Pacific International Journal, Vol. 7(4); 2024
ISSN (Print) 2663-8991, ISSN (Online) 2616-4825[1]
DOI: 10.55014/pij.v7i4.649
https://rclss.com/index.php/pij

Mediating Effect of Sustainability to Supply Chain Resilience and Performance Among Construction Companies in Beijing, China

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Abstract: This study investigates the integration of sustainable supply chain management (SSCM) principles and supply chain resilience (SCR) strategies in the context of the construction industry in Beijing. Sustainable practices in supply chains are increasingly recognized as critical for enhancing resilience against disruptions and improving overall performance. The research synthesizes existing literature on SSCM and SCR, highlighting theoretical foundations, empirical evidence, and frameworks. Key findings underscore the interplay between sustainability initiatives, such as resource management and environmental stewardship, and resilience factors like flexibility and redundancy. Case studies from Beijing illustrate practical applications, demonstrating how sustainable practices mitigate risks and enhance adaptability in construction supply chains. The study concludes with recommendations for future research directions and practical implications for industry stakeholders aiming to foster resilient and sustainable supply chain practices.
Keywords: Sustainable supply chain management, supply chain resilience, construction industry, environmental sustainability, resource management

Introduction

1.1Background of the Study

In the dynamic and rapidly evolving landscape of the construction industry in Beijing, China, the integration of sustainability practices has emerged as a critical determinant of organizational resilience and performance. With increasing global awareness of environmental impact and social responsibility, construction companies face mounting pressure to adopt sustainable supply chain practices while maintaining operational efficiency and competitive advantage. Understanding how sustainability mediates the relationship between supply chain resilience and performance is paramount to navigating these challenges effectively.

1.2 Problem Statement

Despite growing recognition of the importance of sustainability, there remains a gap in understanding its precise role as a mediator between supply chain resilience and performance within the context of construction companies in Beijing. While resilience is crucial for adapting to disruptions, sustainability initiatives encompassing environmental, social, and economic dimensions are believed to enhance resilience and overall performance. This study seeks to empirically explore and validate these relationships to provide actionable insights for industry stakeholders.

1.3 Objectives of the Study

The primary objective of this study is to investigate the mediating role of sustainability in the impact of supply chain resilience on the performance of construction companies in Beijing, China. Specifically, the study aims to:

- Analyze the Demographic Profile of Construction Companies: To examine the distribution of construction companies in terms of their form of organization, number of employees, and years of operation.
- Evaluate the Level of Supply Chain Performance: To assess the current state of supply chain performance among construction companies.
- Assess the Supply Chain Resilience: To determine the resilience of construction companies' supply chains in terms of their ability to handle disruptions, maintain optimal inventory, engage in open dialogue with suppliers, and adopt advanced technologies.
- Examine the Sustainability Levels: To evaluate the social, environmental, and economic sustainability practices of construction companies.
- Investigate the Mediating Role of Supply Chain Sustainability: To explore the mediating effect of supply chain sustainability on the relationship between supply chain resilience and performance.

1.4 Significance of the Study

This research holds significant implications for both theory and practice in supply chain management and sustainable

[Received 11 May 2024; Accepted 10 August 2024; Published (online) 20, August, 2024]

development. By elucidating the complex interplay between resilience, sustainability, and performance, the study contributes empirical evidence to enhance strategic decision-making in construction supply chain management. Insights gained will inform policy development, guide corporate sustainability initiatives, and foster resilience-building strategies tailored to the unique challenges of Beijing's construction industry.

1.5 Scope and Limitations

This study focuses exclusively on construction companies operating within Beijing, China, thereby providing insights specific to the region's socio-economic and environmental context. Limitations include potential sample bias, data availability constraints, and the generalizability of findings beyond the study area. Despite these limitations, the study offers valuable insights into the transformative potential of sustainability practices in enhancing supply chain resilience and performance within the construction sector.

