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Key Enablers of Resilient and Sustainable Construction Supply Chains: A Systems Thinking Approach

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Abstract: In the globalized world, one significant challenge for organizations is minimizing risk by building resilient supply chains (SCs). This is important to achieve a competitive advantage in an unpredictable and ever-changing environment. However, the key enablers of such resilient and sustainable supply chain management are less explored in construction projects. Therefore, the present research aims to determine the causality among the crucial drivers of resilient and sustainable supply chain management (RSSCM) in construction projects. Based on the literature review, 12 enablers of RSSCM were shortlisted. Using the systems thinking (ST) approach, this article portrays the interrelation between the 12 shortlisted resilience enablers crucial for sustainability in construction projects. The causality and interrelationships among identified enablers in the developed causal loop diagram (CLD) show their dynamic interactions and impacts within the RSSCM system. Based on the results of this study, agility, information sharing, strategic risk planning, corporate social responsibility, and visibility are the key enablers for the RSSCM. The findings of this research will enable the construction managers to compare different SCs while understanding how supply chain characteristics increase or decrease the durability and ultimately affect the exposure to risk in the construction SCs.

Keywords: causal loop diagram; construction management; resilient supply chain; sustainable supply chain; supply chain management; systems thinking

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1. Introduction

A supply chain (SC) consists of a network of organizations involved in different processes and activities for delivering services to users. An SC produces value through upstream and downstream linkages in products and services delivered to the end-user [1]. Thus, an SC consists of several entities: upstream (supply), downstream (distribution), and the final consumer [2]. In line with the global sustainability drive, academic researchers have recently focused on designing sustainable SC (SSC) networks. Such SSCs can potentially impact the efficiency of the global SCs [3,4]. A balance between economic, social, and environmental factors has become increasingly crucial for SSCs as consumers demand sustainable products [4–7]. However, as world businesses have become intensely competitive and unpredictable, sustainability in the SC is often threatened [8]. Unforeseen circumstances frequently disrupt businesses and their SC, questioning the continuity of the SC [9,10]. Sustainability is hard to achieve when there are persistent SC disruptions. Therefore, to achieve reliable SSCs, the resilience capabilities of the organizations must be developed and improved. Thus, it is essential to investigate whether the SCs need resilience to be sustainable [11,12].

While the terms SC and sustainability have been explored by various researchers, resilient and sustainable supply chain management (RSSCM) has not been explored holistically. Resilience in supply chains is the ability to anticipate and withstand disruptions, respond to them, and effectively recover from disruptions [13]. RSSCM is defined as the management of resources toward satisfying stakeholder expectations to create high resilience and sustainability in an organization's supply chain [14]. The literature on sustainable supply chain management (SSCM) and SC resilience highlight that no systematic study has been performed to date that incorporates SC resilience and sustainability, particularly in developing countries [15]. This is in line with the general dearth of research in such countries [16,17].

Nevertheless, among the relevant studies, Pettit et al. [18] mentioned that SC resilience is a prerequisite for SC sustainability that increases system complexity. Chowdhury et al. [19] emphasized the development of the systems thinking (ST) approach to address the increasing complexity. ST is the ability to see the world as a dynamic system; everything is related to everything else, and an individual item may not be achieved in isolation [20–22]. Accordingly, RSSCM cannot be achieved independently, and a holistic assessment of the system is needed. This presents a gap in the existing literature that is targeted in the current study. The elementary idea of this research is to demonstrate the relationship between SC resilience and SC sustainability through the causal loop diagram (CLD). The developed CLD considers the RSSCM a holistic system and comprises its key enablers and linkages. Based on the above, this paper has the following objectives:

To identify the key resilience enablers for sustainable SCs.

To determine the causality among the identified key resilience enablers for sustainable SCs.

To achieve these objectives, this study uses the ST approach, a holistic method focused on the interrelationship of the constituent parts of a system and addressing the inherent complexity. ST is a conceptual problem-solving methodology that considers issues in their entirety (at the systems level). The findings of this study will help achieve a competitive advantage in an unpredictable construction environment where change is imperative. Moreover, this will lower the organizational risk by enabling real-time insights into all operations across the SC networks.

It is expected that the construction organizations would be empowered to optimize and adjust their processes and logistics and move towards an RSSCM. Further, the results of this study will help make SCs more resilient and sustainable, resulting in lower costs, enhanced manufacturing efficiency and flexibility, and consequently higher profits for construction organizations. The associated RSSCM can handle disruptive events, respond quickly, and resume normal operations after the disruption. This study is a novel attempt to determine the causality among the identified enablers of resilience in SCs using the ST approach. It utilizes Vensim® for developing the CLDs of RSSCM in developing economies.

The paper is organized as follows. Firstly, the background and introduction are presented in Section 1. Secondly, in the Section 2, SSCM and resilient SC management are presented, followed by RSSCM and ST approaches. In this step, the key enablers of resilience in developing countries' sustainable construction SCs are identified. Thirdly, the Section 3 is described, articulating the data collection and data analysis process. In the Section 4, findings and outcomes are deliberated, and a CLD is developed. Finally, the paper is concluded, and limitations, recommendations, and directions for further research are presented.

2. Literature Review

2.1. Sustainable Supply Chain Management (SSCM)

An SC is a network that connects all the people, organizations, resources, and activities involved in producing and distributing a product [2]. It encompasses everything from delivering source materials from the supplier to the manufacturer and eventual delivery to the end-user [1]. It is the process of managing how goods and services evolve from concept to finished product [3]. Modern SCs are complicated systems where various players work together in distinct steps to deliver various products to customers [23]. In order to decrease the uncertainties and disruption risks and increase the SCs' resilience and flexibility, independent businesses must collaborate [24]. SCM encompasses all aspects of an organization's operation integrated into one system [4].

