Barriers to the adoption of sustainable construction in Pakistan: A System Dynamics approach.

By

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This thesis is dedicated to my beloved mother.

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ABSTRACT

The construction sector is inherently a complex industry with a high resource usage having adverse environmental effects and has profound social and economic impacts. The construction industries of developing countries like Pakistan face scarcity of resources and energy shortage and require such an approach that negates the ill effects of construction and promote an ecofriendly, equitable social and economic growth. An effective approach in this regard is Sustainable Construction. The first step in the adoption of this approach in Pakistan is the identification of barriers that are impeding its adoption. This research identifies the various barriers in the adoption of Sustainable Construction in context of Pakistan's construction industry and deciphers the complex causal relationships existing amongst these barriers. Barriers are identified through preliminary questionnaire which incorporates the input of industry professionals as well as the existing literature, afterwards the causal relationship and polarities amongst these barriers are determined through a detailed questionnaire form which a Causal loop diagram is prepared and a System dynamics model is suggested to address these barriers.

This research will help in a better understanding of these barriers and their interrelationship thus helping in minimizing or eradicating these barriers and promoting sustainable construction practices in Pakistan.

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SD	System Dynamics
SC	Sustainable Construction
CLD	Causal Loop Diagram

Introduction

1.1 Background of the study

Sustainable development is a guiding paradigm for development globally (Bartelmus, 2000). It is a term which is used in a broad sense and has many definitions and implications but the most cited definition is the one that was proposed in the Brutland report(Schaefer & Crane, 2005) which states that "Sustainable development is the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The concept of SD rests fundamentally on three pillars namely economic sustainability, environmental sustainability and social sustainability(Mensah, 2019). It requires the promotion of social well-being, equitable economic growth and environmental protection(Koehler & Hecht, 2006). It aims at achieving social progress, economic growth and environmental equilibrium(Gosling-Goldsmith et al., 2019).

The concept of sustainable development was extended to construction industry in 1990s.Sustainable construction is the creation of a healthy built environment using resource efficient, ecologically based principles (C. J. Kibert, 1994). It is the contribution of construction industry to sustainable development

Sustainable construction should minimize the effect of a building over the course of its lifetime while maintaining the safety and comfort of its occupants without discounting its economic viability (mohamad bohari et al., 2016)The construction sector is responsible for more than half of the global resource usage (Edwards, 2001)Together building and construction are responsible for 39% of all carbon emissions in the world and 36% of global energy usage (United Nations Environment Programme, 2019).

Pakistan is a developing country (Country classification by World Economic Situation and Prospects (WESP) 2019), which is facing severe energy crisis (Azad & Akbar, 2015) and a number of environmental challenges (Sohail & Qureshi, 2011) hence strengthening the need for sustainable construction practices to be followed .Pakistan has listed the development of sustainable infrastructure as one of its targets in its national initiative for sustainable development goals but achieving sustainable construction in developing countries is complex and relatively more challenging not only because of difficult social and economic conditions but also due to technical issues (Serpell et al., 2013).

The nature of sustainability is multidimensional, dynamic and complex (Nguyen & Bosch, 2013) and construction process is also a complex dynamic system (Bertelsen & Sven, 2003).Sustainability is a moving target which is getting enhanced as our understanding improves (Hjorth & Bagheri, 2006),thus it can be viewed as an unending process which is not defined by specific goals or having specific methods for its achievement (Mog, 2004).

System dynamics approach emerged as a result of pioneering work of jay Forrester in MIT in 1950s (Yearworth, 2014). It is an effective approach for analyzing the interactions and relationship among the variables in a system (Guan et al., 2011)This approach helps us to understand the changes in a system with time and to resolve real life problems using simulations. It is a thinking methodology and simulation technique that was specifically developed to study dynamic behavior in complex systems and provides us with a powerful tool for coping with sustainable development (Hjorth & Bagheri, 2006)

This study is aimed at investigating the barriers in the adoption of sustainable construction in Pakistan using a system dynamics approach. Barriers shall be identified from literature and questionaries' shall be used for analysis. The Relative importance index of these barriers shall be calculated on the basis of which a system dynamics model shall be prepared.

The construction industry is a highly complex industry with a high resource usage (Edwards, 2001), having adverse effects on the environment and is related to the socio economic development of a country. The construction sector in developing countries is not only responsible for improving the quality of life but is also responsible for maintaining the social and environmental sustainability of development endeavors.

Construction practices in developing countries like Pakistan should maintain the concept of sustainability right from their inception to closure so that the current needs of the country shall be satisfied without compromising the ability of the future generations to meet their own needs. Sustainable construction is facing barriers in Pakistan so there is a need to identify these barriers in order to mitigate the adverse effect of construction on the people and planet.

There is an increasing concern for sustainable practices to be followed in all fields, Identifying the barriers in the implementation of sustainability is the first step towards its achievement (Horhota et al., 2014).This study will help us to identify the barriers in the adoption of sustainability in Pakistani construction industry, thus promoting sustainable construction practices and helping in achieving sustainable development.

1.2 Research problem

Pakistan is a developing country which is facing severe energy crisis and a number of economic and environmental challenges (Azad & Akbar, 2015), hence strengthening the need for sustainable construction practices to be followed .There is a lack of research in terms of recognizing the barriers of sustainable construction in Pakistan and analyzing their effect on the adoption of sustainable construction. The complexity between these barriers need to be identified in order to eliminate these barriers: a system dynamics approach can be used.

1.3 Research Gap:

The construction sector has done extensive research on impediments for achieving sustainability. 12 challenges that stifle the use of sustainable construction in development projects in England were identified by (Williams & Dair, 2007). According to (Arif et al., 2009), major obstacles to the adoption of sustainable construction in India include poverty, cultural changes, unrestricted and negligent technology use, a dearth of adequate educational programmes, and a lack of research and innovation. According to (Pitt et al., 2009), constraints to the use of sustainable construction include cost, a lack of established standards, a lack of construction regulations, less awareness among clients, a dearth of understanding of the business case, a lack of proven alternative technologies, a lack of client demand, and planning policy.

Lack of client understanding, underlying knowledge gaps, and process flaws were identified by (Häkkinen & Belloni, 2011) as the three significant constraints to adoption of sustainable construction in Finland. According to an analysis of the Chilean construction market by Serpell et al. (2013), the main impediments are a lack of integrated design, affordability, and financial incentives. (AlSanad, 2015) examined the drivers and barriers for sustainable construction in Kuwait and discovered that lack of knowledge was the main obstacle to its adoption. In their analysis of the Malaysian construction market, Alia et al. (2016) found that the main obstacle to the implementation of sustainable construction was stakeholders' lack of information and awareness to the use of sustainable building methods. . Azeem et al., (2017) studied the barriers in construction of green buildings in Pakistan and identified five factors namely technical barriers, resource and regulations barriers, socio barriers, socio cultural and governmental barriers, economic and innovation related barriers and management barriers.

1.4 Research Question:

How can we address the complexities arising in adoption of sustainable construction in Pakistan?

1.5 Justification for the selection of this topic:

The construction industry is a highly complex industry with a high resource usage (Edwards, 2001), having adverse effects on the environment and is linked to the socio economic development of a country. The construction sector in developing countries is not only responsible for improving the quality of life but is also responsible for maintaining the social and environmental sustainability of development endeavors.

Construction practices in developing countries like Pakistan should maintain the concept of sustainability right from their inception to closure so that the current needs of the country shall be satisfied without reducing competence of the future generations to meet their own needs. Sustainable construction is facing barriers in Pakistan so there is a need to identify these barriers in order to mitigate the adverse effect of construction on the people and planet.

There is an increasing concern for sustainable practices to be followed in all fields, Identifying the barriers in the implementation of sustainability is the first step towards its achievement (Horhota et al., 2014).This study will help us to identify the impediments in the achievement of sustainability in Pakistani construction industry, thus promoting sustainable construction practices and helping in achieving sustainable development

1.6 Objectives:

The Objectives of this research are:

- To identify barriers in the adoption of sustainable construction in Pakistan.

- To evaluate the importance and interconnectivity of these barriers.
- To develop a system dynamics model to address complexity in the adoption of sustainable construction in Pakistan.

1.7 Relevance to national Needs:

The Pakistani national economy, the environment, and the construction sector are all interrelated. (R. Khan, 2005). In Pakistan construction industry generates millions of tons of waste daily (Akhund et al., 2018)and utilizes a large amount of energy. The overall share of industrial sector in GDP of Pakistan is 20.3 % from which 12 % belongs purely to the construction sector (F. Ullah et al., 2017). Pakistan is facing severe energy shortage (Mujahid Rafique, 2017), economic crisis and environmental issues (Sherani, 2020). Sustainable construction practices will help in boosting the economy as well as maintaining the balance of natural eco system. Only after recognizing the Barriers causing complexity in adoption of sustainable construction, it will be possible to eradicate these factors and make our construction industry sustainable.

1.8 Areas of Application:

Areas of application are construction management and sustainable construction.

