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Adoption of Sustainable Supply Chain Management for Performance Improvement in the Construction Industry: A System Dynamics Approach

Maria Ghufran [1], Khurram Iqbal Ahmad Khan [1,*], Muhammad Jamaluddin Thaheem [2], Abdur Rehman Nasir [1] and Fahim Ullah [3]

[1] Department of Construction Engineering and Management, National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan; mghufran.cem17nit@student.nust.edu.pk (M.G.); abdur.nasir@nit.nust.edu.pk (A.R.N.)
[2] Geelong Waterfront Campus, School of Architecture and Built Environment, Deakin University, Geelong, VIC 3220, Australia; jamal.thaheem@deakin.edu.au
[3] Springfield Campus, School of Surveying and Built Environment, University of Southern Queensland, Springfield Central, QLD 4300, Australia; fahim.ullah@usq.edu.au
* Correspondence: khurramiqbal@nit.nust.edu.pk

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Abstract: Sustainable supply chain management (SSCM) involves the managing of information, materials, cash flows, and collaboration among enterprises along the supply chain, integrating sustainable development goals. This research paper aims to determine challenges in SSCM adoption and to address related complexity using the system dynamics (SD) approach utilizing modeling and simulation techniques. This research identified challenges from the literature using content analysis. Causality among these identified challenges was determined using interviews and questionnaire surveys that led to the development of a causal loop diagram (CLD), which was used in the development of the SD model. Among the 19 shortlisted variables, CLD had IV reinforcing and II balancing loops. Moreover, CLD was used to build an SD model with two stocks, and a new stock named 'project performance' was added to envisage the cumulative impact of all stocks. The model was simulated for five years, and the results predict that the lack of top management commitment and corporate social responsibility adversely affects project performance. This implies that there is a need to improve numerous factors, in particular corporate social responsibility and top management commitment, which would lead to the adoption of SSCM, thus leading to a performance improvement for the construction industry (CI). The model was validated using boundary adequacy, structure, and parametric verification tests, which showed that the developed model is logical and approximately replicates the industry's actual system. The research findings will help the CI practitioners to adopt sustainability principles in terms of the supply chain and will not only enhance productivity and performance but will also help in the minimization of delays, promote long-term relations, and reduce communication gaps and project complexities.

Keywords: causal loop diagram; developing economies; sustainable supply chain management; system dynamics; systems thinking

1. Introduction

Construction is the largest employment-generating industry in a country and plays a crucial role in its economy [1,2]. The foremost concern of the CI is the improvement of the social, economic, and environmental sustainability indicators [3,4]. This industry has to face challenges, which include low profit margin and continuous project budget and schedule overruns [5,6]. Other issues consist of fragmentation, lack of coordination and trust among various supply chain stakeholders [7,8], use of traditional contracting methods, lack of environmental regulations, and the labor-intensive construction industry [9–11].

The supply chain consists of a series of interconnected entities that are engaged in a variety of different activities [12,13] that yield value through upstream and downstream linkages in goods and services from suppliers to the best customer [14,15]. It encompasses all those entities and processes, which are involved in accomplishing a customer order [16]. More stakeholders are involved in the management of resources, information, and processes [17,18]. Sustainability has been an important issue for the CI. The triple bottom line (TBL) perspective of sustainability includes economic (profit, cash flows, income), environmental (natural resources, energy conservation, land use) and social (education, equity, well-being, quality of life) performance [19–21], which is customary to characterize sustainable development in supply chains [22–26]. However, current sustainability studies are fundamentally associated with the improvement of environmental issues, exclusively their interface with economic ones [27]. The social perspective on sustainability has been regarded as the least defined and weakest pillar of sustainability, despite being frequently quoted but rarely examined [28,29].

Most of the research in the SSCM area primarily enlightens the environmental perspective, in contrast to the social perspective of sustainability [30,31]. Studies that still are focusing on the social dimension pay their attention to a single aspect of the dimension and do not look at the broader view, where the human factor plays a crucial role in social sustainability [4]. The last few decades have seen the emergence of a modern SSCM concept [31]. Ahi and Searcy [32] define SSCM as the creation of coherent supply chains by integrating economic, environmental, and social concerns with the foremost inter-structural business processes designed to manage resources, knowledge, and capital efficiently to meet stakeholder requirements [33]. According to Galal and Moneim [10], research has been carried out on SSCM in developed countries, but there is a lack of research when it comes to developing countries. Social sustainability, which assists the vulnerable workers and helps suppliers in the development of persisting relationships [34–36], appears missing from the research radar [4,37–39]. Discussing the construction sector, especially, the constructor sector of developing countries, there is an absence of research on SSCM [15,40–42]. Some research focuses on green supply chain management (GSCM) but pays no attention to the social perspective having a major impact [43–48]. Incorporating the social aspect in the supply chain concept will lead towards more sustainable supply chains [48–52]. Most research concentrates on the traditional concept of sustainability, with no explicit focus on the social aspect [53–61]. Moreover, regarding adoption, no specific study has been conducted to address complexity from the perspective of the construction industry [62–67]. To bridge this gap, this study will address the challenges causing complexity in the adoption of SSCM for performance improvement in the construction industry.

There is a need for the adoption of SSCM in the construction sector that focuses on the social aspect in addition to the environmental and economic aspects [68,69]. Incorporating social aspects in the supply chain concept will lead towards more sustainable supply chains [39]. However, the adoption of SSCM is not a straightforward process and involves complexity in terms of its adoption at various levels in the supply chain. The SD approach is used to simplify complexity in the adoption of SSCM using a feedback mechanism [40]. SD modeling has been used for strategic planning and policy analysis [41–43]. Therefore, keeping this in mind, the purpose of this research is to address the challenges causing complexity in the adoption of SSCM using the SD approach, utilizing modeling and simulation techniques leading to performance improvement in the construction industry.

The paper's structure consists of the following sections. Firstly, the background and introduction of the study are presented. Secondly, the literature review section acquaints readers with SSCM, followed by the SD approach. Reviewing the literature also identified the challenges in the adoption of SSCM in developing countries. Thirdly, the process for conducting research is described, which articulates the process for the data collection, data analysis, development of CLD, and SD model. Fourthly, the collection and review of data illustrate how data are obtained and evaluated. Fifthly, the findings and outcomes are deliberated along with the development of the CLD and SD model. The paper is finalized by providing conclusions, recommendations, and directions for added research in the last section.

2. Literature Review

The CI is fragmented, having issues such as communication gaps, design and construction separation, and poor collaboration among various stakeholders [9,44]. Supply chain management (SCM) is an implicit approach for the effective management of the CI [30,45]. The supply chain of a corporation comprises merchants, external suppliers, and end users called customers [46–49].

SCM is to plan, implement, and control supply chain operations at their best level [14,50,51,69] that targets building trust and association among supply chain partners [6,52,53]. Construction supply chain management (CSCM) helps in achieving integration among the supply chain stakeholders such as suppliers, designers, merchants, contractors, subcontractors, and customers [45,54,55]. Sustainability is a multi-dimensional concept [56], a relationship between social, environmental, and economic realities, with constraints that constantly alter [39,57]. The review highlights the importance of the SSCM and SD approach in addressing the complexity issues in terms of the adoption of SSCM.

2.1. Sustainable Supply Chain Management (SSCM)

SSCM is apprehended as the unification of sustainable development and supply chain management, whereby sustainable development is most often explained as incorporating environmental, social, and economic issues [58]. The systematic alignment and accomplishment of an organization's social, environmental, and economic goals and objectives through the strategic alignment of substantial inter-organizational business procedures are referred to as SSCM [37]. All members of a supply chain must adhere to environmental and social requirements to make it sustainable [59]. In sustainable supply chains, the participants need to meet environmental, economic, and social requirements to stay in the supply chain [60,61].

