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Article

Decoding Social Sustainability in Construction Projects: Analysis of Project Dynamics and Impact

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Abstract: Sustainable development (SD) is of prime importance in the present world, where resources are depleting fast and causing conflicts among nations to control essential resources. Since the construction industry (CI) consumes most of these resources, Construction Sustainability (CS) is a key focus of SD. Among the three pillars of sustainability, i.e., economic, environmental, and social, the first two have been amply addressed by researchers. However, the social aspects have been neglected or under-researched so far. The current research humbly attempts to fill this gap. Accordingly, a System Dynamics Model (SDM) has been developed to address this issue. After a comprehensive literature review, questionnaire survey, content analysis, and gathering the opinions of ten experts from CI, 11 key factors of social CS were identified. Using the system thinking approach, a causal loop diagram (CLD) was developed to assess the intensity and polarity of these factors. The CLD encompassed eight reinforcing loops and one balancing loop. Based on the CLD, an SDM was developed and simulated over 3 years. Primarily, the SDM had two stocks: "Government support for sustainable construction" and "Stakeholder awareness and knowledge". An additional stock named "Construction Sustainability" was added to observe the combined effect of the system. The results showed that CS increased over time. The CLD and resulting SDM help in understanding the complex interaction of the social CS factors and thereby addressing the associated complexity of the effects of these varied factors on a project. Such knowledge can be valuable for anyone dealing with projects where social factors play a significant role. The proposed SDM provides a structured approach to understanding and visualizing the intricate relationships and feedback loops within a social system, aiding in more effective decision making and problem solving.

Keywords: causal loop diagram; construction sustainability; social sustainability; sustainable development; system dynamics

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1. Introduction

Global resources are depleting fast; thus, the focus on sustainable development (SD) has increased manifold recently. This has led to debates and dialogues between the different disciplines addressing nature and society, paving the way towards holistic SD [1]. During the World Summit for SD held in Johannesburg in September 2002, the importance of the construction industry (CI) was stressed as a critical enabler of SD. The CI is a significant consumer of global resources. The contribution of buildings alone is between 20% and 40% towards global energy consumption; such a big ratio cannot remain unnoticed [2]. Therefore, it is imperative that Construction Sustainability (CS) or sustainability in construction is made a key focus of modern studies. A broader concept of CS includes environmental, economic, social, and cultural aspects [3]. CS focuses on the integration of social equity, economic efficiency, and cultural diversity [4]. Neglecting social sustainability factors in the CI can contribute to difficulties in project completion. A lack of attention to aspects such as community engagement, social equity, and stakeholder involvement may lead to dissatisfaction and resistance from the community, ultimately impacting the project's success. Failure to consider social sustainability factors in construction projects can hinder timely project completion. This often renders sustainability assessment frameworks ineffective as they fail to align with community needs.

CS is not limited to energy consumption and covers a wide spectrum. CS reduces the wastage of resources such as wood, steel, concrete, etc., through recycling and reusing [5]. As part of CS, effective waste management minimizes its negative environmental impact by reducing, recycling, and properly disposing of waste [6]. Cleaner technologies and sustainable designs are used to tackle air and water pollution caused by greenhouse gas emissions and other pollutants [7]. CS also leverages water-efficient practices to reduce water wastage during construction works. Different methods, such as harvesting rainwater, water-saving fixtures recycling, etc., are used for this purpose [8]. From the above, we can see that the application of Construction Sustainability goes way beyond energy consumption and provides a holistic view to achieving CS.

Åsa Casula Vifell [9] expressed that among the three commonly accepted pillars of SD, the social dimension is often the most imprecise in terms of CS. Hilger [10] argued that while working on a project, people focus more on the environmental and economic aspects of the project as far as sustainability is concerned and often neglect or fail to consider the social side of it. With the changing requirements of the present world, CS frameworks prepared by developed countries needs to be tailored with reference to the social system of the target country. This is because the social aspects included in the current frameworks are not in line with the traditions and social environment of many developing countries [11,12].

While undertaking projects in the sustainability domain, emphasizing the environmental and economic aspects is very important. However, neglecting or giving less importance to the social dimension puts the project at risk, which may compromise its successful completion. Social factors are not given much attention in the planning phase. They are also challenging to manage as they are qualitative, and measuring their impact or intensity is strenuous. However, such factors can stall any project's progress if mismanaged. Social elements place a human-centric focus on sustainability, recognizing that the well-being and empowerment of people are essential for sustainable development [13].

Projects are undertaken in communities with diverse perspectives, needs, and concerns. To gain community support, addressing their concerns and looking after their needs is imperative to ensure smoother delivery of the projects. This can be achieved only when the community's social issues are properly understood and catered to [14].

Planners should be able to understand the culture, values, and norms of the community and plan the project to align with the above aspects to create goodwill for the project among the community. Researching social elements allows for identifying and mitigating such risks, promoting smoother project implementation, and minimizing adverse consequences [15].

Effective policymaking and planning necessitate a deeper insight into society's social issues where the project is being undertaken to mitigate the risks and achieve CS. While there has been a global surge in research on the social aspects of sustainability, investigations on CS are still lacking in developing countries, forcing us to focus this study on developing countries [16].

Social sustainability in construction refers to the fair and equitable treatment of individuals and communities affected by construction activities, ensuring their participation, access to resources, and protection of their rights [17]. Kibert defines CS as "Social sustainability in construction encompasses the development of inclusive, safe, and supportive built environments that enhance the quality of life for present and future generations.

It fosters community engagement, promotes social justice, and addresses stakeholders' diverse needs and aspirations" [18].

If social sustainability factors are not researched, several consequences can occur, severely putting the project at risk for completion, thus creating a hurdle for CS. Suppose social inequalities arise in a community where a project is being undertaken. In that case, they will negatively impact the project's CS as the community will resist the project and cause opposition to the activities to be undertaken for the project [13].

Different stakeholders are involved in projects, so it is important to understand the social issues related to all the stakeholders and create harmony among them to successfully complete the project, leading to CS. With a complete understanding of the stakeholders' social issues, it is easier to ensure an equal distribution of benefits and reduce the differences among the stakeholders. In return, the project team can gain stakeholders' support and engage them effectively to enhance the chances of successful project completion and achieving CS.

Different studies have been carried out to address this issue; however, these studies lack one or more aspects. For example, a holistic approach (such as systems thinking) for addressing the complexity of social factors has not been leveraged so far. The cause-and-effect approach is also missing in these studies to interpret the effects of social factors on other project aspects. These studies also lack the future projection to predict the influence of social factors on CS. For this reason, we are looking into the social factors that are related to sustainable construction and are causing a break into the mass implementation of sustainable construction, which brings us to the primary research questions that are required to be addressed to achieve social sustainability in the construction industry:

1. What are the key social factors that significantly influence Construction Sustainability (CS) in developing countries?
2. What causal relationships exist among the identified social factors affecting CS in developing countries?
3. How can a System Dynamics Model (SDM) be developed to capture the complexity of implementing CS, focusing on the social aspects?

Accordingly, a research gap is evident that has been targeted in the current study. The aim is to provide a holistic study on the effects of social factors on CS by using system dynamics to deal with the complex relationships among these factors. Accordingly, this study has the following objectives:

1. To identify and list the key social factors affecting CS in developing countries.
2. To determine the causality among identified factors and their interconnectivity and develop a CLD to apprehend the causes and effects.
3. To develop an SDM to address the complexity in the implementation of CS with a focus on the social aspect.

Overall, this study adopts the system thinking (ST) approach to deal with the complexities related to the social CS factors. PRISMA (Preferred Reporting Items for Systematic reviews and meta-Analyses) [19] is used to conduct a systematic literature review for retrieving relevant CS factors. Pertinent social factors were extracted from the literature that were ranked and statistically analyzed using a preliminary questionnaire shared through Google Docs with the thirty CI respondents from developing countries. A detailed questionnaire was then shared with these respondents to determine the influence of these factors on each other and formulate relationships, a polarity matrix, and a causal loop diagram (CLD). Subsequently, an SDM was prepared using the Vensim 7.0 software. System dynamics has been used in several different complex problem-solving issues [20]. It can manage the complex interrelationships and loops of different components of any relevant system [21]. This modeling approach enhances our understanding of the dynamic nature of social factors, contributing to a more comprehensive analysis of their impact on the overall project, which in turn helps in addressing the hurdles in the project execution.

The novelty of this study lies in its integration of the ST approach and PRISMA methodology and the application of advanced SDM tools within the context of developing countries. While previous research has often overlooked the unique challenges faced by projects in such regions, the current study specifically focuses on understanding and addressing complexities related to social CS factors within the CI of developing countries.

By adopting the ST approach, we transcend traditional linear thinking and delve into the intricate web of interactions characterizing social systems. The use of PRISMA ensures a rigorous and systematic review of the literature, focusing on developing countries to extract pertinent social CS factors. An in-depth statistical analysis and the ranking of these factors through a tailored questionnaire, involving thirty respondents from developing countries, add further to the contribution of the current study. This not only provides a robust foundation for subsequent modeling but also captures the nuances specific to developing regions. Few studies delve into such granular levels of analysis, especially within the context of developing countries. Our approach aims to unravel the intricate interplay of social CS factors, offering a comprehensive understanding of their influences on each other. The introduction of SDM, implemented through Vensim version 7.0 software, adds another dimension to the current study. While system dynamics has been applied in complex problem-solving scenarios [11], its application in the realm of CS in developing countries, particularly in addressing hurdles within project execution, is less explored. This modeling approach not only enhances our understanding of the dynamic nature of social factors but also contributes to a more nuanced analysis of their impact on overall project outcomes.

This study is divided into 5 sections; it starts with a literature review in Section 2 leading to the research methodology in Section 3. In Section 4, the results and discussion are incorporated. Finally, Section 5 includes the conclusion of this study.

2. Literature Review

2.1. Sustainable Development and Construction Sustainability

SD is enabled when society can express all its requirements and be involved in decision making. This compels everyone to act responsibly, fairly, effectively, sensitively, and with a view to long-term development (FIDIC 2012). The World Commission on Environment and Developments (Oxford University Press, 1987) expressed that SD can be achieved when people are able to satisfy their aspirations for a better life. Further, all their basic needs can be met without compromising the ability of future generations to leverage resources. Researchers have identified that project planners mainly focus on the economic and environmental parameters, often neglecting the social aspects affecting CS [22–25]. However, this must change if the aim is to achieve CS in line with the global sustainability initiatives and the United Nation's Sustainable Development Goals (UN-SDGs).

2.2. Stakeholders Involvement

Knight and Pearce [26] highlighted that different stakeholders are involved in construction projects with a range of requirements. These stakeholders are affected positively and negatively during project execution. Rohracher [27] explained that when working on the design of a project, it is very important to understand the social interrelations that are deeply rooted in the designing, constructing, and operating processes of the construction project. The decision-making process can be improved by adopting transparency involving all relevant stakeholders and data sharing between these stakeholders. Further, due weightage must be assigned to the social factors involving all the stakeholders of the project to achieve holistic CS [28].

2.3. Social Aspects in Construction Sustainability

Social factors can have a significant impact on CS, as the way people interact with buildings and their environment can influence the demand for CS practices, materials, and designs. As the public becomes more aware of the environmental impact of construction, demand for sustainable practices in the industry is increased. Education and training of construction workers and professionals can affect the adoption of sustainable practices [29]. To change the industry procedures from a linear to circular approach, it is imperative that all stakeholders work collectively and are taken on board in decision making [30]. Collaboration and engagement with local communities can help construction companies identify sustainability priorities and incorporate them into their projects.