Literature Review

2.1 Introduction:

The current chapter summarizes literature and earlier studies relevant to barriers in sustainable construction. This chapter comprises of literature about construction sector, sustainable development, sustainable construction, barriers in sustainable construction and system dynamics. It incorporates all the relevant literature for a better understanding of concepts and findings of this research study.

2.2 Characteristics of Construction Industry:

The construction sector is a particularly complex sector. (Edwards, 2001) having profound social ,environmental and economic impacts (Sev, 2009) . It is responsible for resource depletion, emission of global greenhouse gases, environmental damage and high levels of energy demand (Ortiz-rodriguez et al., 2009). The challenge concerning the building industry is its high unsustainability .Global construction industry has the capability to improve economic, social and environmental sustainability (Yilmaz & bakıs,2015).

2.3 Sustainable Development:

Sustainable Development is a broad term which has been defined by different authors in different ways. The most cited definition of sustainable development defines it as “the type of development that meets the needs of the current generation without compromising the ability of the future generations to meet their needs”(C. J. Kibert, 1994). Understanding how natural environment and the human social and economic world are deeply intertwined is necessary for understanding sustainable development., it requires a holistic approach of looking at the human life and the world (Blewitt, 2012).

The concept of Sustainable Development has three dimensions or pillars which are as follows:

2.3.1) Economic sustainability:

It implies the fulfillment of current consumption levels without compromising the needs of future .(Lobo et al., 2015). Economic sustainability requires the process of economic decision making to be made in an equitable manner based upon the principles of sustainability (Zhai & Chang, 2018).

2.3.2) Environmental sustainability:

The central concept of environmental sustainability is that consumption of natural resources should be less than their regeneration and waste should not be accumulated faster than it can be dissipated by the environment (Okeniyi et al., 2020).It implies giving the world in a better state to the upcoming generations and protection of the natural environment and maintaining the ecological balance (Sev, 2009)

2.3.3) Social sustainability:

Social sustainability intends to create a social organization system that mitigates poverty(Lobo et al., 2015) . It can be defined as an advancement that is viable with agreeable development of common society, fostering an environment conductive to the viable dwellings of and socially assorted gatherings while simultaneously uplifting social incorporation, while enhancing the personal satisfaction for all portions of the populace.

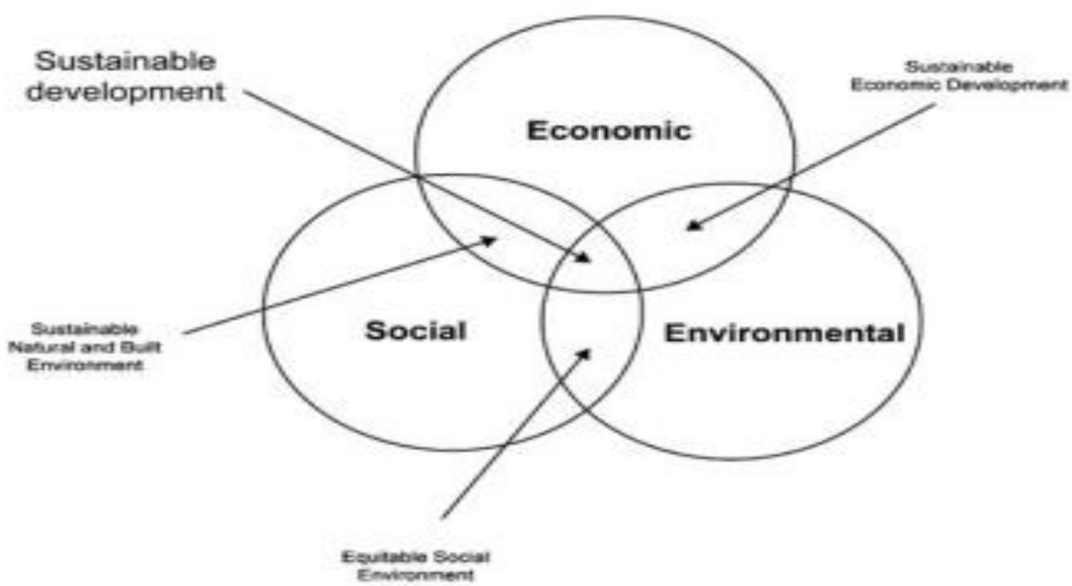


Figure 2.1. Venn diagram of three dimensions of sustainable construction (Raath & Hay, 2018)

2.4) Sustainable Construction:

Sustainability is an enveloping concept that is related to every aspect of infrastructure development (Sev, 2009).The concept of sustainability was extended to the construction industry in 1990s. Sustainable construction alludes to the utilization of sustainability principles to the construction industry. (Sev, 2009) defined it as the building industry's contribution to sustainability. (Du Plessis, 2007) depicts it as a coordinated approach seeking to establish settlements that affirm human dignity and create economic fairness as well as restore and maintain balance between the built and natural environments.

The concept of sustainable construction revolves around seven basic principles which are as follows:

There are seven principles for sustainable construction:

1. Limiting resource consumption to a minimal level
2. Reuse of resources to the maximum extent.
3. Using resources that are renewable and recyclable.
4. Protect the natural environment.
5. Create an environment that is healthy and non-toxic.
6. Application of life cycle costing.
7. Enhancing the Quality of the build environment.(C. Kibert, 2008).

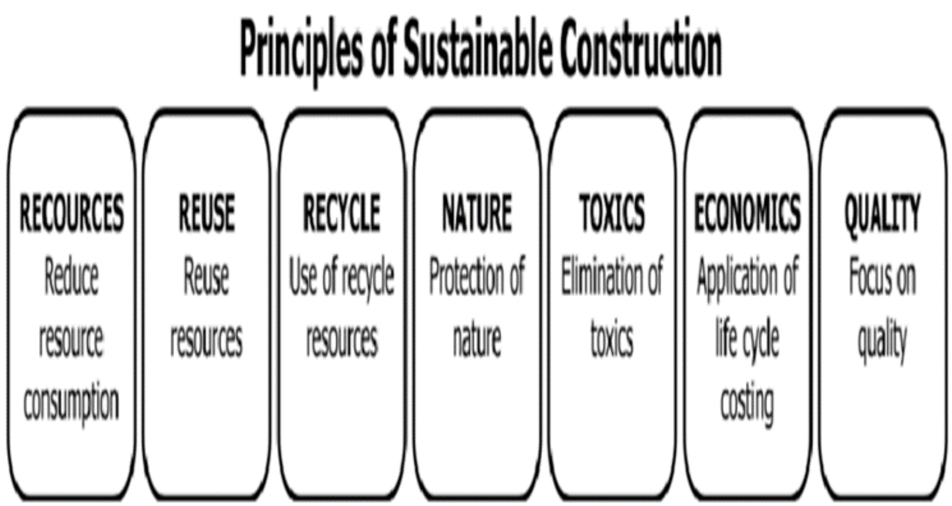


Figure 2.2 principles of sustainable construction

2.5) Benefits of Sustainable construction:

- Users, investors, contractors, workers, and the entire society can benefit from sustainable construction's beneficial environmental, social, and economic implications. (Khalfan et al., 2015).
- Adopting sustainable construction will cause the construction industry's greenhouse gas emissions to be significantly reduced. (Osuizugbo et al., 2020).

2.6) Comparison between sustainable construction and Green building:

The terms sustainable and green are interchangeably used in literature but these two have different meanings and implications. A sustainable building is always green but a green building is not always sustainable.

The core contrast between green and sustainable building is that sustainable construction addresses all the three aspects of sustainability i.e. Social, Economic and Environmental right from the planning up to the closure phase of a construction endeavor whereas green construction focuses only upon the Environmental aspect of sustainability. Sustainable construction methodologies rely on eco-friendly principles, having no significant environmental footprint, exhibit a closed material loop, and blends into the landscape after the service life of the structure is over (Sinha et al., 2013), whereas green construction is the type of construction that is environment friendly and having efficient resource usage (C. Kibert, 2008) .

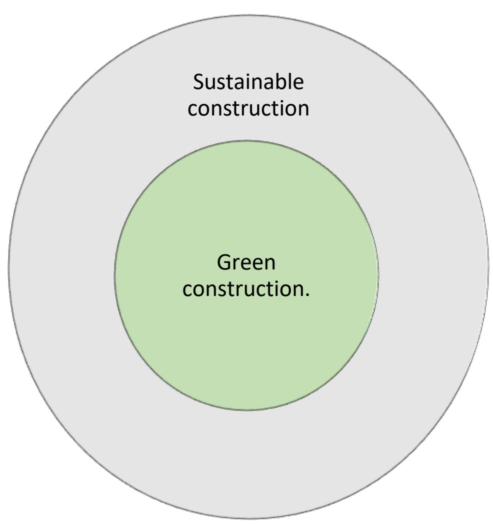


Figure 2.3 Relationship between sustainable construction and green construction

2.7) Construction Industry of Pakistan:

Pakistan being a developing country is undergoing strong relative growth in construction (Farooqui et al., 2018). This sector is the source of employment for almost 4 million people (Zahoor et al., 2015) but this sector is highly unsustainable as it is estimated to produce about 30% of the total waste material and consumes about 47% of the energy produced (Owais et al., 2018) . Pakistan is currently facing severe energy crisis (Azad & Akbar, 2015) and several environmental challenges (Sohail & Qureshi, 2011), hence strengthening the need for a sustainable environment in its construction industry.

