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A Holistic View of Construction Sustainability: Integrating Social Dynamics with System Dynamics

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***Abstract*— Resource constraint is being experienced in the world with increasing population and resources are being consumed more rapidly thus generating a rift among countries to control resources. Construction industry (CI) is a major consumer of assets, ensuring sustainability is vital for overall sustainable development. While economic and environmental aspects of sustainability have received considerable attention from researchers, the social dimension has often been overlooked or insufficiently researched. This study aims to address this gap by examining the significant role of social factors in influencing construction sustainability practices.**

The research involved a thorough literature review encompassing PRISMA analysis, expert opinion through questionnaire, content analysis, and consultation with the industry experts to identify the 11 key drivers. Through a combination of expert engagement and literature review, eleven key social factors were identified and their impact on construction sustainability was assessed. Causal Loop Diagram (CLD) was prepared to illustrate the complex interactions among these factors. The CLD featured eight reinforcing loops and one balancing loop, illustrating the potential impact of these social factors on construction sustainability, either positively or negatively.

The findings indicate that addressing these social factors can lead to an increase in construction sustainability over time. The CLD serves as a valuable instrument for comprehending the complex interconnections and feedback loops within the social system that influence construction sustainability. This insight is essential for stakeholders involved in endeavors where social factors are of considerable importance, enabling them to make more informed decisions and effectively address the complexities associated with these factors.

***Index Terms*— Sustainable Development, Construction Sustainability, Social Sustainability, PRISMA.**

I. INTRODUCTION

The concept of sustainability was first introduced in 1972, during the United Nations' international conference on the Human Environment in Stockholm [1]. This event marked the beginning of a global conversation about the interconnectedness of environmental, social, and economic well-being – a concept often referred to as the "Triple Bottom Line" [2]. Practicing environmental sustainability, such as green construction, can lead to economic benefits through cost savings and social benefits through improved health and well-being of workers [3]. However, measuring social sustainability at the micro level is complex. Unlike environmental and economic indicators, social indicators are difficult to identify, select, and quantify due to the diverse views and priorities of stakeholders, the wide variety of stakeholders involved, and the subjectivity of socio-related factors [4]. Social sustainability is often described as the engagement of employees, local communities, clients, and the supply chain to meet the needs of current and future populations and communities [5]. It involves considering the impact of construction projects on where users live, work, play, and engage in cultural activities [6], ensuring inclusion through designs that consider underrepresented groups (e.g., accessibility for the elderly and disabled), and advocating for worker safety by eliminating potential hazards during the design phase [7]. Despite the challenges, integrating stakeholder interests is key to achieving sustainability. However, diverse interests and perceptions make this a difficult task. Addressing these challenges is crucial, as social sustainability is just as important as economic and environmental sustainability – intangible benefits may be just as valuable as tangible ones [8]. By prioritizing social sustainability, we can create buildings and communities that are not only environmentally and economically sound but also socially equitable and inclusive.

II. LITERATURE REVIEW

When it comes to sustainability frameworks, they are extremely beneficial to the CI and open the door for occupants who are healthier. The researchers discovered that project planners had largely disregarded the social factors influencing Construction Sustainability (CS) in favour of the economic and environmental factors [9]. According to [10], the various domain people are part of the project with a variety of requirements, and they are impacted both favourably and unfavourably as the project progresses through different phases. Guidelines for meeting the needs and expectations of project stakeholders who are impacted in one way or another were provided by [11]. According to [12], it is crucial to comprehend the social relationships that are ingrained in the planning, building, and management of

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construction projects when working on their designs.

The researchers' realization to address the social factors in developing countries was demonstrated by the indicators they developed in Iran to assess the social sustainability of the urban infrastructure [13]. For example, the state of multi-criteria infrastructure assessment studies that took social factors into account was reviewed by [14]. Furthermore, [15] developed a conceptual framework that is well suited for analysing the social criteria in building projects by combining empirical studies and a review of the literature. The most prevalent social issues privacy, healthy indoor environments, social participation, safety, security, accessibility, identity, physical resilience, satisfaction, cultural values, etc. were acknowledged by both literature and practice to be related to social issues.

In order to create a system for citizen participation, social sustainability in construction can be achieved by combining physical design with social infrastructure to foster social and cultural life [16]. According to [17], the Global Reporting Initiative established categories, such as labour practices, human rights, decent work, and society responsibility, which demonstrate how these significant issues are addressed from their point of view in order to achieve the SD. [18] placed a high value on construction safety and recommended that designers and architects collaborate for the design to reduce and control the potential hazards which is a crucial step in achieving the SS.