Cultural factors such as values, beliefs, and traditions influence CS practices. For instance, communities that prioritize environmental sustainability may place a greater emphasis on building practices that are eco-friendly. Similarly, construction projects should respect cultural heritage and protect historical sites. Incorporating cultural heritage preservation into construction projects can help build sustainable relationships with local communities. By promoting diversity and inclusion, construction firms can attract a broader pool of talent, bring different perspectives and experiences to projects, and create a more welcoming and equitable work environment. Sourcing materials locally also positively impacts CS by reducing transportation emissions and supporting local businesses. By working with local communities, environmental groups, and other stakeholders, construction companies can better understand their concerns and incorporate their feedback into their projects. Similarly, cultural values and beliefs also influence CS. For example, in some cultures, there is a strong emphasis on preserving natural resources or minimizing waste, which can lead to more CS practices. Ensuring that a building or infrastructure project is accessible to people with disabilities and the elderly also contributes to social CS. Multiple studies have expressed social CS as a methodological way to promote safety and well-being in society [31,32].

2.4. Wide Spectrum of Social Sustainability

Social CS is a vast subject that covers a wide spectrum of issues ranging from safety requirements to physiological and psychological issues [33]. A framework was established for the assessment of social CS in residential buildings in Pakistan, highlighting the importance of social factors in attaining Construction Sustainability [34]. Valdes-Vasquez and Klotz [35] also presented a framework for the social considerations in construction projects to achieve CS. Alyami and Rezgui [36] developed a social assessment framework for residential buildings in Saudi Arabia. The social CS of the urban infrastructure was assessed by developing the indicators in Iran in another study [37].

Sierra [38] reviewed the current state of multi-criteria infrastructure assessment studies that included social aspects. The authors identified common CS criteria used in the assessment methods regarding infrastructure: mobility and accessibility, safety, identity and cohesion, etc. Atanda [39] leveraged literature review and empirical studies to develop a conceptual framework for analyzing CS in building projects. The most common social issues included privacy, indoor environment quality, health, social participation, safety, security, accessibility, identity, physical resilience, satisfaction, and cultural values. Moreover, recent social CS assessment frameworks of developing countries highlighted by relevant studies mostly include cultural heritage, open space, health and wellbeing, satisfaction, privacy, etc. [40].

Social CS can be attained by amalgamating physical design with the social infrastructure and encouraging citizen participation [41]. A. Lindman [42] explained the Global Reporting Initiative for social sustainability to include labor practices, human rights, decent work, and society's responsibility to attain SD. Behm [43] emphasized construction safety and suggested the collaboration of architects and design engineers from the start of the design process to address the hazards during construction activities and achieve CS. Labuschagne and Brent [44] emphasized professional ethics as one of the most important social factors in achieving CS. Toole and Carpenter [45] proposed developing procedures for dealing with disadvantaged, distant, and future people to achieve social CS.

One of the main factors in achieving social CS is the stakeholders' engagement as indicated by many researchers [44]. While dealing with the other social factors, the opinions of community groups must be taken on board as it can cause undue delays if their demands or concerns are not addressed properly [46]. The global definition of social sustainability highlights gathering and addressing the needs of all the stakeholders involved in a project [47]. Bramley and Dempsey [47] highlighted the inclusion of the sustainability of a community and the equity of access in CS. Hammer [48], emphasizing the social CS, stated that the profitability, productivity, and morale of a team are badly affected by any accident occurring on the site due to negligence of the safety protocols. Diversity, employment, health, safety, community involvement, education, and training are some social CS factors indicated by relevant studies [49,50]. CS must also include the perspective of underrepresented groups, e.g., accessibility for elderly and disabled people, to make the design more acceptable and usable by all. Involvement of key stakeholders in the planning and designing phases is important. During the process of design decisions, public hearings may be conducted by the stakeholders and government agencies to inform local people of the project [42–44].

2.5. Complexity and Social Construction Sustainability

Assessing the social CS factors is a challenging task. Social CS factors are often complex, multifaceted, and difficult to quantify. These factors are often qualitative, making it hard to develop standardized metrics to measure them. Additionally, social CS factors are often context-specific, and may not be applicable in all cases. Hence, it is not straightforward to indicate, select, and measure the social indicators compared to the environmental and economic indicators to achieve CS [25,51].

2.6. System Dynamics and Social Construction Sustainability

Forrester introduced SD in 1961. Since then, it has been used in addressing several complex problems [20]. SD can model the complex interrelationships and loops of different components of any relevant system [21]. SD is a reliable methodology to help researchers solve complex systems by using a series of instinctive tools, such as CLDs and stock and flow diagrams.

As evident from previous discussions, social factors affecting CS are complex. Further quantification of the effects of social factors on CS is tricky. Due to this complex nature, a methodology with an inherent ability to address complex issues with multiple dimensions and effects is needed. SD emerges as one such method that is leveraged in this study. To address the complexities of social CS, SDM is developed and used to achieve the following:

1. Identify and analyze the feedback loops of the social factors affecting CS.
2. Develop and understand the cause-and-effect relationships of social CS factors.
3. Understand the nonlinear dynamics and complex relationships of the variables in the system.
4. Evaluate the long-term impacts of policies and interventions to address the social CS.
5. Identify potential trade-offs and unintended consequences of the social factors.
6. Formulate a mathematical representation of the system and simulate its behavior over time.

A range of software is available for developing SDMs. These include Stella Professional 10.0, AnyLogic 8.8.6, Vensim 7.0, and iThink 9.0. This study uses Vensim 7.0 ® for the development of the CLD and the associated SDM.

3. Methodology

This research analyzes the influence of social factors on CS and consequently develops an SDM for pertinent simulations. For this purpose, the research has been divided into 5 stages, as shown in Figure 1. In stage 1, after the literature review, a research gap was identified, leading to the formulation of research objectives. In stage 2, social factors were identified, and a content analysis was performed to prioritize these factors. In stage 3, an influence matrix was prepared, which led to the development of CLD. In stage 4, an SDM was prepared. In stage 5, results and discussion are presented followed by the conclusions and recommendations.

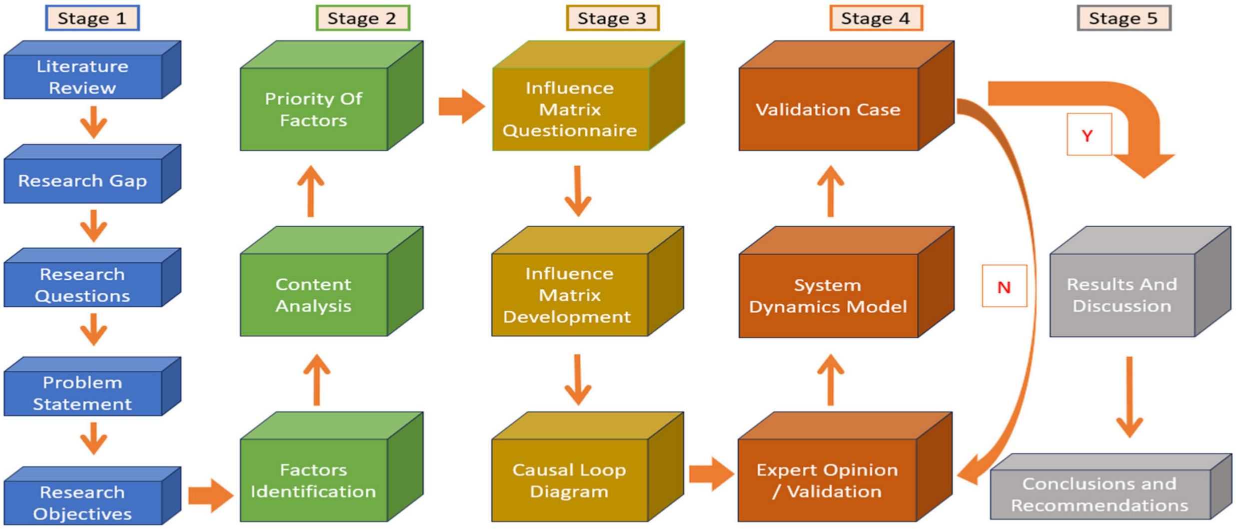


Figure 1. Research methodology flowchart.

3.1. Literature Analysis and Systematic Review (PRISMA)

A systematic literature review was carried out to determine the research gap, leading to the formation of research questions and objectives. For literature retrieval, different platforms such as Web of Science, Scopus, American Society of Civil Engineers, Elsevier-Science Direct, and Google Scholar were used to study articles published from 2001 and onwards [52,53]. Also, Boolean operators like "AND" and "OR" along with parentheses were used as conjunctions to combine keywords in the search, resulting in more focused and productive results and eliminating inappropriate articles that were not related to our field of interest. The strings used for the research of journals were (("complex system model" OR "System dynamic model") AND ("social aspect of sustainable construction" OR "social sustainability")) AND (("construction industry" OR "construction project")).

Based on the research gap and questions, research objectives were formed, completing stage 1 of the research. Retrieval and evaluation of the papers were carried out using the PRISMA (Preferred Reporting Items for Systematic reviews and meta-Analyses) technique [19,54]. Figure 2 shows the PRISMA diagram for the systematic literature review conducted in this study. The inclusion criteria for the articles included that the keywords were in the title, the keywords section, or the abstract of the paper and that the paper was published in a scientific peer-reviewed journal. Accordingly, exclusion criteria included review articles, conference proceedings, editorial letters, non-English papers, and papers that were not aligned with the primary focus of this research. A total of 178 articles were analyzed, which were reduced to 72 articles based on the mentioned inclusion and exclusion criteria.

The reduction in the number of journals from the initial pool of 178 to the final selection of 64 occurred after a rigorous screening process following Ullah et al.'s method [55]. The initial search gave a broader range of journals, including articles that, upon closer examination, did not align closely with the research focus of pointing out social factors affecting CS and system dynamics applications to resolve the issues. It is not uncommon to initially encounter a higher number of potentially irrelevant articles. However, in a well-refined screening process, more strict criteria are applied to focus on the social factors and system dynamics application, eventually reducing the number of relevant articles [56]. Despite rejecting irrelevant journals at the outset, further screening revealed additional articles that did not elaborate on the search objective to give specific information on social factors aligned with the study. In such articles, the importance of social factors was generally emphasized. Still, more focus was placed on the economic and environmental aspects. Hence, these were rejected as well. These were then used to extract the social CS factors for this research.