2.8) Complexity in Sustainable construction

A complex system is such a system which comprises of a multitude of entities which displays a high level of interactivity (Richardson et al., 2000). The construction industry is complex and fragmented industry and complexity is the key characteristic of construction industry (Mohd Nawi et al., 2014). The nature of sustainability is multidimensional, dynamic and complex (Nguyen & Bosch, 2013). Sustainability is a dynamic target which is getting enhanced as our understanding improves (Hjorth & Bagheri, 2006).

2.9) Systems Thinking and System dynamics

Systems thinking is a problem solving approach for understanding how things as a part of whole affect each other. Systems thinking refers to solve a problem by taking a whole system into consideration rather than taking its parts into consideration individually (Ackoff, 2010).

(Arnold & Wade, 2015) described it as “A collection of analytical techniques that work together to make it easier to recognize and interpret systems, assess their behavior, and design changes that will have the intended results. These abilities function as a system”.

The utilization of System Dynamics is an efficient technique for the analysis of a complex system(Xu & Coors, 2012). This approach can break complex systems into smaller, understandable components (Khan et al., 2016). It is a thinking methodology and simulation technique that was specially formulated to understand dynamic behavior in complex systems and provides us with a powerful tool for coping with sustainable development (Hjorth & Bagheri, 2006).A causal loop diagram (CLD) is created to establish correlation between variables and to infer the balancing and reinforcing feedback mechanisms in the entire system. (Nguyen & Bosch, 2013). Every pair of variables in SD models has a cause and effect showing that the variables may shift in the identical or contrasting direction. Polarities only anticipate what would happen in the event of a change; they do not portray how variables behave. (Sterman, 2000).

2.9) Barriers in adoption of sustainable construction:

The following 27 barriers were identified from the literature which are shown in table 2.1.

Table 2.1: Barriers identified from Literature

Sr. No.	Barrier	Frequency	Source
1	Higher initial cost	18	(Williams & Dair, 2007),(Pitt et al., 2009),(Wang, 2013), (Serpell et al., 2013), (Djokoto et al., 2014), (AlSanad, 2015), (Okeniyi et al., 2020), (Ametepey et al., 2015), (mohamad bohari et al., 2016), (Asrul et al., 2017), (Athapaththu et al., 2016), (Tjarve & Zemīte, 2016), (Tafazzoli, 2018), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Özlük & Çivici, 2020), (Osuizugbo et al., 2020), (Ohiomah & Aigbavboa, 2020), (Karji et al., 2020)

2	Lack of legislation	12	(Serpell et al., 2013), (Schoengrund & O'brien, 2014), (AlSanad, 2015), (Ametepey et al., 2015)(Athapaththu et al., 2016), (Tafazzoli et al., 2019), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Özlük & Çivici, 2020), (Osuizugbo et al., 2020), (Ohiomah & Aigbavboa, 2020)
3	Lack of public awareness	10	(Djokoto et al., 2014), (AlSanad, 2015), (Ametepey et al., 2015), (Asrul et al., 2017) , (Tafazzoli et al., 2019), (Susanti et al., 2019), (Tokbolat et al., 2020) (Özlük & Çivici, 2020), (Osuizugbo et al., 2020), (Ohiomah & Aigbavboa, 2020)
4	Lack of incentives	8	(Serpell et al., 2013), (Djokoto et al., 2014), (AlSanad, 2015), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Pham et al., 2020), (Özlük & Çivici, 2020), (Osuizugbo et al., 2020)
5	Lack of expertise	13	(Williams & Dair, 2007), (Wang, 2013), (Djokoto et al., 2014), (Ametepey et al., 2015), (AlSanad, 2015), (Asrul et al., 2017), (Athapaththu et al., 2016), (Tafazzoli, 2018), (Durdyev et

			al., 2018), (Munyasya & Chileshe, 2018), (Osuizugbo et al., 2020)
6	Lack of knowledge	9	(Ikediashi et al., 2012), (Wang, 2013), (Serpell et al., 2013), (Athapaththu et al., 2016), (Tafazzoli et al., 2019), (Özlük & Çivici, 2020), (Ohiomah & Aigbavboa, 2020)
7	Lack of Training	5	(Ikediashi et al., 2012), (Serpell et al., 2013), (Ametepey et al., 2015)
8	Lack of government interest	5	(Williams & Dair, 2007), (Djokoto et al., 2014), (Ametepey et al., 2015)
9	Lack of client understanding	4	(Pitt et al., 2009), (Özlük & Çivici, 2020), (Ohiomah & Aigbavboa, 2020)
10	Extension of project schedule	4	(Wang, 2013), (Serpell et al., 2013), (Tafazzoli, 2018) (Tafazzoli et al., 2019),

11	Long payback period	4	(Pitt et al., 2009), (Wang, 2013), (Ametepey et al., 2015), (Osuizugbo et al., 2020)
12	Lack of client demand	6	(Williams & Dair, 2007), (Pitt et al., 2009), (Djokoto et al., 2014), (Ametepey et al., 2015), (Athapaththu et al., 2016), (Tafazzoli et al., 2019), (Osuizugbo et al., 2020)
13	Lack of integrated design	3	(Williams & Dair, 2007), (Djokoto et al., 2014), (Karji et al., 2020)
14	Lack of Resources	5	(Serpell et al., 2013), (Schoengrund & O'brien, 2014), (AlSanad, 2015), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018)
15	Non availability of sustainable construction material	4	(Wang, 2013) , (Ametepey et al., 2015), (Tafazzoli, 2018)
16	Resistance to change	4	(Wang, 2013), (AlSanad, 2015), (Durdyev et al., 2018), (Pham et al., 2020)

17	Lack of Cooperation among stakeholders	2	(Ikediashi et al., 2012), (Athapaththu et al., 2016)
18	Lack of management commitment	3	(Pham et al., 2020), (Karji et al., 2020)
19	Lack of Proven alternate technologies	3	(Williams & Dair, 2007), (Pitt et al., 2009), (AlSanad, 2015)
20	Lack of policy enforcement	3	(Tafazzoli et al., 2019), (Susanti et al., 2019), (Osuizugbo et al., 2020)
21	Lack of technology	3	(Pham et al., 2020), (Karji et al., 2020)
22	Lack of planning	2	(Pitt et al., 2009), (Munyasya & Chileshe, 2018)
23	Lack of strategy to promote SC	2	(Djokoto et al., 2014), (Tokbolat et al., 2020)

24	Lack of Clear benefits	2	(AlSanad, 2015), (Osuizugbo et al., 2020)
25	Limited knowledge and understanding of subcontractors	1	(Wang, 2013)
26	Higher cost of sustainable materials and products	1	(Wang, 2013)
27	Lack of Sustainability measurement standards	3	(Pitt et al., 2009), (Ametepey et al., 2015), (Osuizugbo et al., 2020)

These barriers are ranked in table on the basis of their obtained literature score where impact of each of them is assessed via detailed literature review. Each impact is designated a number (Low as 1, Medium as 3 and high as 5). The most frequently occurring impact score is then selected for each barrier. Literature score is calculated by Formula 2.1

$$Literature\ Score = \frac{Impact\ Score \times Frequency}{Highest\ possible\ score \times Total\ Research\ papers}$$

(Equation 2.1)

After calculating the literature score, it is then converted into normalized score by using Formula 2.2

$$Normalized\ Literature\ score = \frac{Individual\ Literature\ Score}{Sum\ of\ Literature\ Score}$$

(Equation 2.2)

This technique is employed to reduce factors having low significance (W. Ullah et al., 2018).

Table 2.2: Literature ranking of identified Barriers

Sr. No.	Barrier	Literature Score	Normalized Score	Cumulative Normalized Score
1.	Higher initial cost	0.75	0.158172232	0.158172232
2.	Lack of legislation	0.5	0.105448155	0.263620387
3.	Lack of public awareness	0.416666667	0.087873462	0.351493849
4.	Lack of incentives	0.333333333	0.07029877	0.421792619
5.	Lack of expertise	0.325	0.068541301	0.490333919
6.	Lack of Training	0.25	0.052724077	0.543057996
7.	Lack of knowledge	0.225	0.04745167	0.590509666

8.	Lack of government interest	0.208333333	0.043936731	0.634446397
9.	Lack of client demand	0.175	0.036906854	0.671353251
10.	Lack of client understanding	0.166666667	0.035149385	0.706502636
11.	Extension of project schedule	0.166666667	0.035149385	0.741652021
12.	Long payback period	0.166666667	0.035149385	0.776801406
13.	Lack of integrated design	0.125	0.026362039	0.803163445
14.	Lack of Resources	0.125	0.026362039	0.829525483
15.	Non availability of sustainable construction material	0.1	0.021089631	0.850615114
16.	Resistance to change	0.1	0.021089631	0.871704745
17.	Lack of Cooperation among stakeholders	0.083333333	0.017574692	0.889279438
18.	Lack of Proven alternate technologies	0.075	0.015817223	0.905096661

19.	Lack of management commitment	0.075	0.015817223	0.920913884
20.	Lack of policy enforcement	0.075	0.015817223	0.936731107
21.	Lack of technology	0.075	0.015817223	0.95254833
22.	Lack of planning	0.05	0.010544815	0.963093146
23.	Lack of strategy to promote SC	0.05	0.010544815	0.973637961
24.	Lack of Clear benefits	0.05	0.010544815	0.9841827772
25.	Limited knowledge and understanding of subcontractors	0.025	0.005272408	0.989455185
26.	Higher cost of sustainable materials and products	0.025	0.005272408	0.994727592
27.	Lack of Sustainability measurement standards	0.025	0.005272408	1

Research Methodology

The methodology employed in the current study will be discussed in this chapter. After extensive review of literature a research gap was identified which helped in formulating the research objectives. Afterwards Studies were conducted and a system dynamics model was employed to address the situation.

