in manufacturing industries should adopt a holistic approach to green supply chain management by aligning environmental, technological, financial, and organizational strategies. Managers should invest in advanced technologies such as AI, blockchain, and IoT to enhance traceability, transparency, and risk management. Training and education initiatives should be prioritized to build a green culture among employees and stakeholders.

Firms should also proactively engage with regulatory bodies and adopt incentive-based policies to align corporate practices with sustainability goals. Most importantly, managers should view economic feasibility not as a barrier but as a strategic opportunity to generate value through sustainable innovation, efficiency improvements, and long-term resilience.

Authors' Contributions

Authors contributed equally to this article.

Declaration

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

Transparency Statement

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

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethics Considerations

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

References

Almeida, R. P., Ayala, N. F., Benitez, G. B., Kliemann Neto, F. J., & Frank, A. G. (2022). How to assess investments in Industry 4.0 technologies? A multiple-criteria framework for economic, financial, and sociotechnical factors. *Production Planning & Control*, 1-20. https://doi.org/10.1080/09537287.2022.2035445

Bagheri, M., & Javadian, N. (2022). *Presenting a Model for Optimizing a Multi-Echelon Closed-Loop Supply Chain Network* Iran University of Science and Technology]. Tehran.

Dang, C., Wang, F., Yang, Z., Zhang, H., & Qian, Y. (2022). Evaluating and forecasting the risks of small to medium-sized enterprises in the supply chain finance market using blockchain technology and deep learning model. *Operations Management Research*. https://doi.org/10.1007/s12063-021-00252-6

Hu, W., & Tresirichod, T. (2024). Impact of Green Entrepreneurial Orientation on Sustainable Performance: The Mediating Role of Green Intellectual Capital and Green Supply Chain Management. *Asian Administration & Management Review*, *7*(1). https://so01.tci-thaijo.org/index.php/AAMR/article/view/272653

Jafari Eskandari, M., & Emami Salout, H. (2022). A Multi-Objective Optimization Model for Risk Assessment in a Sustainable Closed-Loop Supply Chain Under Parameter Uncertainty: Using the Conditional Value at Risk (CVaR) Approach. *Industrial Management Studies*, *20*(66), 251-298. https://jims.atu.ac.ir/article_11435.html?lang=en

Jiang, Y., Zhang, Y., Yeganeh, A. J., & Zhao, D. (2024). Resilience of Green Building Supply Chain: Capabilities, Risks and Influence Mechanism. *Journal of Green Building*, *19*(3), 41-69. https://doi.org/10.3992/jgb.19.3.41

Judijanto, L., Utami, E. Y., & Harsono, I. (2024). Green Supply Chain Finance: A Bibliometric Review of Financing Instruments, Challenges, and Opportunities. *West Science Interdisciplinary Studies*, *2*(03), 647-655. https://doi.org/10.58812/wsis.v2i03.745

Kazancoglu, Y., Yuksel, D., & Sezer, M. (2022). A Green Dual-Channel Closed-Loop Supply Chain Network Design Model. *Journal of Cleaner Production*, *332*, 130062. https://doi.org/10.1016/j.jclepro.2021.130062

Kumar, S., Sigroha, M., Kumar, K., & Sarkar, B. (2022). Manufacturing/remanufacturing based supply chain management under advertisements and carbon emissions Process. *RAIRO-Operations Research*, *56*, 831-851. https://doi.org/10.1051/ro/2021189

Lerman, L. V., Benitez, G. B., Müller, J. M., de Sousa, P. R., & Frank, A. G. (2022). Smart green supply chain management: a configurational approach to enhance green performance through digital transformation. *Supply chain management*, *27*(7), 147-176. https://doi.org/10.1108/SCM-02-2022-0059

Liao, F., Hu, Y., Chen, M., & Xu, S. (2024). Digital transformation and corporate green supply chain efficiency: Evidence from China. *Economic Analysis and Policy*, *81*, 195-207. https://doi.org/10.1016/j.eap.2023.11.033

