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Circular Economy in the Construction Industry: A Step towards Sustainable Development

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Abstract: Construction is a resource-intensive industry where a circular economy (CE) is essential to minimize global impacts and conserve natural resources. A CE achieves long-term sustainability by enabling materials to circulate along the critical supply chains. Accordingly, recent research has proposed a paradigm shift towards CE-based sustainability. However, uncertainties caused by fluctuating raw material prices, scarce materials, increasing demand, consumers' expectations, lack of proper waste infrastructure, and the use of wrong recycling technologies all lead to complexities in the construction industry (CI). This research paper aims to determine the enablers of a CE for sustainable development in the CI. The system dynamics (SD) approach is utilized for modeling and simulation purposes to address the associated process complexity. First, using content analysis of pertinent literature, ten enablers of a CE for sustainable development in CI were identified. Then, causality among these enablers was identified via interviews and questionnaire surveys, leading to the development of the causal loop diagram (CLD) using systems thinking. The CLD for the 10 shortlisted enablers shows five reinforcing loops and one balancing loop. Furthermore, the CLD was used to develop an SD model with two stocks: "Organizational Incentive Schemes" and "Policy Support." An additional stock ("Sustainable Development") was created to determine the combined effect of all stocks. The model was simulated for five years. The findings show that policy support and organizational incentive schemes, among other enablers, are critical in implementing a CE for sustainable development in CI. The outcomes of this study can help CI practitioners to implement a CE in a way that drives innovation, boosts economic growth, and improves competitiveness.

Keywords: causal loop diagram; circular economy; construction industry; sustainable development; system dynamics

1. Introduction

The construction industry (CI) is the world's largest user of natural resources. Traditionally, the CI has utilized a non-sustainable, linear economic model based on the "take, make, dispose of" concept in the past and continues to do the same [1]. The linear approach does not allow constructed facilities to be dismantled and reused. Therefore, they become obsolete when the facility ends its useful life [2]. However, this must change in the era of focus on sustainability and global greening initiatives.

The Circular Economy (CE), which has captured the interest of researchers and practitioners in the last decade, is contrary to this ineffective and unsustainable linear economic paradigm [3]. Regardless of the various schools of thought and definitions, the CE aims to maintain resources flowing at their best value within boundaries. This ensures that no new natural resources are needed to manufacture materials and that waste is minimized [3]. Aside from resource circularity in closed-loop systems, the CE focuses on better resource management by rethinking and reducing unnecessary consumption. Product fragmentation, intensification of product use, and increased production efficiency are examples of projects in which better resource management is incorporated by rethinking and reducing unnecessary consumption [3]. The CE's foundation is built on better resource management through lower consumption and replacing the "end-of-life" concept with the reusing, recycling, and recovering materials and components [4].

The CI faces many problems, including a non-linear economy, the absence of financial assistance, lack of proper technology, non-supportive infrastructure, and lack of political will towards sustainable development [3]. Uncertainties caused by fluctuating raw material prices, shortages of materials, increasing demand, urbanization, climate change, absence of proper waste management infrastructure, and use of wrong recycling technologies all lead to complexities in the CI [5]. There seems to be controversy on the cause of problems and how to address them. However, complexity is beyond the scope of any single organization to comprehend and respond [6]. Implementing CE principles in CI will lower industry costs; reduce negative environmental effects; make urban areas more livable, productive, and convenient; and help deal with these process complexities [7]. Although the notion of the CE has gained traction in academia, business, and government, its widespread implementation remains limited [8]. This implementation is in its nascency in the CI. Regardless of its implementation status, the CE has emerged as one of the most crucial and contemporary approaches to addressing sustainability [9]. Accordingly, like its industrial counterparts, the CE's implementation in the CI must be investigated and facilitated to attain the global sustainability targets.

According to Kirchherr et al. [10], the CE aspires to contribute to sustainable development. Suárez-Eiroa et al. [11] claim that the CE operates within sustainable development. However, there has been little research on utilizing CE principles in the built environment holistically and systematically. For instance, Geissdoerfer et al. [12] proposed a framework indicating that the CE assists in realizing sustainability ambitions. Ritzén and Sandström [13] identified barriers to a CE for sustainable development in the CI and categorized them into financial, structural, operational, and technological categories. Schöggl et al. [14] concluded that the most commonly used R-strategies are recycling, remanufacturing, repair, and reuse. Walker et al. [15] provided important strategies for how organizations might use CE practices to attain sustainability.

Sparrevik et al. [16] concluded that assessing environmental performance for CE in the CI is a recursive structure for its successful implementation. Moreover, recent research has advocated an additional paradigm shift to a sustainability-based CE [17–19]. Bilal et al. [20] proposed that further research regarding implementing CE for CI in developing countries is needed. Accordingly, further empirical research is necessary to address the complexities of implementing CE principles for the sustainable development of the CI [21,22]. In addition, there is a need to quantitatively address the effects of CE on sustainable development [12,23]. From the perspective of the CI, studies addressing the complexity of implementing the CE for sustainable development are limited [23], which is predominantly evident in developing countries. Therefore, a larger research gap is presented in this context, requiring a holistic study focused on developing countries to address the complexity of CE implementation in the CI for sustainable development. Therefore, this study targets this research gap and quantitatively addresses the complexity of implementing a CE for sustainable development in developing countries.

The United Nations' (UN) 17 Sustainable Development Goals (SDGs) aim to make the world a better place for people and the environment by 2030 [24]. By adopting the SDGs in 2015, 193 countries agreed to address the world's most pressing issues [25]. The CE contributes to the achievement of the UN's SDGs [26]. This possibility abounds in the many ways in which individuals and corporations engage while enabling the CE. The CE can start with the basics and have a big impact, opening new avenues for collaboration to maintain and develop value through revitalized buildings, meaningful occupations, and enhanced mobility [27]. The SDGs provide a new prism through which global needs and objectives can be transformed into economic alternatives for the CI. The 17 SDGs can be divided into five categories or the 5Ps: people, planet, prosperity, peace, and partnership [28]. These 5Ps of the SDGs necessitate collaboration between several players, including governments, institutions, and corporations. Because the CI is a crucial stakeholder, it is critical that it establishes methods for aligning its business strategies with the SDGs. Since the introduction and approval of the UN 2030 agenda, academics and practitioners from various fields have been working hard to research possible SDGs implementation techniques [26]. The CI should be no exception to this, and uplift from the lens of UN SDGs is needed while striving to enable CE in the CI.

Based on the above discussion, construction is inferred as a resource-intensive industry where the existing economic practice may not be sustainable. The arising uncertainties in CI lead to complexities. The SDGs have been less focused on by researchers exploring CE implementation in developing countries [29,30]. Nevertheless, regarding implementation, studies have provided various strategies. However, specific research to address the complexity of implementing the CE for the sustainable development of the CI is minimal and particularly evident in the case of developing countries [31]. This presents a critical gap requiring the attention of the researchers targeted in the current study. Accordingly, the current study aims to address the complexity arising in implementing CE for the sustainable development of the CI with a focus on developing countries. The SD approach that has been widely used in dealing with complexities is utilized in this study [32,33]. The current study has the following objectives:

1. To identify the key enablers of the CE which lead towards sustainable development in the CI.
2. To determine the causality among CE enablers, reducing uncertainty and leading towards sustainable development in the CI.
3. To develop an SD model to address complexity related to sustainable development due to a CE in the CI.

This study uses the systems thinking (ST) approach to determine the causality among key CE enablers. Furthermore, SD is used for model development and simulations. ST is a holistic method focused on the establishment and dynamic interrelationship of constituent parts of a system to address the inherent complexity [32]. SD is a methodology based on ST that addresses process complexity using simulation techniques [33,34]. The results of this study will help CI practitioners implement the CE in a way that drives innovation, boosts economic growth, and improves competitiveness. By implementing CE principles in CI, industry costs would be lowered, negative environmental impacts reduced, inherent complexities tackled, and resilience of urban areas enhanced to make them more livable, productive, and convenient.

The remaining paper is structured as follows. First, an overview of the existing literature on CE and sustainable development is presented in Section 2. Next, the study's methodology is discussed in Section 3. Next, Section 4 provides the study's findings and discussion. Finally, the paper concludes with Section 5, providing key takeaways, limitations, and future directions.

2. Literature Review

2.1. Circular Economy (CE)

The CE is defined as a system designed to be restorative and regenerative to decouple economic growth from resource utilization [7]. The concept of a CE was first proposed in the twentieth century to emphasize the development of the ecological industry [35]. The

CE is considered a solution to diminish the dependency on resource extraction. It is a condition for preserving the current way of life by sustaining the value of resources and keeping them in circulation [36,37]. It is a business strategy that eliminates the "end of life" concept from the production, distribution, and consumption stages [38].