3.1) Introduction

The focus of this study is the complexity in adoption of sustainable construction in Pakistan using a system Dynamics model. This research is carried out in various phases, the diagrammatic representation for the methodology adopted in this study is shown in figure 3.1.

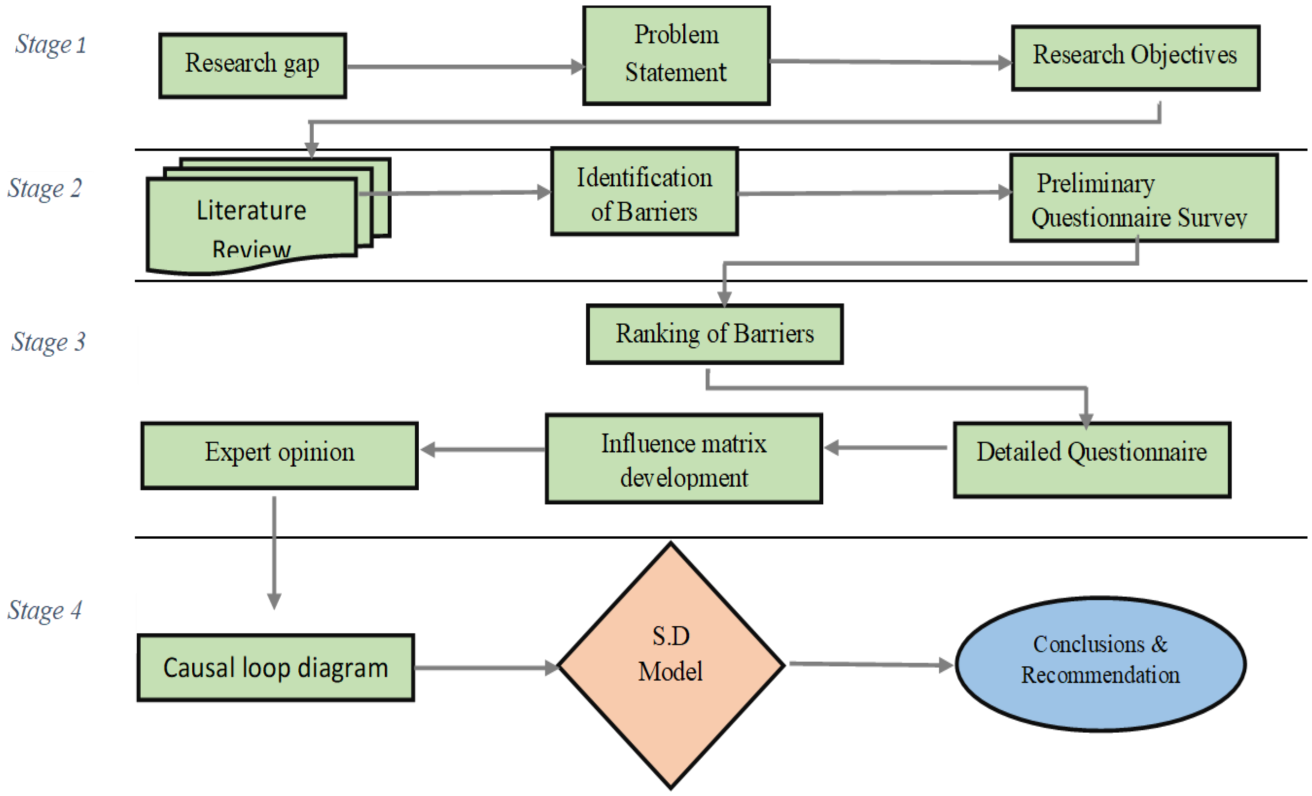


Figure 3.1 : Flow chart of research methodology

3.1.1) Phase 1: Identification of research objectives.

This phase involved the detail review of literature in order to identify a research gap. For this purpose Books, research articles and conference papers were thoroughly reviewed to unearth a research problem .After the development of a research problem the objectives of this research were defined, which helped in answering what are the objectives of this research.

The Objectives of this research are:

- To identify barriers in the adoption of sustainable construction in Pakistan.
- To evaluate the importance and interconnectivity of these barriers.
- To develop a system dynamics model to address complexity in the adoption of sustainable construction in Pakistan.

3.1.2) Phase 2: Literature Review and preliminary Survey

Literature Review was carried out to identify the barriers in adoption of sustainable construction. 24 Research Papers were reviewed for identification of barriers related to adoption of sustainable construction. Data analysis revealed a total of 27 barriers. Afterwards content analysis was conducted for selection of most important barriers.

The barriers identified from literature were ranked on the basis of their literature score and impact value was assigned to each barrier after the detailed review of literature. The impact value of each barrier was then quantified by assigning numbers (1 to low, 3 to medium and 5 to high). The highest frequency impact was then assigned to each barrier. Afterwards, the individual literature score of each barrier was converted into normalized literature score by dividing the individual score with the sum of literature score. Normalized score was afterwards arranged in a descending order and cumulative normalized score was calculated which helped in eliminating less important factors.

A preliminary survey form was created via **Google®** forms in which respondents belonging to diverse backgrounds were asked to rank the barriers in the adoption of SC in Pakistan on a Likert scale (1=very low, 2= low, 3=medium, 4=high and 5= very high). A total of 63 responses were collected which are deemed enough for a preliminary survey (Zahoor et al., 2015). A total of 12 factors were finalized after the preliminary survey.

The details of survey are as follows:

Qualification		Years of experience		Type of organization	
Graduation	41	0-5	50	Government	13
Post-graduation	22	6-10	8	Semi Government	11
PHD	0	11-20	4	Private	49
Total	63	>20	1	Total	63
		Total	63		

Table 3.1: Respondents Characteristics

Content analysis was performed on the factors obtained from literature and from the responses obtained from industry. The literature scores were normalized based on their total literature score. Similarly, the field data was also normalized based on their overall score.

ANOVA test was performed on data which showed P value of 1.Factors were ranked based upon 60/40 principle (60 for respondents normalized score and 40 for literature normalized score .Factors having cumulative score up to 60 percent were shortlisted to encompass maximum influence (Naveed & Khan, 2021) , the total number of shortlisted factors came out to be 12 .

Barrier	Barrier No.	60/40	CUMULATIVE	Ranking
Higher initial cost	3	0.08131398	0.08131398	1
Lack of public awareness	24	0.064222052	0.145536033	2
Lack of legislation	7	0.059923606	0.205459638	3
Lack of incentives	8	0.051377642	0.25683728	4
Lack of expertise	19	0.050664629	0.30750191	5
Lack of government interest	14	0.046396741	0.35389865	6
Lack of client understanding	4	0.042831678	0.396730328	7
Lack of knowledge	2	0.04210848	0.438838808	8
Lack of client demand	15	0.041405653	0.480244461	9
Lack of Training	1	0.040682455	0.520926916	10
Lack of integrated design	13	0.03355233	0.554479246	11
Lack of Resources	20	0.03355233	0.588031576	12

Table 3.2) Shortlisted Barriers from content analysis

3.1.3) Phase 3: Detailed Survey for Shortlisting of Interrelationships and Polarity

This phase comprised of the conduction of a detailed questionnaire-based survey for the evaluation of causal interrelationships and polarity of the shortlisted barriers. During this phase, expert opinion was also incorporated for development of causal loop diagram and influence matrix. Influence matrix was formulated upon the basis of relative importance index **(RII)** of each identified barrier in the construction industry and polarity of each relationship (+ or -) was determined. This was undertaken to make the causal loop diagram evocative and significant to the construction industry of Pakistan(Tahir et al., 2021).

3.1.4) Phase 4: Development of a System dynamics model

This phase is a crucial phase of this exploratory research. In this phase a System Dynamics Model was developed on the basis of Causal loop Diagram (CLD) and Stock and flow Diagram to eradicate the convolutions in the adoption of Sustainable Construction in Pakistan. This model focused on increasing the adoption of Sustainable Construction in Pakistan.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Preliminary Survey (Phase 1):

A preliminary questionnaire-based survey was carried out for which a questionnaire form was developed in Google Forms and it embodied two sections. Industry professionals were questioned about the influence of each barrier on a Likert scale. PARETO analysis was used for shortlisting barriers that had an impact score up to 60 % and twelve barriers were finalized through 60/40 ratio.