Most of the associated research in the field of SSCM is chiefly concentrated on the environmental dimension, in contrast to the social dimension [24,62]. Social sustainability in supply chains is about social interactions [63] between the supply chain stakeholders [64,65]. As the CI is labor-intensive, hence, it develops a standard in social sustainability practices across supply chains [10,66]. Although different facets of human rights (e.g., child and forced labor, freedom of association, and discrimination) and business practice can be included in social sustainability, modeling initiatives have tended only to focus on some of the more specific and quantifiable social aspects [67]. During the past two decades, the published literature has highlighted health and safety, child labor, pressure from the competition, consumer requirements, and employee union pressures as a few key points whose consideration needs time [68]. The social dimension is regarded as the most vulnerable pillar of sustainable development [69]. Recently, much consideration has been given to the social dimension of sustainability, whereas the interaction between the environmental and the social dimension is still an important unexplored terrain [36,70–72].

The CI in developing countries is one of the most complex, fragmented, time-sensitive, and resource-intensive industries [73–75]. There is a need for the adoption of SSCM practices leading to performance improvement of the construction sector.

2.2. System Dynamics: An Approach to Deal with Complexity

The SD approach is used to address complexities in the adoption of SSCM using a feedback mechanism [40,53,76]. It is a beneficial methodology for the comprehensive evaluation of a complex system [77]. It is an iterative modeling process that incorporates the use of stocks, flows, feedback loops, table functions, and time delays [76]. An important feature of the SD approach is that it tracks and interprets a given system over a period, combining different theories philosophies and techniques that help in providing useful framing, understanding the behavior shown by the management system [77]. For the economic and social progress of a country, construction activities are an important index [1]. Recently, a remarkable growth has been seen in many developing countries in terms of the amount, size, and complexity of major projects. The SD approach is opted for a better understanding of organizational dynamics and to deal with all the complexities involved in any project [40].

2.3. Identification of Challenges from Literature

After a comprehensive literature review, challenges causing hindrance in the adoption of SSCM with a particular focus on social dimension in the CI were identified. In total, 30 research papers were reviewed for the identification of challenges. Data analysis revealed 82 challenges (58 social, 14 economical, 10 environmental) in the adoption of SSCM. The social sustainability challenges include human rights, fair labor practices, health, safety, wellness, diversity, equity, work-life balance, empowerment, and community engagement [63,78,79]. The environmental challenges include green investments, waste minimization, product quality, etc. [12,25]. The economic challenges include high costs for waste disposal, product price, and so [25,65]. The identified challenges from the literature were rated based on their normalized score obtained via content analysis, with the impact of each challenge (high, medium, low) being evaluated via a comprehensive review of the literature [78], as shown in Table 1. A quantitative number was assigned to each impact (high as 5, medium as 3, and low as 1). The highest frequency impact was selected for each challenge. Equation (1) depicts the calculation of the literature score [78], where N is the total number of papers considered to identify the challenges, A is the maximum possible score, and frequency depicts the repetition of challenges in papers.

Table 1. Ranking of challenges via normalized literature score.

Sr.#	Challenges	Nature	Normalized Score	Rank	Source
1	Lack of top management commitment	Social	0.071	2	[56,63,79–81]
2	Lack of training and education	Social	0.066	1	[18,25,56,82,83]
3	Complexity to design, reuse, recycle product	Environmental	0.051	59	[12,13,25,27,84,85]
4	Financial constraints	Economic	0.051	72	[13,48,56,65,80,82,86]
5	Supply chain configuration	Social	0.041	7	[12,18,65,87–89]
6	Organizational culture	Social	0.036	30	[12,18,79,90,91]
7	Health and safety	Social	0.031	44	[10,18,69,79,85]
8	Lack of awareness	Social	0.025	26	[63,80,83,92,93]
9	Company policies	Social	0.025	31	[13,80,84,86,87]
10	Environmental performance	Environmental	0.025	65	[79,83,87,89,94]
11	Lack of trust	Social	0.020	20	[56,81,82,89]
12	Less involvement in environmental related programs and meetings	Environmental	0.020	63	[13,27,86,93]
13	High cost for waste disposal	Economic	0.020	69	[13,25,86,92]
14	Return on investment	Economic	0.020	74	[13,18,65,86]
15	Suppliers' top management commitment	Social	0.018	4	[13,56,81,95]
16	Lack of resource (human)	Social	0.018	11	[13,83,86,92]
17	Lack of corporate social responsibility	Social	0.015	18	[13,86,93,96]
18	Child labor and forced labor	Social	0.015	46	[18,87,91]
19	Discrimination	Social	0.015	47	[87,91]
20	Human rights	Social	0.015	51	[18,79,91]
21	Stakeholder engagement	Social	0.012	56	[18,56,87,91,93]
22	Lack of awareness about reverse logistics	Social	0.010	17	[13,56,79,86]
23	Suppliers firm culture	Social	0.010	5	[65,83,84]
24	Inadequate performance measurement	Social	0.010	24	[56,92]
25	Vendor selection	Social	0.010	29	[93]
26	Lack of strategic planning	Social	0.010	34	[80,87]
27	Employment creation	Social	0.010	54	[10,91]
28	Gender inequality	Social	0.010	55	[10,87]
29	Green induced changes	Environmental	0.010	60	[27,65]

Table 1. *Cont.*

Sr.#	Challenges	Nature	Normalized Score	Rank	Source
30	Product quality	Environmental	0.010	61	[80,94]
31	Lack of effective environmental measures	Environmental	0.010	62	[13,86]
32	Lack of government support to adopt environmental friendly policies	Environmental	0.010	64	[13,86]
33	Product price	Economic	0.010	75	[65,93]
34	Economic uncertainty	Economic	0.010	7	[48,92]
35	Cost of third part certification	Economic	0.010	79	[64,95]
36	Availability of funds	Economic	0.010	81	[48,63]
37	Suppliers firm size	Social	0.009	6	[65,90]
38	Lack of technical expertise	Social	0.009	12	[13,56,86]
39	Lack of customer awareness	Social	0.009	14	[13,86]
40	Disbelief about environmental benefits	Social	0.009	16	[13,96]
41	Philanthropy	Social	0.009	45	[18,79,91]
42	Labor practices	Social	0.009	49	[18,91,93]
43	Maintaining environmental suppliers	Social	0.006	10	[13,86]
44	Fear of failure	Social	0.006	13	[13,86]
45	Perception of out of responsibility zone	Social	0.006	15	[13,86]
46	Suppliers' human skills	Social	0.005	3	[65]
47	Resistance to change	Social	0.005	21	[56]
48	Unwillingness to share risks and rewards	Social	0.005	22	[56]
49	Cross functional conflicts	Social	0.005	23	[56]
50	Employee involvement	Social	0.005	28	[90]
51	Resistance to change to reverse logistics	Social	0.005	32	[80]
52	Low commitment of partners	Social	0.005	35	[81]
53	Reliability of supply	Social	0.005	39	[81]
54	Poverty	Social	0.005	43	[91]
55	Wages	Social	0.005	48	[91]
56	Unethical practices	Social	0.005	50	[91]
57	Sustainable sourcing	Social	0.005	52	[91]
58	Local sourcing	Social	0.005	53	[91]
59	Collaboration with suppliers	Social	0.005	57	[27]
60	Collaboration with customers	Social	0.005	58	[27]
61	Usage of renewable materials	Environmental	0.005	66	[86]
62	Waste minimization	Environmental	0.005	67	[18]
63	Eco-efficiency	Environmental	0.005	68	[18]
64	Eco-friendly packaging cost	Economic	0.005	70	[25]
65	Cost of sustainability and economic conditions	Economic	0.005	71	[25]
66	Green investments	Economic	0.005	73	[65]
67	Non availability of bank loans	Economic	0.005	76	[92]
68	Distribution of cost benefits	Economic	0.005	80	[64]
69	Initial buyer and supplier investment	Economic	0.005	82	[92]
70	Lack of information sharing between construction firms and suppliers	Social	0.004	19	[13,27,86,96]
71	Poor supplier commitment	Social	0.003	27	[25,90]
72	Reluctance of the support of dealers, distributors, and retailers	Social	0.003	33	[80]
73	Closer links between demand and supply	Social	0.003	37	[81]
74	Problems in maintaining environmental suppliers	Social	0.003	38	[83]
75	Initial burden on suppliers		0.003	40	[92]
76	Lack of legitimacy	Social	0.003	41	[90]
77	Supplier commitment	Social	0.003	42	[90]
78	Cost concern hinders	Economic	0.003	78	[83]
79	Focal firms' previous sustainability experiences	Social	0.001	8	[65]
80	Suppliers' location	Social	0.001	9	[65]
81	Suppliers lack resources	Social	0.001	25	[86,92]
82	Frequent meetings	Social	0.001	36	[81]

$$\text{Literature Score} = \text{Impact score} \times \frac{\text{Frequency}}{\text{A} \times \text{N}} \tag{1}$$

The literature score was converted into the normalized score by dividing the individual literature score of each challenge by the sum of the literature score. The normalized score was then arranged in descending order and the cumulative score was calculated. This technique was used for the elimination of less significant factors [3].