The CE focuses on minimizing waste, reuse, recycling, and recovery of resources. It is a novel approach to achieving sustainable development [39]. CE uses the product's end-of-life as a substantial economic material resource [40]. It encourages disruptive innovations in product-service systems, social and eco-innovations, efficient usage of resources, and sustainable consumption [41]. The transition from a linear economy (LE) to a CE is a real challenge. However, achieving this will help accomplish the long-term sustainability goals [42]. The CE is thought to have aided in transforming the conventional LE into a closed substance economy, which is required and beneficial for developing a sustainable society [12].

CE principles are becoming increasingly popular as a practical option for accomplishing sustainable goals [21,43]. New tools are needed to help practitioners, decision-makers, and governments embrace more CE practices and reap the holistic benefits. Kirchherr et al. [10] discovered that of the 114 descriptions of CE, 35–40% deal with the waste hierarchies reduce, reuse, recycle (3R) framework. However, the CE concept does not always address all aspects of sustainability. Specifically, it is silent on the social aspect of sustainability, an emerging criticism of its association with sustainability. Nevertheless, academics, industry leaders, and politicians are interested in exploring the benefits of implementing the CE paradigm to improve the economic system's sustainability [3]. From this, it can be concluded that there is a crucial need to implement CE for sustainable development in the CI—a key contributor to the global economies.

2.2. CE Concept for Sustainable Development in the CI

The CE concept helps foster sustainable development [16]. The primary issue in sustainable growth with LE is that it pursues continual economic expansion at the cost of environmental degradation, with no clear grasp of whether this enhances social fairness [44]. As a result, global sustainability concerns are on the rise. If the CE is to serve as a model for sustainable development, it must address these concerns. Accordingly, environmental constraints, social equity, and economic prosperity should all be addressed in the CE criteria [45].

According to Xu et al. [28], the CE is the outcome of almost a decade of global economies' endeavors to promote sustainable development. According to Yaduvanshi et al. [46], the CE is widely recognized as a tool for achieving sustainable development. However, it is unclear how a CE concept that excludes a key facet of sustainable development (social consideration) may lead to a model that can be termed sustainable [10]. First, despite its promotion as a concept for sustainable development, it is unclear if the CE can promote economic growth while preserving the natural environment and increasing social fairness for future generations [47,48]. Second, as Merli et al. [49] pointed out, the lack of research on how the CE addresses social wellbeing indicates that this should be a top priority. Third, understanding how the CE will improve social fairness and developing new indicators to effectively evaluate these changes would necessitate a collaborative effort across disciplines. In this context, Mongsawad [50] concluded that greater emphasis must be paid to establishing innovative strategies for changing production and consumption patterns that allow the CE to reduce its reliance on virgin resources while increasing the consumption of secondary materials.

CE principles are incredibly relevant to the CI, with the building sector being a major worldwide consumer of commodities such as energy, materials, and resources [51]. For its high resource intensity, the CI draws the most attention throughout the CE transition [19]. Although there are numerous hurdles that the CI will face in a holistic implementation of a CE, these adjustments are both achievable and essential [17]. A CE in the CI is considered one of the main priorities for national economic development, making its investigation critical and much needed [11].

The CE concept is becoming a well-known solution to some of the world's most urgent crosscutting sustainable development issues [16]. The CE offers an excellent platform for economic growth. It helps to create new, more sustainable jobs while reducing reliance on nonrenewable resources and the production of negative externalities [52]. However, a collective commitment from society is needed for widescale adoption. The CE transfers growth and opportunity from current consumption patterns to a continuous and long-term system [53].

2.3. CE and United Nations' (UN's) Sustainable Development Goals (SDGs)

The CE aims to achieve innovation in industries and infrastructure, enable economic growth, sustainable cities and communities, tackle climate change and reduce harmful life of materials which are priority areas of the United Nations Sustainable Development Goals (UNSDGs) [54]. After the Millennium Development Goals (MDGs), the UN set these goals in 2015 to protect the planet, eradicate poverty, and ensure that all people enjoy peace and prosperity by 2030.

United Nations set 169 targets in 2015 to track progress toward 17 SDGs [55]. These targets were developed through international and interdisciplinary collaboration, allowing countries to develop their context-specific tactics. Schroeder et al. [21] concluded that the CE could directly contribute to the achievement of several SDGs, including SDG6 (clean water and sanitation), SDG7 (affordable and clean energy), SDG8 (decent work and economic growth), SDG12 (responsible consumption and production), and SDG15 (Life on land). According to Howden-Chapman et al. [56], the CE can assist in achieving SDG 6 (provide universal access to water and sanitation) and SDG 11 (make cities inclusive, safe, resilient, and sustainable) by improving housing conditions in informal settlements. SDG 8 (inclusive and sustainable economic growth, employment, and decent work) and SDG 9 (resilient infrastructure, sustainable industry, and innovation) focus on providing opportunities to apply CE solutions, such as improving working conditions in unorganized sectors processing secondary resources or establishing industrial symbiosis networks for resource-efficient industrial development such as the case of CI [56,57].

2.4. Implementation Complexities of the CE in the CI

Uncertainties caused by fluctuating raw material prices, shortage of materials, increasing demand, urbanization, climate change, absence of proper waste infrastructure, and use of wrong recycling technologies all lead to complexities in the CI [33]. Industries perceive the CE as a method to integrate economic, societal, and environmental interests by transforming linear economies (LEs) into circular economies (CEs) to obtain the best product value [58]. Unfortunately, this integration comes at the cost of increased complexity in various ways [59].

The CI's current complexity management techniques focus on reducing complexity locally rather than acknowledging the importance of complexity for viable CE networks [60,61]. Complexity refers to elements that can be influenced directly as a control variable within the system's bounds and reach and items that cannot be controlled [62]. Therefore, the CE focuses on improving systems rather than components [63]. This system perspective and the reality that each player must have this perspective and understanding to contribute effectively to a CE opens new possibilities for collaboration but at the cost of increased complexity [33,64].

Circularity presents a whole new set of opportunities for creating and capturing value, but it comes at the cost of close interconnectedness between stakeholders and systems, increasing the management and process complexity [65]. Moreover, the lack of adequate modeling tools makes modeling CE challenging for researchers and practitioners [66]. For example, no key modeling techniques are used in designing a CE. Regardless, the CE is thought to be one of the finest alternative instruments for resolving the conflict between economic growth and society's long-term development by designing a restorative and regenerative economy [67].

Complexity is beyond the comprehension and response capabilities of any single organization [68]. There is frequently dispute regarding what is causing the issues and how to solve them. As a result, employing CE concepts in the CU might cut industrial costs, eliminate negative environmental consequences, make metropolitan areas more livable, productive, and convenient, and assist in dealing with the process complications [69]. The complexity issues are addressed using the SD approach in this study, which is widely used to model the behaviors of complex systems [70].

2.5. The SD Approach for Handling CE Implementation Complexities in the CI

The SD methodology was established based on the system's feedback linkages. It is a method of researching and solving complex problems employing computers, focusing on policy analysis and design [34]. An SD technique is employed for CE implementation to link the system variables, which is complicated and may change over time [71]. Models of SD can be used to simulate various situations that dynamically capture complex relationships [72]. It is a useful method for evaluating a complex system in its entirety [34], based on an iterative modeling process [73].

A causal loop diagram (CLD) is created to determine the relationship between variables and to balance and reinforce feedback loops in the system [74]. SD models are developed for modeling and simulating the variables in CLDs. All SD models are composed of variables of three types: stock, flow, and auxiliary. The flows are of two types: physical/material and information, which could interact and respond to others [75]. Variables and the stocks and flows are essential to a stock–flow diagram. The feedback loops in the CLD play a crucial role in the simulation of the SD model. Variables and stocks and flows are part of the essential form of the stock–flow diagram, in which feedback loops play a crucial role in the simulation of the model [76]. The SD approach is notable for tracking and interpreting a given system through time, incorporating various ideas, philosophies, and techniques that assist in framing and understanding the management system's behavior [33,77].

In a previous study, the SD model was developed to study the causes of design productivity loss [78]. To maximize employee productivity, the SD model was used to model cost components that needed to be controlled and assess the changes in the supply chain of subcontractors and supervisors. In addition, the SD approach is used to describe the SC selection process, which is based on a complex interconnected structure of several elements that influence the SCs' work quality [79]. The CE is an economic concept that proposes ingenious ways to transform the current linear consumption system into a circular one. SD can help model nascent strategies such as the CE to achieve sustainable development [80].