II. Literature Review

2.1. Introduction to Sustainable Supply Chain Management

Sustainable Supply Chain Management (SSCM) is a comprehensive approach that integrates sustainability principles into supply chain practices. This concept emphasizes environmental, social, and economic aspects, aiming for a balance that promotes long-term viability [1]. The evolution of SSCM has been significantly influenced by global initiatives such as the United Nations Sustainable Development Goals (SDGs), which provide a framework for sustainable practices across various sectors [2].

2.2. Key Concepts and Theoretical Foundations

Supply Chain Resilience

Supply chain resilience refers to the ability of a supply chain to anticipate, prepare for, respond to, and recover from disruptions [3]. This concept is crucial for maintaining supply chain performance under adverse conditions. Studies have identified various factors influencing resilience, such as flexibility, redundancy, and collaboration. Furthermore, resilience is seen as a mediator between sustainability practices and overall supply chain performance.[4]

Sustainability in Supply Chain Management

Sustainability in supply chain management involves incorporating environmental and social considerations into traditional supply chain activities [5]. The integration of sustainability can enhance supply chain resilience by promoting practices that are adaptable to changing conditions and reducing dependencies on non-renewable resources[6].

2.3. Empirical Evidence and Case Studies

Sustainability Practices in the Construction Industry

The construction industry faces unique challenges related to sustainability, including resource management, waste reduction, and environmental impact (Ma & Lin, 2016). Case studies from Beijing highlight the importance of integrating sustainability into supply chain practices to enhance resilience against delays and disruptions[7]. These studies demonstrate that sustainable practices can improve project outcomes and stakeholder satisfaction.

Impact of COVID-19 on Supply Chain Resilience

The COVID-19 pandemic has underscored the importance of supply chain resilience. Research indicates that industries with robust sustainability practices were better positioned to manage the disruptions caused by the pandemic[8]. This period provided valuable insights into the interplay between resilience and sustainability, suggesting that integrated approaches can mitigate the impacts of global crises.

2.4. Frameworks and Models

Conceptual Frameworks

Several conceptual frameworks have been proposed to understand and enhance supply chain resilience and sustainability. For instance, Ali et al.[9] present a concept mapping framework that integrates resilience constructs, providing a holistic view of supply chain dynamics. Similarly, Linton et al. [10]discuss sustainable supply chains by highlighting the importance of balancing economic, environmental, and social goals.

Quantitative Models

Quantitative methods have been developed to analyze and improve supply chain resilience. Hosseini et al. [11] review various quantitative approaches, emphasizing their role in identifying vulnerabilities and optimizing resilience strategies. These models are essential for making informed decisions that enhance supply chain sustainability and performance.

III. Research Methodology

3.1 Research Design

The study employed a descriptive-correlational research design to investigate the relationships between supply chain resilience, sustainability, and performance among construction companies in Beijing, China. This design facilitated the analysis and interpretation of data collected through structured questionnaires, focusing on exploring how sustainability

mediates the impact of supply chain resilience on performance.

3.2 Respondents of the Study

The study targeted a population of 512 construction companies operating in Beijing, China, as identified from the Beijing Statistical Yearbook. A sample size of 220 companies was determined using Raosoft sample size calculator, with a 5% error margin and 95% confidence level. Respondents included general managers, operations managers, or project managers who provided insights into their company's supply chain dynamics and sustainability practices.

3.3 Data Gathering Instrument

The primary data collection instrument was a structured questionnaire designed to capture information on company profiles, supply chain performance indicators, supply chain resilience factors, and sustainability practices. The questionnaire underwent rigorous validation by field experts and statisticians to ensure reliability and validity of the data.

3.4 Data Gathering Procedure

Data collection was conducted electronically using the Questionnaire Star APP Platform, ensuring efficient distribution and collection of responses from selected companies. Third-party data collection agencies were engaged to enhance data comprehensiveness and accuracy. Respondents were provided with clear instructions and timelines for completing the questionnaire, and reminders were sent as necessary to improve response rates.