3. Method and Materials

This study is conducted in IV phases as presented in Figure 1.

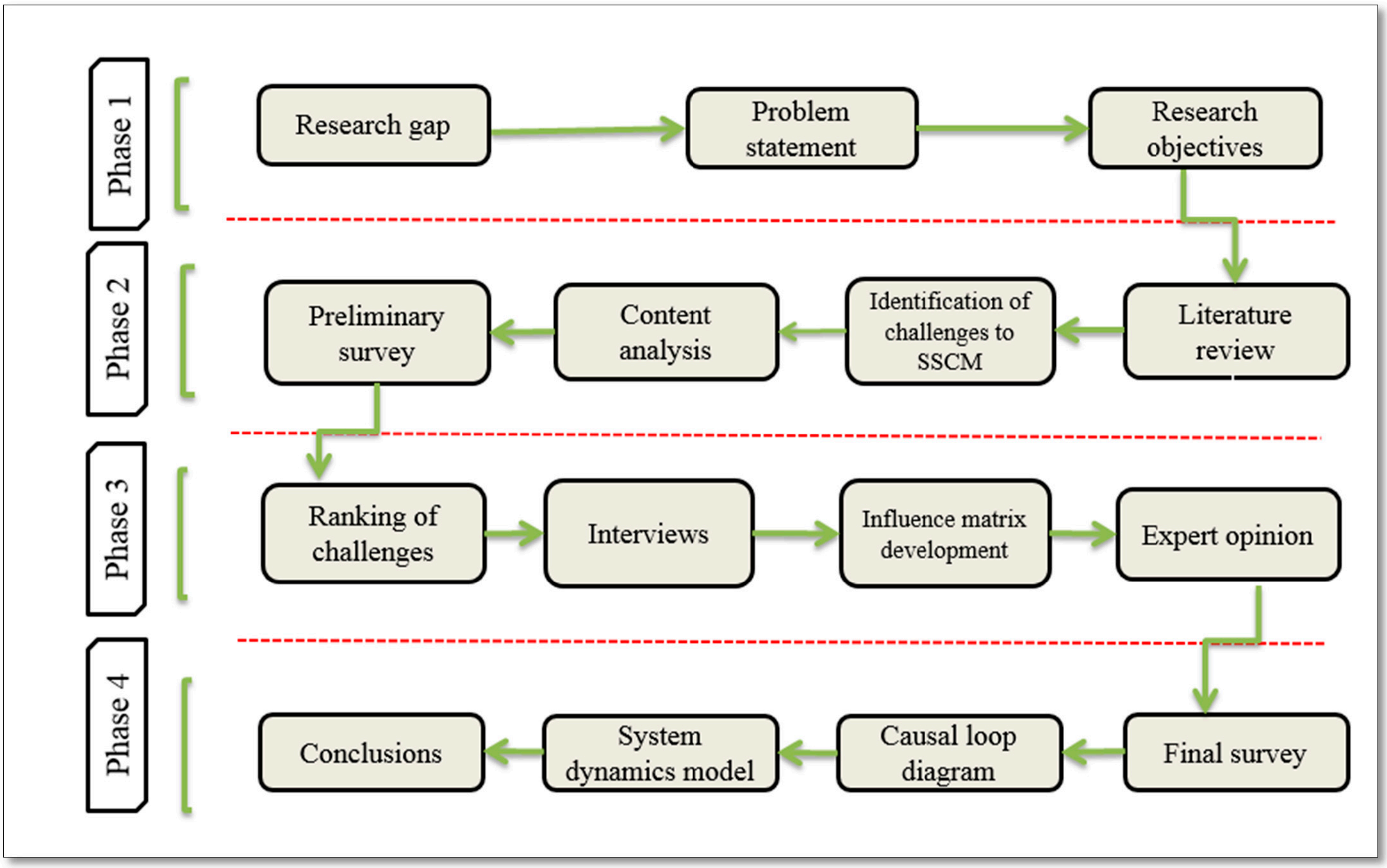

Figure 1. Methodology chart.

3.1. Data Collection and Analysis

The first phase involved the scrutiny of the literature in establishing the research gap, which helped in the development of the problem statement, followed by the identification of research objectives. In the second phase, data analysis revealed 82 challenges (58 social, 14 economical, 10 environmental) in the adoption of SSCM. A preliminary survey was conducted in which respondents were asked to rate the importance of each challenge on a scale of 1 (extremely low impact) to 5 (extremely high impact). The collective score from the field and literature data was used to determine the final ranking of challenges. The top 30 factors were shortlisted (20 social, 5 economical, 5 environmental). The response rate for this survey was 30 (in numbers). According to Chan [57], a sample size of 30 or above is generally accepted, so this data includes respondents from Brazil, Morocco, Bangladesh, Qatar, Maldives, and Pakistan. Based on the preliminary survey, the field score was also calculated and then normalized.

A one-way ANOVA analysis was used to see if there were any statistically significant differences in values when evaluated through weighing ratios i.e., 40/60, 50/50, 30/70, etc. Obtaining a *p*-value of 1 between the combinations of different ratios proposed insignificant disparity. After ANOVA analysis, a 60/40 weighting distribution (60% Field, 40% Literature) was adopted in the third phase, and PARETO analysis was used to shortlist the factors having a 50% impact score [78,97]. The ranking of these factors along with the codes assigned is presented in Table 2.

Table 2. Shortlisting of factors having 50% impact.

Code	Challenges	60 R/40 L	Cumulative Score	Rank	Nature of Challenge
C1	Lack of top management commitment	0.0346	0.0346	1	Social
C2	Lack of training and education	0.0346	0.0692	2	Social
C26	Complexity to design, reuse, recycle product	0.0285	0.0977	3	Environmental
C21	Financial constraints	0.0285	0.1261	4	Economical
C3	Supply chain configuration	0.0224	0.1485	5	Social
C4	Organizational culture	0.0203	0.1688	6	Social
C5	Health and safety	0.0183	0.1871	7	Social
C6	Lack of awareness	0.0183	0.2054	8	Social
C7	Company policies	0.0183	0.2237	9	Social
C27	Environmental performance	0.0163	0.2400	10	Environmental
C8	Lack of trust	0.0163	0.2562	11	Social
C29	Less involvement in environmental related programs and meetings	0.0163	0.2725	12	Social
C23	High cost for waste disposal	0.0163	0.2888	13	Economical
C22	Return on investment	0.0163	0.3050	14	Economical
C9	Suppliers' top management commitment	0.0154	0.3204	15	Social
C10	Lack of resource (human)	0.0154	0.3359	16	Social
C11	Lack of corporate social responsibility	0.0142	0.3501	17	Social
C12	Child labor and forced labor	0.0142	0.3643	18	Social
C13	Stakeholder engagement	0.0142	0.3785	19	Social
C30	Product quality	0.0142	0.3928	20	Environmental
C14	Lack of awareness about reverse logistics	0.0130	0.4057	21	Social
C15	Discrimination	0.0122	0.4179	22	Social
C16	Human rights	0.0122	0.4301	23	Social
C17	Suppliers firm culture	0.0122	0.4423	24	Social
C20	Inadequate performance measurement	0.0122	0.4545	25	Social
C19	Lack of strategic planning	0.0122	0.4667	26	Social
C18	Gender inequality	0.0122	0.4789	27	Social
C28	Lack of government support to adopt environmental friendly policies	0.0122	0.4910	28	Environmental
C24	Product price	0.0122	0.5032	29	Economical
C25	Economic uncertainty	0.0122	0.5154	30	Economical

In this phase, interviews were conducted, in which industry professionals were asked about the existence of interrelationships among the identified challenges and, in addition, the polarity among these in phase 1. This resulted in 95 relationships, which helped in the development of the influence matrix. These professionals were asked about the root cause of each challenge in phase 3. A total of 24 relationships and 19 challenges (having interrelationships) were shortlisted that helped in the development of the CLD. A total of seven industry professionals were contacted in this phase. In this phase, expert opinion was acquired (for shortlisting interrelationships among challenges and determination of polarity) that helped in the development of the influence matrix shown in Figure 2. The value of 1 indicates that there is a positive relationship between the two challenges, whereas –1 indicates a negative relationship between them.