4.1.1 Ranking of barriers on the basis of literature and industry score:

The literature scores and the normalized scores obtained from industry input were combined to obtain the final ranking of these barriers. Ratio of **60/40** (60% score for industry & 40% for literature) was used for this purpose.

Sr. No.	Barrier	Individual Score (60/40)	Cumulative Score	References
1	Higher initial cost	0.08131398	0.08131398	(Williams & Dair, 2007),(Pitt et al., 2009),(Wang, 2013), (Serpell et al., 2013), (Djokoto et al., 2014), (AlSanad, 2015), (Okeniyi et al., 2020), (Ametepey et al., 2015), (mohamad bohari et al., 2016), (Asrul et al., 2017), (Athapaththu et al., 2016), (Tjarve & Zemīte, 2016), (Tafazzoli, 2018), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Özlük & Çivici, 2020), (Osuizugbo et al., 2020), (Ohiomah & Aigbavboa, 2020), (Karji et al., 2020)

2	Lack of public awareness	0.064222052	0.145536033	(Djokoto et al., 2014), (AlSanad, 2015), (Ametepey et al., 2015), (Asrul et al., 2017) , (Tafazzoli et al., 2019), (Susanti et al., 2019), (Tokbolat et al., 2020) (Özlük & Çivici, 2020), (Osuizugbo et al., 2020), (Ohiomah & Aigbavboa, 2020)
3	Lack of legislation	0.059923606	0.205459638	(Serpell et al., 2013), (Schoengrund & O'brien, 2014), (AlSanad, 2015), (Ametepey et al., 2015)(Athapaththu et al., 2016), (Tafazzoli et al., 2019), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Özlük & Çivici, 2020), (Osuizugbo et al., 2020), (Ohiomah & Aigbavboa, 2020)
4	Lack of incentives	0.051377642	0.25683728	(Serpell et al., 2013), (Djokoto et al., 2014), (AlSanad, 2015), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Pham et al., 2020), (Özlük & Çivici, 2020), (Osuizugbo et al., 2020)
5	Lack of expertise	0.050664629	0.30750191	(Williams & Dair, 2007), (Wang, 2013), (Djokoto et al., 2014), (Ametepey et al., 2015), (AlSanad,

				2015), (Asrul et al., 2017), (Athapaththu et al., 2016), (Tafazzoli, 2018), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018), (Osuizugbo et al., 2020)
6	Lack of government interest	0.046396741	0.35389865	(Williams & Dair, 2007), (Djokoto et al., 2014), (Ametepey et al., 2015)
7	Lack of client understanding	0.042831678	0.396730328	(Pitt et al., 2009), (Özlük & Çivici, 2020), (Ohiomah & Aigbavboa, 2020)
8	Lack of knowledge	0.04210848	0.438838808	(Ikediashi et al., 2012), (Wang, 2013), (Serpell et al., 2013), (Athapaththu et al., 2016), (Tafazzoli et al., 2019), (Özlük & Çivici, 2020), (Ohiomah & Aigbavboa, 2020)
9	Lack of client demand	0.041405653	0.480244461	(Williams & Dair, 2007), (Pitt et al., 2009), (Djokoto et al., 2014), (Ametepey et al., 2015), (Athapaththu et al., 2016), (Tafazzoli et al., 2019), (Osuizugbo et al., 2020)
10	Lack of Training	0.040682455	0.520926916	(Ikediashi et al., 2012), (Serpell et al., 2013), (Ametepey et al., 2015)
11	Lack of integrated design	0.03355233	0.554479246	(Williams & Dair, 2007), (Djokoto et al., 2014), (Karji et al., 2020)

12	Lack of Resources	0.03355233	0.588031576	(Serpell et al., 2013), (Schoengrund & O’brien, 2014), (AlSanad, 2015), (Durdyev et al., 2018), (Munyasya & Chileshe, 2018)
13	Non availability of sustainable construction material	0.031413293	0.619444869	(Wang, 2013) , (Ametepey et al., 2015), (Tafazzoli, 2018)
14	Resistance to change	0.031413293	0.650858161	(Wang, 2013), (AlSanad, 2015), (Durdyev et al., 2018), (Pham et al., 2020)
15	Extension of project schedule	0.031403107	0.682261268	(Wang, 2013), (Serpell et al., 2013), (Tafazzoli, 2018) (Tafazzoli et al., 2019)
16	Long payback period	0.031403107	0.713664375	(Pitt et al., 2009), (Wang, 2013), (Ametepey et al., 2015), (Osuizugbo et al., 2020)
17	Lack of Cooperation among stakeholders	0.029987268	0.743651642	(Ikediashi et al., 2012), (Athapaththu et al., 2016)
18	Lack of management commitment	0.029274255	0.772925898	(Pham et al., 2020), (Karji et al., 2020)
19	Lack of policy enforcement	0.029274255	0.802200153	(Tafazzoli et al., 2019), (Susanti et al., 2019), (Osuizugbo et al., 2020)
20	Lack of planning	0.027135218	0.829335371	(Pitt et al., 2009), (Munyasya & Chileshe, 2018)
21	Lack of strategy to promote SC	0.027135218	0.856470588	(Djokoto et al., 2014), (Tokbolat et al., 2020)
22	Lack of clear benefits	0.027135218	0.883605806	(AlSanad, 2015), (Osuizugbo et al., 2020)
23	Limited knowledge and understanding of subcontractors	0.02499618	0.908601986	(Wang, 2013)

24	Lack of Sustainability measurement standards	0.02499618	0.933598167	(Pitt et al., 2009), (Ametepey et al., 2015), (Osuizugbo et al., 2020)
25	Lack of Proven alternate technologies	0.023559969	0.957158136	(Williams & Dair, 2007), (Pitt et al., 2009), (AlSanad, 2015)
26	Lack of technology	0.023559969	0.980718105	(Pham et al., 2020), (Karji et al., 2020)
27	Higher cost of sustainable materials and products	0.019281895	1	(Wang, 2013)

Table 4.1: Ranking of barriers on 60/40

4.1.2 Shortlisted Barriers:

The barriers pertaining to 60% of the cumulative normalized score were finalized and twelve factors were considered which possessed cumulative normalized score under 60 %.The shortlisted barriers are shown in the table

Barrier	Barrier No.	60/40	CUMULATIVE	Ranking
Higher initial cost	3	0.08131398	0.08131398	1
Lack of public awareness	24	0.064222052	0.145536033	2
Lack of legislation	7	0.059923606	0.205459638	3
Lack of incentives	8	0.051377642	0.25683728	4
Lack of expertise	19	0.050664629	0.30750191	5
Lack of government interest	14	0.046396741	0.35389865	6
Lack of client understanding	4	0.042831678	0.396730328	7

Lack of knowledge	2	0.04210848	0.438838808	8
Lack of client demand	15	0.041405653	0.480244461	9
Lack of Training	1	0.040682455	0.520926916	10
Lack of integrated design	13	0.03355233	0.554479246	11
Lack of Resources	20	0.03355233	0.588031576	12

Table 4.2: Shortlisted barriers up to 60% of cumulative normalized score

4.2 Detailed Questionnaire Survey (Phase-2)

A final questionnaire survey of 132 causal relationships along with polarity was generated via Google Forms®. For the purpose of convenience industry professional were asked to give their opinion regarding the interrelationship and polarity of the barriers in a grid format.

4.2.1. Sample Size

A sample size of 100 industry practitioners was targeted for this survey however 69 completed questionnaires were retrieved from respondents across the country. This represented a favorable response rate of 69% (Bangdome-Dery, 2018).

4.2.2. Respondents Detail

With Regards to the qualification of the respondents 57 % of the respondents had a graduation degree in civil engineering, 40% of the respondents had a Master's Degree and the remaining 3% of the respondents had a higher educational degree i.e. Doctorate. The professional experience of 63% of the respondents ranged from 1-5 years and 23% of the respondents had 6 to 10 years of experience. 11% exhibited 11 to 15 years of professional experience and 3% exhibited a professional experience spanning more than 20 years.

Majority of the respondents were working in contractor organization followed by those working in consultant organizations and educational institutes. The remaining respondents were suppliers, regulatory bodies and design organizations.

Table 4.3: Respondents characteristics

Job Nature	Number	Percentage
Total responses = 69		
Job Title		
Client	4	6%
Consultant	19	29%
Contractor	23	34%
Educational Institute	15	23%
Supplier	2	3%
Designer	2	3%
Regulatory body	4	6%
Education		
Bachelors (B.Eng./B.Sc.)	39	57%
Master (M.Sc.)	27	40%
Doctorate (PhD/D.Eng.)	2	3%
Professional Experience		
0 to 5 years	43	63%
6 to 10 years	16	23%
11 to 15 years	8	11%
21 and above	2	3%

4.2.3. Normality and reliability check

The Cronbach's Alpha test, which has a benchmark value of 0.7, is used to evaluate the dependability and internal data consistency. Higher scores indicate the data's dependability and narrative coherence. The result of Cronbach's Alpha was 0.936, indicating that the data is internally consistent and reasonably credible(Taber, 2018).