Stakeholder participation from the outset is crucial to achieving social sustainability in construction and has been identified by numerous researchers as a key component of SS [19]. Community groups are important when addressing other social factors because they can have a negative impact on a project by causing budget increases and unjustified delays if their requests or concerns are not properly addressed on time [20]. [21] drew attention to the expanded scope of the SS, which now encompasses equity of access and community sustainability. [22] focusing on social sustainability, elaborated that accident on the site as a result of disregard for the site's safety procedures has a negative impact on the profitability, productivity, and team morale. In order to achieve the SS in the construction, the following social factors were identified by the [11] diversity, employment, health, safety, community involvement, education, and training. In order to make the design more acceptable by meeting the needs of all stakeholders and improving our understanding of human behaviour, SS also incorporates the point of view and thinking of the lessened groups. In order to influence the public and achieve the desired results for everyone's benefit, government agencies and stakeholders hold public hearings during the design decision-making process, which makes stakeholder involvement crucial from the planning and designing phase.

It can be difficult to quantify the social elements that influence the sustainability of construction. Social factors are frequently intricate, multidimensional, and challenging to measure. It is challenging to create standardized metrics to measure social factors because they are frequently qualitative and challenging to measure. Furthermore, social factors are frequently context-specific, which means that an effective solution in one setting might not be the same in another. It is determined that SS is highly diverse and complex based on the literature. According to researchers, identifying, choosing, and measuring social indicators in order to attain sustainability when compared to environmental and economic indicators is not at all simple [23].

III. METHODOLOGY

This study examines how social factors impact Construction Sustainability (CS) and subsequently constructs a Causal Loop Diagram (CLD) for simulation purposes. The research is structured into four stages. In the first stage, a literature review revealed a research gap that prompted this study. The second stage involved identifying social factors and conducting a content analysis to prioritize them. The third stage consisted of creating an influence matrix, which informed the development of the CLD. In the fourth stage results were presented along with the discussion leading to the conclusions. Steps followed for the research are shown as per figure 1 shown below.

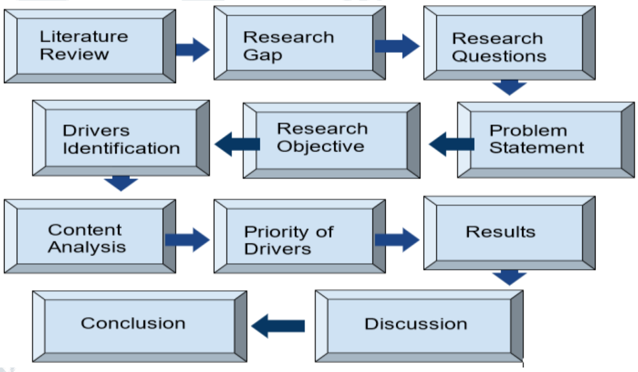

Fig 1: Sequence of research

The literature review guided towards the specific goal to determine where the research is most lacking. It was used as a basis for the research queries to lead to research questions. To perform the literature analysis different platforms such as Elsevier, Google Scholar, Web of Science, Science Direct and American Society of Civil Engineers played major role [26, 27]. Using the information and observations gathered during this process some areas were found lacking and were thus decided to be the focus point of the research questions. the problem statements and research objectives were developed according to explore this research gap. This marked the first stage in research. PRISMA (Preferred Reporting Items for Systematic reviews and meta-Analyses) [28] was used for the accuracy and relevance of research and to do systematic literature review as shown in Figure. 2. A total of 178 articles were found from different research databases to include Google Scholar, Research Gate, Web of

Science, Scopus, and others. After screening basing on inclusion and exclusion criteria of PRISMA 72 articles were selected to extract the social factors for the research.