CODE	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30
C1		1	1	1	1	1	-1	1			-1				1				-1	1	1	1				1	-1			
C2	1			1		1	1	1											1	1						1		1		
C3	1	1		1	1	1	1	1			1				1				1	1		1				-1		1		
C4					1		1				1				1						1	1						-1		
C5												-1									1							-1		
C6		1	-1									1			1				1		1	1				1	-1			
C7				1							1				1											1	1			
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Figure 2. Influence matrix.

Based on 24 relationships, in the fourth phase, the next step was to determine the impact of one variable on another. This helped in the development of equations and functionalizing the SD model. This was accomplished using a bi-section questionnaire developed in Google® Docs [78]. The questions in the head section were about general information about the respondents, such as qualification, experience, job title, and so on. The second section is comprised of the Likert scale from 0 to 5, where 0 shows no impact and 5 shows a very high impact. The questionnaire survey was distributed to respondents in various developing countries via email, and professional networks such as LinkedIn. Over 1500 scholars and field personnel were contacted, yielding a total of 125 responses. The central limit theorem is often satisfied when the sample size is 30 or greater [57]. After the data were collected, they were arranged, and the responses were tested for consistency and reliability using simple statistical tools. The Cronbach's coefficient alpha technique was used to assess the data's reliability and consistency. The minimum acceptable value for Cronbach's alpha is 0.7 [98]. The data collected had a Cronbach's alpha value of 0.97, indicating that they were reliable and consistent.

3.2. *Survey Demographics*

The final survey demographic details are given in Table 3 and shown in Figures 3 and 4. A multitude of construction professionals were pursued, including construction managers, designers, site managers, assistant managers, and planning engineers, but the most responses were received from project managers (18%). A total of 43 respondents had more than 10 years of construction experience, indicating that 35% of the responses came from experienced professionals. Organization-wise, a total of 68% of responses were obtained from private firms and 24% of responses were obtained from semi-government firms, as shown in Figure 3. M.Sc. holders accounted for 43% of responses, while Ph.D. holders accounted for 9%, implying that highly skilled professionals accounted for 52% of all responses. BE graduates accounted for a respectable 42% of responses, although B. Tech holders accounted for just 6% of total responses. Most respondents hold high qualifications, which validate their opinion's credibility. Information on awareness about SSCM is important in the CI, and the findings reveal that more than 77% of respondents have a moderate to an exceptional understanding of SSCM.

Table 3. Data Demographics.

Profile	Frequency	Percentage
	Job Title	
CEO	5	4%
Project Director	6	5%
Project Manager	12	10%
Construction Manager	9	7%
Assistant Manager	12	10%
Project manager	22	18%
Planning Engineer	15	12%
Site Manager	4	3%
Architect/Designer	6	5%
University Professor	10	8%
Other	24	19%
	Years of Experience	
0–5	55	44%
6–10	27	22%
11–20	21	17%
>20	22	18%
	Qualification	
Diploma Holder	7	6%
Graduate	53	42%
Post-Graduate	54	43%
PhD	11	9%
	Understanding of SSCM	
No understanding at all	5	4%
Slight	24	19%
Moderate	77	62%
Exceptional	19	15%

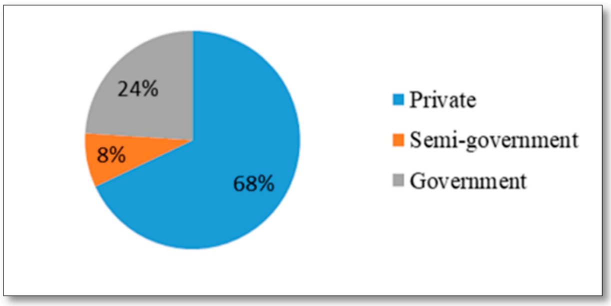

Figure 3. Organization type.

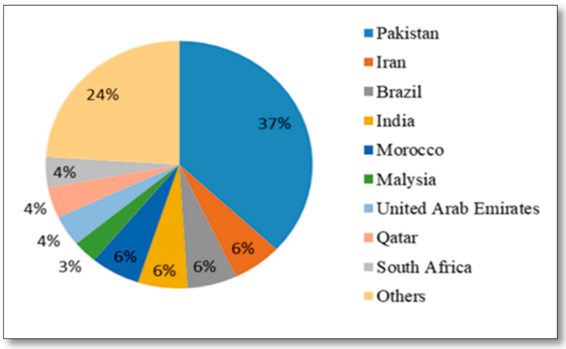

Figure 4. Regional distribution of respondents.

3.3. Regional Distribution of Responses

A total of 125 responses were obtained from 20 countries, as displayed in Figure 4. Responses were received from countries including Pakistan (37%), Brazil (6%), India (6%), Morocco (6%), UAE (4%), Qatar (4%), South Africa (4%), Malaysia (3%), and from other developing countries (24%). As the focus of the study was limited to developing countries, responses were received only from those countries.

3.4. System Dynamics Approach

A CLD is developed to determine the relationship among variables, balancing and reinforcing feedback loops in the holistic system [40,99]. In SD models, every pair of variables has a cause and effect, indicating that the variables can move in the same or opposite direction [100]. Polarities among links only predict what would happen if there is a change, they do not show the behavior of variables [101–104]. Tracing the variable's effects as they propagate around the loop determines polarity [40]. A reinforcing loop is represented by "R", which depicts actions that produce a result and then lead to more actions that produce more results in the identical direction, whereas a balancing loop is represented by "B", which generates the system's state in the opposite direction [104].

4. Results and Discussions

4.1. Causal Loop Diagram

The CLD was constructed based on interrelationships using VENSIM®. To endorse its importance and applicability to the CI, the CLD was developed based on expert opinions from construction personnel with over 15 + years of experience. The explanation of the CLD comprising of six loops, i.e., four reinforcing and two balancing, is given below:

4.1.1. Reinforcing Loop R1

Figure 5 shows if there is an increase in lack of top management commitment, there would be an increase in issues in the supply chain configuration leading to an increase in lack of training and education. This increase will lead to an increase in lack of awareness, which shows increased complexities to design, reuse, and recycle products that will lead to decreased environmental performance, showing an increase in the lack of government support for the adoption of environmentally friendly policies. This decrease would lead to an increase in health and safety issues, which leads to an increase in lack of top management commitment. Hence, this loop shows that lack of top management commitment reinforces various environmental and social challenges to SSCM adoption.