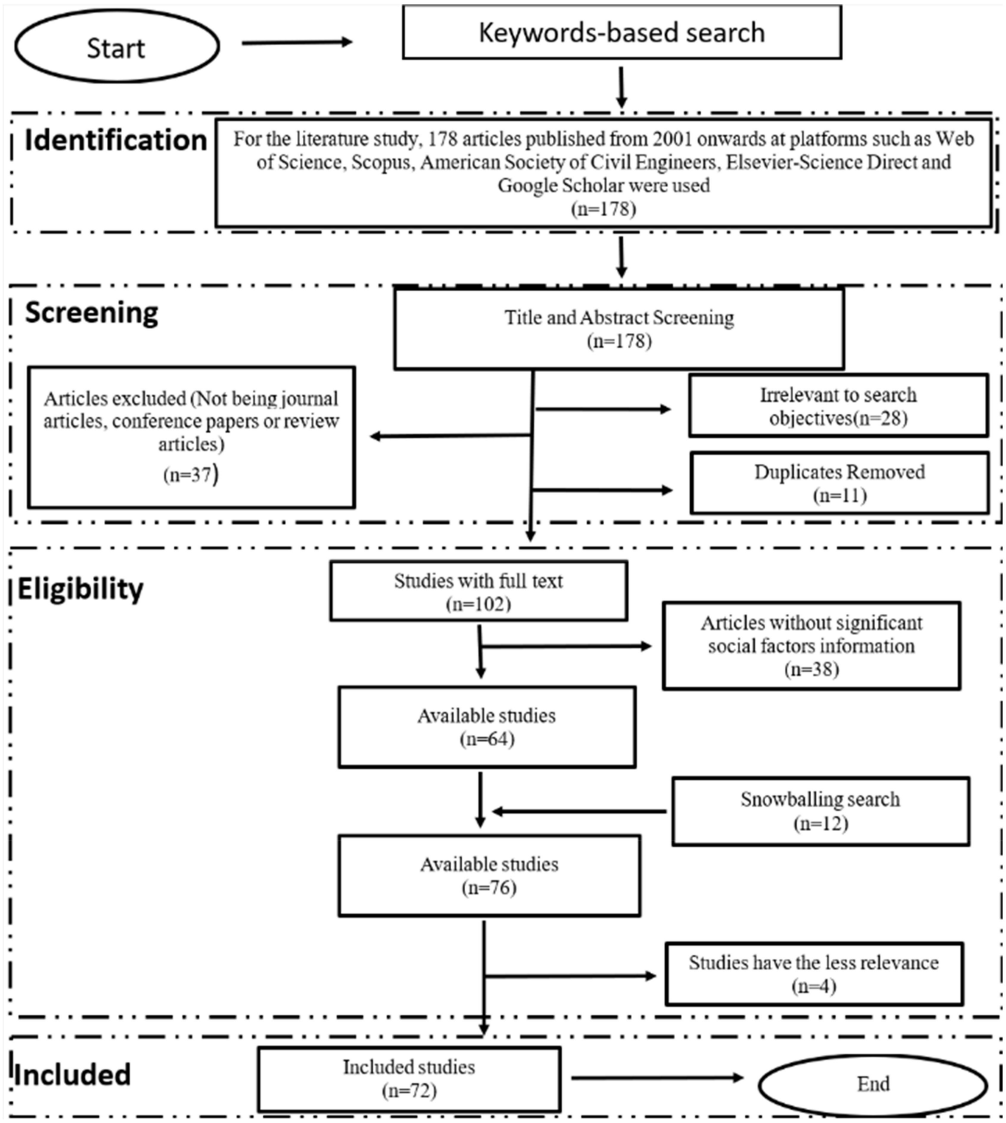


Figure 2. PRISMA diagram.

3.2. Desk Study Phase

In stage 2, an in-depth scrutiny of the literature was carried out to find the key social factors affecting CS as shown in Table 1 [52]. A total of 27 social factors affecting CS were identified from the 72 shortlisted articles. Thereafter, a content analysis of the literature was carried out to rank these factors in order of priority based on the normalized score. Each factor was rated with a high, medium, and low influence level based on the published literature. A literature score (LS) based on the Relative Importance Index (RII) [57] was calculated using Equation (1), where W represents the highest frequency, A is the maximum possible score, and N is the number of papers considered for detailed review. The normalized literature score (NLS) was then obtained using Equation (2), where the LS of each factor was divided by the sum of the LSs of all factors. The resultant social factors are shown in Table 2.

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

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

Table 1. Preliminary list of significant factors affecting Construction Sustainability.

S. No.	Social Factors Affecting Construction Sustainability	Sources
1	Stakeholder awareness and knowledge	[58–64]
2	Cultural preservation	[61,64–67]
3	Resistance to adopting modern approach to sustainable buildings (all stakeholders)	[61,62,64,68]
4	Fear of the cost of adopting sustainable material	[63,64]
5	Uplifting economy through local employment and procurement	[64,67,69,70]
6	Health and safety of native community	[59,61,64–67,71,72]
7	No inclination to preserve resources	[68,69]
8	Community development	[61,65,66]
9	Travel delays and congestion	[66,73,74]
10	Poor quality of life	[73,75]
11	Delivering services that enhance the local environment	[65,66,75]
12	Deterioration of historic value artifacts	[76]
13	Existing trends and cultural traditions	[77]
14	Lack of common understanding among stakeholders	[60,63]
15	Degradation of recreational facilities	[73,75]
16	Increased road accidents	[73,76]
17	Government support for sustainable construction	[60,62,74,78]
18	Native skills development	[61,70,72]
19	Physical space restriction	[66,77]
20	Native people's comfort and satisfaction	[71]
21	Relationships and communication improvement	[16,60,72]
22	Level of community involvement, interest, and demand	[59,65,71,78,79]
23	Equality for all	[77]
24	Modification of aesthetics	[66,71]
25	Security assurance	[16,65,74]
26	Public participation in the project	[16,59,60,70,72,79]
27	Community relocation	[72,74]

Table 2. Shortlisted list of significant factors affecting Construction Sustainability.

S. No.	Factors Affecting Construction Sustainability	Normalized Field Score (FS)	Normalized Literature Score (LS)	Total Score 60%FS/40%LS	Cumulative Normalized Total Score
1	Stakeholder awareness and knowledge	0.030928	0.096228	0.057048	0.057048
2	Cultural preservation	0.030928	0.082756	0.0516592	0.1087072
3	Resistance to adopting modern approach to sustainable buildings	0.041237	0.063510	0.0501462	0.1588534
4	Fear of the cost of adopting sustainable material	0.051546	0.046189	0.0494032	0.2082566
5	Uplift economy through local employment and procurement	0.041237	0.061586	0.0493766	0.2576332
6	Health and safety of native community	0.041237	0.057737	0.047837	0.3054702
7	Government support for sustainable construction	0.041237	0.051963	0.0455274	0.3509976
8	Community development	0.041237	0.050808	0.0450654	0.396063

Table 2. *Cont.*

S. No.	Factors Affecting Construction Sustainability	Normalized Field Score (FS)	Normalized Literature Score (LS)	Total Score 60%FS/40%LS	Cumulative Normalized Total Score
9	Level of community involvement, interest, and demand	0.041237	0.042725	0.0418322	0.4378952
10	Poor quality of life	0.041237	0.042340	0.0416782	0.4795734
11	Delivering services that enhance the local environment	0.030928	0.050038	0.038572	0.5181454

3.3. Data Collection and Analysis Phases

3.3.1. Preliminary Survey Phase

To verify the relevance of the social CS factors identified from the literature, these factors were further verified and ranked by soliciting the opinions of field experts. For this purpose, a preliminary survey was conducted to collect field scores (FS) from thirty experts from developing countries such as Sri Lanka, Nepal, Pakistan, Bhutan, and Bangladesh. In the FS survey, respondents were asked to assign scores from 1 to 5 (very low to very high) to each factor reflecting its impact on CS. After data collection through the preliminary survey, statistical tests were employed to check the normality and reliability of the data using SPSS® version 23. To rank these factors, FS and LS were used in the ratio of 60%(FS)/40%(LS) as shown in Table 2. Shortlisted listed factors along with their reference from literature are shown in Table 3. Factors were shortlisted based on cumulative normalized scores up to 51% as the cut-off point [52] as shown in Figure 3.

Table 3. Shortlisted significant social factors affecting Construction Sustainability.

Sr. No.	Social Factors Affecting Construction Sustainability	Sources
1	Stakeholder awareness and knowledge	[58–64]
2	Cultural preservation	[61,64–67]
3	Resist to adopting conventional approach to sustainable buildings (all stakeholders)	[61,62,64,68]
4	Fear of the cost of adopting sustainable material	[63,64]
5	Uplift economy through local employment and procurement	[64,67,69,70]
6	Health and safety of native community	[59,61,64–67,71,72]
7	Community development	[61,65,66]
8	Poor quality of life	[73,75]
9	Delivering services that enhance the local environment	[65,66,75]
10	Level of community involvement, interest, and demand	[59,65,71,78,79]
11	Government support for sustainable construction	[60,62,74,78]

The reduction in factors is based on recent studies such as those by Ghufran et al. [80] and Riaz et al. [81], who used the reduction in factors to achieve relevant and precise results. A large number of factors can lead to a highly complex model, making it challenging to understand and interpret the relationships between variables, as simplicity and clarity are crucial in system dynamics modeling. Based on the above, social factors were reduced from 27 to 11. A similar approach was used by Amin et al. [82]. These considerations ensure that the resulting CLD and SDM are simple yet robust and applicable, providing meaningful insight into the social factors affecting CS.

The data on the social factors affecting CS for the model were collected from developing countries, as these factors depend on the culture and values of the society. Hence, they differ depending on the country and region, as highlighted by Paprotny [83] in their study of the convergence of developing and developed countries. The author found that these two groups have large differences in some fields and less in others. Further, the model could be applied to developed countries, and a larger dataset was required to analyze social factors retrieved from developed countries. In the current study, data were collected from developing countries. Based on the collected data, a System Dynamics Model was developed using Equations (4) to (7) based on factors relevant to developing countries. To use the same model for developed countries or make it more generalized, the underlying factors in the SDM and its base equations need to change.

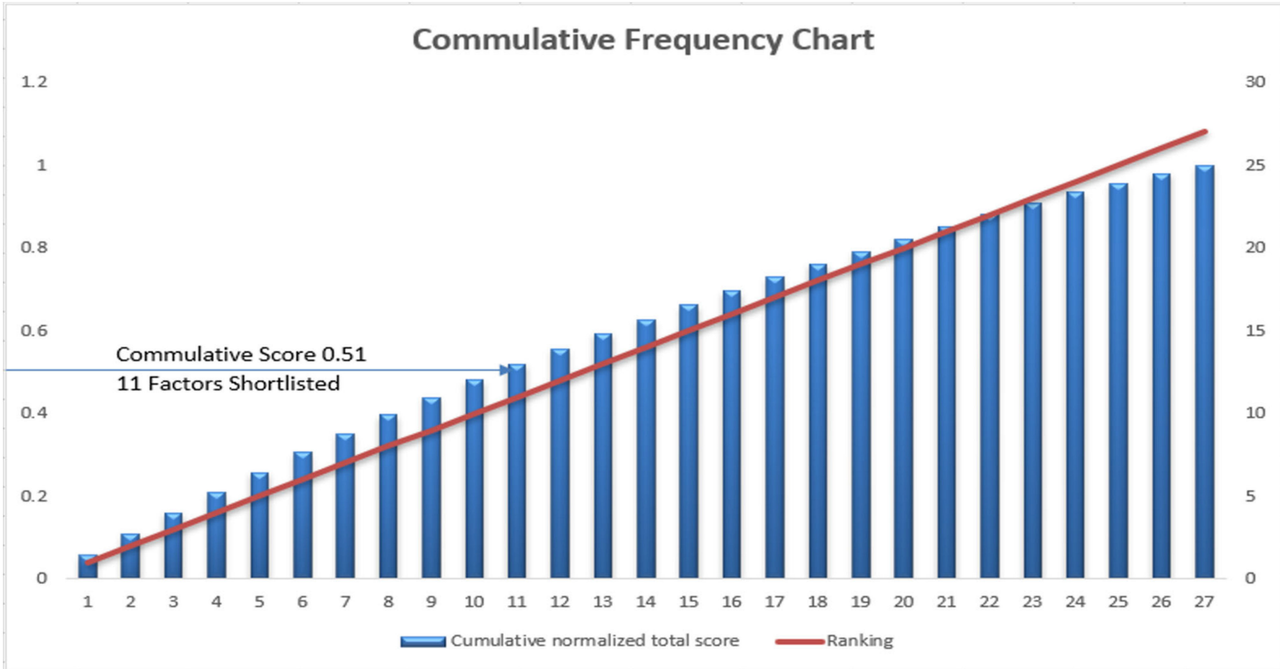


Figure 3. Cumulative frequency chart.