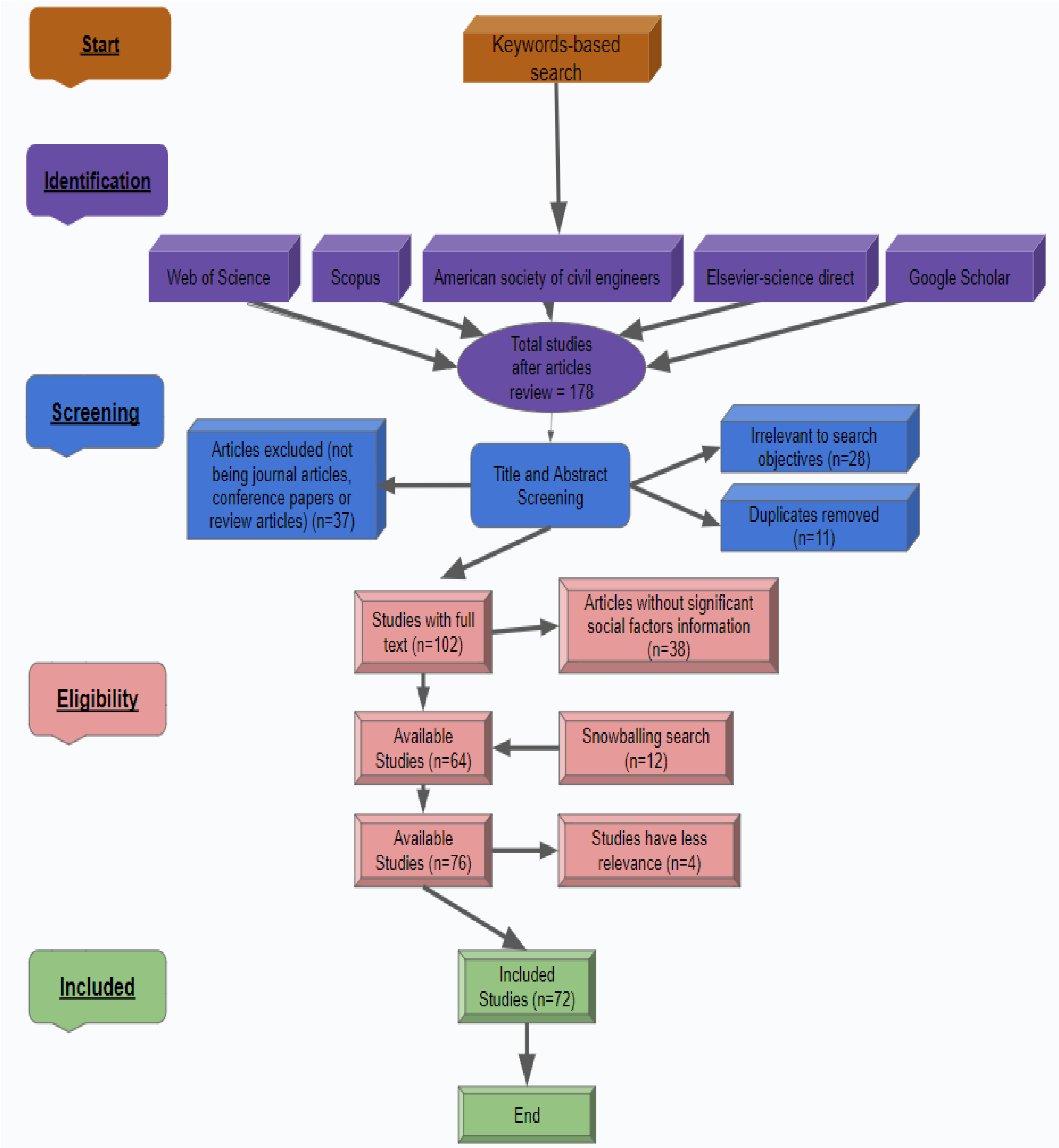

Figure 2. PRISMA flow diagram

To determine the normalized score of the literature findings, content analysis was conducted, which was then utilized to rank these factors by their level of importance. Equation (1) was used to calculate the Literature Score (LS) (Azman et al., 2019). W stands for the highest frequency, A for the maximum possible score, and N for the number of papers considered for a detailed review. Classification of each factor was done ranging from high to low as per the data collected from the literature. Next, using Equation (2) which divided the sum of the LS of all factors by the LS of each factor the normalized literature score (NLS) was calculated. Table 1 displays the social factors that were sorted using the above methodology, ranked with the references.