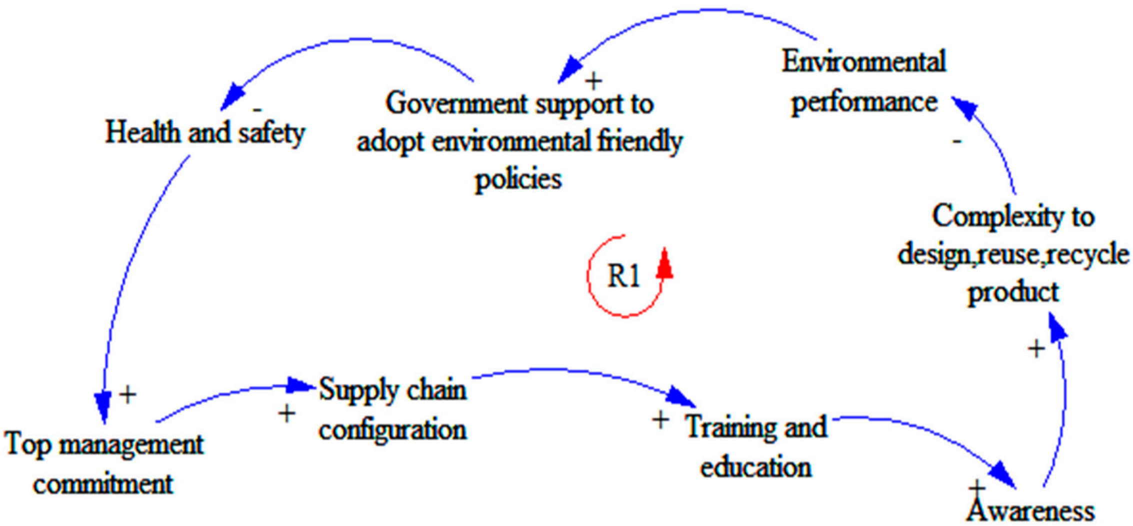

Figure 5. Reinforcing loop R1.

4.1.2. Reinforcing Loop R2

Figure 6 shows if there is an increase in lack of top management commitment, there would be an increase in issues in the supply chain configuration leading to an increase in lack of training and education. This increase will lead to an increase in lack of awareness, which will lead to an increase in lack of strategic planning that leads to an increase in inadequate performance measurement, due to which there would be an increase in lack of trust. This increase will lead to an increase in the lack of top management commitment. Hence, this loop shows that lack of top management commitment reinforces various social challenges to SSCM adoption.

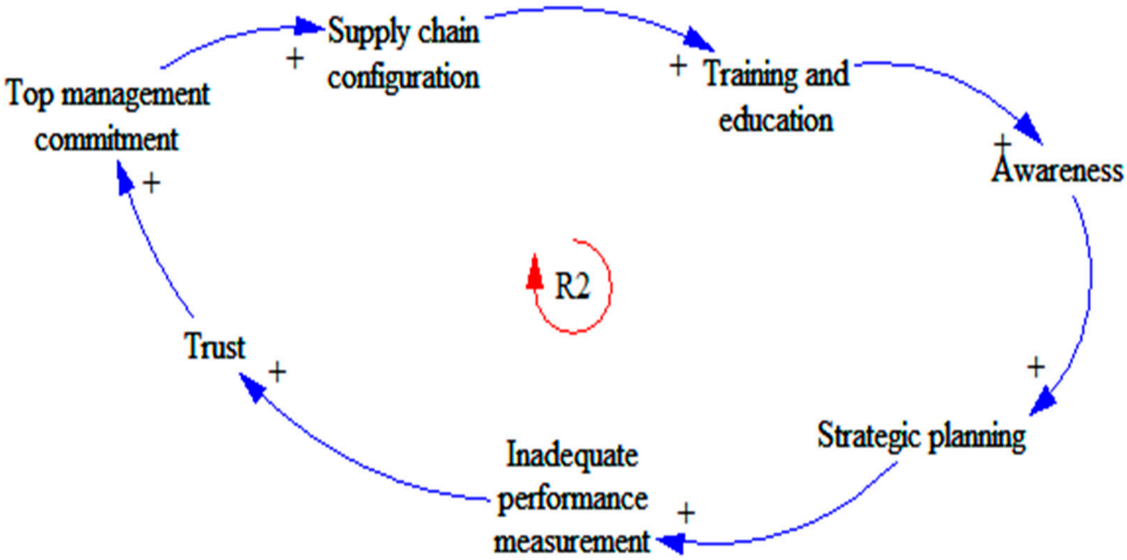

Figure 6. Reinforcing loop R2.

4.1.3. Reinforcing Loop R3

Figure 7 illustrates that an increase in lack of corporate social responsibility will lead to an increase in child labor and forced labor, which increases discrimination that again leads to an increase in lack of corporate social responsibility. Hence, this loop shows how the lack of corporate social responsibility can reinforce social issues such as child labor and discrimination.

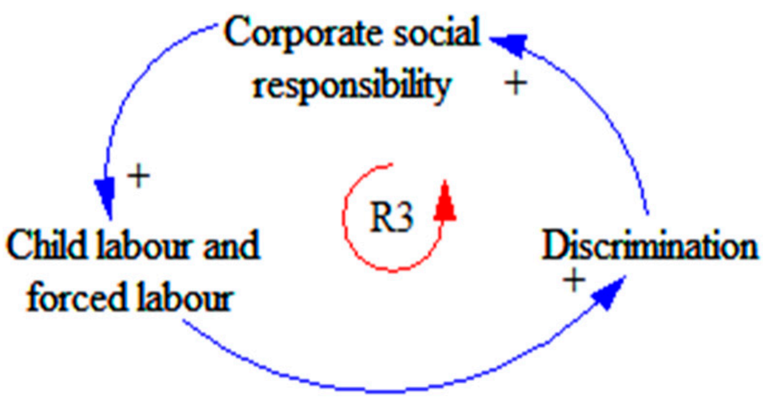

Figure 7. Reinforcing loop R3.

4.1.4. Reinforcing Loop R4

An increase in lack of top management commitment leads to an increase in financial constraints, which lead to an increase in child labor and forced labor (as shown in Figure 8). This increase leads to an increase in discrimination that leads to an increase in lack of corporate social responsibility, which again leads to an increase in lack of top management commitment. This loop elaborates on how social and financial challenges to SSCM adoption reinforce each other.

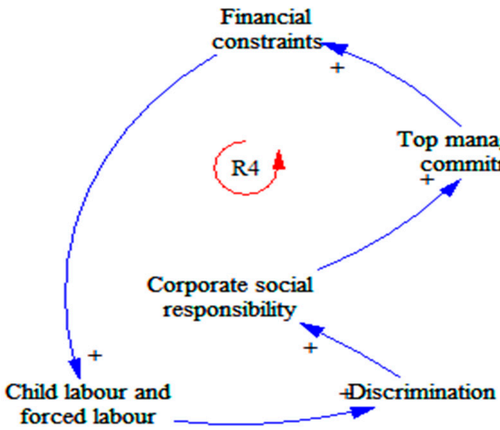

Figure 8. Reinforcing loop R4.

4.1.5. Balancing Loop B1

An increase in lack of top management commitment will lead to an increase in financial constraints, which promotes economic uncertainty (as shown in Figure 9). Increased economic uncertainty will lead to a decreased return on investment, which leads to an increase in lack of top management commitment. This loop elaborates the effect of top management commitment on economic challenges to SSCM adoption.

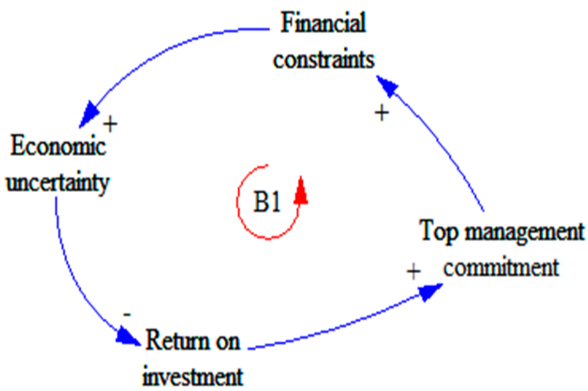

Figure 9. Balancing loop B1.

4.1.6. Balancing Loop B2

Considering balancing loop B2 (as shown in Figure 10), an increase in lack of top management commitment will lead to a decrease in company policies. This will lead to an increase in the deterioration of organizational culture, which leads to an increase in the lack of corporate social responsibility leading to an increase in lack of top management commitment. This loop explains the effect of social challenges on each other.