SSCM includes all three pillars of sustainability, i.e., environmental, social, and financial, throughout the production lifecycle. The lifecycle includes product design and production to material sourcing, processing, packaging, shipping, warehousing, distribution, consumption, return, and disposal [25,26]. The SSCM effectively and efficiently manages interrelated environmental, social, and economic aspects in the global supply chains [27]. In sustainable SCs, the participants must meet environmental, economic, and social requirements [28]. The assumption is that competition would be preserved by fulfilling consumer demands and associated economic criteria.

SSCM has gained significant recognition with a surge in scholarly publications over the past few years. Such sustainable SCs lead to Value Management (VM) [29]. Value engineering (VE) or VM is a systematic process to increase the value of a product. It is a strategy that examines and optimizes the function of each item and its associated cost to increase the value of the project or product [30]. When it comes to construction projects, VE can be very beneficial. Using VE early in the project can save time and money in the long run, resulting in a higher return on investment and more cost savings. VE encourages substituting less expensive materials and technologies without affecting the product's functionality. VE helps improve the performance of construction SCs by cutting costs through supply chain integration while maintaining a high quality of service, thus making them more sustainable [31].

In the SCM, the social aspect of sustainability has been less addressed than the environmental and economic dimensions [32]. SC sustainability aims to include environmental, economic, and social efforts into traditional, cost-oriented SCM strategies [3,24]. A sustainable SC is described as an interaction among organizations in an SC that provides holistic environmental and social benefits to all SC partners [33,34]. It encompasses businesses' attempts to address the environmental and human impact of their products' path throughout the SCs, i.e., from raw material sourcing to production, storage, and delivery [32,35].

2.2. Resilient Supply Chain Management

Resilience is the supply chain's adaptive capability to plan for unanticipated events and respond to and recover from disruptions by maintaining operational stability at the optimal level of connectivity and control over the structure and function [36,37]. Resilience, in simpler terms, is the ability to recover from adversity [37]. A resilient SC can withstand or avoid the consequences of an SC disruption and recover from one quickly. Resilience is at the core of current thinking regarding SCM [38,39].

A resilient SC can resist or prevent the consequences of an SC disruption and recover from it in an economical and timely manner [40]. Resilience has always been a key factor in ensuring organizational success. Supply chain resilience no longer refers solely to risk management [37]. It is now recognized that managing risk encompasses being better positioned than competitors to deal with disruptions in the SCs. Further resilient SCs provide an advantage to organizations through competitive gains [39].

It is necessary to consider the measurement of resilience to build a resilient system. The level of resilience needed by the system is context-dependent [40]. SC resilience is impacted by the antecedents of capability, vulnerability, SC orientation, and SC design [41,42]. SC disruptions are unexpected events interrupting the usual operation and flow between the SC players: products, components, and materials [43]. Disruptions in SCs are characterized by a high degree of uncertainty that may occur from several sources, such as physical hazards, personal events, information disruptions, environmental disasters, acts of terrorism, and political upheaval [44].

Organizations are more likely to experience a wide range of unforeseen vulnerabilities, producing minor to large disruptions throughout their SCs [45]. Accordingly, these organizations must recognize and focus on their inherent component of the SC, while policymakers should reevaluate methods for making global SCs more resilient [46]. For example, digital technologies have disrupted the construction industry and associated fields [47,48]. Accordingly, construction managers have been focused on creating more resilient SCs to mitigate the effects of disruptions [45]. A resilient SC can tackle the adverse effects of disturbances and substantially reduce the recovery period necessary for construction organizations to return to normal operation [46].

2.3. Resilient Sustainable Supply Chain Management (RSSCM)

RSSCM is the management of resources to meet the needs of stakeholders to attain high resilience and sustainability in the SC [49,50]. Risk management is a key feature of RSSCM. According to Kamalahmadi and Parast [46], SC resilience is a core element of SC management that helps quicker recovery from disruptions. Various methodologies are used to achieve RSSCM. These include Transaction Cost Analysis, Network Perspective, Total Quality Management, and the ST approach [51,52].

At the strategic network design stage, there are linkages between SC resilience and sustainability performance [53]. Fahimnia and Jabbarzadeh [54] elucidate how variations in the resilience level affect the economic, environmental, and social sustainability of an SC. Similarly, the simulation-based model suggested by Ivanov [55] shows how sustainability factors can be linked to SC resilience in multiple ways. Jabbarzadeh et al. [53] considered a situation in which the aims of sustainability and resilience are in contradiction. Nevertheless, facility protection must simultaneously promote sustainability and resilience [56].

Based on the key concepts of SCM and RSSCM in construction projects, the current paper sheds light on the key enablers of resilience in SSCM. The focus is on RSSCM in the construction industries of developing countries.

3. Research Methodology

Research methodology defines how research is to be carried out to achieve its objectives [57]. Accordingly, this research has been divided into three stages to achieve the predefined objectives, as presented in Figure 1, below. These stages are subsequently explained.