3.5 Statistical Treatment of Data

Quantitative data collected from the questionnaires were analyzed using various statistical tools. Frequency and percentage analyses were employed to describe demographic characteristics and survey responses. Weighted mean and standard deviation calculations were used to assess levels of supply chain performance, resilience, and sustainability. The mediating role of sustainability was examined through General Linear Model mediation analysis, while statistical significance was tested using techniques such as Kruskal-Wallis tests to explore differences in performance across categories.

IV: Results and Analysis

4.1. Profile of the Construction Company

Table 1 Distribution of Respondents in terms of form of organization

Form of Organization	Counts	% of Total
sole proprietorship	80	36.36
partnership	89	40.45
corporation	51	23.18
Total	220	100.00

Table 2 Distribution of Respondents in terms of number of employees

Number of Employees	Counts	% of Total
Less than 200 people	39	17.73
201-500 people	56	25.45
501-1000 people	44	20.00
1001-10000 people	42	19.09
10000 and above	39	17.73
Total	220	100.00

Table 3 Distribution of Respondents in terms of years of operation

Years of Operation	Counts	% of Total
5-10 years	36	16.4
11-15 years	53	24.1
16-20 years	59	26.8
21-30 years	35	15.9
30 years and above	37	16.8
Total	220	100.00

Sole proprietorships constitute a significant portion at 36.36%, partnerships at 40.45%, and corporations at 23.18%. Regarding workforce size, the majority of companies employ between 201 to 500 people (25.45%), followed closely by those with 501 to 1000 employees (20.00%). The distribution across years of operation shows a relatively balanced spread, with companies operating for 11 to 20 years comprising over 50% of the sample. These findings underscore the varied

demographics of construction firms in Beijing, influencing their supply chain dynamics, sustainability initiatives, and overall performance strategies.

4.2. Level of Supply Chain Performance of Construction Companies

Table 4 Supply Chain Performance

Items	Mean	SD	Interpretation
1. construction material deliveries in our company consistently arrive, on time.	4.95	1.59	Good
2. we adjust material stocks to meet project demand while minimizing excess inventory.	5.14	1.43	Good
3. the materials in the company are consistently available within the anticipated timeframe.	4.93	1.43	Good
4. orders are fulfilled accurately.	4.97	1.56	Good
5. the supply chain has streamlined processes in our company.	5	1.58	Good
6. the supply chain has optimal budget management across procurement, production, and distribution activities.	5.11	1.5	Good
Overall	5.01	1.22	Good

The data finds that the level of supply chain performance in construction companies is rated as good, with a mean score of 5.01 and a standard deviation of 1.22. Material stocks are adjusted efficiently to meet project demand while minimizing excess inventory has the highest mean with 5.14 and with the standard deviation of 1.43 and interpreted as good. On the other hand, the materials in the company are consistently available within the anticipated timeframe has the lowest mean of 4.93 and standard deviation of 1.43 and interpreted as good.

Table 5 Supply Chain Resilience

Items	Mean	SD	Interpretation
1. regularly checks suppliers with backup plans make our supply chain stronger.	4.63	2.01	Moderate Resilience
2.maintains optimal inventory balance for efficiency.	4.54	1.9	Moderate Resilience
3conducts open dialogue with suppliers to helps us handle procurement disruptions	4.69	1.86	Moderate Resilience
4. has different suppliers to lessens the impact of supply chain disruption.	4.39	2.06	Adequate Resilience
5. leverages advanced technology for real-time project insights.	4.6	1.99	Moderate Resilience
6.optimizes material procurement by smartly managing lead times and expediting processes.	4.62	1.89	Moderate Resilience
7.adheres to government regulations particularly on transportation of construction materials.	4.65	1.96	Moderate Resilience
8.conducts training to our team in handling supply chain problems.	4.72	1.93	Moderate Resilience

9.has insurance plan to shift risks recover more swiftly from disruptions for the continuity of construction projects.	4.56	1.95	Moderate Resilience
10.moves quickly to get things back on track.	4.61	1.95	Moderate Resilience
11.chooses suppliers based on ethical and sustainable practice	4.5	1.99	Moderate Resilience
12. records all past problems/ disruption to prevent the re-occurrence of it.	4.57	2.01	Moderate Resilience
Overall	4.59	1.51	Moderate Resilience