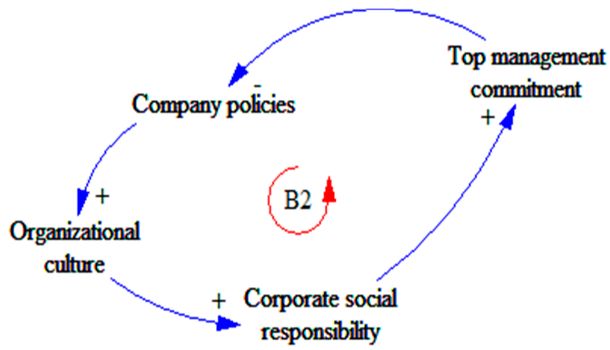

Figure 10. Balancing loop B2.

Figure 11 is a consolidated diagram of all loops. The CLD has been fed into the SD model.

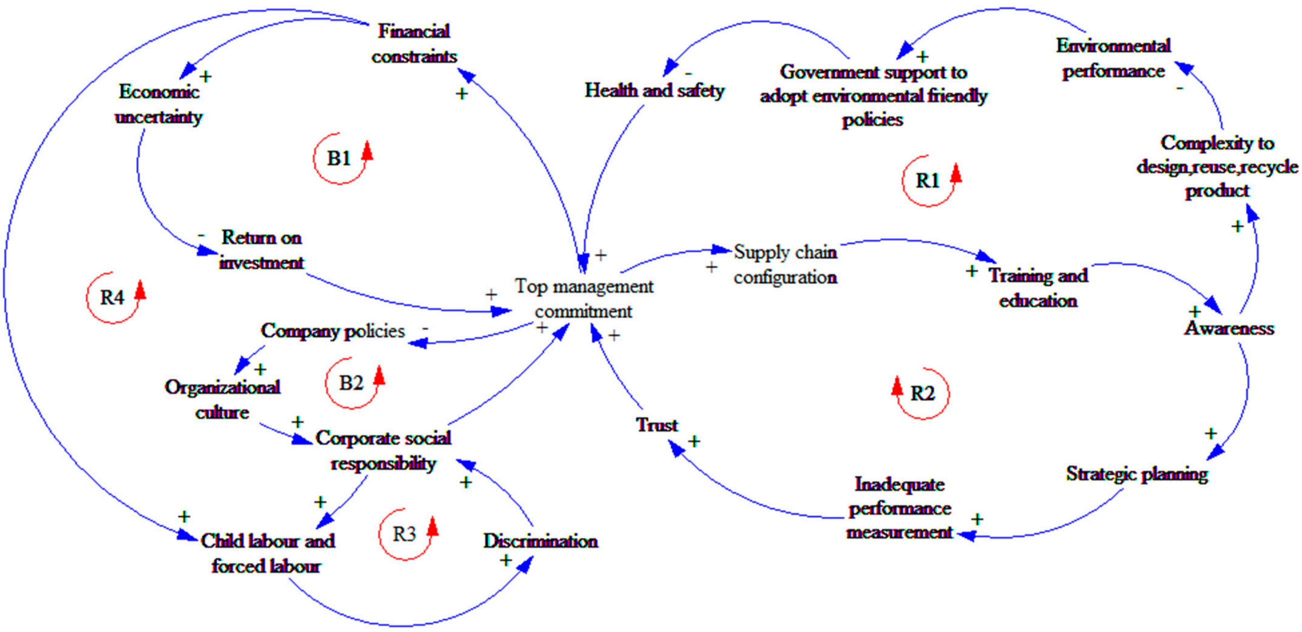

Figure 11. Feedback causal loop diagram.

4.2. System Dynamics Model

The SD model was generated from CLD using VENSIM® [105] shown in Figure 12 below. The model consists of three stocks, including "Top management commitment", "Corporate social responsibility", and "Project performance", governed by inflows and outflows. The top management commitment and corporate social responsibility were selected as stocks, as they were showing accumulation since these were the two challenges that were having most of the interrelationships with the other challenges. Thus, they are showing the combined effect of variables in connection with them, influencing the project performance, which is an additional stock created to represent the cumulative effect of all stocks. The data collected in the final survey also helped in the development of equations in the model.

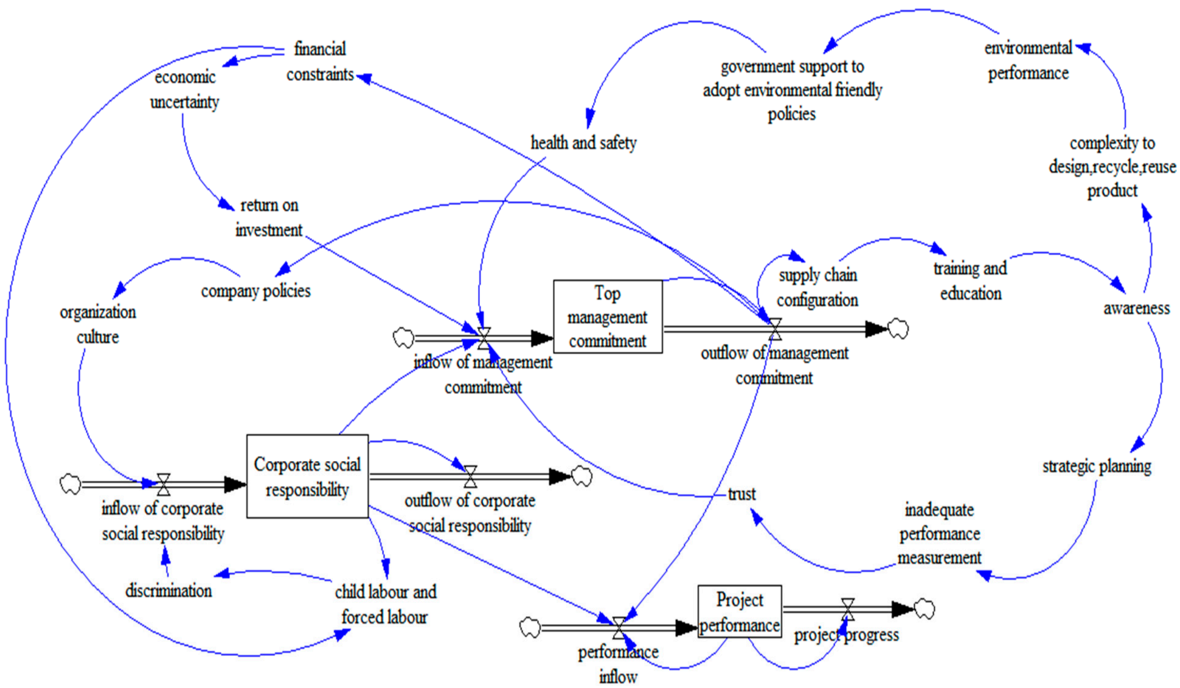

Figure 12. Quantitative SD Model.

4.3. Simulation Results and Discussion

The simulation represents the behavior over a time of 5 years. The decrease in the curve of the simulation graph in Figure 13 with time shows how various endogenous variables (such as discrimination, company policies, child labor, forced labor, etc.) affect the corporate social responsibility (which is the company's assurance to responsibly manage the social, environmental, and economic effects of its operations per consumer demands). The presence of these challenges reduces the performance, due to which delays, and cost overruns are seen.