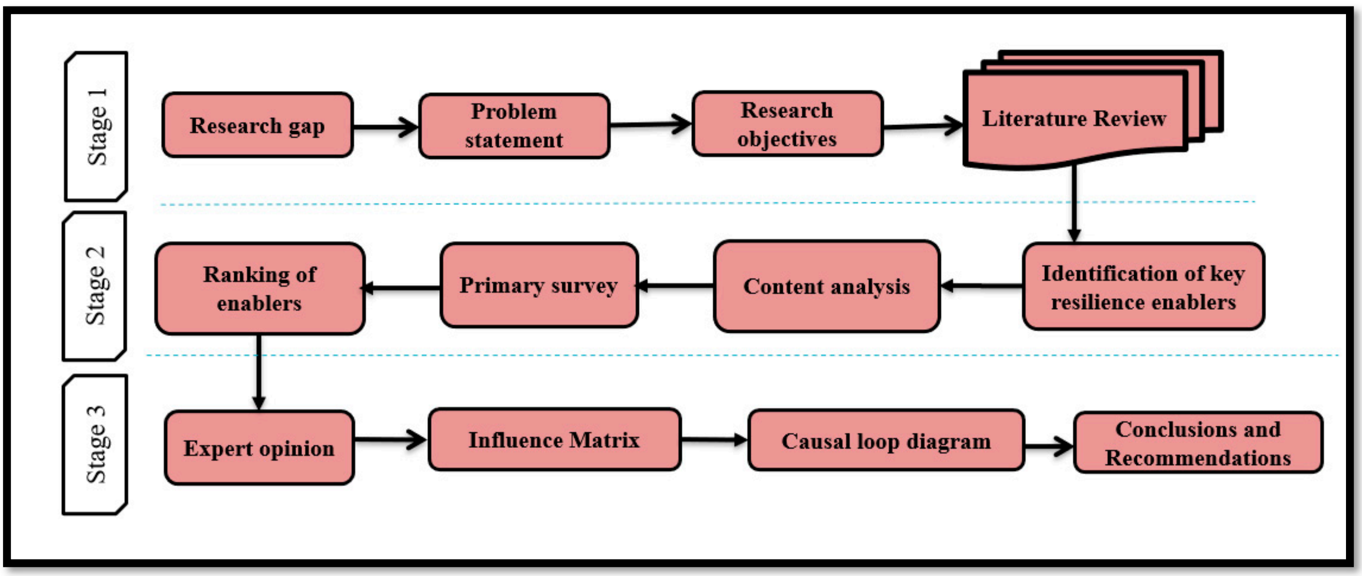

Figure 1. Methodology chart.

3.1. Stage 1: Initial Study

The first stage of the method of the current study comprises the initial study. The initial study was conducted to identify the research gap, draft the problem statement, and formulate the research objectives of the current study. Then, a detailed literature review was conducted to identify the key resilience enablers for sustainable SCs. Following recent studies, the four major databases selected for paper collection include Science Direct, Scopus, Web of Science, and IEEE Xplore [58,59]. The inclusion and exclusion criteria of the referred study were adopted to ensure that the literature review was exhaustive and comprehensive.

3.2. Stage 2: Factors Shortlisting

The second stage of the current study method deals with the shortlisting of key RSSCM factors. Due to the literature review, key resilience enablers for sustainable SCs were identified. A total of 55 articles were scrutinized using the keywords "enablers of resilient construction supply chain" and "enablers of sustainable construction supply chains". The keywords were joined using boolean operators "AND" or "OR", resulting in a total of 26 relevant articles. Initially, 32 enablers were identified from 26 papers published in the last decade that focused on SCs in developing countries. The identified enablers include top management support, adaptability, agility, transparency, leadership, tenacity, resource efficiency, and others, as shown in Table 1.

A quantitative number was assigned to each enabler according to its influence (high as 5, medium as 3, and low as 1) following Rasul et al. [60]. This led to calculating the literature score (LS) using Equation 1, where W is the product of frequency (repetition of enablers in papers) and assigned impact score (5,3,1) following the referred study. A is the highest possible score, and N is the total number of papers considered for enabler identification [60]. The scores are normalized to have a uniform scale.

Normalization is the process of converting values measured on various scales to a theoretically common scale (out of 1). It is a data-shifting and rescaling technique in which data points are shifted and rescaled till they are in the 0 to 1 range. Normalization is required to ensure that the data directly related to the database is considered. Further, each data field contains only one data element, which removes redundant (unnecessary) data. The normalized literature score (NLS) was computed by dividing each enabler's LS by the sum of the literature scores, as shown in Equation 2. The identified 32 enablers from the literature, along with references and the respective NLS, are shown in Table 1.

$$\mathrm{RII} = \left(\sum \mathrm{W}\right)/(\mathrm{A} \times \mathrm{N}) \tag{1}$$

$$\mathrm{NLS} = (\mathrm{LS})/\left(\sum \mathrm{LS}\right) \tag{2}$$

A primary survey was conducted to calculate the field scores with a response rate of 106. The final ranking of enablers was based on the combined field and literature data score, with a weightage of 60/40 (60 percent of the respondent's normalized score and 40% of the literature's normalized score). Factors having a 50% impact score were then shortlisted [16,61].

Statistical tools are used to check the reliability of the data. The IBM® SPSS® Statistics software platform is a robust statistical software platform. This software is one of the most widely used statistical packages, capable of handling and analyzing large amounts of data [4,60]. Accordingly, it was used to check the normality and reliability of the data in the current study by applying basic statistical tests (Cronbach's alpha). The threshold value for Cronbach's alpha is 0.7. Any value of the data above 0.7 shows its reliability. A Cronbach alpha value of 0.92 was obtained in this study, showing that the data are highly reliable for further analysis [4]. Table 1 represents the collective NLS and ranks of the 32 enablers. Moreover, the classification categories of the papers are also elaborated in Table 1, where "S" represents the classification of the factors into the category of "sustainability" and "R" represents the "resilience" category.

Table 1. Enablers identification via the literature review.