3.3.2. Sample Size

Slovin's formula, given in Equation (3), was used to calculate the sample size (n) for this study given the population size (N) and a margin of error (e).

$$n = N/(1 + Ne^2) \quad (3)$$

where n = no. of samples, N = total population, e = error margin/margin of error. Keeping in view Slovin's formula with "N" at 115 and "e" at 0.05, the sample size was calculated to be 89 for our study.

Accordingly, 115 responses were collected from experts in developing countries including Qatar, the Philippines, Saudi Arabia, United Arab Emirates, Bangladesh, Sri Lanka, and Pakistan. Based on the assigned scores, 11 factors were shortlisted as shown in Table 4.

Developing countries were selected to study social factors affecting Construction Sustainability following the studies by Thaheem et al. [84] and Ghufran et al. [85]. The criteria was chosen to provide a diverse range of social and cultural contexts for which countries and respondents were selected from different geographic locations, ensuring a comprehensive understanding for the impact of social factors on Construction Sustainability. The same methodology has also been used by Riaz et al. [81].

The World Bank's classifications were used to determine the economic standing, which divides economies into four income groups: low income, lower-middle income, upper-middle income, and high income. The current study focused mainly on lower-middle- and upper-middle-income countries. This selection aligns with Rostow's stages of economic growth theory [86].

Additionally, the sample size of respondents was based on Slovin's formula as per the study by Ghufran et al. [80], as mentioned in Section 3.3.2 in this paper. A threshold of 89 respondents was determined as a reasonable number of respondents for the current study. The respondents were selected based on their knowledge and experience in CS. This was ensured by checking the public data for the respondents on their organizational profiles and social media such as LinkedIn [87]. This ensured that the study gathered insights from individuals with a deep understanding of the subject matter, for which more than 75% of the respondents had more than five years of experience, as shown in Table 4.

The respondents included project managers (24), construction managers (8), project directors (11), project/site engineers (13), planning engineers (12), and resident engineers (12) with 86% of individuals having a moderate or exceptional understanding of the CS projects, making the data more reliable. About 27.2% of the respondents were affiliated with clients, 32.8% with consultants, and 40% with contractors. In total, 65% of the respondents had experience of more than 6 years and up to 20 years. The respondents included 37.4% graduate, 46.9% post-graduate, 11.3% PhD degree holders, and 4.4% diploma holders indicating high-level-educated respondents. Only major categories have been mentioned for brevity in the above respondents' details. It is important to note that the survey encompassed diverse roles, including academics, researchers, planning engineers, and contract engineers. While not individually enumerated, these additional categories contribute to the overall count of 115 respondents, reflecting the comprehensive representation of various professional backgrounds within this study.

3.3.3. Detailed Survey Phase

In stage 3, a comprehensive survey was conducted to find out the interrelationship intensity and polarity of the social factors affecting CS. The survey targeted expert respondents from developing countries through Gmail, Facebook, WhatsApp, and LinkedIn using the snowballing approach.

A questionnaire was sent to more than 350 respondents and a total of 110 responses were collected, reflecting a response rate of 31%. As per Malterud and Siersma [88], "information power" dictates the number of respondents needed for a study. Hence, if information is gathered from a sample highly relevant to a study, then a lower number of respondents is needed. The size of a sample with sufficient information power depends on (a) the aim of the study, (b) sample specificity, (c) the use of established theory, (d) the quality of dialogue, and (e) the analysis strategy. Based on these factors, 110 respondents were selected for this study. The consistency and reliability of the data were assessed using Cronbach's alpha with a threshold value of 0.7 and above reflecting its reliability [89]. Moreover, the RII values were less than 1, proving the validity of the data [90].

For data collection, respondents from developing countries were approached, which included Nepal, Congo, Bangladesh, Ghana, Sri Lanka, Malaysia, Saudi Arabia, Bhutan, Iran, Liberia, South Africa, Turkey, and Sudan.

This research was focused on developing countries, and accordingly, an effort was made to distribute the questionnaire across the developing countries. However, responses from the respondents were received unevenly, which is a normal pattern in data collection across the regions. Such patterns have been observed in studies such as those by Ghufran et al. [80] and Thaheem et al. [84]. This may have been influenced by factors such as having less exposure to social CS and varying levels of interest and awareness about the research topic [82]. Nevertheless, the impact of this bias was minimized through the analysis of the gathered data to check their conformity with the research data and industrial practices and norms and then the validation of the model results through experts with vast construction field experience.

These developing countries were selected as less research has been reported on social CS in these countries [84,91]. Overall, among the respondents, 33% were affiliated with government, 27% with semi-government, and 40% with private organizations, presenting a useful mix of experts from different organization types to capture different sectors' feedback.

The demographic detail from the survey shows that 18% of the respondents had a PhD, 39% were postgraduates, 32% were graduates, and 11% were diploma holders, as shown in Figure 4. Other demographic details are shown in Table 4 below.

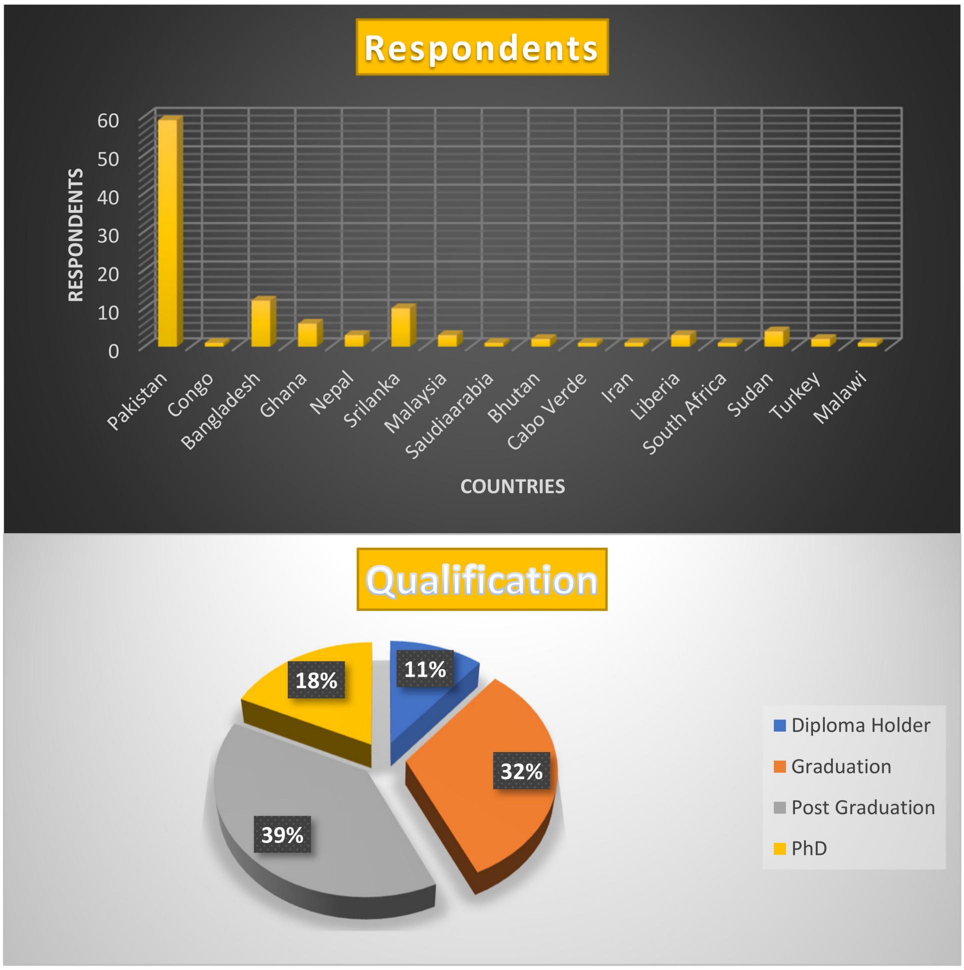


Figure 4. Detailed survey respondents' demographic details.

During the data collection, some anomalies were observed, which were addressed to achieve the accuracy and reliability of the data. Some values were missing in a few responses, and some duplications were found during data sifting, which were excluded. The format and units of the data were checked to remove inconsistencies to validate the data. Furthermore, data was thoroughly checked to remove mistakes that occurred due to manual data entry. Validation of the data was rechecked by gauging the results of the model. Eventually, the data validation was carried out by consultation with the experts, after which the model simulation results further confirmed the data cleansing accuracy.

In this section, respondents were assessed on their comprehension of CS through a dedicated question. To ascertain the knowledge levels, respondents were asked to rate their understanding on a scale ranging from "No understanding at all" to "Exceptional" [80]. The goal was to evaluate the depth of respondents' understanding of CS principles and practices.

Following the finalization of the 11 identified social factors crucial for CS, the next imperative was to understand the relationship of each social factor with the 10 other social factors to visualize their interdependencies. A detailed survey was conducted to gauge the type of relationship between these social factors, i.e., direct or inverse relationship, and their mutual impact following Riaz et al. [81] and Thaheem et al. [84].

Table 4. Demographic details of respondents.

Type		Frequency	Percentage
Organization	Academia	29	26.3%
	Client	21	19.1%
	Consultant	22	20%
	Contractor	33	30%
	Client/Consultant	3	2.7%
	Consultant/Academia	2	1.9%
Professional Experience (Years)	0–1	1	0.9%
	1–5	24	21.8%
	6–10	13	11.8%
	11–15	26	23.6%
	16–20	28	25.4%
	>20	18	16.5%
Designation	Project Director	14	12.7%
	Construction Manage	18	16.3%
	Resident Engineer	9	8.2%
	Planning Engineer	17	15.4%
	Educationist	14	12.7%
	Researcher	23	20.9%
	Architect/Designer	5	4.5%
	Site Engineer	8	7.5%
	BIM Engineer	2	1.8%
Understanding sustainable construction	No understanding at all	5	4.5%
	Slight	20	18.2%
	Moderate	58	52.7%
	Exceptional	27	24.5%

In this regard, respondents were asked to gauge and mention the type of relationship and its intensity between these presented social factors. When the intensity of one social factor increases the intensity of another, a direct relationship exists between these two social factors. When an increase in the intensity of one social factor results in a decrease in the intensity of the other social factor, it is called an inverse relationship. The intensity of these impacts was categorized as low, medium, and high. These assessments identified 14 direct relationships and 6 inverse relationships based on the high-intensity impacts, as outlined in Table 5. This examination is a foundation for comprehending how these social factors affect and interact with devising the strategy to impact CS positively.

Table 5. Impacting factors with polarity.