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$$RII = \sum W / (A \times N) \quad (1)$$

$$NLS = (LS) / (\sum LS) \quad (2)$$

Table 1: Social drivers from literature affecting construction sustainability

S. No.	Construction Sustainability Drivers	References
1	Awareness and Knowledge of Stakeholders	[29-35]
2	Preserving Cultural Heritage	[32, 35-38]
3	Stakeholder resistance to adopting sustainable building practices	[32, 33, 35, 39]
4	Cost Concerns Regarding Sustainable Materials	[34, 35]
5	Boosting Local Economy through Employment and Procurement	[35, 38, 40, 41]
6	Indigenous community health and safety	[30, 32, 35-38, 42, 43]
7	Reluctance to Preserve Resources	[39, 40]
8	Promoting Community Development	[32, 36, 37]
9	Traffic Congestion and Travel Disruptions	[37, 44, 45]
10	Substandard Living Conditions	[44, 46]
11	Environmental Services Enhancement	[36, 37, 46]
12	Degradation of Historical Artefacts	[47]
13	Preservation of Local Traditions	[48]
14	Stakeholder Misalignment	[31, 34]
15	Deterioration of Recreational Amenities	[44, 46]
16	Rising Traffic Accident Rates	[44, 47]
17	Government Inadequacy in Sustainable Construction	[31, 33, 45, 49]
18	Indigenous Skills Enhancement	[32, 41, 43]
19	Space Limitations	[37, 48]
20	Indigenous Community Well-being	[42]
21	Relationships and communication improvement	[16, 31, 43]
22	Enhancing Stakeholder Relations	[30, 36, 42, 49, 50]
23	Promoting Social Equality	[48]
24	Aesthetic Alterations	[37, 42]
25	Ensuring Safety and Security	[16, 36, 45]
26	Public engagement and project governance	[16, 30, 31, 41, 43, 50]
27	Community resettlement	[43, 45]

In order to authenticate the social drivers from the literature there was a need to validate these drivers and refined them by gathering feedback from industry practitioners in the field. For this purpose, a field investigation (FS) was done from the respondents of the relevant field to grade the social drivers impact ranging from 1 to 5. SPSS® was further used to check the data meets the reliability and normality requirements. Subsequently, the factors were ranked using a combination of Field Score (FS) and Literature Score (LS) in a ratio of 60% (FS) to 40% (LS), as illustrated in Table 2.

Table 2: Shortlisted social drivers affecting construction sustainability

S. No.	Construction Sustainability Drivers	Normalized industry score (FS)	Normalized literature score (LS)	Total score 60%FS / 40%LS	Cumulative Normalized Total Score
1	Awareness and Knowledge of Stakeholders	0.030928	0.096228	0.057048	0.057048
2	Preserving Cultural Heritage	0.030928	0.082756	0.0516592	0.1087072
3	Stakeholder resistance to adopting sustainable building practices	0.041237	0.063510	0.0501462	0.1588534
4	Cost Concerns Regarding Sustainable Materials	0.051546	0.046189	0.0494032	0.2082566
5	Boosting Local Economy through Employment and Procurement	0.041237	0.061586	0.0493766	0.2576332
6	Indigenous community health and safety	0.041237	0.057737	0.047837	0.3054702
7	State endorsement for Sustainable Construction	0.041237	0.051963	0.0455274	0.3509976
8	Promoting Community Development	0.041237	0.050808	0.0450654	0.396063
9	Public engagement and project governance	0.041237	0.042725	0.0418322	0.4378952
10	Substandard Living	0.041237	0.042340	0.0416782	0.4795734
11	Environmental Services Enhancement	0.030928	0.050038	0.038572	0.5181454

For this purpose, 115 responses were gathered from developing nations such as Pakistan, Bangladesh, Philippines etc. These responses were used to shortlist 11 factors based on scores from both the LS and FS, as presented in Table 2. Selection of the drivers was based on achieving the 51% cumulative normalized score as a datum line [26]. Respondents are as shown in Fig 3