Sr.#	Enablers	References	Category	NLS	Sr.#	Enablers	References	Category	NLS
1	Top Management Support	[62–66]	S	0.035	17	Information Security	[43,62,63,65,67,68]	S	0.025
2	Adaptability	[11,18,62,67,69,70]	R, S	0.042	18	Strategic Risk Planning	[18,43,62,64,67,68,71,72]	S	0.034
3	Visibility	[11,18,43,62,66,67,69–75]	R, S	0.106	19	Corporate Social Responsibility	[43,67,72]	S	0.035
4	Health	[18,62]	S	0.014	20	Contingency Planning	[43,62,65,66,71,76]	S, R	0.030
5	Compatibility	[49,62–66,69]	S	0.056	21	Safety Stock	[62,69,73,76]	S, R	0.035
6	Quality Awareness	[77]	R	0.007	22	Flexible Transportation	[43,49,62,68,69,71,73]	S, R	0.030
7	Responsiveness	[76,77]	R	0.014	23	Resource Efficiency	[49,63,68,72]	S	0.013
8	Technological Capability	[70,77]	R	0.021	24	Transparency	[49,65,68,72]	S	0.014
9	Agility	[63,66,67,69–72,77,78]	S, R	0.092	25	Self-Regulation	[75,78]	S	0.013
10	Supply Chain Security	[64,69]	S	0.021	26	Market Sensitivity	[66,68,70,71]	R, S	0.021
11	Collaboration	[18,43,49,62,65–67,69–71,79]	R, S	0.092	27	Tenacity	[73]	R	0.007
12	Swift Trust	[11,64,66,67,70,71]	R, S	0.030	28	Leadership	[66,71,79]	S	0.021
13	Risk and Revenue Sharing	[67,70]	R, S	0.014	29	Just in Time	[73,76,77]	R, S	0.035
14	Information Sharing	[11,43,64,65,67,70,71,73,79]	R, S	0.085	30	Proper Scheduling	[64]	S	0.001
15	Flexible Structure	[62,63,67,69–71,73,76]	R, S	0.034	31	Composure	[71]	S	0.007
16	Risk Management Culture	[67,70]	R, S	0.014	32	Reasoning	[62,78]	S	0.003

3.3. Stage 3: Systems Thinking Approach

The third stage of the current study method deals with the ST approach. ST is a cognitive endeavor that is more systematic, abstract, and planned [80]. Although the hierarchical thinking process is complex, not all processes and cognition are always complicated [20]. ST is a conceptual problem-solving methodology that considers issues in their entirety rather than dealing with them individually [81]. A CLD is used to ascertain the relationship between variables and balance and reinforce feedback loops in a complex environment [82]. Polarities are assigned to the loops to show their reinforcing or balancing impact. Polarities within links merely anticipate what will happen if something changes and do not demonstrate how variables behave [21,83]. The polarity of a variable is determined by tracing its effects as they propagate around the loop [80].

The ST approach focuses on how the integral parts of a system interact and operate over time in complex networks. Accordingly, it has been used in this research to deal with the complexities of the RSSCM. The ST approach would make it easier for SC managers to overcome disruptions and vulnerabilities and build an RSSCM. The global business has become increasingly volatile, and uncertainties frequently interrupt the functions of the SC. Accordingly, SC managers can use ST to get ideas about disruption mitigation [21]. Furthermore, managers can know the association amongst different variables in the CLD, how the variables are linked, and the antecedents via the ST approach.

In this stage of the study, expert opinion was acquired to determine the polarity and interrelationships among the enablers, which resulted in the development of an influence matrix. Stella Professional, AnyLogic, Vensim ®PLE, and iThink are some of the software packages used to design CLDs and associated system dynamics models. This research utilized Vensim® PLE for CLD development based upon the shortlisted enabler's interrelationships. This is because Vensim® is the most powerful package in terms of computing speed, capabilities, and flexibility [58]. In terms of capacity, performance, and functionality, Vensim® PLE is unrivaled. The optimization possibilities are powerful and the simulation speed is rapid. Thus, it has been used to develop the CLDs that represent the causality among the key enablers of RSSCM. The CLD provides a snapshot of all the important relationships in the RSSCM system [82]. In addition, it visualizes key variables and their relationships, composed of balancing and reinforcing loops [83,84].

3.4. Data Collection and Analysis

Demographics of Primary Survey Respondents

After the content analysis, a primary survey was conducted to shortlist the key resilience enablers. Due to the lack of research on developing economies, these countries were identified following Samans et al. [85]. The questionnaire was floated to over 2000 respondents via LinkedIn®, ResearchGate®, Facebook®, and organizational emails. A total of 106 responses were received, including those from Pakistan (37%), South Africa (14%), Malaysia (9%), Turkey (8%), UAE (7%), India (6%), Saudi Arabia (5%), Iran (4%), and from other developing countries (10%), as shown in Figure 2. The respondents' profiles are shown in Table 2 below.

As shown in Table 2, 12% of respondents had 0–1 year of experience, 9% had 2–5, 18% had 6–10, 10% had 11–15, 7% had 16–20, and 24% had experience of more than 20 years. Regarding qualification, 6% of respondents were diploma holders, 52% had a graduate degree, 36% had a post-graduate degree, and 6% were Ph.D. holders. In addition, 33% of respondents were from the government sector, whereas 53% and 14% were from private and semi-government sectors. To check the level of knowledge of the respondents about the understanding of the topic, respondents were asked to rank their level of knowledge of the topic as no understanding at all, slight, moderate, and high, respectively. Accordingly, 55% of the respondents had a moderate level of knowledge about RSSCM, 28% of respondents had a high level of knowledge, and 17% had slight to no knowledge of the research topic.

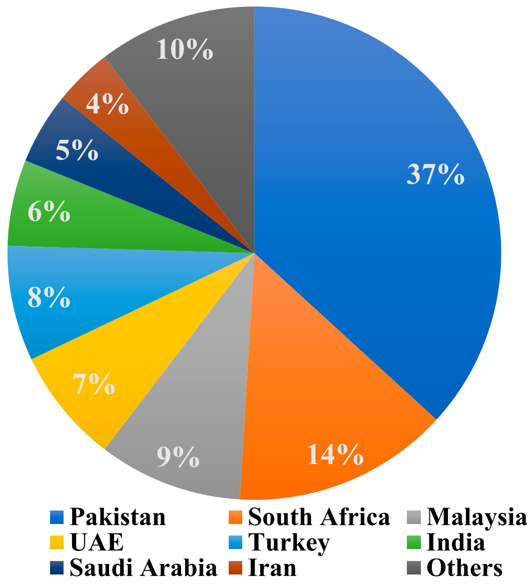

Figure 2. Regional distribution of respondents.

Table 2. Frequency distribution of responses.