S. N.	Impacting Factor	Impacted Factor	Mean	RII	Polarity
1	Fear of the cost of adopting sustainable material	Government support for sustainable construction	3.69	−0.74	Inverse
2	Delivering services that enhance the local environment	Government support for sustainable construction	3.78	0.76	Direct
3	Health and safety of native community	Government support for sustainable construction	3.74	0.75	Direct
4	Cultural preservation	Stakeholder awareness and knowledge	3.85	0.77	Direct
5	Poor quality of life	Stakeholder awareness and knowledge	3.78	−0.76	Inverse
6	Government support for sustainable construction	Stakeholder awareness and knowledge	3.71	0.74	Direct
7	Community development	Cultural preservation	3.61	0.72	Direct

Table 5. *Cont.*

S. N.	Impacting Factor	Impacted Factor	Mean	RII	Polarity
8	Level of community involvement, interest, and demand	Cultural preservation	3.82	0.76	Direct
9	Government support for sustainable construction	Resistance to adopting conventional approach to sustainable buildings	3.40	−0.68	Inverse
10	Level of community involvement, interest, and demand	Fear of the cost of adopting sustainable material	3.79	−0.76	Inverse
11	Resistance to adopting conventional approach to sustainable buildings	Fear of the cost of adopting sustainable material	3.80	0.76	Direct
12	Government support for sustainable construction	Uplift economy through local employment and procurement	3.47	0.69	Direct
13	Uplift economy through local employment and procurement	Health and safety of native community	4.76	0.95	Direct
14	Stakeholder awareness and knowledge	Health and safety of native community	3.79	0.76	Direct
15	Stakeholder awareness and knowledge	Community development	3.64	0.73	Direct
16	Stakeholder awareness and knowledge	Level of community involvement, interest, and demand	3.96	0.79	Direct
17	Government support for sustainable construction	Level of community involvement, interest, and demand	3.43	0.69	Direct
18	Community development	Poor quality of life	3.66	−0.73	Inverse
19	Resistance to adopting conventional approach to sustainable buildings	Delivering services that enhance the local environment	4.42	−0.88	Inverse
20	Uplift economy through local employment and procurement	Delivering services that enhance the local environment	3.85	0.77	Direct

3.3.4. Systems Thinking and System Dynamics Modeling Phase

Stage 3 helped with the extraction of CS factors and assessing the direct or inverse relationship between them. The impact of the 11 social factors on each other was also captured, ranging from low, medium, to high influence. The mean of the influence was calculated, leading to the RII score. The polarity of the relationship among the factors, whether direct or indirect, was calculated to formulate the CLD as shown in Table 5. In Table 5, both the impacting and impacted factors are presented along with the intensities and polarities of the relations. This helped develop the CLD.

Interviews were conducted with field experts with more than 10 years of experience in CI to solicit information on the linkages between the social factors affecting CS. The experts pointed out the polarity of the relationships, as shown in Table 5. Based on this information, an influence matrix was created showing the influence and polarities of the factors. Different important and relevant loops were formed based on the shortlisted social factors following methodology of Bertassini and Zanon [92]. Vensim PLE® was used to formulate the CLD, which was used to create the SDM. The SDM was again validated by the field experts.

4. Results and Discussion

4.1. Relationship and Polarity Matrix (RPM)

The relationship and polarity matrix (RPM) for the social factors affecting CS is shown in Figure 5, developed based on the factors previously listed in Figure 3. The x-axis shows the factors being impacted while the y-axis shows the impacting factors. Positive-sign values indicate direct relationships while negative-sign values indicate inverse relationships among the factors. Out of 11 shortlisted social factors, 14 direct and 6 inverse relationships were established. This RPM was later used to develop the CLD.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
S1		0.77					0.74			-0.76	
S2								0.72	0.76		
S3							-0.68				
S4			0.76						-0.76		
S5							0.69				
S6	0.76				0.95						
S7				-0.74		0.75					0.76
S8	0.73										
S9	0.79						0.69				
S10								-0.73			
S11			-0.88		0.77						

S1 Stakeholder awareness and knowledge
S2 Cultural preservation
S3 Resist to adopt conventional approach to sustainable
S4 Fear of the cost of adopting sustainable material
S5 Uplift economy through local employment
S6 Health and safety of natiʳ ative community
S7 Government support for sustainable construction
S8 Community development
S9 community involvement
S10 Poor Quality of Life
S11 Services that enhance the local environment

Y-Axis = Impacted Factor X-Axis = Impacting Factor

Figure 5. Social factors' relationships and polarity matrix.

It can be observed in Figure 5 that social factor S1 is positively affected by S2 and S7 with an intensity of 0.77 and 0.74 respectively. The impact of S2 is higher than S7, and this effect is directly proportional. Further, S1 is negatively impacted by S10, reflecting an indirect relationship.

4.2. Causal Loop Diagram (CLD)

The CLD was formed using Vensim software. The links between the social CS factors were established based on experts' opinions. Reinforcing loops are employed to illustrate self-reinforcing mechanisms within a system. In these loops, the effects of a change in one variable amplify over time, leading to a cumulative impact on the system. This often results in a system moving towards reflecting either continuous growth or decline, emphasizing the importance of initial conditions. On the other hand, balancing loops are used to depict self-regulating or stabilizing mechanisms. These loops demonstrate how a system tends to maintain equilibrium or counteract deviations. In balancing loops, changes in one variable trigger counterbalancing forces, working to bring the system back to a desired state, thus promoting stability. Together, these loops work like Newton's third law where every action has an equal but opposite reaction, thus keeping the system in check or a state of balance. A total of nine loops were identified in the CLD with eight reinforcing loops and one balancing loop as shown in Figure 6. These loops are explained below in detail.

4.2.1. Reinforcing Loop R8 (Enhancing Quality of Life)

Reinforcing Loop R8, as shown in Figure 7, indicates that to enhance the quality of life of a local community, it is essential for the stakeholders to remain aware of CS and its benefits in the long and short term. This awareness will lead to community development and improvement in their quality of life. The loop also reflects the importance of devising ways and means to enhance the knowledge of all stakeholders about CS and its holistic benefits to the community. The importance of awareness in driving positive change aligns with the work of Senge [93], who emphasized the role of mental models and shared vision in organizational learning, a concept that extends to community development.

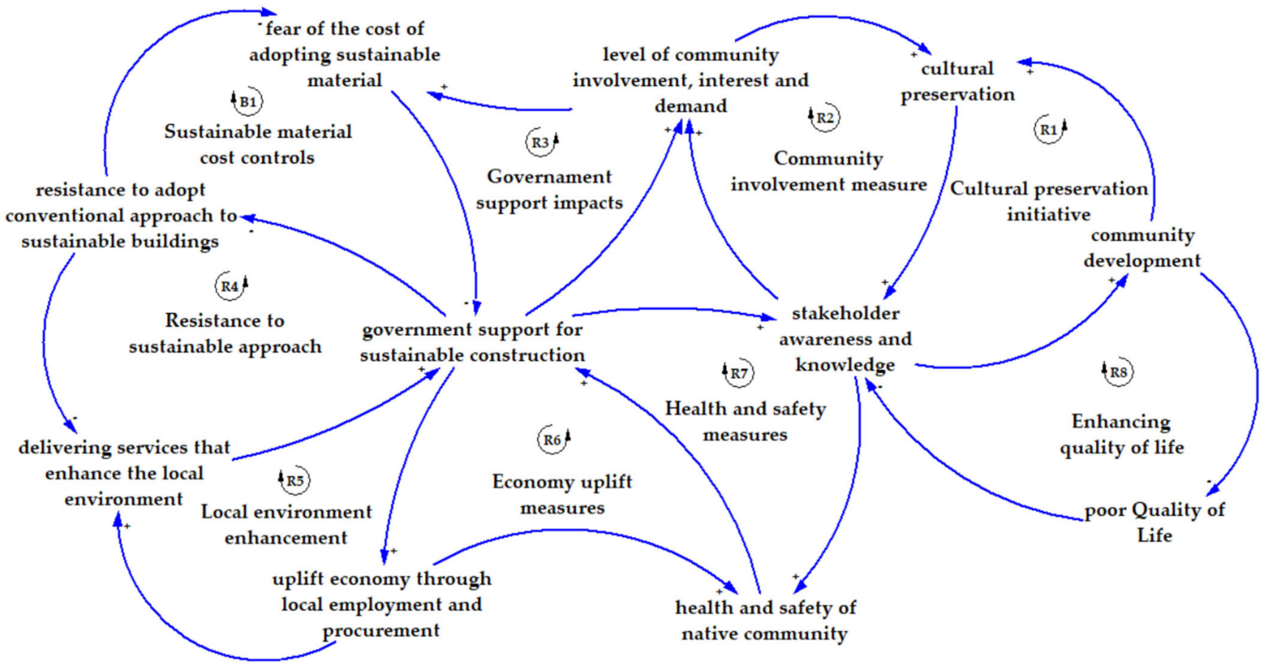


Figure 6. Causal loop diagram (designed by authors).

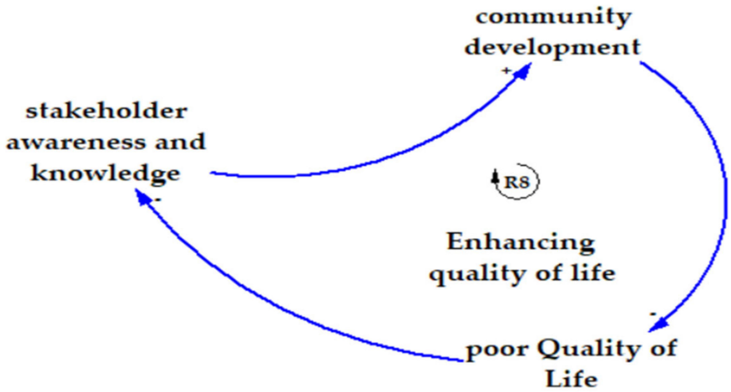


Figure 7. Reinforcing Loop R8 (designed by authors).

Furthermore, the idea that increased awareness contributes to community development is consistent with research on the social aspects of sustainability, as highlighted by Dresner [94]. The author stressed the significance of community engagement in achieving SD goals. Similarly, the loop's emphasis on effective communication strategies resonates with studies in communication and sustainability. For instance, Heath and Palenchar [95] discussed the importance of strategic communication in influencing public understanding and behavior.

4.2.2. Reinforcing Loop R1 (Cultural Preservation Initiative)

Reinforcing Loop R1, as shown in Figure 8, reflects the importance of cultural preservation, starting with the stakeholder awareness of CS and knowledge of the subject area. This step leads to the development of the community by promoting SD among the community through increased awareness. It also achieves cultural preservation by adopting new techniques and negotiating with all the other stakeholders to respect their desire to preserve their culture. This knowledge helps build awareness of all the stakeholders to devise sustainable ways to undertake complicated projects and meet the requirements of the people to preserve their culture, thus creating a win–win situation for all the stakeholders.

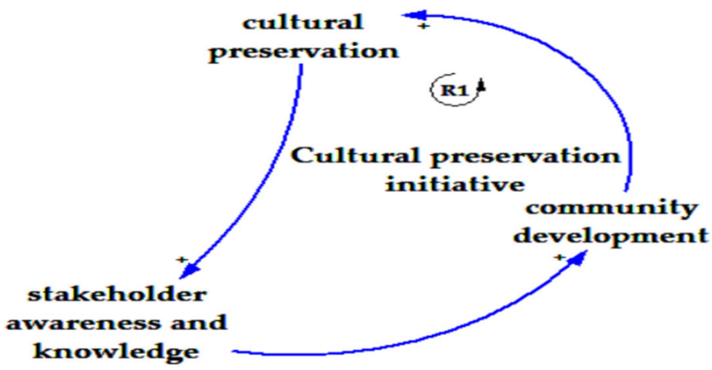


Figure 8. Reinforcing Loop R1 (designed by authors).

Berkes [96] advocated for the role of local communities in sustainable resource management, emphasizing the integration of cultural factors into CS to achieve SD. Li [97] studied negotiation in project management and provided a foundation for understanding the importance of stakeholder cooperation in achieving cultural preservation goals. Susskind and McKearnen [98] contributed to the discussion of collaborative decision making and the creation of win–win situations in SD based on the participation of local communities.

4.2.3. Reinforcing Loop R2 (Community Involvement Measure)

Reinforcing Loop (R2), as shown in Figure 9, indicates that CS-aware and knowledgeable stakeholders are pivotal to involving the community in the projects by instigating their interests. Further, these can help create harmony among all stakeholders and help address the demands and requirements of all stakeholders. This further helps remove project hurdles and reap holistic project benefits, such as cultural preservation, as a community is in a better position to communicate their concerns about preserving the culture to the project team. This way, the community is involved in project planning, and proactive measures can be taken to address their concerns.