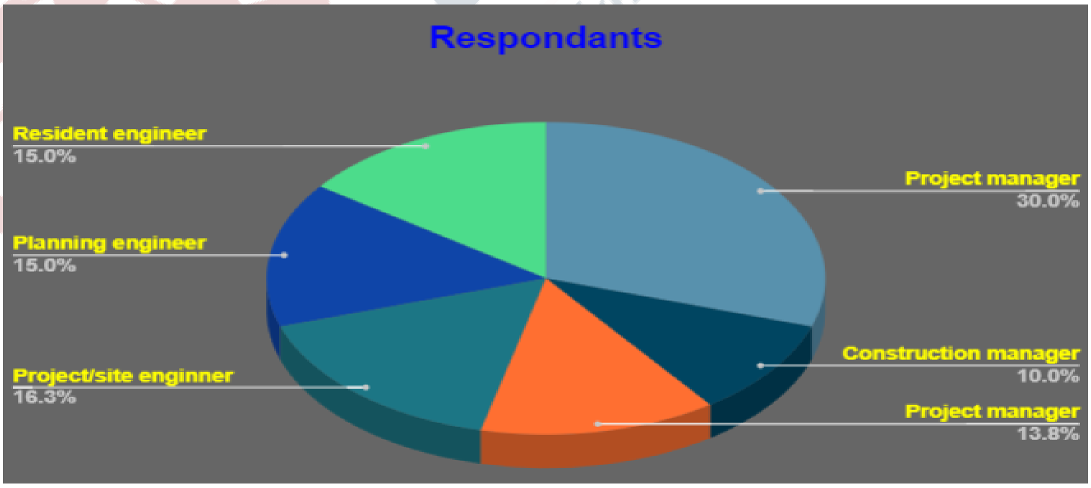

Figure 3. Respondents profile

In the third stage, an extensive survey was undertaken to determine the intensity and direction of the relationships among the social factors influencing CS. Over 350 questionnaires were distributed, resulting in 110 responses and a response rate of 31%. The survey specifically targeted experts from developing countries. This stage was instrumental in identifying CS factors and evaluating their direct or inverse correlations. With the help of this survey impact level of the shortlisted social drivers ranging from low to high was also determined which further led to determine the Relative Importance Index (RII) score. In order to make the CLD it is very important to find the type of relationship either direct or inverse that exists between the social drivers of construction sustainability which was also determined.

IV. RESULTS AND DISCUSSIONS

In order to understand the relationship among the social sustainability drivers and how they behave under different conditions it is necessary to construct the Causal loop diagram which was done using Vensim PLE® as shown in Figure 3. Balancing and reinforcing loops were used to give good understanding of the system and to explain the phenomenon of changes taking place in the system by the interaction of the different social drivers and its effects on the construction sustainability. Once change takes place in the drivers then it brings changes in the system and with the passage of time this change becomes more pronounced showing a reasonable change in the overall system. As a result of this either there will be growth in the system or conversely system will start diminishing. This leads to the conclusion that changes are very important to monitor in any system to control or change the outcome to desired levels. Balancing loops play very important role of stabilising the system as they generate a counter force to deal with the changes occurring in any variable. In order to keep the system in balance it follows the Newton's third law so that every action is met with the equal and opposite reaction.