Table 4.4: *Cronbach's Alpha Benchmark values(Taber, 2018)*

Results of Cronbach's Alpha and internal Consistency	
Cronbach's alpha Value (α)	***Internal Consistency***
α ≥ 0.93	Excellent
0.93> α ≥ 0.91	Strong
0.90>α ≥ 0.84	Reliable
0.84>α ≥ 0.81	Robust
0.80> α≥0.75	Fairly High
0.75> α	Low

4.2.4. Influence Matrix

Influence matrix was devised in consonance with the results of the pilot and detailed questionnaire survey, as well as the interpretation and analysis of the data. Values in the lower half of the matrix represented information gleaned from expert viewpoints, which helped to modify the causal loop diagram.

To make the causal loop relevant and confirm that feedback loops are flowing in the same direction, expert opinion was implemented. Following that, expert comments and the improved influence matrix (MI) shown below were used to adjust the directions of a few interrelations.

Influence matrix was inferred from relative importance index of finalized components and causal loop diagram was derived from important causal interactions. Causal relationships with RII values ≥ 0.75 or a mean value of 3.75 ≥ m > 5 are chosen for further investigation.

	V1	***V2***	***V3***	***V4***	***V5***	***V6***	***V7***	***V8***	***V9***	***V10***	***V11***	***V12***
V1	1											-0.86
V2		1				0.85						
V3		0.84	1									
V4	-0.84			1								

V5				1						0.84		
V6			-0.79			1					0.81	
V7							1					
V8						0.83		1				
V9						0.82	0.84		1			
V10						0.86				1		
V11				0.80				0.79			1	0.75
V12						-0.86						1

V1: Higher Initial Cost V2: Lack of Public AwarenessV3: Improper legislationV4: Performance Based IncentivesV5: Lack of expertiseV6: Lack of government interest V7: Lack of client understanding V8: Lack of knowledgeV9: Reduced Client demand V10: Inadequate training V11: Lack of Integrated design V12: Lack of Resources

Y-Axis = Influenced Factor X-Axis = Influencing Factor

Table 4.5: Influence Matrix

4.3 Causal loop diagram

A causal loop diagram (CLD) is created in accordance with interrelationships that have a mean influence value greater than 3.75. It is made up of three reinforcing loops and one balancing loop. The CLD has been improved in relationship with expert building professionals with an experience spanning more than a decade to make it less convoluted and more purposeful.

The next phase was to make certain that all feedback loops were coextensive, and that certain interrelationships that were leading away from the system were not overlooked (Dhirasasna & Sahin, 2019) . The CLD comprised of four reinforcing and two balancing loop and each loop is explained in detail below.

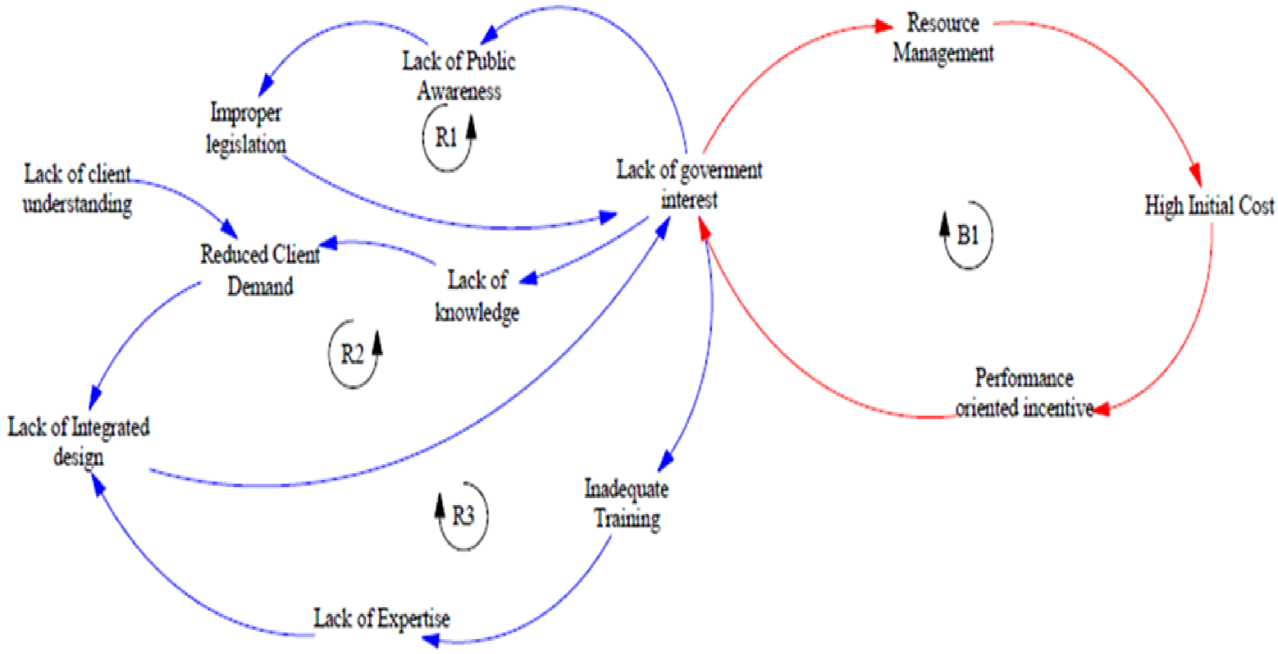


Figure 4.1: Causal loop diagram

4.3.1 Awareness Barrier (Reinforcing loop R1)

Reinforcing loop R1 implies that a decrease in public awareness inhibits the formulation of proper legislation. In such a case Laws that are enforced lack certain necessary provisions which in turn leads to lack of interest on part of the government.

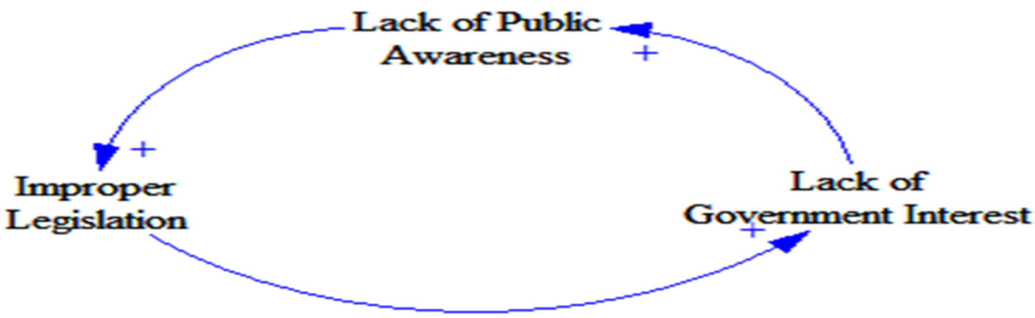


Figure 4.2: Reinforcing Loop R1

4.3.2 Knowledge barrier (Reinforcing loop R2)

This loop implies that reduced knowledge regarding Sustainable construction hampers the demand of client consequently leading to a reduction in the formulation of integrated design. Due to the Non availability of proper integrated design Government Interest diminishes.

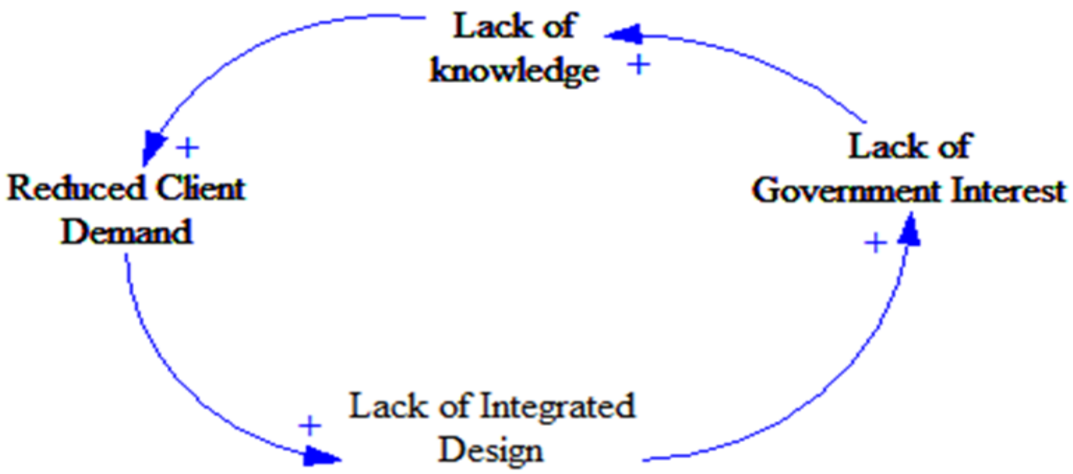


Figure 4.3: Reinforcing loop R2

4.3.3 Training Barrier (Reinforcing loop R3)

This loop implies that improper training hampers the improvement of skillsets of industry professionals that causes a reduction in the formulation of integrated designs, this phenomenon leads to lack of interest on part of the government.