According to survey data, the supply chain resilience evaluation of Beijing Construction Company has an overall composite mean of 4.59 and a standard deviation of 1.51 meaning it is moderate resilience. Specifically, among the various evaluation indicators, the regular inspection score of the supplier's backup plan is 4.63, the inventory balance maintenance score is 4.54, the open dialogue score with suppliers is 4.69, the diversified supplier selection score is 4.39, the use of advanced technology for real-time project insight score is 4.60, the intelligent management of material procurement score is 4.62, the compliance with government regulations score is 4.65, the team training score is 4.72, the insurance plan score is 4.56, the ability to quickly restore the supply chain score is 4.61, and the ethical and sustainable practice score for selecting suppliers is 4.50. The score for recording past problems to prevent recurrence is 4.57.

4.3. Level of sustainability of construction companies

Table 7 Social sustainability

Items	Mean	SD	Interpretation
1. actively connect with local communities, understanding their needs and concerns to build positive relationships.	5.12	1.74	Moderately Sustainable
2. ensures ethical treatment and safe working conditions for all employees throughout the supply chain.	4.85	1.7	Moderately Sustainable
3. fosters an inclusive workforce environment that values diversity.	4.9	1.73	Moderately Sustainable
4. implements robust safety protocols and training programs to prioritize workers' health and safety.	4.82	1.81	Moderately Sustainable
5. guarantees fair wages for workers at all levels, supporting economic well-being.	4.95	1.66	Moderately Sustainable
6. lnvest in employee training and development programs for personal and professional growth.	4.9	1.8	Moderately Sustainable
7. supports local businesses and economies by sourcing materials and services locally when possible.	4.85	1.76	Moderately Sustainable
8. upholds human rights standards, ensuring no contribution to violations in company operations.	4.95	1.7	Moderately Sustainable
9. contributes to community development through social initiatives, philanthropy, and other community investments.	4.84	1.67	Moderately Sustainable
10. ensures ethical practices throughout the supply chain, endorsing responsible sourcing and production methods.	4.8	1.8	Moderately Sustainable
Overall	4.9	1.35	Moderately Sustainable

According to survey data, the evaluation of social sustainability by construction enterprises is 4.9 (standard deviation of 1.35), which belongs to a moderate level of sustainability. Specifically, among the various evaluation indicators, the score for active interaction with the local community is 5.12, the score for employee rights and safety protection is 4.85, the score for diversified and inclusive work environment is 4.9, the score for safety training and health protection is 4.82, the score for fair pay is 4.95, the score for employee training and development is 4.9, the score for localized procurement is 4.85, the score for human rights protection is 4.95, the score for social responsibility investment is 4.84, and the score for

supply chain ethical practice is 4.8.

Environmental Sustainability

Table 8 Environmental sustainability

Items	Mean	SD	Interpretation
11. prioritizes carbon footprint reduction in transportation and manufacturing.	5.21	1.77	Moderately Sustainable
12. implements energy-efficient measures for facilities, machinery, and operations to save costs and reduce environmental impact.	4.96	1.68	Moderately Sustainable
13. streamlines waste management, minimizing construction waste and maximizing recycling for improved resource efficiency.	4.81	1.8	Moderately Sustainable
14.Increases procurement of sustainable construction materials in line with corporate sustainability goals.	4.91	1.73	Moderately Sustainable
15. Introduces water conservation strategies in construction to optimize usage and contribute to environmental stewardship.	4.94	1.61	Moderately Sustainable
16. Incorporates biodiversity preservation in construction, ensuring protection of natural habitats.	4.92	1.77	Moderately Sustainable
17. enhances toxic material management for compliance and promote non-toxic alternatives.	5.01	1.77	Moderately Sustainable
18. Integrates emission control technologies in construction equipment to minimize air pollution.	4.98	1.67	Moderately Sustainable
19. conducts lifecycle assessments for projects, identifying opportunities to minimize environmental impact.	4.72	1.71	Moderately Sustainable
20. engages suppliers to adopt sustainable practices, aligning the entire supply chain with environmental responsibility.	4.8	1.78	Moderately Sustainable
Overall	4.93	1.34	Moderately Sustainable