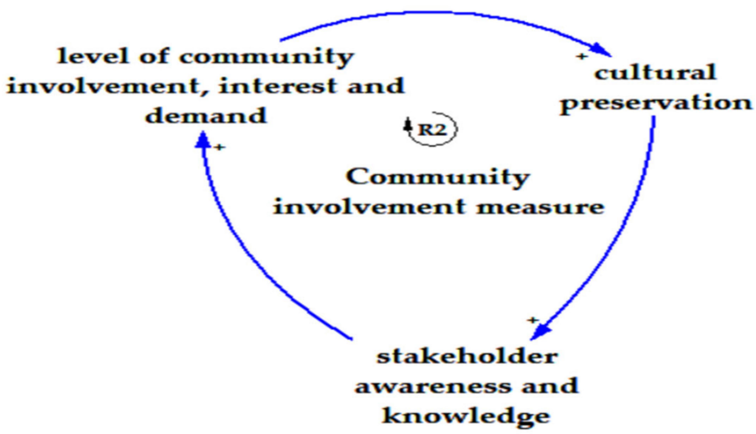


Figure 9. Reinforcing Loop R2 (designed by authors).

The loop suggests that informed stakeholders can initiate community involvement, fostering stakeholder harmony. This idea is supported by studies on stakeholder collaboration in project management, such as that by Larson and Gray [99]. The emphasis on stakeholder awareness aligns with the study by Mitchell and Agle [100], who discussed the pivotal role of stakeholder knowledge and awareness in shaping organizational behavior.

The loop emphasizes community involvement in project planning in line with Turner [101], who stressed the significance of community engagement in project management processes.

4.2.4. Reinforcing Loop R3 (Government Support Impacts)

Figure 10 shows Reinforcing Loop R3, representing the government's support for CS. With proper support and tailored initiatives, the government can support CS for holistic adoption by the community and other stakeholders. Mebratu [102] discussed the role of government policies in promoting SD along similar lines.

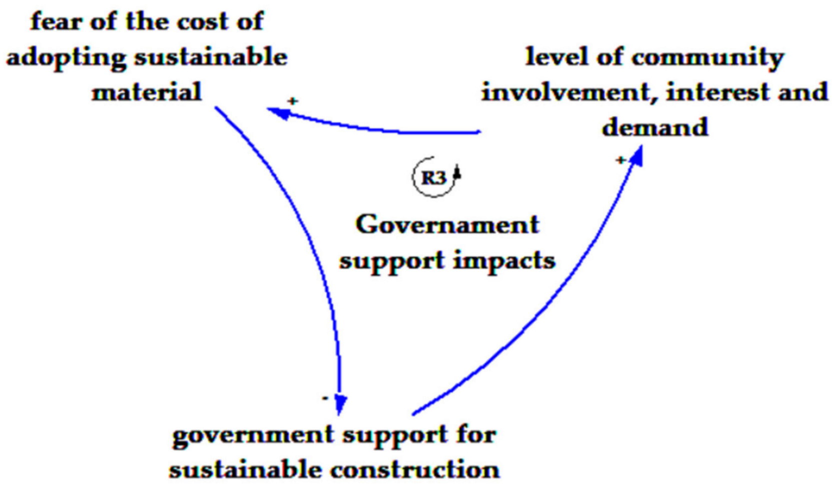


Figure 10. Reinforcing Loop R3 (designed by authors).

Jordan [103] also discussed the role of government policies in shaping sustainability practices. Through government support, the awareness levels of the community regarding CS can be garnered to enhance their interest in the project. Also, additional incentives by the government encourage sustainability adoption at all levels. Building on the concept of additional incentives by the government, Shen and Yen [104] investigated the impact of financial incentives on the adoption of green building practices and argued that incentives can help enhance the adoption of such practices.

Initiatives and supporting campaigns through media, seminars, conferences, newspapers, social media, etc., can help raise awareness of CS. It also helps stakeholders overcome the fear of costs overrun in using sustainable materials and practices. This is aligned with Lam [105] who delved into the role of communication in promoting CS practices.

4.2.5. Reinforcing Loop R4 (Resistance to Sustainability Adoption)

Reinforcing Loop R4, as shown in Figure 11, displays that government support for CS plays a vital role in ensuring the provision of appropriate environmentally friendly services in the area. This in turn helps reduce the resistance to the change from conventional to CS methods. Leppelt [106] explored the impact of government policies on reducing resistance to SD and concurred with the above claims. Johnson [107] explored the influence of government policies on overcoming resistance to sustainability in the construction industry and agreed that such policies can help curb the inherent barriers.

Government support and incentives are pivotal in convincing the project stakeholders involved to adopt CS techniques. Walker [108] investigated the influence of government policies on stakeholders' decisions in sustainable building and concurred that such policies have a positive impact on decision making.

Increased awareness also helps enhance adoption as argued by Liu [109]. Further flexibility by stakeholders to work as a team and reap holistic benefits rather than enforcing individual agendas is also pivotal to CS adoption. This is aligned with the study of Kunz [110], who discussed the role of collaboration and flexibility in SD.

Policy development also enables the government to propose and implement measures and laws when solutions are mutually agreed upon to facilitate the industrial transition towards CS. This claim is aligned with Jabeen [111], who discussed the role of government regulations in promoting sustainable practices in the CI.

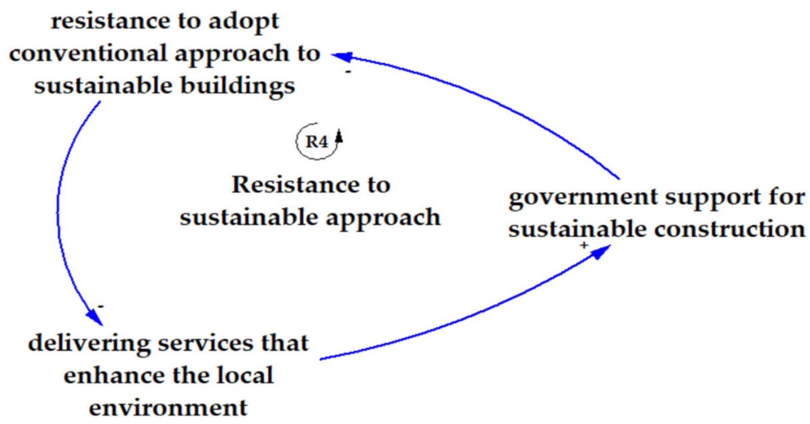


Figure 11. Reinforcing Loop R4 (designed by authors).

4.2.6. Reinforcing Loop R5 (Local Environment Enhancement)

Reinforcing Loop R5, as shown in Figure 12, presents a method to enhance the local environment. As the awareness of CS is limited, it becomes the government's responsibility to provide extra support for incentivizing the adoption of CS. Chen [112] explored the role of government incentives in promoting sustainable practices in CI and emphasized the need for such incentives. Such adoptions enable the generation of economic activity for the community, providing them jobs and helping improve the quality of life. Ding [113] also examined the economic impacts of CS practices on local communities and highlighted their advantages.

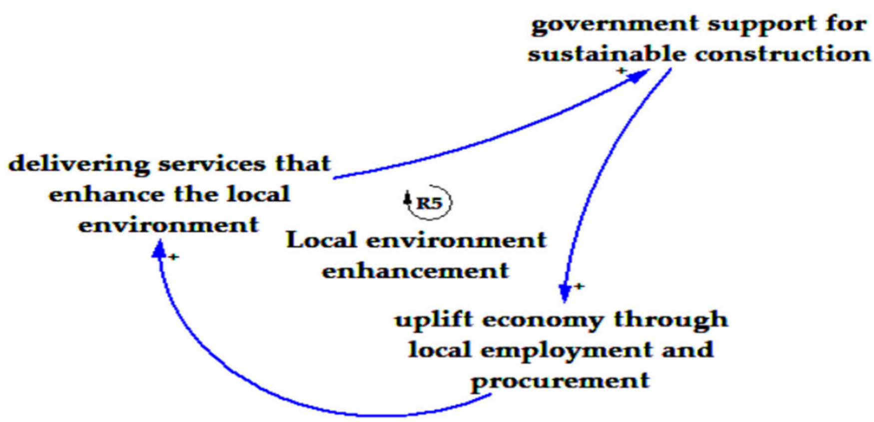


Figure 12. Reinforcing Loop R5 (designed by authors).

CS projects enhance the local environment by enlightening the key stakeholders and local community about the benefits such projects bring to the community and the environment; hence, more focused preservation measures can be taken and demanded by the community. De Medeiros [114] shed light on the impact of CS on the overall well-being and quality of life of communities. Mostafa [115] elaborated on the role of stakeholder engagement in CS and its positive effects on the local environment.

4.2.7. Reinforcing Loop R6 (Economy Uplifting Measure)

Reinforcing Loop R6, as shown in Figure 13, reveals that government support for CS uplifts the economy and provides health and safety benefits to the community. Wu [116] explained the health and economic impacts of CS practices and explained their impact on communities.

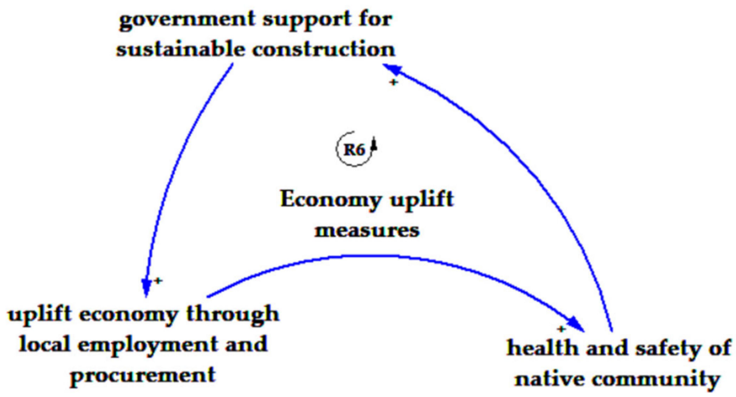


Figure 13. Reinforcing Loop R6 (designed by authors).

CS projects provide financial benefits to all the stakeholders and jobs to local communities, ensuring better consideration measures for local development in addition to promoting and providing business to local businesses. Irizarry [117] elaborated on the economic aspects of CS and its impact on local employment. Similarly, Dastbaz [118] discussed the impact of CS on local business opportunities.

SD also brings about health facilities and enhanced security measures due to the involvement of the government and other high-profile individuals visiting the project. Van den Dobbelsteen [119] discussed the broader impacts of CS on communities and explained how such adoption uplifts the local community.

4.2.8. Reinforcing Loop R7 (Health and Safety Measures)

Reinforcing Loop R7, as shown in Figure 14, explains that government support for CS enhances stakeholders' understanding of SD practices. Chan [120] agreed on the role of government initiatives in promoting stakeholder engagement and knowledge transfer in construction projects.

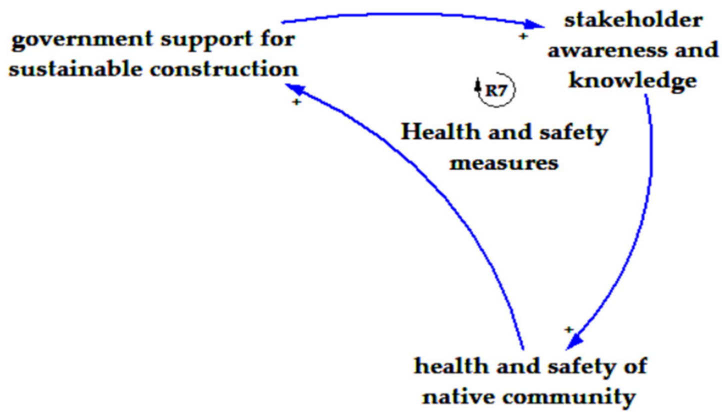


Figure 14. Reinforcing Loop R7 (designed by authors).