3. Research Methodology

To achieve the objectives set in the current study, this research was divided into four stages, as demonstrated in Figure 1. In Stage I, the initial scrutiny of the literature was conducted. After scrutinizing the literature, the research gap was identified, which led to the development of the problem statement. Research objectives were formulated based on the problem statement as presented in the introduction section of the current study.

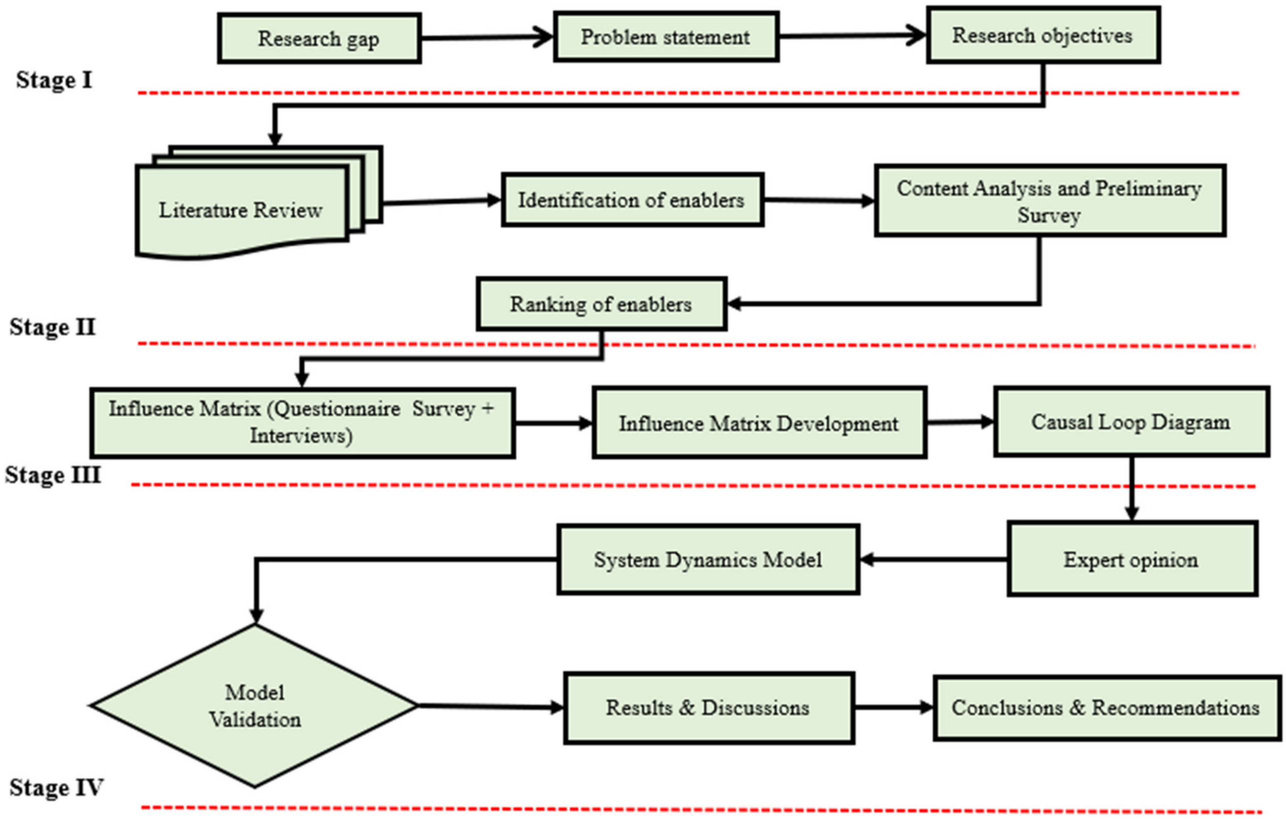

Figure 1. Research Methodology Flowchart.

Detailed scrutiny of the literature was performed to identify crucial enablers of CE for sustainable development in CI in Stage II. As per recent studies, Science Direct, Scopus, Web of Science, and IEEE Xplore are the four major databases chosen for paper collection [81,82]. The relevant studies' inclusion and exclusion criteria were used to ensure that the literature evaluation was complete and comprehensive. A total of 31 enablers of CE in the CI were shortlisted from 35 research articles published from 2010 and onwards. As previously mentioned, these enablers were ranked based on a normalized score from content analysis following the relevant studies. First, the influence of each enabler was measured as high, medium, and low through a careful literature review. After that, each enabler was assigned a number (1 for low, 3 for medium, and 5 for high) following [68,83]. The literature score (LS) calculation was done using the Relative Importance Index (RII), shown in 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. LS was then normalized to obtain the normalized literature score (NLS) by dividing each enabler's LS by the sum of LS, as shown in Equation (2). The identified enablers, references, and NLSs are shown in Table 1.

A preliminary survey was also conducted to identify the key enablers from the practitioners' perspective. This survey was conducted to shortlist the enablers. Literature score from content analysis and field score from this survey with a 60/40 ratio was utilized in the ranking of enablers following [82,84]. The respondents were asked to score each enabler's impact on a scale of 1 to 5, where 1 shows a low, 3 shows medium, and 5 shows high impact. This survey obtained 30 responses from developing countries, including Turkey, Iran, Morocco, the UAE, South Africa, and Pakistan, which resulted in a shortlist of 10 enablers.

$$\mathrm{RII} = \frac{\sum \mathrm{W}}{\mathrm{A} \times \mathrm{N}} \tag{1}$$

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

Table 1. Enabler's identification via Literature Review.

Sr. No	Enabler	NLS	References
1	Government financial support	0.1213	[1,85–91]
2	Strict regulations	0.1070	[1,23,86,87,92–95]
3	Extension of product life cycle	0.1070	[88–90,92,93,96,97]
4	Organizational incentive schemes	0.0999	[1,23,38,58,86,93,94]
5	Innovative and smart technologies	0.0856	[1,38,86,89,93,95]
6	Awareness through workshops and education programs	0.0713	[3,38,46,92,98,99]
7	Policy support	0.0642	[46,93,96,100–102]
8	Resource durability	0.0342	[23,85,91,93,94,103,104]
9	Collaboration among different parties	0.0342	[23,58,87,89,94,97,98,105]
10	Political priority	0.0285	[90,99,100,102]
11	Material circularity	0.0285	[86,99,100]
12	Management support	0.0257	[23,87,93,96]
13	Social recognition	0.0214	[58,85,87,100,106]
14	Supportive infrastructure to facilitate reuse	0.0214	[96–98]
15	Accessibility to transparent data	0.0171	[3,58,96,100]
16	Transparency of supply chain	0.0171	[86,93,94,107]
17	Flexible decision making	0.0171	[1,94,95,97]
18	Consumer demand	0.0128	[86,92,101,106]
19	Organizational big data management	0.0128	[91]
20	Organization culture	0.0086	[85,86,93,100,101,106]
21	Risk reduction through tax levies	0.0086	[86]
22	Team commitment	0.0086	[86,101]
23	Training and education	0.0086	[86,95]
24	Regulations and standards	0.0086	[38,102]
25	Digitalization (Virtualization)	0.0057	[93,102,103,105]
26	Consumer behavior	0.0043	[58,86,91,101]
27	Leadership	0.0043	[58,100,102]
28	Supportive vision	0.0043	[86,97,98]
29	Development of skills and capabilities	0.0043	[94,99,102]
30	Legislation	0.0043	[23,58,86]
31	Stakeholders' early involvement	0.0029	[86,103]

In Stage III, a comprehensive survey was conducted in which the respondents from the developing economies were asked about the existence of interrelationships and polarity among the shortlisted enablers. Data were collected using LinkedIn®, Facebook®, Gmail®, and ResearchGate®. The questionnaire was sent to 200 respondents. A total of 108 valid responses were obtained from this survey; thus, the response rate is 54%. The consistency and reliability of the data were assessed using Cronbach's coefficient alpha. The threshold value for Cronbach's alpha is 0.7. Any value of the data above 0.7 shows its reliability [108]. Moreover, the RII score values were less than 1, proving the validity of the data [109].

The Cronbach's alpha value for the data collected was 0.91, suggesting that the data are reliable and consistent. This led to 14 relationships among the enablers, which led to the development of the influence matrix, as illustrated in Section 4.1.