Profile	Frequency	Percentage
	Total responses = 106	
	Job title	
CEO	4	4%
Construction Manager	5	5%
Assistant Manager	14	13%
Site Manager	11	10%
Architect/Designer	7	7%
Planning Engineer	14	13%
Project Manager	16	15%
Project Director	10	9%
Academician	12	12%
Others	13	12%
	Years of Professional Experience	
0–1	13	12%
2–5	31	29%
6–10	19	18%
11–15	11	10%
16–20	7	7%
>20	25	24%
	Education	
Diploma Holder	6	6%
Graduation	55	52%
Post-Graduation	39	36%
PhD	6	6%
	Organization type	
Government	35	33%
Semi-Government	15	14%
Private	56	53%
	Understanding of resilience and risk management in supply chains	
No understanding at all	8	8%
Slight	10	9%
Moderate	58	55%
High	30	28%

4. Results and Discussions

4.1. Factors Shortlisting

Table 3 represents the collective scores and ranks of the 32 enablers. The normalized literature score (40%) and normalized field score (60%) were selected to calculate the collective score to rank the enablers. After arranging factors in descending order with respect to their collective score, enablers with a cumulative percentage normalized score up to 51 percent were shortlisted for further analysis.

Table 3. Ranking via collective score.

Sr.No	Enablers	Normalized Literature Score (40%)	Normalized Field Score (60%)	Collective Score	Rank
1	Top Management Support	0.014	0.023	0.038	6
2	Adaptability	0.017	0.019	0.036	8
3	Visibility	0.042	0.019	0.061	1
4	Health	0.006	0.023	0.029	15
5	Compatibility	0.023	0.019	0.041	5
6	Quality Awareness	0.003	0.023	0.026	21
7	Responsiveness	0.006	0.023	0.029	17
8	Technological Capability	0.008	0.019	0.027	20
9	Agility	0.037	0.023	0.060	2
10	Supply Chain Security	0.008	0.019	0.027	19
11	Collaboration	0.037	0.019	0.055	3
12	Swift Trust	0.012	0.019	0.031	13
13	Risk and Revenue Sharing	0.006	0.019	0.024	22
14	Information Sharing	0.034	0.019	0.053	4
15	Flexible Structure	0.014	0.019	0.032	11
16	Risk Management Culture	0.006	0.019	0.024	23
17	Information Security	0.010	0.014	0.024	24
18	Strategic Risk Planning	0.014	0.019	0.032	10
19	Corporate Social Responsibility	0.014	0.019	0.033	9
20	Contingency Planning	0.012	0.019	0.031	15
21	Safety Stock	0.014	0.014	0.028	18
22	Flexible Transportation	0.012	0.019	0.031	14
23	Resource Efficiency	0.005	0.019	0.024	25
24	Transparency	0.006	0.019	0.024	26
25	Self-Regulation	0.005	0.019	0.024	27
26	Market Sensitivity	0.008	0.014	0.023	28
27	Tenacity	0.003	0.019	0.022	29
28	Leadership	0.008	0.023	0.032	12
29	Just in Time	0.014	0.023	0.038	7
30	Proper Scheduling	0.001	0.019	0.019	30
31	Composure	0.003	0.009	0.012	31
32	Reasoning	0.001	0.009	0.011	32

A Pareto Chart was used in this study to show the cut-off point for key enablers, as shown in Figure 3. It is a bar graph showing the variables and their ordered percentages.

In addition, it shows the ordered frequency counts of values for the different levels of a variable [86]. A Pareto chart aims to separate the significant aspects of a problem from the trivial ones [4]. In this case, the cut-off point for variable selection was set at 51 percent for cumulative normalized scores [4,86]. The total number of elements under this score was 12, identified as the key enablers. These include visibility, agility, collaboration, information sharing, compatibility, top management support, just in time, adaptability, corporate social responsibility, flexible structure, strategic risk planning, and leadership. The x-axis of Figure 3 represents the variables, and the y-axis displays the combined score and cumulative percentages of the enablers obtained from Table 3.

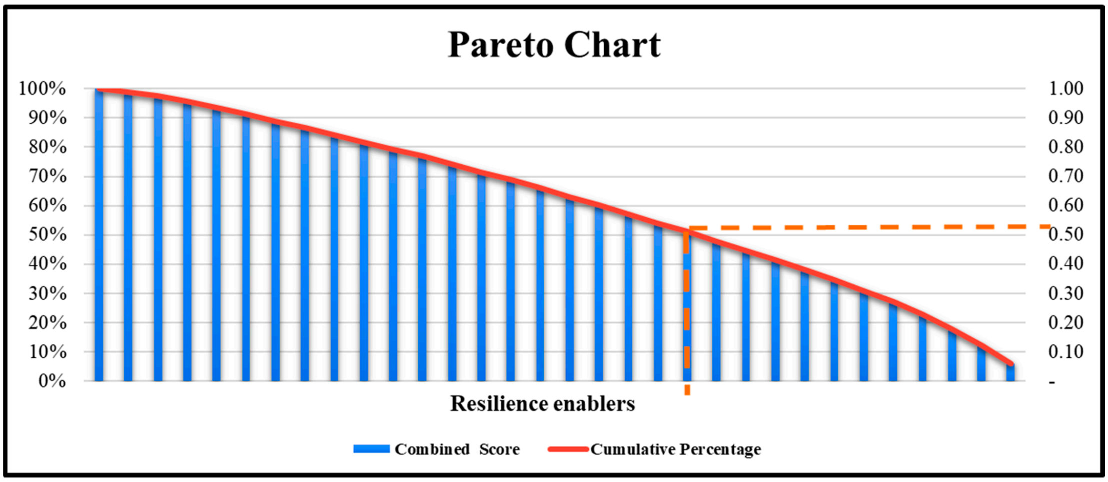

Figure 3. Shortlisting of enablers using 50% impact.