According to survey data, the environmental sustainability evaluation of construction companies is 4.93 (standard deviation is 1.34), showing a medium level of sustainability. Specifically, among the various evaluation indicators, prioritizing carbon footprint reduction scored 5.21, implementing energy-saving measures scored 4.96, optimizing waste management scored 4.81, sourcing sustainable building materials scored 4.91, and introducing water conservation strategies scored 4.94 , with a score of 4.92 for protecting biodiversity, 5.01 for enhancing toxic substances management, 4.98 for integrating emission control technologies, 4.72 for conducting project life cycle assessments, and 4.8 for promoting suppliers to adopt sustainable practices. These data show that construction companies have achieved certain results in environmental sustainability, and various indicators show a medium level of sustainability. However, there is still room for improvement, especially in waste management and project life cycle assessment, where corporate performance is slightly insufficient. Taken together, these results provide important reference and guidance for construction companies in environmental sustainability practices.

Economic Sustainability

Table 9 Economic Sustainability

Items	Mean	SD	Interpretation

21. awards contracts to local businesses to boost the local economy.	4.78	1.85	Moderately Sustainable
22. maintains fair wages and benefits for all workers.	4.69	1.77	Moderately Sustainable
23. optimizes budget use in procurement, production, and distribution.	4.76	1.7	Moderately Sustainable
24. mitigates economic risks to ensure supply chain resilience.	4.77	1.79	Moderately Sustainable
25. reduces production costs while maintaining or improving quality.	4.83	1.69	Moderately Sustainable
26. contributes to local job creation and retention.	4.87	1.79	Moderately Sustainable
27. Invests in technology for enhanced efficiency and competitiveness.	4.79	1.73	Moderately Sustainable
28. ensures a financially healthy supply chain by monitoring key indicators.	4.88	1.72	Moderately Sustainable
29. contributes to local tax revenue for community economic development.	4.53	1.8	Moderately Sustainable
30. engages in initiatives supporting local economic growth.	4.78	1.87	Moderately Sustainable
Overall	4.77	1.37	Moderately Sustainable

According to survey data, Beijing Construction Company's evaluation of economic sustainability is 4.77 (standard deviation of 1.37), showing a moderate level of sustainability. Specifically, among the various evaluation indicators, the score for local economic support is 4.78, the score for worker compensation and benefits is 4.69, the score for budget optimization is 4.76, the score for economic risk management is 4.77, the score for production cost control is 4.83, the score for local employment support is 4.87, the score for technology investment is 4.79, the score for supply chain financial health is 4.88, the score for local tax contribution is 4.53, and the score for measures supporting local economic growth is 4.78. In terms of economic sustainability, the overall performance of construction companies in Beijing is "moderately sustainable". These data show that Beijing Construction Company has achieved certain results in economic sustainability, with various indicators showing a moderate level of sustainability. However, there is still room for improvement, especially in terms of local tax contributions and economic growth support, which are slightly inadequate.

4.4. Mediating Role of Supply Chain sustainability to the effect of supply chain resilience to supply chain performance.

Table 10 Summary of Regression Analysis Results

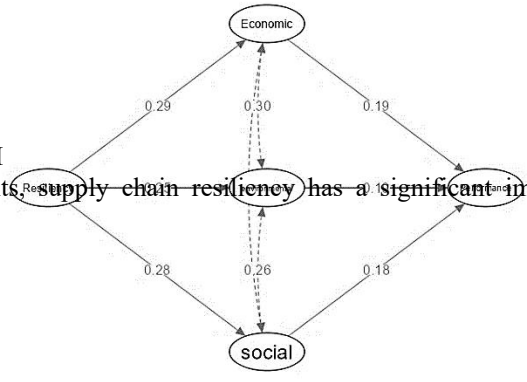
Variable	β	df	t	p	Decision to Ho	Interpretation
(Intercept)	0	218	66.44	< .001	Reject	Significant
Resiliency	0.405	218	6.53	< .001	Reject	Significant