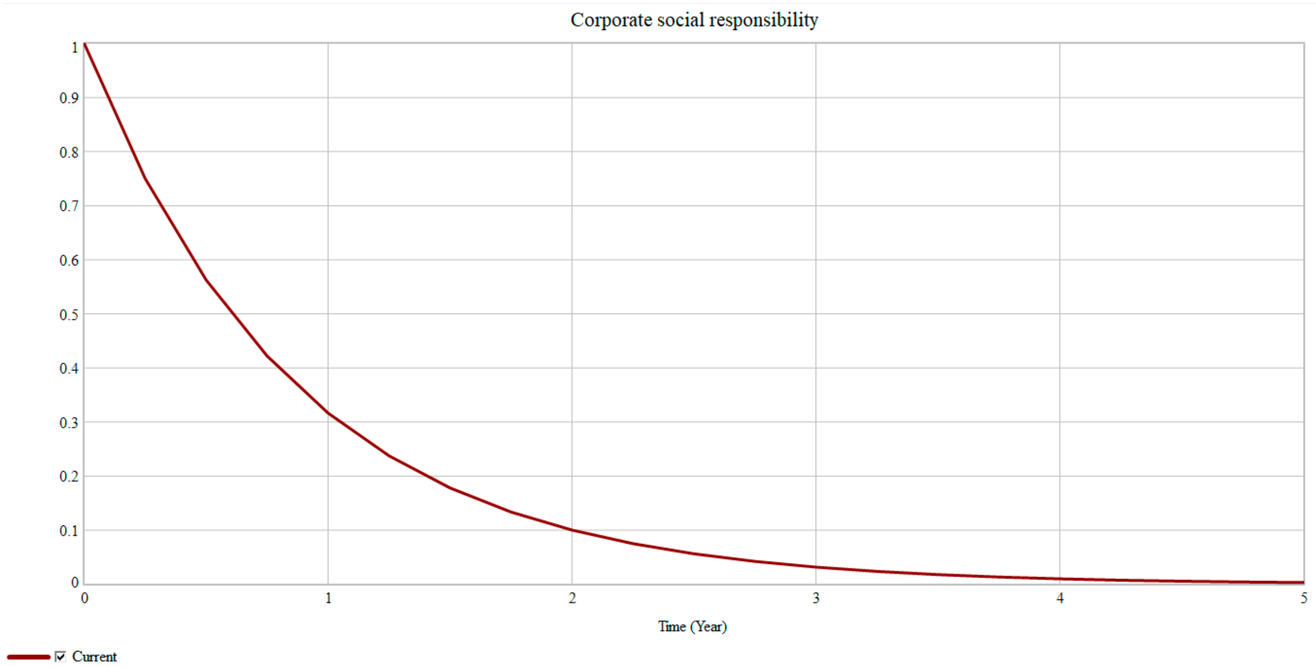

Figure 13. Simulation graph (corporate social responsibility).

The decrease in the curve of the simulation graph in Figure 14 with time shows how various endogenous variables (such as supply chain configuration, lack of trust, financial constraints, return on investment, etc.) affect the top management commitment, i.e., due to how these variables' different problems, such as lack of communication and coordination, different cost, and time overruns, are seen, which imparts a negative impact on project performance.

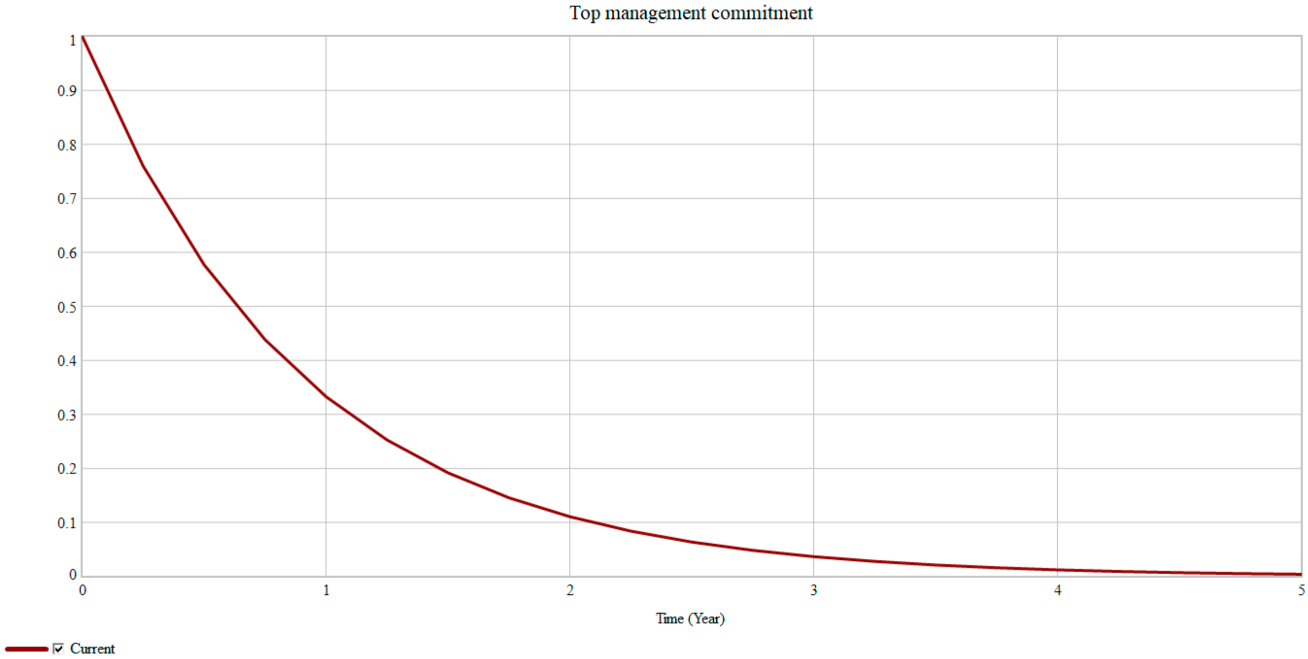

Figure 14. Simulation Graph (top management commitment).

The simulation graph in Figure 15 signifies that due to a decrease in corporate social responsibility and top management commitment, project performance gradually decreases.

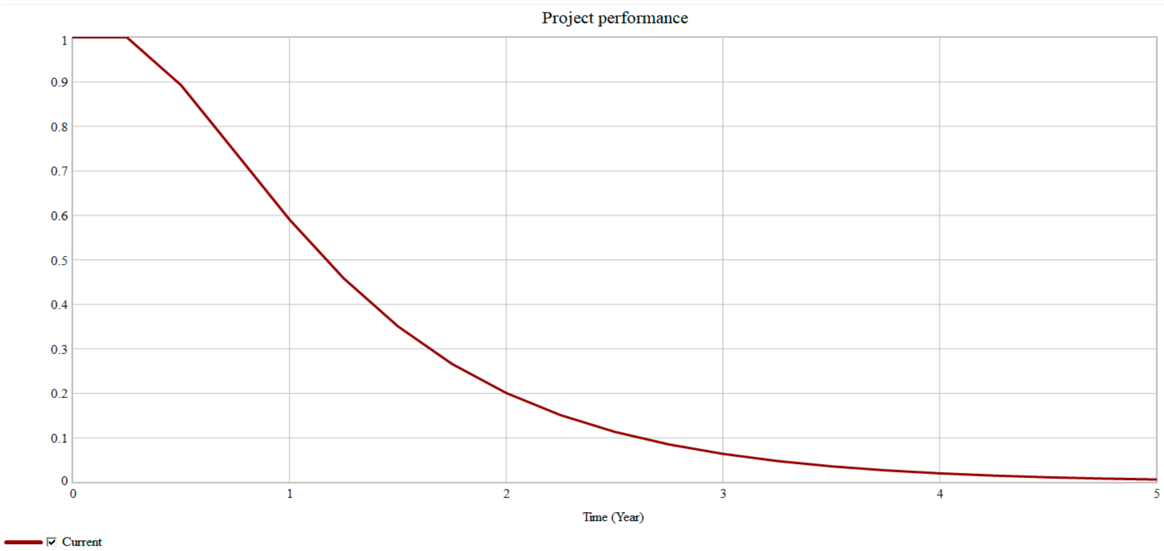

Figure 15. Simulation graph (project performance).

The overall simulation results shown in Figure 16 predict that due to a decrease in corporate social responsibility there would be a decrease in top management commitment, which affects the performance of the project, decreasing gradually until it decreases to a minimum level, i.e., zero. This implies that there is a need to improve numerous factors, in particular, corporate social responsibility and top management commitment, which would lead to the adoption of SSCM leading to performance improvement of the CI.