4.2. Influence Matrix

The Influence Matrix (IM) for the CLD was developed based on expert opinion. The IM shows interrelationships and polarities of influence (positive or negative) among the variables. In this case, IM shows 16 relationships among 12 enablers where a value of +1 indicates a direct relationship and −1 indicates an indirect relationship, as shown in Figure 4.

Code	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
E1					1							1
E2	1											
E3		1										
E4	1		1									
E5				1								
E6				1								
E7		1										
E8		1										
E9						1					1	
E10							1					
E11								-1		1		
E12									1			

E1: **Visibility**; E2: **Agility**; E3: **Collaboration**; E4: **Information Sharing**; E5: **Compatibility** E6: **Top Management Support**; E7: **Just in Time**; E8: **Adaptability**; E9: **Corporate Social Responsibility** E10: **Flexible Structure**; E11: **Strategic Risk Planning**; E12: **Leadership**

Figure 4. Influence matrix.

4.3. Causal Loop Diagram (CLD)

The CLD was constructed to show the loops, polarities, and images of variables. Vensim® was used for the construction of the CLD. A total of 16 substantial interrelationships were addressed by the CLD, of which one was indirect and the other 15 were direct in terms of polarity. The CLD was developed based on the opinions of 15 construction personnel with over 20 years of experience in developing countries. In addition, a wider experience of the respondents helped confirm the CLDs' significance and applicability to the construction industry. Figure 5 is a consolidated CLD developed in the current study. It comprises five loops, i.e., four reinforcing and one balancing loop. The explanation of each loop is given below.

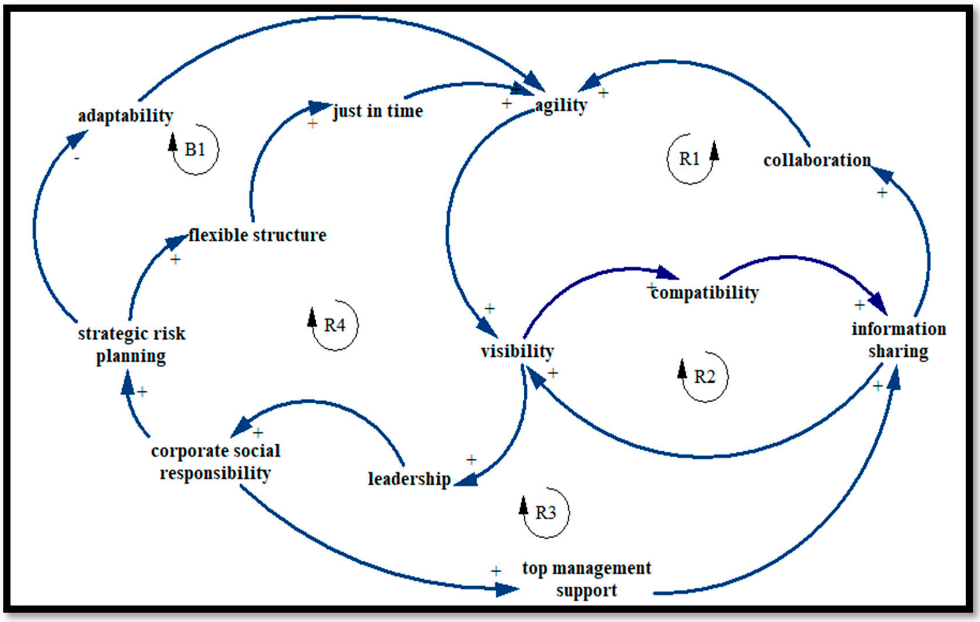

Figure 5. Causal loop diagram.

4.3.1. Reinforcing Loop R1

Reinforcing loop R1 demonstrates that an increase in visibility increases compatibility, leading to increased information sharing. Furthermore, an increase in information sharing promotes collaboration, which increases agility. This further increases visibility, as shown in Figure 6. Hence, this loop clarifies that if there is a visible SC, there would be a more amicable relationship among SC partners, leading to information sharing and cooperation, and ultimately the SC would be faster and more resilient.

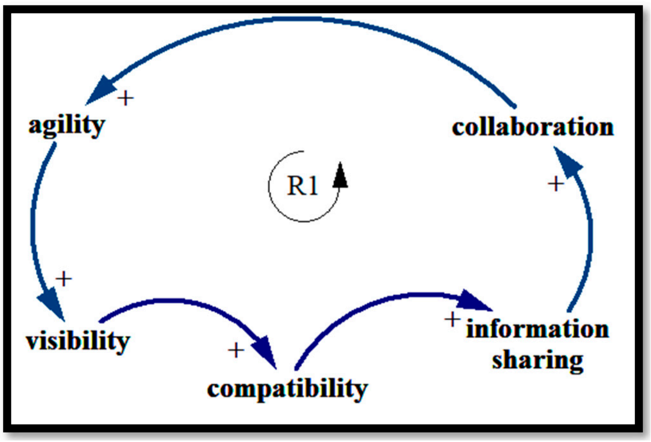

Figure 6. Reinforcing loop R1.

4.3.2. Reinforcing Loop R2

R2, as presented in Figure 7, illustrates that an increase in visibility leads to an increase in SC compatibility. Furthermore, this increase leads to increased information sharing that promotes visibility. This loop elucidates that a more visible SC will lead to an amicable relationship among the partners and more information sharing.

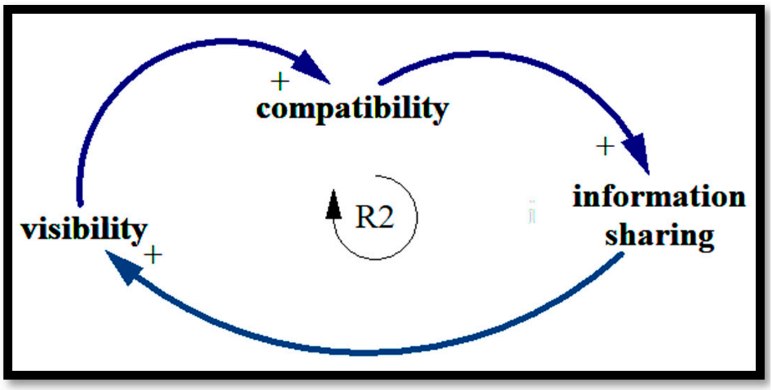

Figure 7. Reinforcing loop R2.