Nayal, K., Raut, R. D., Yadav, V. S., Priyadarshinee, P., & Narkhede, B. E. (2022). The impact of sustainable development strategy on sustainable supply chain firm performance in the digital transformation era. *Business Strategy and the Environment*, *31*, 845-859. https://doi.org/10.1002/bse.2921

Ningrum, E., Nugroho, A., Darmansyah, D., & Ahmar, N. (2024). A Scoping Review of Green Supply Chain and Company Performance. *International Journal of Quantitative Research and Modeling*, *5*, 26-30. https://doi.org/10.46336/ijqrm.v5i1.608

Piao, G., & Xiao, B. (2023). Analyzing the Effectiveness of Finance in Supply Chain in Solving the Financing Difficulties of SMEs Based on Grey Theory Model. *Computational Intelligence and Neuroscience*, *2022*, 7608937. https://doi.org/10.1155/2022/7608937

Rachid, B., Roland, D., Sebastien, D., & Ivana, R. (2024). Risk Management Approach for Lean, Agile, Resilient and Green Supply Chain. *World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, *11*(4), 742-750. https://publications.waset.org/10006688/risk-management-approach-for-lean-agile-resilient-and-green-supply-chain

Ramezani, M., Mahdavi, I., & Babaei, E. (2022). *A New Model for Designing a Resilient-Sustainable Closed-Loop Supply Chain Network* Mazandaran University of Science and Technology].

Rashid, A., Baloch, N., Rasheed, R., & Ngah, A. H. (2024). Big data analytics-artificial intelligence and sustainable performance through green supply chain practices in manufacturing firms of a developing country. *Journal of Science and Technology Policy Management*.

Saadi, E., Fathi Hafshejani, K., & Radfar, R. (2022). Designing a Multi-Objective Mathematical Model for a Closed-Loop Supply Chain with a Supplier Selection Approach and Consideration of Discounts. *Engineering Management and Soft Computing*, *7*(2), 73-113. https://www.magiran.com/paper/2270155/designing-a-multi-objective-closed-loop-supply-chain-mathematical-model-with-supplier-selection-approach-and-considering-discount?lang=en

Seyed Nejad Fahim, S. R. (2024). Analyzing the Role of Strategic Management Accounting in Sustainable Supply Chain Management (Case Study: Food Manufacturing Companies in Gilan Province). *Green Development Management Studies*.

Shahriari, M., & Gholami, M. (2022). Competition in Collecting Returned Products Between Manufacturer and Retailer Under Greening and Quality Improvement of Products in a Closed-Loop Supply Chain. *Production and Operations Management*, *13*(3), 137-158. https://jpom.ui.ac.ir/article_26927.html?lang=en

Soon, A., Heidari, A., Khalilzadeh, M., Antucheviciene, J., Zavadskas, E. K., & Zahedi, F. (2022). Multi-Objective Sustainable Closed-Loop Supply Chain Network Design Considering Multiple Products with Different Quality Levels. *Systems*, *10*(4), 94. https://doi.org/10.3390/systems10040094

Yu, W., Chavez, R., Feng, M., & Wiengarten, F. (2024). Integrated green supply chain management and operational performance. *Supply Chain Management: An International Journal*, *19*(5/6), 683-696.

Zadeh, K., Harsej, F., Sadeghpour, M., & Molani Aghdam, M. (2023). Designing a multi-echelon closed-loop supply chain with disruption in the distribution centers under uncertainty. *Journal of Industrial and Management Optimization*, *19*(4), 2582-2615. https://doi.org/10.3934/jimo.2022057

Zhang, R. (2024). Methods for Carbon Reduction Through Green Supply Chain Management in the Automotive Industry. *Frontiers in Business Economics and Management*, *17*(3), 301-303. https://doi.org/10.54097/s5vaf884