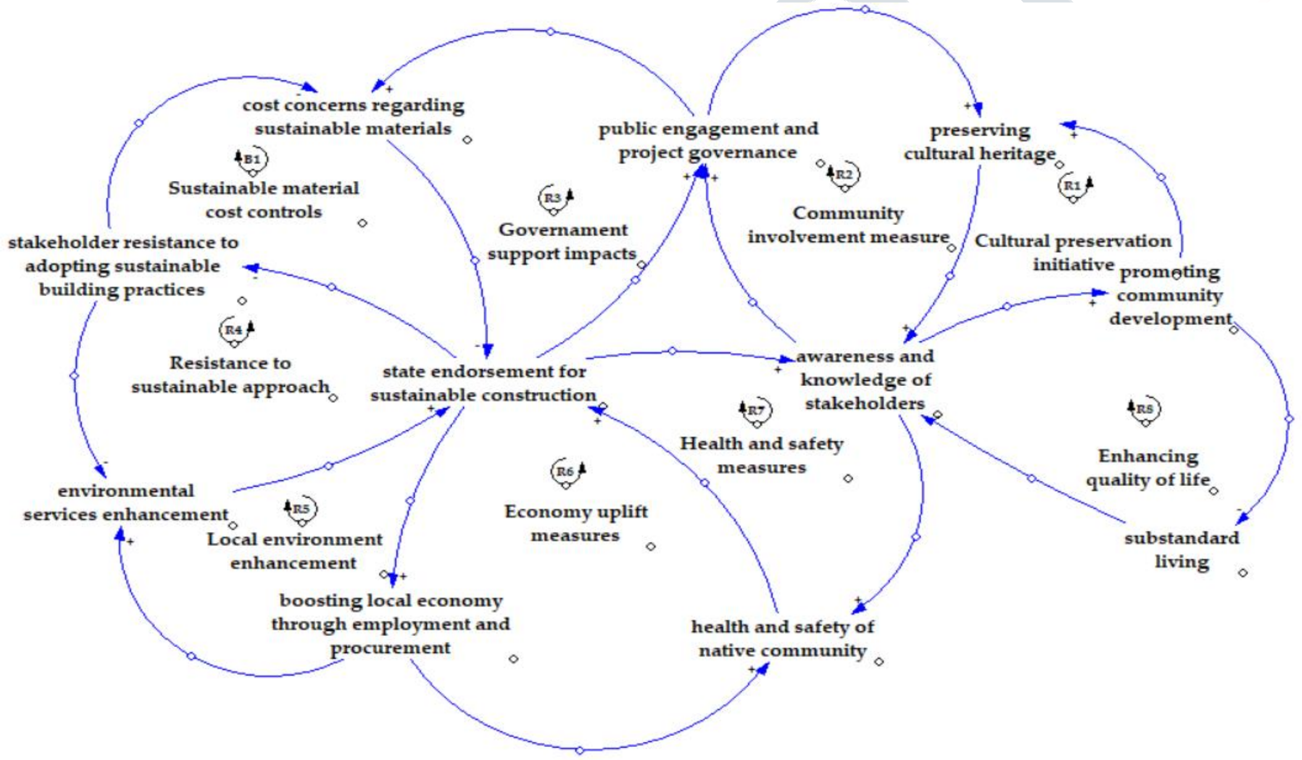

Figure 4. Causal loop diagram

The CLD has recognized total of nine loops containing both the balancing loops and the reinforcing loops, as depicted in Figure 4. From these loops we come to know that even a small change in one variable can create a big effect with the time thus creating a big change in the overall system. The importance of initial conditions is prominently shown by how the system can either depict continuous growth or decline.

The analysis has shown that the eight reinforcing loops and one balancing loop were all found to be having an impact on each other. This resulted in a very complex relationship between the system variables. The cause and effect relationship describe the interaction between these social factors, portraying them as central elements in the system as one change can impact and result in alternating all the others in the sustainability system. The important recurring connections between eight reinforcing loops within the constructed CLD highlights the impact of one on the other factor. The entire system is impacted by change in one factor and it creates a domino effect which has prominent effects on the environment. The social CS factors have established connection between factors and loops. This has established the impotence of how construction sustainability needs a knowledgeable and well-informed approach.

To achieve CLD validation, the knowledge base was collected from very experienced professionals who had very good grip on the subject of social factors influence on the sustainability. Their input was crucial for validating the model, explaining in depth the methodology of the system to give good understanding. The involvement of these experts gives the real-world experience and thus validate the CLD model. This helps ensure that the social factors behaviour and their interaction among each other accurately explains the system thus proposing very dynamic solutions to achieve the construction sustainability by addressing these social drivers.

V. CONCLUSIONS

The cost factor and lack or restricted access to resources is the major reason and focus for the Sustainable Development (SD). In this scenario, the Construction sector utilizes a considerable share of resources. Achieving the sustainability in construction is pivotal in addressing these challenges, offering a way to reduce the costs and provide alternate and reasonable resources as a by-product environmental impacts will also lessen .as this align with the United Nations Sustainable Development Goals (UN-SDGs) it's an added benefit. Despite its importance, societal and cultural factors influencing sustainability in construction have often been overlooked, leading to incomplete models and limited acceptance. This issue is more pronounced in developing countries.

Addressing these social factors is essential for the successful execution of any project and for achieving comprehensive sustainability. The conclusions have shown that increasing government influence in form of policies and rules for CS and increasing awareness and knowledge of stakeholders are key to positively impacting projects. This can lead to greater public engagement and project governance in CS projects. The model also suggests that as stakeholders become more knowledgeable about CS, the market for such materials becomes stable and thus cost factors start to reduce with better supply and demand.

To overcome resistance to adopting CS, the knowledge base should be increased and good experiences of successful projects should be highlighted. This, in turn, can increase industry capacity for these environmentally friendly materials, it will increase local agricultural and mining outputs by creating employment and procurement opportunities in CS-related fields. Additionally, addressing these factors can help preserve cultural heritage and foster harmony among stakeholders, contributing to project success. Furthermore, addressing these social factors can lead to a reduction in the substandard living experienced by natives in project areas and can contribute to community development.

Given the qualitative nature of social factors, converting them into quantitative entities through a model can be challenging but is very beneficial. This model aims to quantify social factors into equations, assigning them mathematical values to represent the intensity of their effects. This methodology can help increase the success rate of CS projects.

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