4.3.3. Reinforcing Loop R3

Reinforcing loop R3 shows that increased visibility promotes leadership, leading to increased corporate social responsibility. This, in turn, promotes top management support, leading to increased information sharing, which again leads to increased visibility, as displayed in Figure 8. This loop explains how leadership reinforces corporate social responsibility and top management support and leads to a more visible SC with increased information sharing among the SC partners.

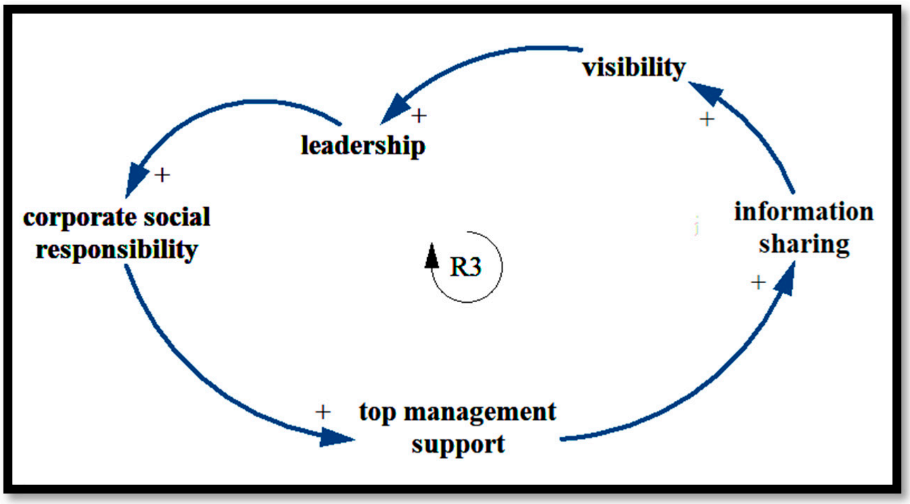

Figure 8. Reinforcing loop R3.

4.3.4. Reinforcing Loop R4

Reinforcing loop R4 illustrates that increased visibility promotes leadership, increasing corporate social responsibility and strategic risk planning. An increase in strategic risk planning promotes a flexible structure that leads to a just-in-time approach. This, in turn, promotes agility, which will increase visibility, as shown in Figure 9. This loop clarifies that when leadership reinforces corporate social responsibility, there would be a flexible SC structure leading to a just-in-time approach that will make the SC faster and more visible. This is due to the strategic risk planning process.

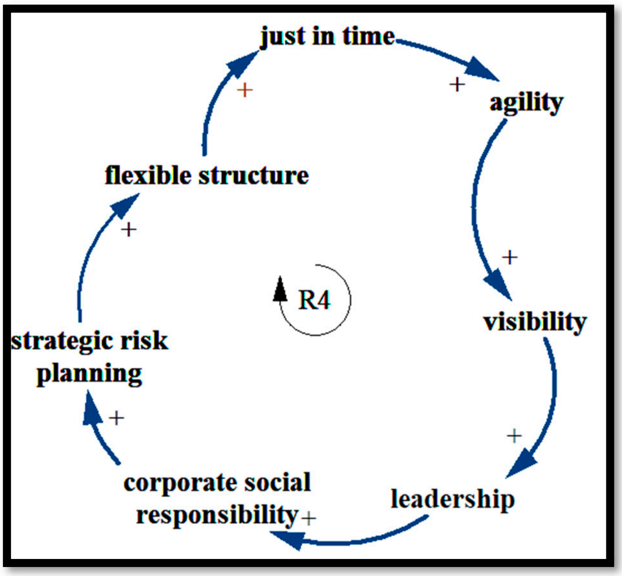

Figure 9. Reinforcing loop R4.

4.3.5. Balancing Loop B1

Balancing loop B1 depicts that an increase in strategic risk planning leads to decreased adaptability, leading to a decrease in agility. A decrease in agility leads to a decrease in visibility which decreases leadership. A decrease in leadership will decrease corporate social responsibility, leading to a decrease in strategic risk planning, as shown in Figure 10. This loop explains the balancing effect of strategic risk planning on adaptability.

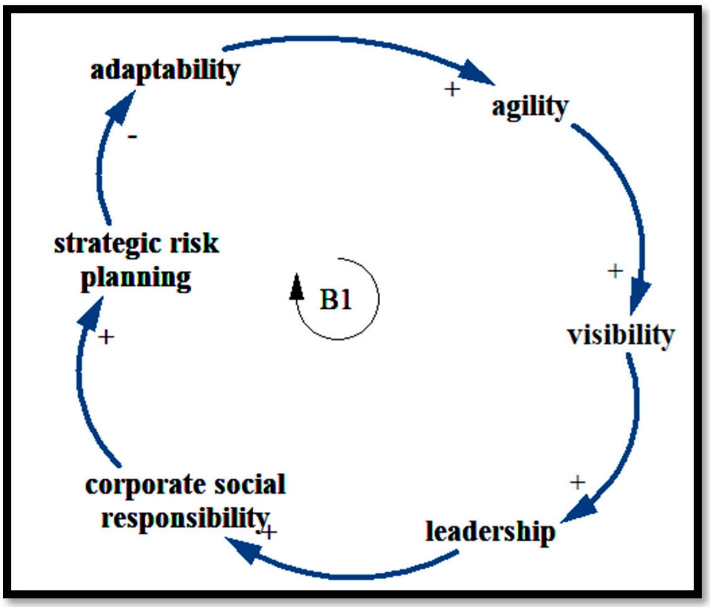

Figure 10. Balancing loop B1.