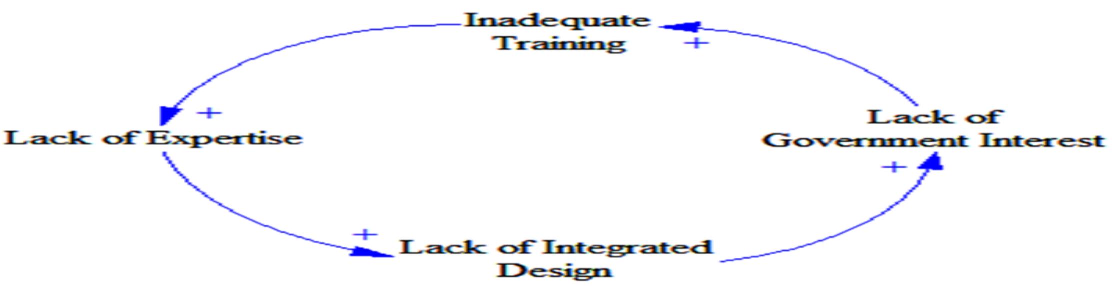


Figure 4.4: Reinforcing loop R3

4.3.4 Resource Barrier (Balancing loop B1)

It implies that effective resource management can lead to a reduction in the higher initial costs of sustainable construction endeavors. Reduction in initial/upfront costs creates a gap for awarding financial incentives for sustainable construction which can lead to enhancing government interest.

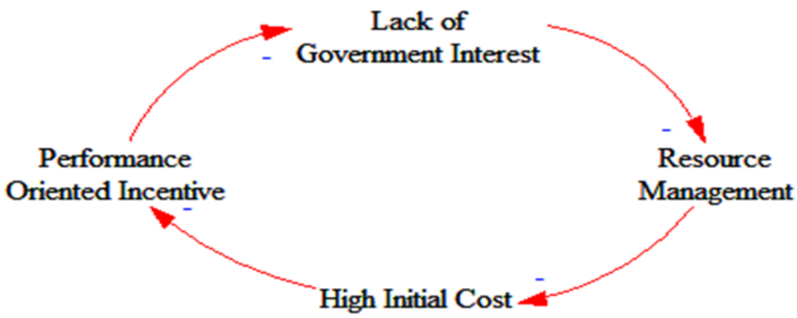


Figure 4.5: Balancing loop B1

4.4 Stock and Flow Diagram

Stock and flow diagram originated from the causal relationships of the causal loop diagram. Lack of Government Interest and Lack of integrated design were recognized as two basic stocks. An additional Stock named as Sustainable construction was integrated to observe the convergence of the above mentioned stocks

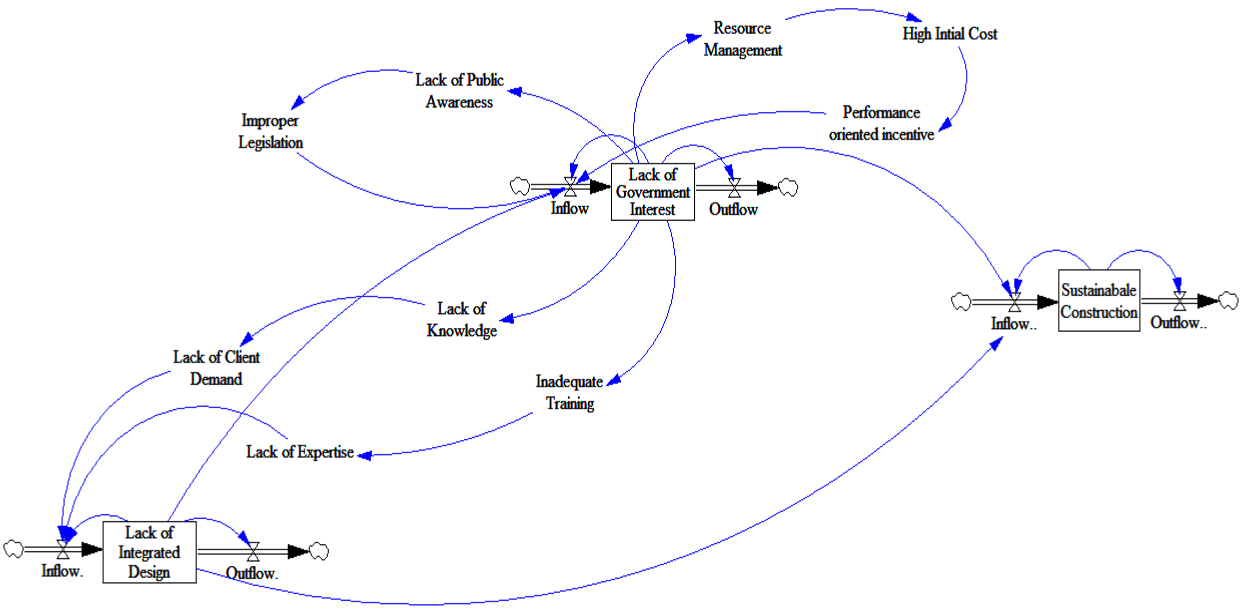


Figure 4.6: Stock and Flow Diagram

4.5. System Dynamics Model

Because the nature of the inquiries was not distinct and unconnected, the mean value was preferred above the mode value for the relative importance index calculation.(Tahir et al., 2021). As a conclusion, 15 causal relationships with RIIs ≥0.75 were determined.

$$\textbf{Mean Value} = {(\mathbf{1} * \textbf{Low} + \mathbf{3} * \textbf{Medium} + \mathbf{5} * \textbf{High})}/{\textbf{Number of respondents}}$$

Equation 4.1

Sr. No.	Influencing Factor	Influenced Factor	Mean	RII	N. RII	Polarity
1	Resource Management	Higher initial cost	4.283582	0.856716	0.069	Indirect
2	Lack of Government Interest	Lack of public awareness	4.253731	0.850746	0.068	Direct
3	Lack of public awareness	Improper Legislation	4.19403	0.838806	0.067	Direct
4	Higher Initial cost	Performance oriented incentives	4.19403	0.838806	0.067	Indirect
5	Lack of training	Lack of expertise	4.19403	0.838806	0.067	Direct
6	Performance oriented incentives	Lack of Government Interest	3.955224	0.791045	0.064	Indirect
7	Lack of integrated Design	Lack of Government Interest	4.074627	0.814925	0.066	Direct
8	Lack of Government Interest	Lack of Knowledge	4.134328	0.826866	0.067	Direct
9	Lack of Knowledge	Reduced Client Demand	4.104478	0.820896	0.066	Direct
10	Lack of Client Understanding	Reduced Client Demand	4.19403	0.838806	0.067	Direct

11	Lack of Government Interest	Inadequate training	4.313433	0.862687	0.069	Direct
12	Lack of Expertise	Lack of Integrated design	4.014925	0.802985	0.065	Direct
13	Reduced client demand	Lack of Integrated design	3.955224	0.791045	0.064	Direct
14	Lack of Government Interest	Resource Management	4.313433	0.862687	0.069	Indirect
15	Improper Legislation	Lack of Government Interest	3.955224	0.791045	0.064	Direct
		SUM=	62.13433	12.42687	1	

Table 4.6: Correlation polarity and relative importance index of final causal relationship

The equations developed through normalized mean influence for inflows and outflows of all stocks are as follows:

1. **Lack of Government Interest(Inflow) = (**0.066*Lack of Integrated Design)+(0.064*Improper Legislation)+(0.064*Performance oriented incentive)+(1*Lack of Government Interest)

2. **Lack of Government Interest (Outflow) = (**1*Lack of Government Interest)

3. **Lack of Integrated Design(Inflow)** = (0.064*Lack of Client Demand)+(0.065*Lack of Expertise)+(1*Lack of Integrated Design)

4. **Lack of Integrated Design (Outflow) = (**1*Lack of Integrated Design)

5. **Sustainable Construction (Inflow)** = -Lack of Government Interest-Lack of Integrated Design+(1*Sustainable Construction)