Stella Professional, AnyLogic, Vensim® PLE, and iThink are some of the software packages used to design CLDs and associated SD models. This research utilized Vensim® PLE for CLD and model development based upon the shortlisted enabler's interrelationships. This is because Vensim® is the most powerful package in terms of computing speed, capabilities, and flexibility [110]. A total of 10 enablers with 14 relationships helped develop the CLD.

Based on 14 relationships, 15 industry experts were contacted in Stage IV. These experts were CI professionals from developing countries, including Turkey, Iran, India, South Africa, and Pakistan, who had relevant experience in the CE domain. They each had experience of more than 20 years in the CI. This helped to find the impact of shortlisted relationships that further assisted in determining the values of the equations of the SD model. The CLD was fed into the SD model, which was further validated using expert opinion.

The demographic details of the respondents of the detailed survey (In Stage III) are shown in Table 2. The respondents include 17 (16%) Construction managers, 14 (13%) Assistant Managers, 10 (9%) Project Directors, 23 (21%) Project Managers, 14 (13%) Architects, 18 (17%) Planning Engineers, and 12(11%) Academics. In terms of the experience of respondents, 2 (1%) had 1 year of experience, 25 (24%) had 2–5 years' experience, 29 (29%) had 5–10 years of experience, 16 (15%) had 11–15, 16 (15%) had 16–20 years of experience, and 17 (16%) had experience of more than 20 years.

Table 2. Demographic details of respondents.

Profile	Frequency	Percentage
Total responses = 108		
Job title		
Construction Manager	17	16%
Assistant Manager	14	13%
Project Director	10	9%
Project Manager	23	21%
Architect/Designer	14	13%
Planning Engineer	18	17%
Academician	12	11%
Professional Experience (Years)		
0–1	2	1%
2–5	25	23%
6–10	29	27%
11–15	16	16%
16–20	16	16%
>20	17	17%
Education		
Graduation	22	20%
Post-Graduation	52	48%
PhD	34	32%
Organization type		
Government	38	35%
Semi-Government	16	15%
Private	54	50%
Understanding of circular economy and sustainable development		
Slight	5	4%
Moderate	23	21%
High	32	31%
Exceptional	48	44%

In relation to educational qualification, 22 (20%) of the respondents were graduate degree holders, 52 (48%) were post-graduate degree holders, and 34 (32%) were Ph.D. degree holders. Organization-wise, 38 (35%) were from government organizations, 16 (15%) were from semi-government organizations, and 54 (50%) were from private organizations. Respondents were also asked about their understanding of the topic. As a result, 5 (4%) of respondents had slight understanding, 23 (21%) had moderate, 32 (31%) had high, and 48 (44%) had an exceptional understanding. This was inquired through a question in the questionnaire.

Due to the lack of research on the developing economies, these countries were identified following [82,111]. The geographical distribution of the respondents is shown in Figure 2. Major respondents were from Pakistan, South Africa, Malaysia, Turkey, Vietnam, Nepal, Uganda, Nigeria, UAE, Brazil, and India.

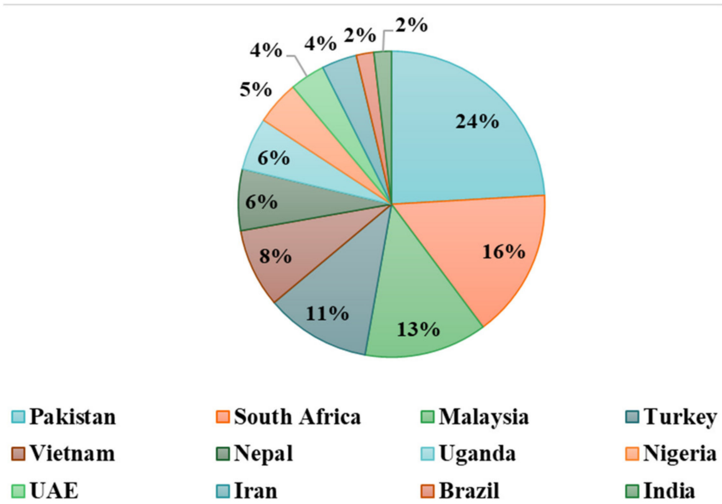

Figure 2. Geographic distribution of respondents.

4. Results and Discussions

A total of 10 enablers of CE for sustainable development in CI were shortlisted from the preliminary survey, as shown in Table 3. The description of each of the enablers is given in Table 3.

Table 3. Shortlisted Enablers.

Sr. No	Enablers	Description	60R/40L	Cumulative Score
1	Government financial support	Financial assistance from the government agency	0.074	0.074
2	Extension of product life cycle	Increasing the life of the product using reduce, reuse, and recycle approach	0.068	0.141
3	Organizational incentive schemes	An arrangement under which a company makes extra payments to employees to reward good performance other than financial.	0.060	0.201
4	Innovative and smart technologies	Use of technology to provide cognitive awareness	0.059	0.260
5	Strict regulations	Rigid and precise rules to be obeyed completely	0.053	0.313
6	Policy support	The support from the government available to the organization for the transition toward the circular economy	0.051	0.364
7	Awareness through workshops and education programs	Programs designed to teach practical skills, techniques, or ideas	0.044	0.407
8	Resource durability	Long-lasting resources/environmentally friendly materials	0.034	0.441
9	Political priority	The degree to which political parties pay attention to an issue	0.031	0.473
10	Material circularity	State of materials being in the loop to ensure uninterrupted supply	0.031	0.504

4.1. Causal Loop Diagram (CLD)

Figure 3 represents the influence matrix, which shows the influence and polarities among the impacting and impacted enablers. The x-axis shows the impacted variable, whereas the y-axis represents the impacting variable. The value of +1 in the matrix shows a positive (direct) relationship, and the value of -1 indicates a negative (indirect) relationship between the enablers following [68,84]. A total of 10 enablers with 14 relationships helped to develop the CLD.

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
D1						1				
D2								1		
D3	1			1						
D4						1				1
D5									-1	
D6			1		1					
D7	1				1					
D8			1							1
D9							1			
D10		1								

D1: Government financial support; D2: Extension of product life cycle; D3 : Organizational Incentive schemes; D4: Innovative and smart technologies; D5: Strict regulations; D6: Policy support; D7: Awareness through workshops and education; D8: Resource durability; D9: Political priority; D10: Material circularity

Figure 3. Influence Matrix.

Vensim® was used to develop the CLD, which was constructed on the expert opinion of professionals with over 20 of experience. The CLD comprises VI loops, i.e., five reinforcing loops and one balancing. The description of each loop is given below, and the consolidated diagram is shown in Figure 4.

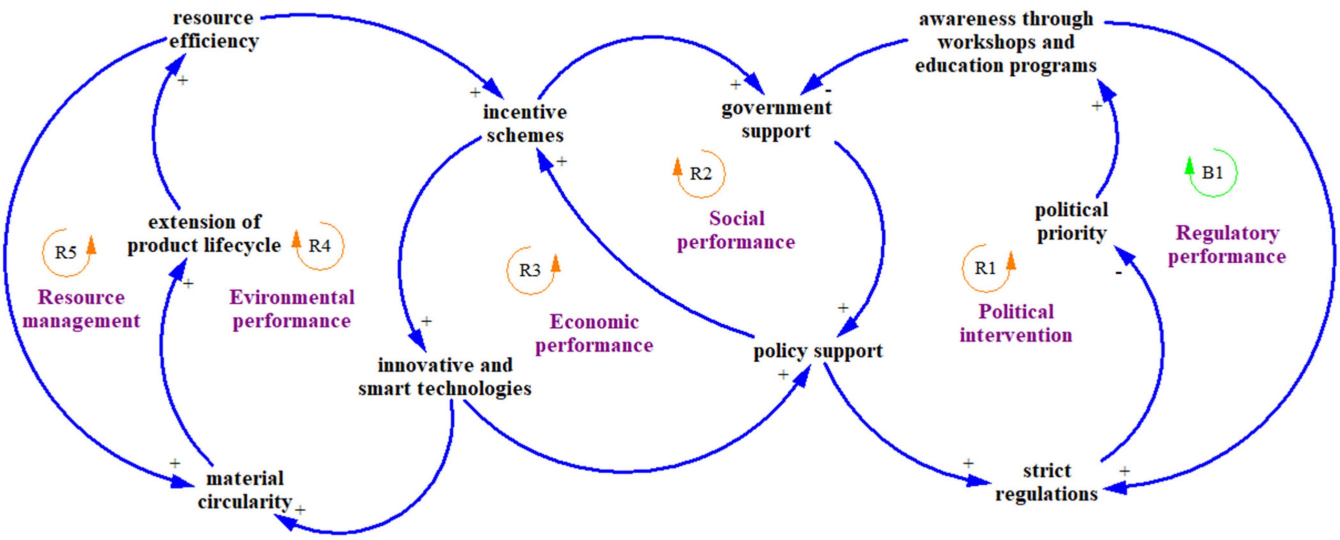

Figure 4. Causal Loop Diagram.