4.4. Loop Analysis

The magnitude and speed of influence on system outputs serves as a thorough criterion for loop classification [14,71]. Table 4 summarizes the results for each feedback loop. It predicts the speed, strength, and nature of the influence of the loop [87]. The four reinforcing loops, R1, R2, R3, and R4, have a strong influence with a low speed. This indicates that these loops hold great potential but will take time and be long-lasting.

Table 4. Overall loop analysis results.

Loop	Speed of Influence	Strength of Influence	Nature of Influence
R1	Slow	Strong	Reinforcing
R2	Slow	Strong	Reinforcing
R3	Slow	Strong	Reinforcing
R4	Slow	Strong	Reinforcing
B1	Fast	Strong	Balancing

On the contrary, B1 is fast, having a balancing effect. Reinforcing loops have a resonant effect that lasts for a long period, whereas balancing loops have a fading impact that lasts for a short time. The CLD's validity was qualitatively assured and verified through expert opinion [88]. All four reinforcing loops have a strong influence with a slow speed. On the contrary, the balancing loop has a fast speed and strong influence [88]. The results of this study can enable organizations to acclimate to disruptions by sourcing their inputs from a versatile or redundant supply base that allows a business to move suppliers when production is at risk.

4.5. Discussion

In this study, 32 resilience enablers were selected based on a literature review, as shown in Table 1. These enablers were reduced to 12 key enablers of RSSCM. The shortlisting was achieved through a field survey where the 12 enablers with cumulative normalized scores of up to 51% were selected. These key enablers include visibility, agility, collaboration, information sharing, compatibility, top management support, just in time, adaptability, corporate social responsibility, flexible structure, strategic risk planning, and leadership. The IM, as presented in Figure 4, was developed based on these key enablers. The IM has 16 interrelationships between the 12 key enablers. Finally, the CLD was developed based on the IM, as shown in Figure 5.

The CLD developed in this study comprises five loops: four reinforcing and one balancing loop. Figure 6 clarifies that a more visible and established SC would create a more amicable relationship among SC partners. Such a relationship leads to information sharing and cooperation; ultimately, the SC would be faster and more resilient. Figure 7 shows that if an organization's SC is agile, visible, and has a compatible infrastructure, with proper collaboration and information sharing, it will ultimately make it more resilient to avoid disruptions. This finding is in line with [87].

Moreover, top management support, corporate social responsibility, and strong strategic risk planning can reinforce the resilience of any SC, as shown in Figure 8. The same has been concluded by [14]. Figure 9 highlights that through information sharing, exchange, and integration among SC partners, the RSSCM will increase. This is in line with [89] and clarifies that when leadership reinforces corporate social responsibility, then, due to strategic risk planning, there would be a flexible SC structure, leading to a just-in-time approach. Such an approach will make the SC both faster and more visible. Figure 10 explains the balancing effect of strategic risk planning on adaptability. Overall, adaptability and a just-in-time approach play a key role in enabling RSSCM as they promote the use of minimal raw materials, leading to enhanced sustainability [88].

Table 4 shows the loop analysis of the study. Accordingly, the four reinforcing loops, R1, R2, R3, and R4, strongly influence at lower speeds. This indicates that these loops hold great potential but take some time to materialize. This is in line with [48]. On the contrary, B1 is fast, having a balancing effect. Therefore, the impacts of B1, which may not be that significant, have more chances and speed of occurrence. This encourages the SCM managers to be proactive and take timely measures. Furthermore, reinforcing loops have a resonant effect that lasts for a long period, whereas balancing loops have a fading impact that lasts for a short time. Finally, the CLD's validity was qualitatively assured through expert opinion for verification [88].

The outcomes of the study will help firms acclimatize to disturbances in their SCs. It is the first study of the complexity of resilient and sustainable construction SCs. This study has added to the existing body of knowledge by identifying the enablers that aid in developing a more resilient SC network, bridging the research gap identified by Chowdhury et al. [19], Nguyen and Bosch [20], and Sapiri et al. [21]. These authors emphasized demonstrating the relationship between SC resilience and SC sustainability for developing an RSSCM.

5. Conclusions

Resilience is a key organizational capability for achieving sustainability in the current tempestuous global situation. To develop more resilient and sustainable SC networks, this paper illustrates the crucial enablers of resilience for RSSCM. A total of 32 enablers were extracted from the body of knowledge using a literature review. Data were later collected from the respondents in the construction industry of developing countries. Two types of normalized scoring were used to shortlist the key enablers: industry and the literature. After combining the industry and literature scores, the 32 enablers were reduced to 12. Finally, the top 12 enablers were added to the IM, involved in creating a CLD that showed the relationships between the identified enablers. The CLD show four reinforcing and one balancing loop.

Based on the results of this study, agility, information sharing, strategic risk planning, corporate social responsibility, and visibility are the key resilience enablers for RSSCM in developing countries. These enablers serve as significant tools for organizations to plan for and adapt to disruptions in SCs in construction projects. The causality and interrelationships among these enablers in the developed CLD show their dynamicity and impact within the construction SC system.

The findings of the study will assist organizations in adapting to SC disruptions by acquiring inputs from a flexible supply base that allows them to switch providers when production is threatened. There has not been any published work utilizing the ST methodology for similar purposes. As a result, this study's methodology is innovative, and it is the first to address complexity in the construction sector of developing countries for moving towards an RSSCM.

The limitation of this study consists of the inclusion of respondents only from developing countries. In addition, this study utilized an ST approach for constructing CLDs and did not perform system dynamics modeling. Moreover, this study only considered limited enablers based on the literature review, which may not be exhaustive in the future.

A further study involving participants from developed countries would be more beneficial. Future research can explore the application of the developed CLD to real-time projects. A follow-up study could focus on developing a system dynamics model to explore the constructs of sustainability and resilience in the RSSCM.

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