CS knowledge and information encourage more participation from stakeholders and boost their engagement, which in turn helps with the communication of requirements for uplifting the local community including paying attention to their health and safety. In this context, Ballesteros-Pérez [121] examined the stakeholder involvement for safety management in construction and improved the understanding of its different facets. Pacheco-Torgal [122] also emphasized the broader health implications of CS materials.

CS captures the health benefits and considerations in projects in addition to the attention to the overall safety of the community and surroundings. Howard [123] elaborated on the integration of health considerations in CS projects. Shen [124] also concurred with the above while explaining the safety measures and risk management in construction projects.

4.2.9. Balancing Loop B1 (Sustainable Material Cost Controls)

Balancing Loop B1, as shown in Figure 15, indicates that government support is critical to adopting CS. Zuo [125] elaborated on the effectiveness of government policies in fostering sustainability in the CI. For insights into the connection between stakeholder knowledge, government support, and the adoption of sustainable practices, Hossain [126] explained the importance of knowledge and government support in apprehending and adopting CS.

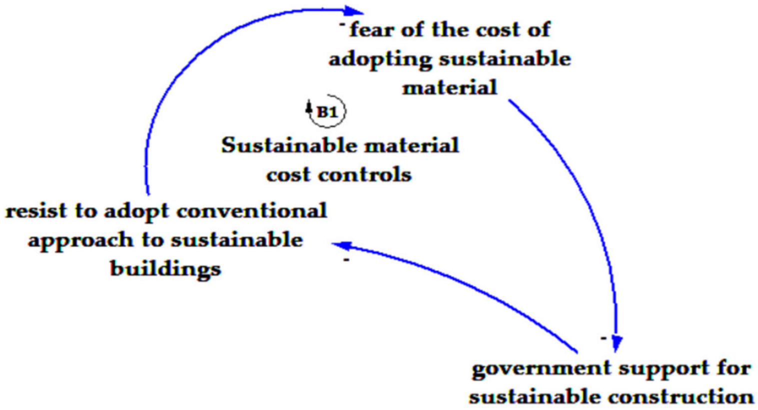


Figure 15. Balancing Loop B1 (designed by authors).

Shifting from the conventional construction approach to CS is only possible when all the stakeholders have good knowledge and awareness of CS. Further, the stakeholders must be supported by the government in adopting CS through measures such as the provision of sustainable materials, training on material usage, importing permissions for relevant equipment, and support from the local industry to adopt sustainable measures, etc. This way, organizations can transition from conventional to CS methods and execute CS without fearing excessive costs. This is aligned with the findings of Rameezdeen [127], who explored the role of governments in promoting CS materials. Akadiri and Chinyio [128] explored the role of the construction industry in promoting sustainable practices and concurred with the above findings.

4.3. Causal Loop Diagram (CLD) Analysis

In the CLD analysis, an in-depth classification was conducted based on the strength, speed, and polarity of the CS factors influencing each other, as outlined in Table 6. This comprehensive examination formed the basis for developing the CLD, focusing specifically on the 11 social CS factors intricately linked to the CI.

Table 6. Loops' speed and nature of influence.

Loop	Strength of Influence	Speed of Influence	Nature of Influence
R1	Strong	Fast	Reinforcing
R2	Strong	Fast	Reinforcing
R3	Strong	Fast	Reinforcing
R4	Strong	Fast	Reinforcing
R5	Strong	Fast	Reinforcing
R6	Strong	Fast	Reinforcing
R7	Strong	Fast	Reinforcing
R8	Strong	Fast	Reinforcing
B1	Strong	Slow	Balancing

The emergent loops from our analysis delineated a compelling narrative: a total of eight reinforcing loops and one balancing loop, each influencing the others. This complex relationship signifies the importance of these factors, portraying them as hubs in the system where changes could trigger cascading effects across the sustainability landscape. The observation of a slow-speed phenomenon among these factors is noteworthy, indicating that while the factors wield substantial influence, the environmental repercussions of alterations will unfold gradually over time.

Within the constructed CLD, the prevalence of eight reinforcing loops highlights the critical connections among these factors. Any modification to one factor is anticipated to resound through the entire network, creating a domino effect with profound and lasting consequences on the environment. This interconnectedness emphasizes the sensitivity of the system to changes in these social CS factors, emphasizing the need for a smart and well-informed approach to Construction Sustainability.

To validate the constructed CLD, ten field experts from developing countries possessing over a decade of experience and expertise in CS were consulted. Their insights into the strength and classification of the loops were sought, contributing to the validation of the model. The engagement of these experts adds a layer of real-world expertise and practicality, ensuring that the CLD accurately represents the complex dynamics and relationships inherent to CS and SD.

4.4. System Dynamics Model

Based on the developed CLD, an SDM was prepared using Vensim as shown in Figure 16. As previously shown in Table 6, RII was calculated based on the mean value extracted from the factors mutually impacting each other. In total, 20 relationships were established, with 14 factors having direct polarity and 6 factors having inverse polarity, as previously shown in Table 6. Two stocks were added to the system, identified in the SDM as "Government support for CS" and "Stakeholder awareness and knowledge". By converging these stocks, another stock was established, referred to as "Construction Sustainability". The mathematical equations for the inflow and outflow of "Government support for CS" stock and "Stakeholder awareness and knowledge" stock are shown in Equations (4) to (7), which are derived from the System Dynamics Model prepared in the Vensim modeling instrument.

$$\text{Government support for CS inflow} = 0.05 \times \text{S11} + 0.049 \times \text{S6} - 0.049 \times \text{S4} + 1.00 \times \text{S} \tag{4}$$

$$\text{Government support for CS outflow} = 1.00 \times \text{S7} \tag{5}$$

$$\text{Stakeholder awareness and knowledge inflow} = -0.05 \times \text{S10} + 0.049 \times \text{S2} + 0.051 \times \text{S7} + 1.00 \times \text{S1} \tag{6}$$

$$\text{Stakeholder awareness and knowledge outflow} = 1.00 \times \text{S1} \tag{7}$$

where S1 represents stakeholder awareness and knowledge, S2 represents cultural preservation, S4 represents fear of the cost of adopting sustainable materials, S6 represents the health and safety of native communities, S7 represents government support for CS, S10 represents poor quality of life, and S11 represents the services that enhance the local environment.

Simulation of SD Model and Discussions

The SDM was prepared based on social factors, and to foresee the effects of these factors on Construction Sustainability, the model was simulated for three years. The simulation outcomes are graphically depicted in Figure 17, providing a visual representation of the stocks within the model. The graphical representation in Figure 17 provides a visualization of social factor intensities over a 3-year time frame. The x-axis denotes the timed progression in years, while the y-axis shows the intensity of the particular social factor for which the graph is being made.

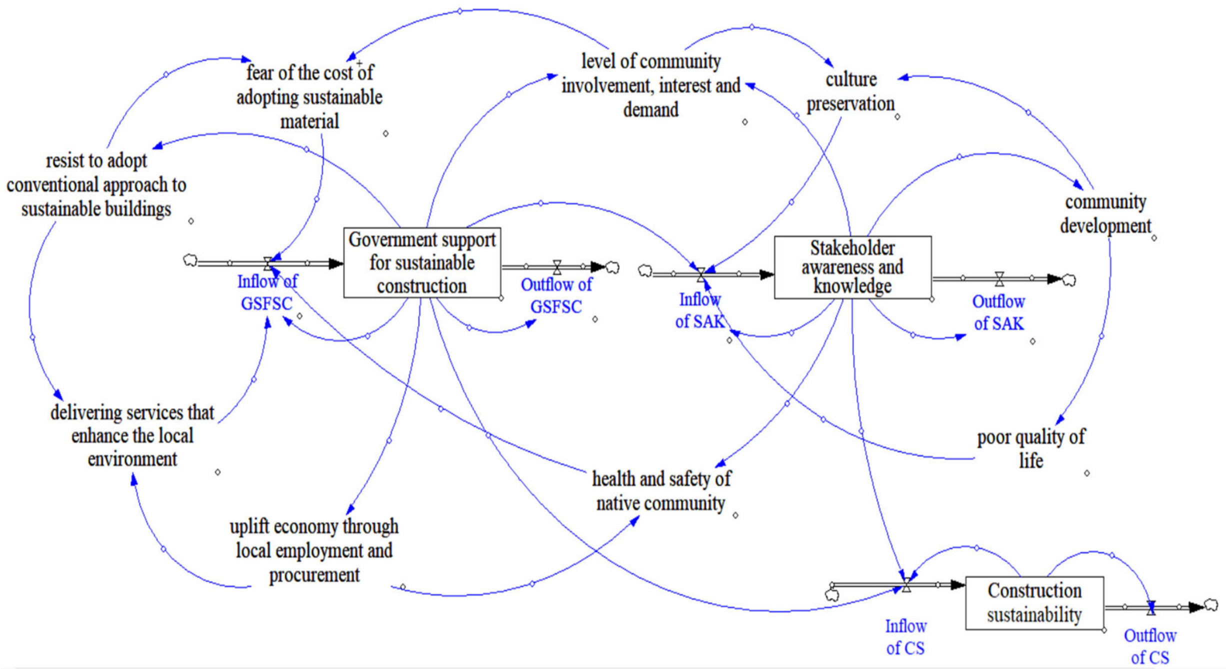


Figure 16. System dynamics model.