4.1.1. Balancing Loop B1—Regulatory Performance

The balancing loop (B1) shows that increased strict regulations can lead to decreased political priority. This will result in an increase in awareness through workshops and education programs, as illustrated in Figure 5. This loop predicts that if the strict regulations are implemented, some political parties will not take an interest in their enforcement, due to which awareness would also be decreased, which is a preliminary step towards the implementation of the CE. This will result in reduced performance of the CI due to the strict implementation of CE principles on one hand and political influence on the other in developing countries.

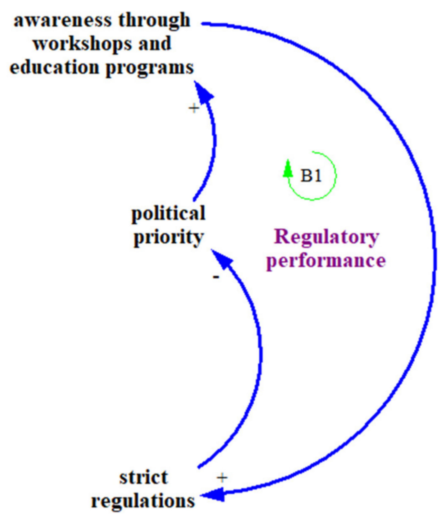

Figure 5. Balancing Loop B1.

4.1.2. Reinforcing Loop R1—Political Intervention

The reinforcing loop (R1) shows that an increase in policy support increases the implementation of strict regulations, leading to a decrease in political priority. Due to this, there is a decrease in awareness through workshops and education programs which leads to the need for increased government financial support, as shown in Figure 6. Hence, this loop shows that if strict regulations are implemented, some political parties will not take an interest in their enforcement, due to which awareness would also be decreased. Strict rules are critical in the implementation and enforcement of policies. A strict regulatory framework can help direct sustainable development to the appropriate level. Due to this decrease in awareness, an increase in government financial support would be required, further leading to an increase in policy support that enhances the interest in the CE paradigm [112,113]. R1 presents how CE implementation can foster CI in developing countries due to the support from the government (financial) and political parties through policies, strict regulations, and awareness programs.

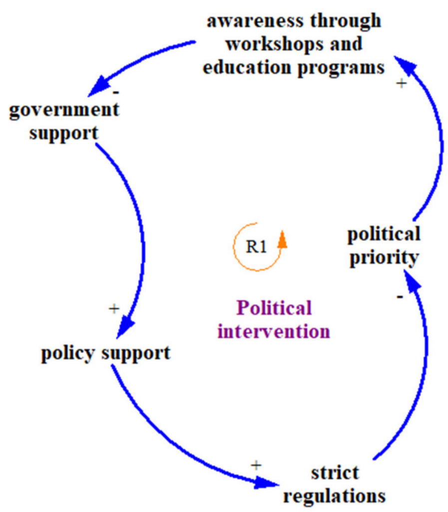

Figure 6. Reinforcing Loop R1.

4.1.3. Reinforcing Loop R2—Social Performance

The reinforcing loop (R2) shows that an increase in government financial support can lead to an increase in policy support, which helps to achieve organizational incentive schemes, as shown in Figure 7. The adoption of sustainable practices is sometimes accomplished by rewarding incentive schemes. Hence, this loop shows that strong financial support can lead to policymaking along with many of the organizational incentive schemes, which will ultimately help enforce the CE policies at the best level [114]. This leads to an increase in social performance, leading to sustainable development in the CI of developing countries via the inclusion of organizational incentive schemes and support via government and policies.

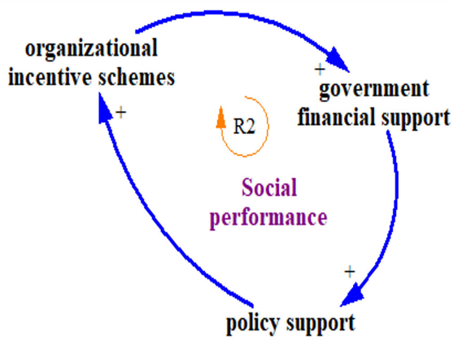

Figure 7. Reinforcing loop R2.

4.1.4. Reinforcing Loop R3—Economic Performance

The reinforcing loop (R3) shows that an increase in policy support can increase organizational incentive schemes, leading to an increase in innovative and smart technology adoption. Such adoption will ultimately reinforce the policy support, as illustrated in Figure 8. Hence, this loop predicts that if policy support is offered, it can lead to the availability of organizational incentive schemes for the CE's successful implementation. Due to the availability of such incentive schemes, the adoption of innovative and smart technologies would be enabled, resulting in stronger policy support [113,115]. R3 shows an increase in the economic performance of CI in developing countries due to the use of smart technologies, organizational incentive schemes, and policy support.

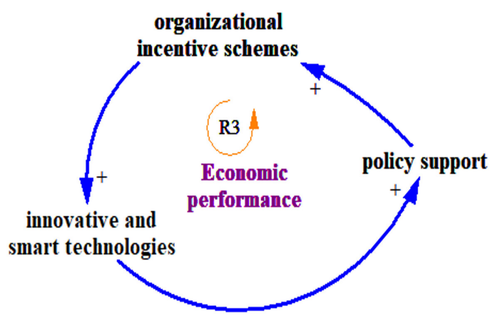

Figure 8. Reinforcing loop R3.

4.1.5. Reinforcing Loop R4—Environmental Performance

The reinforcing loop (R4) shows that an increase in the adoption of innovative and smart technologies can lead to material circularity, due to which there will be an increase in the product life cycle. This increase will lead to an increase in resource durability, leading to a further increase in organizational incentive schemes, as presented in Figure 9. Hence, this loop shows that due to the use of innovative and smart technologies, there would be an increase in material circularity, leading to an increase in the product life cycle. The increase in the product's life cycle shows that the resource durability will increase; in return, more organizational incentive schemes will be provided for the successful implementation of the CE. Product life cycle extension aims to depart from create–use–dispose toward create–use–reuse. This persistent cycle immediately impacts society, ecology, economics, and the environment [116]. R4 presents how the environmental performance is enhanced due to the product lifecycle extension, resource durability, and material circularity, leading to sustainable development in developing countries.

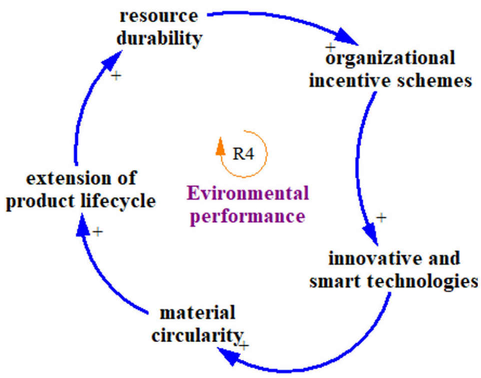

Figure 9. Reinforcing loop R4.

4.1.6. Reinforcing Loop R5—Resource Management

The reinforcing loop (R5) shows that an increase in the material circularity will lead to an increase in the product life cycle's extension, leading to increased resource durability. Such increased durability will further lead to an increase in material circularity, illustrated in Figure 10. Hence, this loop predicts that if the materials remained in the loop (or more circulated and reused), an increase in the product's life cycle would be observed, leading to the efficient utilization and durability of the resources [117]. R5 depicts that resource durability, product lifecycle extension, and material circularity lead toward sustainable development of the CI in developing countries.

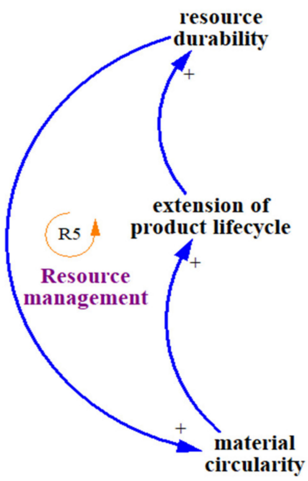

Figure 10. Reinforcing loop R5.

4.2. Loop Analysis

The magnitude and speed of influence on system outputs serve as a thorough criterion for loop classification. Table 4 summarizes the results for each feedback loop in the developed CLD. It predicts the speed, strength, and nature of the influence of the loop. The five reinforcing loops, R1, R2, R3, R4, and R5, strongly influence the system with a low speed. This indicates that these loops hold great potential due to their critical nature but will take time to occur and will be long-lasting.