F-value = 44.14 p-value (F) = <.001 Adjusted R2 = .160 Shapiro-Wilk = .9920 p-value (SW) = .273

According to the regression analysis results, the adjusted R ² the value is 0.16, the F-value is 44.14, and the P-value is<.001, indicating that supply chain resilience has a significant impact on supply chain performance. Specifically, the resiliency coefficient of the supply chain is 0.405, with a t-value of 6.53 and a P-value of<.001, rejecting the null hypothesis, indicating a significant positive relationship between supply chain resiliency and supply chain performance. This indicates that improving the resilience level of the supply chain in construction enterprises can effectively enhance the performance of the supply chain. The following analysis will further explore the mediating effect of sustainability on this relationship, in order to reveal the mechanism by which sustainability affects supply chain performance.

As shown in the above figure, the adjusted R^2=0.16, F=44.14, and P<.001 indicate that the resiliency of the supply chain has a significant impact on supply chain performance.

Figure 3



Structural Equation Modeling, SEM

According to the calculation results, supply chain resiliency has a significant impact on supply chain sustainability

(economic sustainability, environmental sustainability, and social sustainability), with path coefficients of 0.29, 0.25, and 0.28, respectively, indicating that improving supply chain resiliency is beneficial for supply chain sustainability. The role of supply chain sustainability (economic sustainability, environmental sustainability, and social sustainability) in the hypothetical relationship set by the model is relatively small, but it is still significant at the $p<0.05$ level, indicating a positive correlation; The sustainability of the supply chain has a significant positive impact on supply chain performance, with path coefficients of 0.19, 0.19, and 0.18, respectively.

V. Conclusion and Recommendations

Conclusion

The study on the supply chain resilience, performance, and sustainability of construction companies in Beijing reveals several critical insights. The diverse profile of these companies, varying in organizational form, size, and years of operation, underpins their supply chain dynamics and sustainability practices. Supply chain performance is generally good, but there are areas needing improvement, particularly in timely material deliveries and order accuracy. Supply chain resilience is moderate, with companies showing strengths in regular supplier checks, inventory management, and open communication but needing enhancements in supplier diversification and advanced technology usage. The sustainability assessment indicates moderate achievements in social, environmental, and economic domains. Social sustainability highlights community engagement and employee well-being, environmental sustainability emphasizes carbon footprint reduction and waste management, and economic sustainability focuses on fair wages and local economic contributions. The mediation analysis underscores the positive impact of supply chain resilience on performance through sustainability practices, advocating for integrated resilience and sustainability strategies to boost overall supply chain efficiency.

Recommendations

Enhance Material Delivery and Order Accuracy: Construction companies should focus on improving logistics and order management systems to ensure timely delivery of materials and accuracy in orders. Investing in advanced tracking and inventory management technologies can help achieve this.

- Strengthen Supplier Diversification: To bolster supply chain resilience, companies should diversify their supplier base and establish robust backup plans. This will mitigate the impact of supply chain disruptions and ensure continuity of operations.
- Leverage Advanced Technologies: Adoption of advanced technologies, such as real-time data analytics and automation, can significantly improve supply chain processes, enhance project insights, and streamline procurement and distribution activities.
- Focus on Comprehensive Sustainability Initiatives: Companies should integrate social, environmental, and economic sustainability into their core operations. This includes promoting fair labor practices, reducing environmental impact through efficient resource use, and supporting local economies.
- Continuous Improvement and Training: Implementing continuous improvement programs and regular training sessions for employees on handling supply chain challenges will enhance overall resilience and performance.
- Conduct Regular Assessments: Regular assessments and audits of supply chain practices and sustainability initiatives will help identify areas for improvement and ensure alignment with corporate sustainability goals.

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