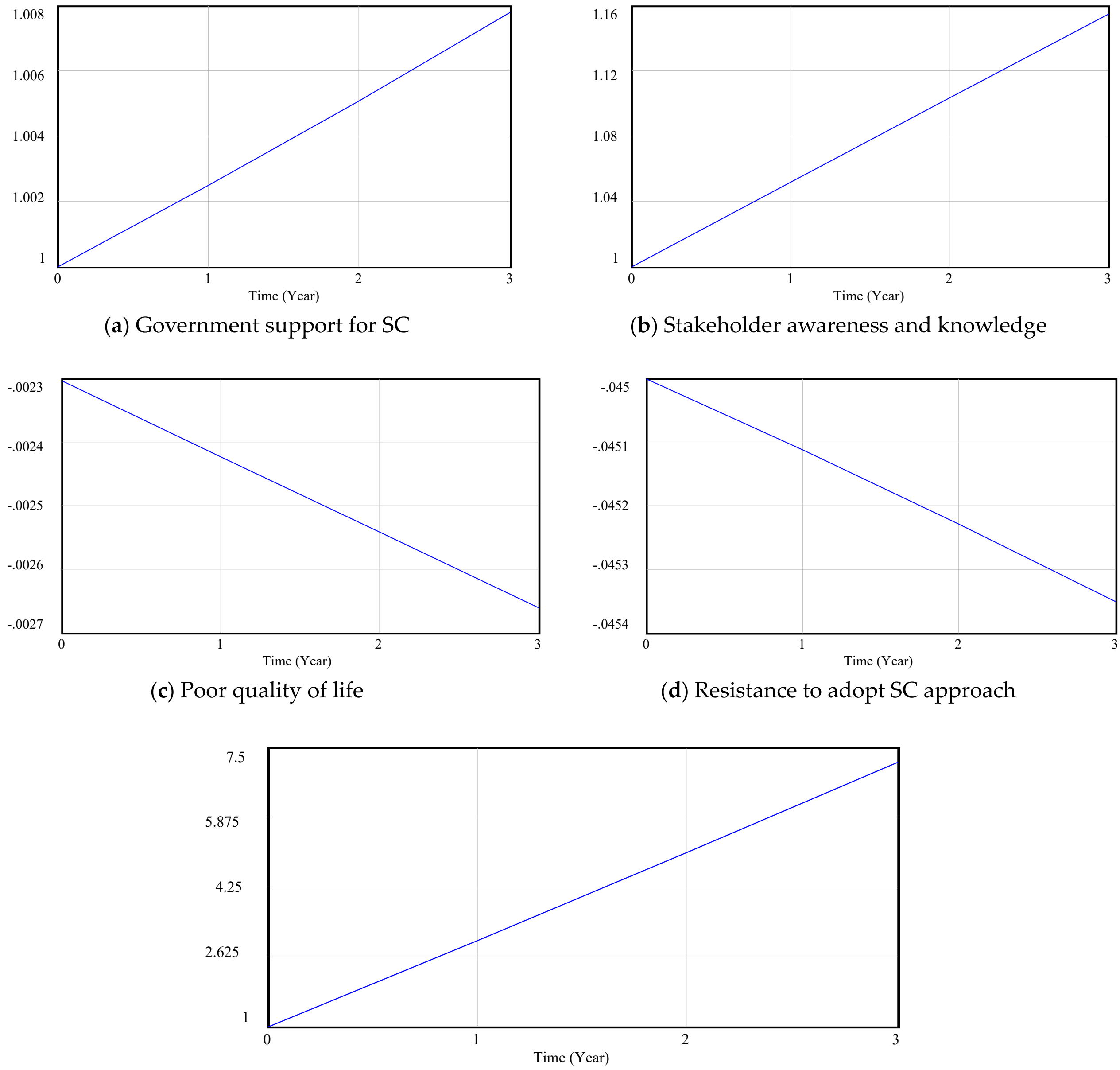
Furthermore, negative values for certain social factors, exemplified by "Poor quality of life" in Figure 17c, show their negative impact within the model. So, the factors that negatively influence a system are reflected by decreasing behavior in the model simulation. This visualization helps identify areas where strategies are needed to reduce the negative influence of these factors over time. Overall, graphical representation serves as a valuable tool for a better understanding of the dynamics and implications of various social factors in the context of Construction Sustainability.

Figure 17a shows the simulation of "Government support for CS". In this simulation, the stock representing "Government Support for CS" exhibited a visible upward trajectory over the three-year span. This upward trend signifies a positive accumulation of support over time, reflecting the model's depiction of the constructive impact of governmental backing. The observed upward trajectory of "Government Support for CS" echoes findings in studies such as that by Liu [129], who highlighted the pivotal role of governmental initiatives in propelling sustainable practices in the CI.

The results show that the stock's value increases with the passage of time, depicting its positive effects on the health and safety of communities. The positive effects on community health and safety align with the study by Zou [130], emphasizing the integral connection between CS practices and improved community well-being. Further CS enhances the local environment by providing services relevant to the community and enhancing trust in the use of sustainable materials. These findings are aligned with Ochoa [131].

As discussions around sustainability gain prominence, these simulation results provide valuable insights for policymakers, industry stakeholders, and communities alike. The positive trends observed in the simulation advocate for continued and strengthened governmental support for CS, emphasizing its potential to foster positive outcomes for community health, safety, and the environment.

The Vensim tool was used to generate these graphs. The SDM's three-year simulation graph was prepared using the Vensim tool. Once the model was prepared, it could simulate the effects of the different factors on each other, resulting in ascending or descending graph lines to reflect increasing or decreasing behavior of the factors over the prescribed timeline [80].



(**a**) Government support for SC (**b**) Stakeholder awareness and knowledge

(**c**) Poor quality of life (**d**) Resistance to adopt SC approach

(**e**) Construction Sustainability

Figure 17. Simulation graphs.

The trajectory of the "Stakeholder Awareness and Knowledge" stock, depicted in Figure 17b, shows a positive evolution over time. Smith [132] highlighted the role of government support in fostering stakeholder awareness and knowledge and argued that such support contributes to enhanced community well-being.

The simulation reveals a consistent increase in the stock value, signifying the augmentation of stakeholder awareness and knowledge within the CS context. The interplay of stakeholder awareness and knowledge, reinforced by government support and cultural preservation, manifests in an improved community quality of life as shown in Figure 17c. The positive impact of cultural preservation on community quality of life aligns with Chen [133], who emphasized the cultural dimensions in influencing community well-being, for positively influencing the overall quality of life.

The convergence of simulation findings with established research reflects the reliability and applicability of the SDM in capturing the dynamics of stakeholder awareness, cultural preservation, and their collective impact on community well-being in terms of CS. The simulation outcomes validate the interconnectedness within the SDM. The relationship between stakeholder awareness, government support, cultural preservation, and community quality of life serves as a testament to the holistic impact of CS practices.

The simulation in Figure 17d presents a declining trend in value over time, reflecting a positive influence on CS adoption. This downward trajectory signifies a reduction in resistance to change, indicating that factors such as government support and other elements discussed above contribute to fostering an environment conducive to sustainable approaches. These findings align with [134], who emphasized that government support plays a pivotal role in mitigating resistance to change in the CI, particularly when transitioning to sustainable practices.

The simulation graph of CS, as shown in Figure 17e, depicts that with positive contribution of the two stocks over time, i.e., “Government support for CS” and “Stakeholder awareness and knowledge”, the trend of CS adoption increases. The rising trend aligns with Li [97], who suggested that the combined impact of government support and increased stakeholder awareness enhances CS adoption.

4.5. Model Validation

Forrester and Senge [135] explained the validation of an SDM structure and used the boundary adequacy, structure verification, parameter verification, dimensional consistency, and extreme conditions tests for this purpose. Accordingly, the current model is based on the CLD, which in turn is developed based on the literature and field experts’ opinions. This model sheds light on the intricate relationships of social CS factors. It further predicts the near-future scenario by simulating the stocks and flows of the model based on social CS factors. The validation of the proposed model is explained as follows:

A boundary adequacy test was performed to check if the concepts and structure of the model for addressing the policy were endogenous. As the model dynamically responded to all the variables and associated changes in the conditions and boundary limits, the model was considered endogenous. The results in response to the changes were aligned with the real-life effects as verified by the field experts.

A structure verification test was used to determine whether the model’s structure was consistent with the relevant descriptive knowledge of the system for which the model was prepared. As the proposed model was derived from the variables identified through the detailed literature review and subsequent verification from field experts, the model can safely be classified as a true representative of a real-life system. The experts also concurred with this assessment, hence verifying the structure of the SDM.

Parameter verification was performed to determine the model’s consistency using relevant mathematical equations and descriptive knowledge of the system. In the model’s underlying functions, both the mathematical and descriptive equations were derived based on the knowledge from the literature duly vetted by field experts. Hence, it can be safely deduced that the model is consistent with the actual system.

A dimensional consistency test was performed to check if each equation of the model dimensionally corresponds to the real system. Accordingly, properly constructed equations representing general relationships between physical variables must be dimensionally homogeneous. All equations of the proposed SDM were developed in consultation with field experts using weightage assigned by experts; hence, it can be inferred that the model is dimensionally consistent. The experts concurred with this assessment.

Finally, an extreme conditions test was performed to check if the model shows a logical behavior when selected parameters are assigned extreme values. The model was tested against extreme conditions using extremely high and low values and the behavior was found to be consistent with real life. The same was also indicated and verified by the experts, hence validating the proposed SDM.

The SDM developed in this study holds substantial practical and research implications. On a practical level, the model serves as a valuable decision-support tool for policymakers, industry stakeholders, and practitioners seeking to foster sustainable practices within the CI. By simulating the relationship among factors such as government support, stakeholder awareness, and cultural preservation, the model provides insights into the dynamics that influence the adoption of CS methods. This allows decision-makers to strategize interventions, optimize policies, and tailor initiatives to enhance the likelihood of successful CS implementation.

In terms of research, the proposed SDM contributes to the evolving literature on CS by providing a comprehensive framework for understanding the systemic relationships among critical factors. Researchers can leverage this model to explore inherent dynamics, validate hypotheses, and conduct scenario-based analyses, fostering a deeper understanding of the complex interactions within the CS factors. Additionally, the model's adaptability makes it a valuable foundation for further refinement and expansion, allowing researchers to incorporate additional variables or refine existing relationships as new insights emerge. Overall, the SDM stands as a flexible tool with practical applicability and the potential to advance scholarly inquiries into the complex dimensions of CS in the CI.

5. Conclusions

The importance of SD has become increasingly pronounced due to rising costs and the depletion of limited resources. Within this context, the CI plays a pivotal role as one of the major sectors consuming a significant portion of resources. CS emerges as a critical component in addressing these challenges. By embracing sustainable practices, the CI can mitigate resource depletion, reduce environmental impacts, and contribute to the broader goals of SD in line with the UN-SDGs.

Social factors affecting CS have been neglected, due to which most of the previous models have failed to achieve holistic results and acceptance. The situation is further exacerbated in developing countries.

This model will greatly impact the smooth execution of any project by addressing the social factors to achieve better CS. The simulation results show that government support for CS, stakeholder awareness, and knowledge about CS must be increased to impact the project positively. This, in turn, will increase the interest and involvement of the community in the CS projects. The model also highlights that the fear of the increased cost of sustainable materials decreases as the stakeholders gain knowledge of CS. Further, to cope with the resistance to adopting CS, it is required to address the lack of knowledge and awareness of CS. These factors, in turn, help uplift the economy by generating employment and procurement in multiple fields linked with CS. By addressing these factors, cultural preservation is achieved, which creates harmony between the different stakeholders, resulting in the successful completion of the project. It paves the way for reducing the poor quality of life of the natives where the project is being undertaken and helps develop the community. As the social factors are qualitative and are difficult to calculate, this model helps to convert the social factors into quantitative entities in the form of an equation. Further, it assigns the social factors a mathematical value showing the intensity of the effect created, which helps achieve CS and is fruitful for the successful completion of the project.

A limitation of this study is that the SDM was developed only for developing countries and may not be globally applicable. However, the proposed model can be extended to developed countries by collecting local factors and involving relevant experts from developed countries. This also offers an opportunity to compare the models and discuss and compare the priorities of people in developing and developed countries. Another limitation of this study is that it encompassed limited number of factors to reflect the system of Construction Sustainability. Furthermore, in the future, SDMs can be developed by focusing on the social considerations of different functional units of society, i.e., clients, contractors, and natives, as they may have different or conflicting thoughts and objectives towards a project.

5.1. Theoretical Implications

This model explains in depth how these social factors can affect CS. These social factors interact with each other positively and negatively. With the help of this model, we can interpret the behavior of the social factors and obtain positive outcomes by addressing the shortcomings in the factors to enhance CS. With this model, we have given these social factors the quantitative dimension to interpret their behavior better and devise tailored methodologies to obtain positive outcomes for CS. As this model was developed for developing countries, researchers can develop a similar model for developed countries in the future. A comparison of both models can give insight into the outcome of how social factors influence the domain of CS in developed and developing countries.

5.2. Practical Implications

Stakeholders can use the model for strategic decision making and to anticipate the consequences of different decisions, aiding in formulation of sustainable strategies. Policymakers can use the model to develop targeted policies and guidelines addressing the identified social factors. The model supports risk mitigation by identifying potential challenges that relevant stakeholders can address. The model allows for scenario analysis, enabling stakeholders to explore the consequences of different scenarios. This can help them intervene and devise strategies to deal with the risks. It empowers stakeholders with tools for strategic decision making, policy development, and managing critical factors, fostering a comprehensive approach to Construction Sustainability.

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