Table 4. Overall loop analysis results.

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

On the contrary, B1 is fast, having a balancing effect. The magnitude and speed of influence on system outputs serve as a thorough criterion for loop classification. This category serves as a screening mechanism, making it easier to prioritize action points. Consider the loop R3, which is reinforcing in nature. All the three variables involved in this continually support each other. Reinforcing loops have a resonant effect that lasts for a long period, whereas balancing loops have a fading impact that lasts for a short time. The CLD's validity was qualitatively assured and verified through expert opinion. The experts were asked to describe the loop's speed, strength, and nature of influence. The results, as previously mentioned, are shown in Table 4.

4.3. System Dynamics Model and Simulations

Vensim® was used to create the SD model from CLD, as illustrated in Figure 11. The model is made up of three stocks: "Organizational Incentive Schemes," "Policy Support," and "Sustainable Development," all of which were influenced by inflows and outflows. The organizational incentive schemes and policy support were chosen as stocks because they showed accumulation and were the two enablers with the highest interrelationships with the other enablers. As a result, they are displaying the cumulative effect of variables in relation to them, affecting sustainable development, which is a new stock established to reflect the holistic influence of the system. The information gathered in the final survey also aided in formulating the model's equations as given in equations 3 to 5:

$$\begin{aligned}\text{Organizational Incentive schemes} = (\text{outflow of policy support} \times 1) + (\text{resource durability} \times 1)\\ + (\text{Organizational Incentive Schemes})\end{aligned} \quad (3)$$

$$\begin{aligned}\text{Policy Support} = (\text{government financial support} \times 0.076) + (\text{innovative and smart technologies} \times 0.067)\\ + (\text{Policy support})\end{aligned} \quad (4)$$

$$\begin{aligned}\text{Sustainable Development} = (\text{outflow of organizational incentive schemes} \times 1) + (\text{outflow of policy support} \times 1)\\ + (\text{Sustainable development})\end{aligned} \quad (5)$$

The three stocks are simulated separately over the 5 years following [68,118]. The reason for the selection of time five years is to give enough time for implementation to take effect. CE is a new concept. Moreover, this study focuses on developing economies where the implementation will take additional time. Therefore, this is simulated for five years. The simulation graph in Figure 12, where the x-axis represents the time. The graph shows that organizational incentive schemes gradually increased linearly over 5 years due to various endogenous variables. This was due to the reinforcing loop in which variables such as innovative and smart technologies, material circularity, resource durability, and product life cycle extension were positively complementing the organizational incentive schemes. This predicts that reinforcing loops R1, R2, R3, and R4 create social, economic, and environmental performance along with the political intervention leading to the sustainable development of the CI in developing countries.

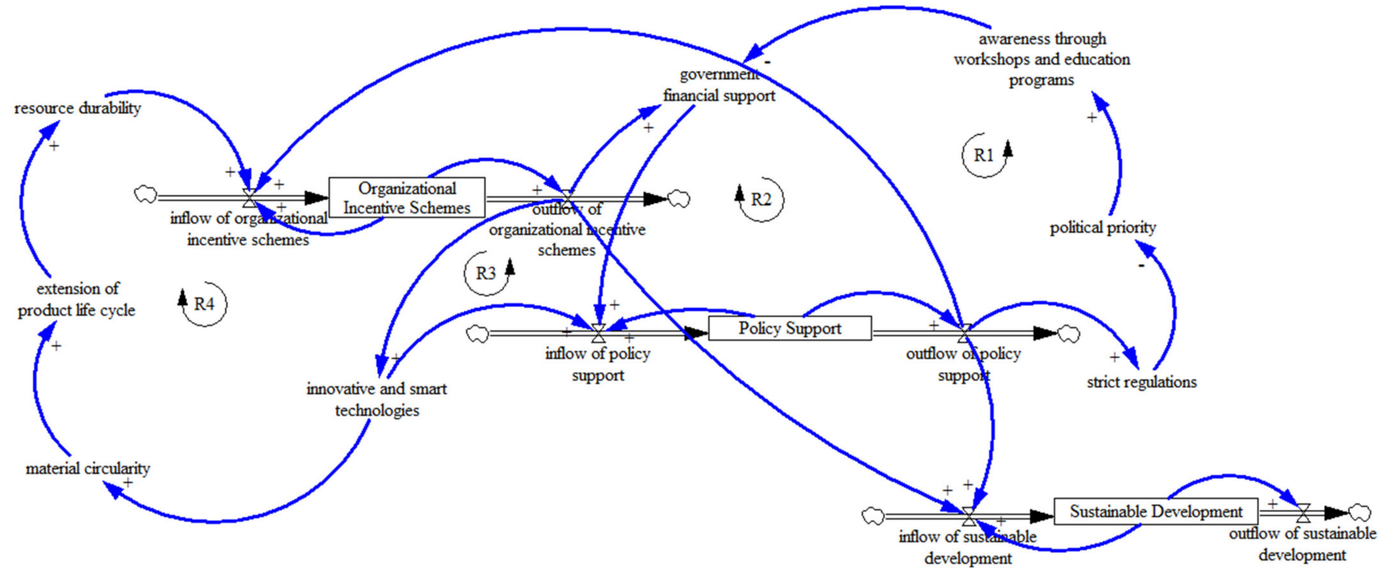

Figure 11. System Dynamics Model.

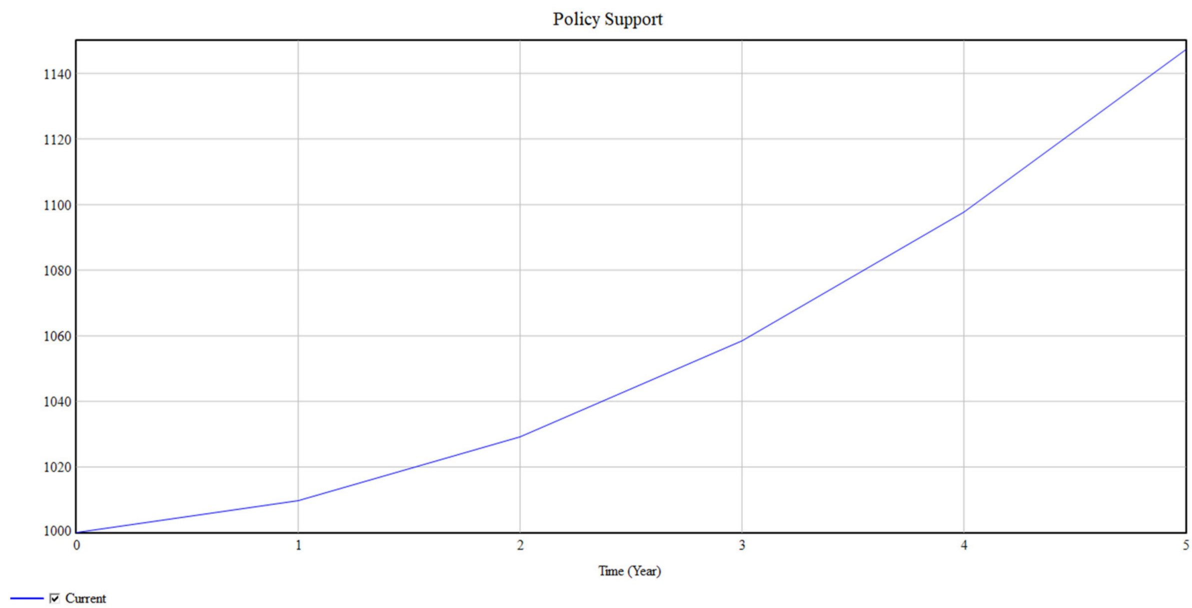

Figure 12. Simulation graph for Policy Support.

The increase in the simulation graph's curve with time in Figure 13 depicts the influence of numerous endogenous variables on policy support. This was due to the reinforcing loops R2, R3, and R4, in which variables such as government financial support, political priority, strict regulations, and awareness through workshops and education programs reinforce each other. The three loops affecting this stock show an increase in the social, economic, and environmental performance of CI, leading to sustainable development due to the enablers of CE in developing countries.