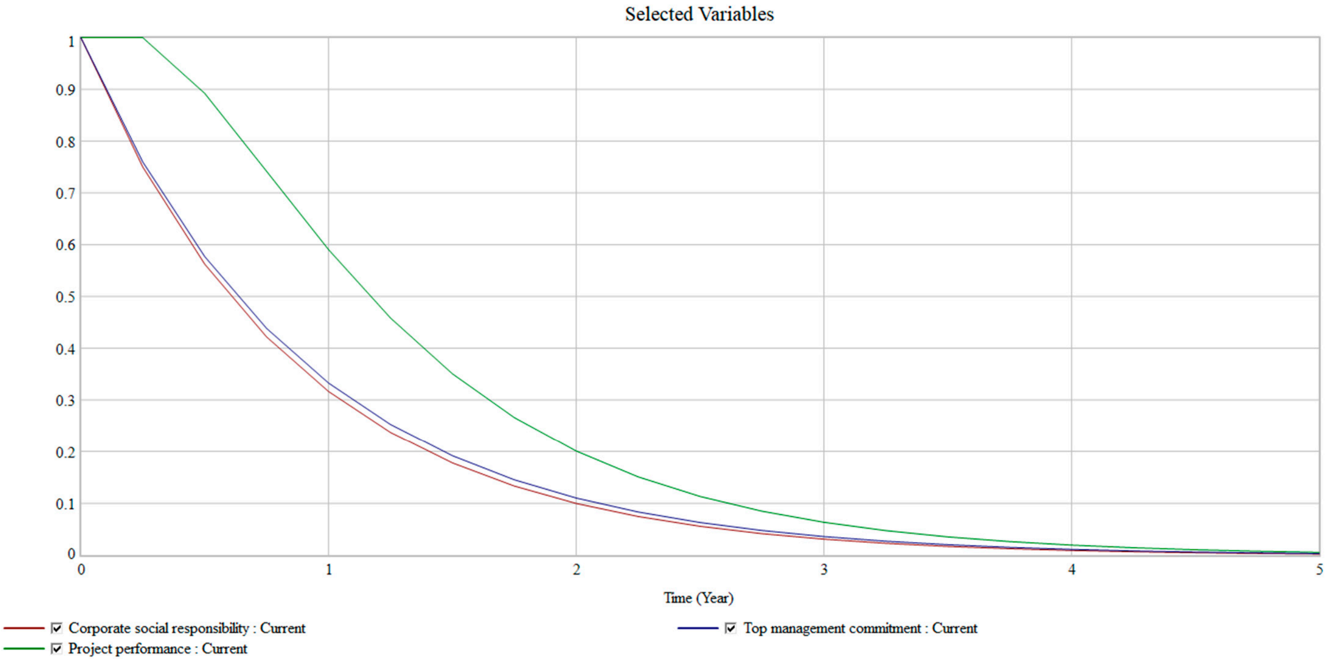

Figure 16. Simulation graph (combined).

4.4. Model Validation

An SD model addresses a specific issue rather than a general issue, and the confidence in using the model to help analyze a specific problem should not be based on whether the model can solve other problems [106,107]. In this regard, the model validity depends on the purpose for which the model is developed [102]. The essence of the developed SD model is to help address complexities in the adoption of SSCM in the CI. Therefore, the validation of model structure is the first step of validating the SD model [108]. Qudrat-Ullah and Seong [109] listed the following three tests for checking the structural soundness of an SD model.

4.4.1. Boundary Adequacy Test

Sterman [102] articulated the purpose of the boundary adequacy test is to check whether all the core concepts in tackling the issue are endogenous to the model and whether the model's behavior changes substantially when boundary assumptions are relaxed. All the challenges are endogenous, such as supply chain configuration, health, and safety, financial constraints, and discrimination, contributing to SSCM. After analyzing all the variables in the SD model, it is obvious that every single one is important, as all of them have been reported in the literature as causing barriers to SSCM adoption.

4.4.2. Structure Verification Test

The objective of the structural verification test is to see whether the model structure matches the descriptive information that was used in the model [110]. The developed CLD is based on variables identified from the literature, and then field professionals are provided with the influencing interrelations amongst all variables. Therefore, the model's structure is realistic and closely reflects the real industry system. So, this is in line with the methodology trialed by Qudrat-Ullah and Seong [109].

4.4.3. Parametric Verification Test

The mathematical functions developed to link the variables are based on responses from field experts that ensure empirical and theoretical foundations as well as the model verifies parametric verification test. Hence, the model was validated by the aforementioned tests, was validated by taking expert opinions from a total of 12 industry professionals and is in line with the methodology followed by Qudrat-Ullah and Seong [109].

5. Conclusions and Implications

SSCM assists the establishment of well-coordinated supply chains by combining economic, economic, and social factors with strategic inter-organizational business processes that efficiently manage content, knowledge, and resources to meet the stakeholders' needs. The nature of the CI is such that it does not support a coherent supply chain. The supply chain consists of stakeholders such as clients, consultants, and contractors that are mostly working in silos, in particular, the CI of developing countries. There are a lot of issues associated with the supply chain including environmental, social, and economic constraints. There exists a huge challenge, creating complexity, in terms of the adoption of SSCM in the CI, in particular, of developing countries. SD has been adopted to address the complexity in terms of the adoption of SSCM in the CI of developing countries, which has resulted in the development of a CLD and an SD model. The methodology of this study is its novelty, as it is the first research on addressing challenges causing complexity in the adoption of SSCM in the CI.

A total of 82 challenges were extracted from the literature. Data were later collected from the industry on the extracted challenges, to present the industry trends about their perceived criticality in view of various developing countries. After combining the industry and literature scores, using Pareto analysis the top 30 challenges were incorporated into the influence matrix. Out of 95 relationships, field experts confirmed 24 relationships (among 19 challenges), which were then used to develop a CLD depicting a clear picture of interconnections among the identified challenges. The developed CLD comprises IV reinforcing and II balancing loops, which further led to the development of the SD Model. The developed model shows the effect of challenges on "Top Management Commitment" and "Corporate Social Responsibility", which eventually impart an effect on the performance of the project. The simulation results predict that due to the lack of top management commitment and lack of corporate social responsibility, project performance decreased gradually to zero after a certain period. Thus, if top management commitment and corporate social responsibility are addressed, then project performance would improve, as these are the two challenges having most of the interrelationships.

The research findings will help the practitioners to adopt sustainability principles in terms of the supply chain and will not only enhance productivity and performance but also help minimize delays, promote long-term relations, and reduce communication gaps and project complexities. The SD approach is recommended for CI practitioners as it helps to deal with the complexity issues.

No similar work with the current study using system dynamics methodology has been published yet. Therefore, this methodology is the novelty of the study as it is the first study addressing complexity in the adoption of the sustainable supply chain management in the construction industry.

5.1. Theoretical Contribution

The study findings provide pragmatic suggestions for improving the CI's performance. It is the first attempt to study the complexity in the adoption of sustainable supply chain management in the CI. This study has added to the existing literature by identifying the challenges in the adoption of SSCM, bridging the research gap articulated by Galal [10], who suggested that there is a need to address the complexity quantitatively in the adoption of SSCM.

5.2. Managerial Contribution

From the perspective of managers and practitioners, the study findings indicate that that the lack of top management commitment and corporate social responsibility adversely affects project performance. This implies that there is a need to improve numerous factors, in particular, corporate social responsibility and top management commitment that would lead to the adoption of SSCM leading to performance improvement of the CI. The research findings will help the construction industry's practitioners to adopt sustainability principles at all levels in terms of the supply chain and to enhance the productivity and performance of this sector. This will ultimately help minimize delays, promote long-term relationships, and reduce communication gaps and project complexities.

6. Limitations and Future Research

The SD approach is recommended for CI practitioners as it helps to deal with complexity issues. Discussing the limitation of the study, one of the limitations is the inclusion of respondents only from developing countries. A further study could be more useful if it involves participants from the developed world. A further study may be directed towards the application of the developed model in the CI. Further research investigating the fourth pillar of sustainability, Culture, will help to develop more understanding among various supply chain stakeholders.

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