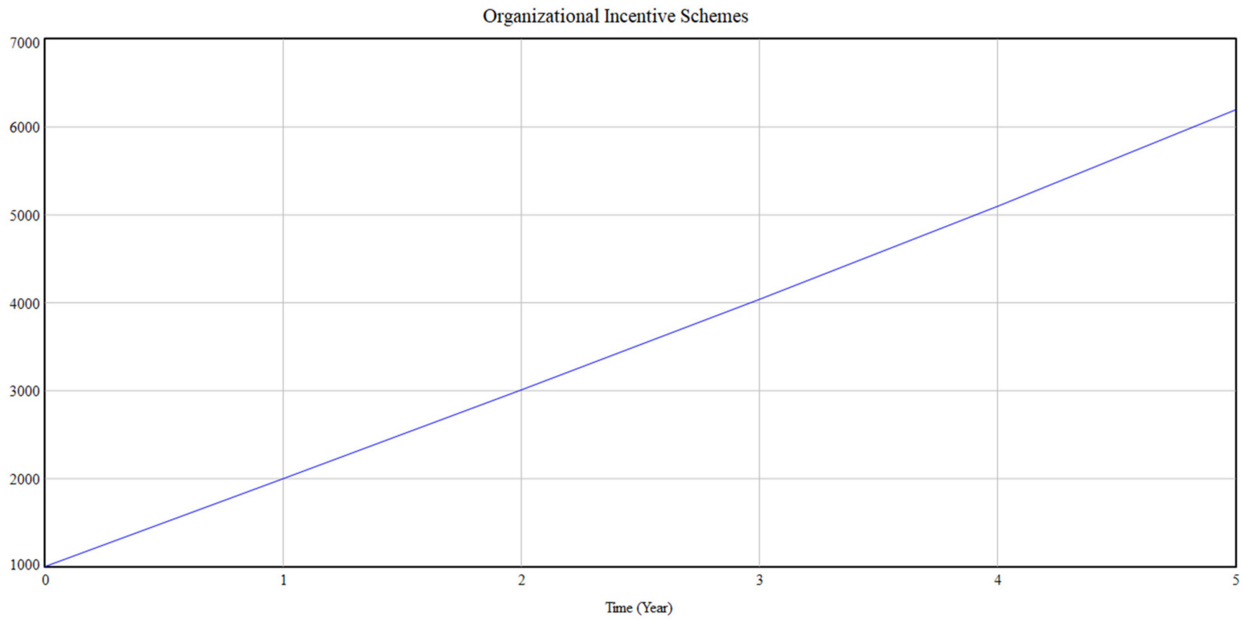

Figure 13. Simulation graph for Organizational Incentive Schemes.

The simulation graph in Figure 14 signifies that sustainable development gradually increases over five years due to the increase in organizational incentive schemes and policy support.

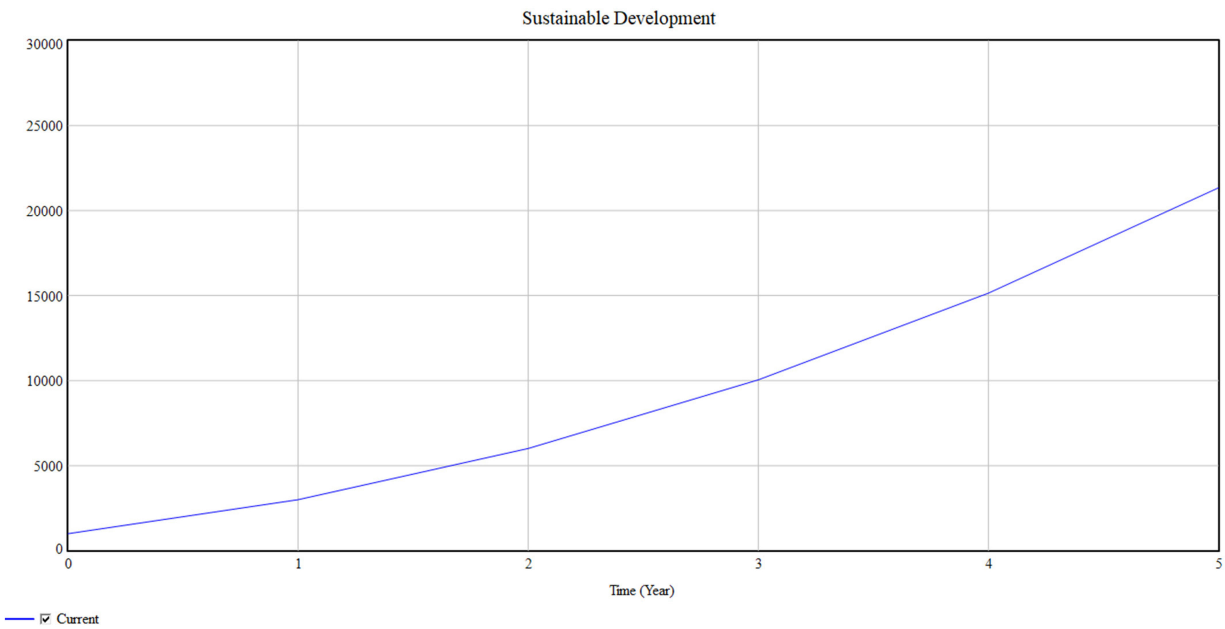

Figure 14. Simulation graph for Sustainable Development.

The overall simulation results predict that due to the increase in organizational incentive schemes, there would be an increase in policy support, ultimately leading to the sustainable development of the CI in developing countries, as illustrated by the simulation graph in Figure 15. This shows that there is a need to incorporate various enablers, especially the organizational incentive schemes and policy support, to achieve sustainable development in the CI. Therefore, the model justified that sustainable development would increase over time. The reinforcing loops contribute to the sustainable development of the CI, incorporating the enablers of a CE in developing countries. As a result, the social, environmental, and economic performance of the CI is improved, as illustrated by the graphs.

This will lead the CI to more sustainable choices. As a result, the overall performance of the CI will be improved over time.

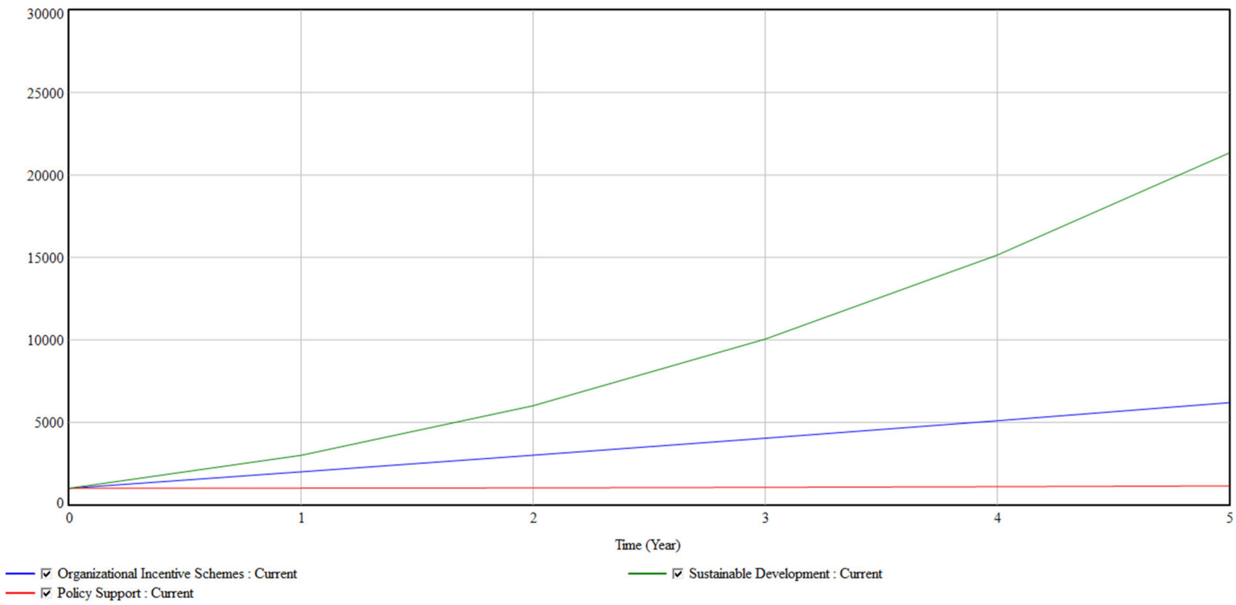

Figure 15. Combined Simulation graph.

4.4. Model Validation

The confidence in adopting an SD model to help evaluate a specific problem should not be predicated on the model's capacity to tackle the other problems. In this aspect, the model's validity is determined by its intended use. The purpose of the established SD model, as stated above, is to assist in the resolution of complications in implementing a CE for sustainable development in the CI of developing countries.

The first step in verifying an SD model is to validate its structure. Boundary adequacy, structure verification, and parametric verification tests are used to determine the structural validity of an SD model [119]. A boundary adequacy test examines if the model is endogenous to all the relevant ideas in solving the problem. Furthermore, it assesses if the model's behaviors vary substantially when boundary assumptions are relaxed and if the policy recommendations change when the model boundary is extended [120]. After looking at all the variables in the SD model, each one is critical, as all the variables have been documented in the literature. Therefore, the model is validated through this test.

The structure verification test examines whether the model structure corresponds to the model's requisite descriptive knowledge [121]. The produced CLD is based on factors found in the literature, which are subsequently delivered to field professionals, and the impacting interrelationships between all variables. As a result, the model structure is logical and closely resembles the actual industry system. This is consistent with the methods used by Qudrat-Ullah [119].

As per the parameter verification test, the mathematical functions used to connect the variables are centered on feedback from field experts, ensuring empirical and theoretical underpinnings. Hence, the model is verified through this test.

5. Discussions

In this study, detailed scrutiny of 35 relevant research articles resulted in 31 CE enablers for sustainable development in the CI of developing countries, as shown in Table 1. After content analysis and a preliminary survey, a total of 10 enablers of a CE for sustainable development were shortlisted, which include Government financial support, Extension of the product life cycle, Organizational incentive Schemes, Innovative and smart technologies, Strict regulations, Policy support, Awareness through workshops and education programs, Resource durability, Political priority, and Material circularity, as presented in Table 3. Government support plays a crucial role in implementing CE by providing relevant guidelines. Furthermore, the government's strict regulations are a major enabler of the transition to sustainable development in CI [122]. Such policy support serves as a powerful enabler for sustainable development. The first step in CE implementation is raising awareness through workshops and educational programs [123]. Political priority is a key enabler since it involves the essential plan that the government will utilize to implement CE. Incentive programs are arrangements in which a company pays its employees extra money depending on their best performance. Accordingly, it has been noted that having these schemes result in improved performance [124]. The use of smart technology is a critical enabler in the move to circularity. The use of smart technologies allows for openness and exchange of information regarding re-usable components, thus making it a critical enabler of CE for the sustainable development of CI [125]. The product life cycle extension is also important in CE implementation [126].

The CLD developed in this study comprised four reinforcing loops and one balancing loop. Figure 3 represents the polarities as direct or indirect among the shortlisted enablers. Figure 5 predicts that if strict regulations are implemented, some political parties will not take an interest in their enforcement, which would also decrease awareness. Such decreased awareness decreases the chances of the CE implementation for sustainable development in CI. This is in line with Sachs et al. [122].

Figure 6 shows that if strict regulations are implemented, some political parties will not take an interest in their enforcement, due to which awareness would also be decreased. On the other hand, Figure 7 shows that strong government financial support can lead to policymaking along with many of the incentive schemes, which will ultimately help enforce the CE policies at the national level. This is in line with Walker et al. [15].

Figure 8 predicts that if policy support is offered, it can lead to the availability of organizational incentive schemes for the CE's successful implementation in CI. Figure 9 elaborates that due to the use of innovative and smart technologies, the material would remain in the loop, leading to an increase in the product life cycle. Figure 10 predicts that if the materials remained in the loop, an increase in the life cycle of the product would be observed, leading to the efficient usage of the resources [117].

The model was made up of three stocks: "Organizational Incentive Schemes," "Policy Support," and "Sustainable Development." The simulation graph in Figure 12 shows that organizational incentive schemes gradually increased linearly over five years due to various endogenous variables. The increase in the simulation graph's curve with time in Figure 13 depicts the influence of numerous endogenous variables on policy support. Lastly, the Figure 14 simulation graph signifies that due to the increase in incentive schemes and policy support, sustainable development gradually increases over five years in the CI of developing countries. The overall simulation results predict that due to the increase in incentive schemes, there would be an increase in policy support, ultimately leading to sustainable development, as illustrated by the simulation graph in Figure 15. This shows a need to incorporate various enablers, especially organizational incentive schemes and policy support, to achieve sustainable development.

This study aimed to address the complexity of implementing a CE for the sustainable development of the CI in developing countries. The results displayed how the CE enablers interrelate and help to promote the sustainable development of the CI. If the government and policy support continues at a national level, then sustainable development will be fostered in this sector [35]. Considering the construction sector of the developing economies, CE implementation is an immediate need [127]. The CI of such economies usually follows a non-sustainable mechanism and hence does not contribute to the sustainable development of global CI [23]. When the enlightened enablers in the study are considered particularly, in developing countries, CE implementation can be achieved with time. Such implementation at the national and international levels will increase the productivity and performance of the global CI [123]. Moreover, it will contribute to the economic growth of the host country [7]. The results of this study will help to achieve sustainable development of CI in developing countries.

5.1. Theoretical Implications

In terms of the humble theoretical contributions, it is the first study addressing the complexity of implementing a CE for sustainable development from the perspective of the CI using the SD approach in developing countries. This study contributes to the existing literature by identifying the enablers that aid in the sustainable development of the CI. It humbly bridges the research gap articulated by [12,23], who suggested quantitatively addressing the effects of the CE for sustainable development. The study's findings suggest that incentive schemes, policy support, and associated enablers lead to the sustainable development of the CI in developing countries. Researchers from developing countries can further explore these to develop relevant policies and legislations.

5.2. Practical Implications

From the perspective of managers and practitioners, the study's findings indicate that policy support and incentive schemes, among other enablers, are critical in implementing CE for the sustainable development of CI in developing countries. Through a CE, materials management will be improved through reusing products and materials, encouraging the use of renewable resources, and maintaining sustainable practices. In addition, benefits include reducing pressure on the environment and improving the supply of raw materials, which environmentalists and environmental officers can further investigate. Furthermore, the study's findings will assist CI professionals in incorporating sustainable concepts throughout the production chain, improving this sector's efficiency and performance. This will ultimately help minimize delays, promote long-term relationships, and reduce communication gaps and project complexities. Moreover, the results of this study will enable CI practitioners to implement the CE in a way that drives innovation, boosts economic growth, and improves local and global competitiveness.

6. Conclusions

The current study explores the key enablers of the CE's implementation for the sustainable development of the CI in developing countries. In addition, it addresses the complexity of implementing the CE for sustainable development using an SD approach. For this purpose, a total of 35 research articles were scrutinized, which resulted in 31 crucial enablers of a CE for the sustainable development of CI. These 31 enablers were then shortlisted to 10 enablers based on combined literature and field survey scores. A detailed survey was further conducted, which helped develop a CLD.

Among the 10 shortlisted enablers, the CLD has five reinforcing loops and one balancing loop. Furthermore, the CLD was used to build an SD model with two stocks named "Organizational Incentive Schemes" and "Policy Support"; an additional stock named "Sustainable Development" was created to determine the combined effect of the system. The model was simulated for five years. The findings show that policy support and incentive schemes, among other enablers, are critical in implementing a CE for the sustainable development of the CI in developing countries. The developed model was tested using boundary adequacy, structure, and parametric verification tests, which revealed that it is logical and closely reflects the industry's actual system.

Overall, the implementation of sustainable development in the CI is influenced by policies in the economic context. It can be accomplished in certain cases by promoting inventive techniques or enforcing restrictions. Policies for capacity building, effective urban planning, asset management, and legislation and regulations are important components of such a system. Whether it is supply chain management or energy efficiency, regulations and policies govern how businesses are run. Policies create an ecosystem where businesses work together to form new alliances and promote long-term sustainability. The same applies to a CE for the sustainable development of the CI in developing countries. Hence, this study fills the gap articulated by Geissdoerfer et al. [12] and Dantas et al. [23].

This study contributes to the body of knowledge by assisting CI practitioners in implementing a CE in the CI in a way that drives innovation, boosts economic growth, and improves competitiveness. The CE seeks to shift the paradigm away from the LE by reducing environmental impact and resource consumption while enhancing efficiency throughout the industry. Implementing CE principles in the CI could lower industry costs; reduce negative environmental impacts; make urban areas more livable, productive, and convenient; and deal with the inherent complexities.

The limitation of this study consists of including respondents only from developing countries. Moreover, this study only considered limited enablers based on the literature review, which may not be exhaustive in the future. A further study involving participants from all (other) developed countries would be more beneficial and will add value to the body of knowledge. Compared with the current study, such a study will help highlight the holistic enablers of a CE for sustainable development in the CI of developing countries. A follow-up study could focus on the current model's practical implementation and use case studies for validation. Furthermore, a similar study conducted in both developing and developed countries will provide more holistic evidence for performance comparison of a CE implementation in the global CI.

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