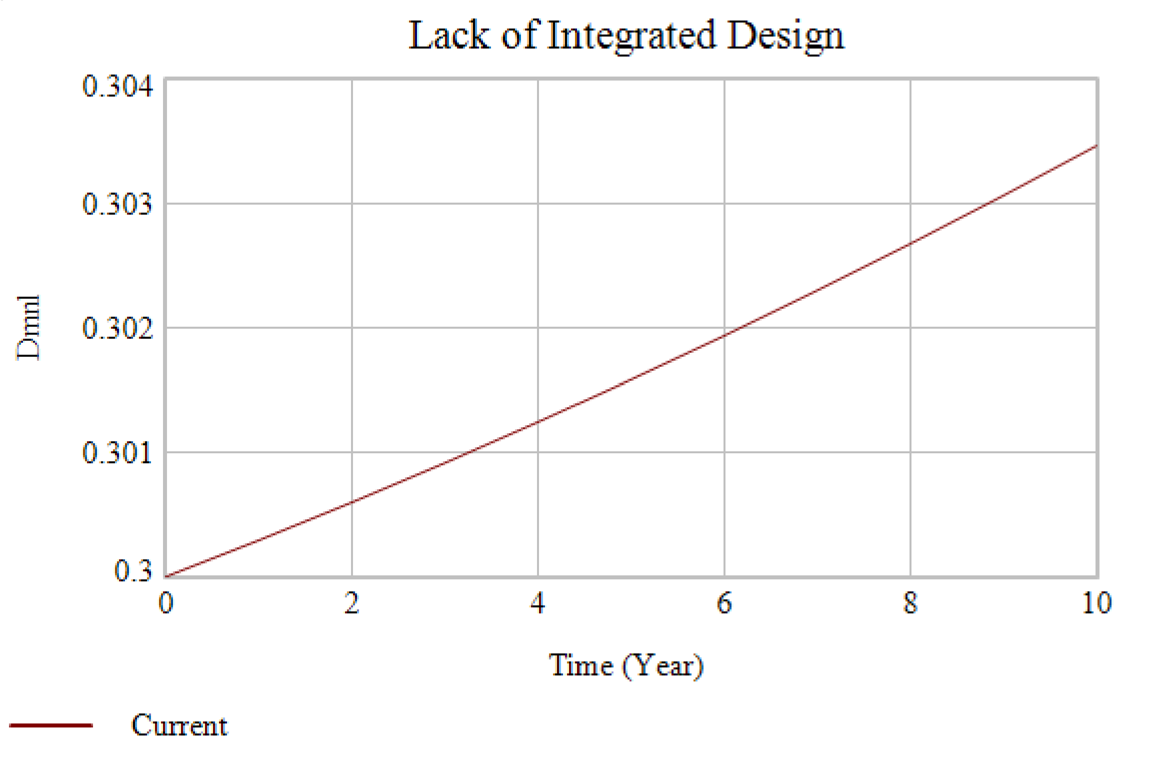
6. **Sustainable Construction (Outflow) = (**1*Sustainable Construction)

4.5.1 Simulation and results

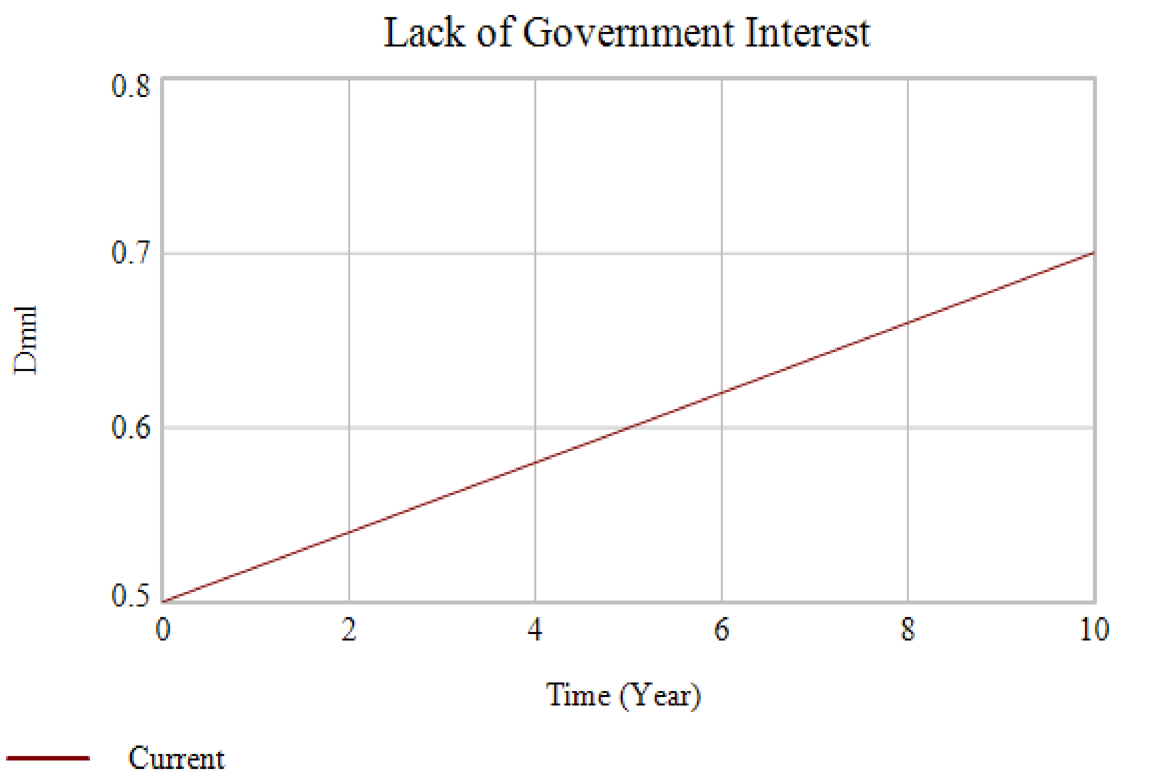
The simulation represented the behavior of this complex system and two stocks namely Lack of government interest and Lack of Integrated Design. An additional stock expressed as Sustainable construction was also simulated to deduce the impact of two stocks that were converged on it.

The model was simulated for a period of 10 years in order to gain a realistic insight into the behavior of the system over the course of time.

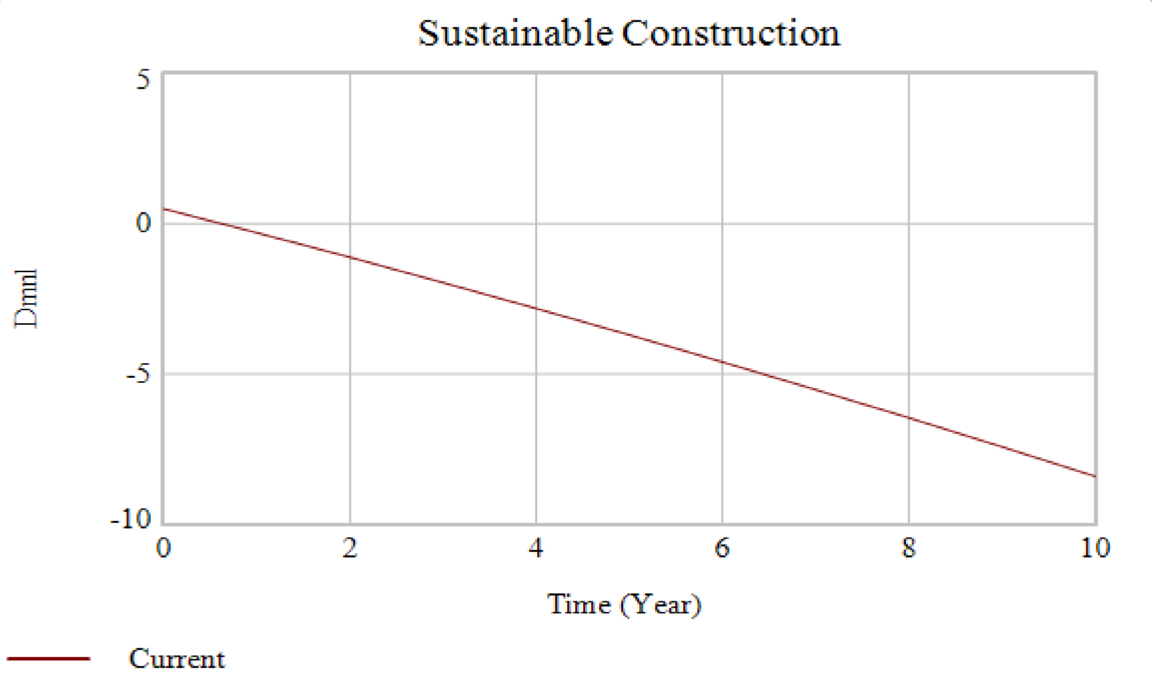
The following three graphs mimic the behavior of the system over the course of time.



The first graph inferred that lack of integrated design will amplify over the course of time if its contributing factors are not mitigated .



This graph denotes an increase in the Lack of Government Interest over the course of time if it is not managed.



The third and final graph depicts the stock namely sustainable construction on which other two stocks are converging. The trend of this graph clearly shows that an increase in lack of integrated design and lack of Government interest will lead to a reduction in sustainable construction over the course of time hence further promoting unsustainable construction practices in Pakistan

4.6. Model Validation

The focal point for validation of system dynamic was intent for which it was generated. The core insight of system dynamic model was to curtail intricacy resultant from implementation of total quality management in the building sector of developing countries. The following four tests were conducted to validate the system dynamic model (Tahir et al. 2021).

1. Boundary Adequacy Test
2. Structure Verification Test
3. Parameter Verification
4. Extreme Condition Verification

Boundary adequacy test: A boundary adequacy test was performed to endorse three different suppositions: whether or not all substantial insights are endogenous to the system, whether model behavior changes significantly as boundary conditions change, and whether or not policy recommendations change as the boundary is extended. With the exception of one variable i.e. the lack of client understanding, everything in the current model is endogenous. Because of this, changing the boundary conditions has no effect on the behavior of the model after simulation and on the policy recommendations.

Structure verification test was conducted to certify that either the structure of this model is consistent and logical. In present system dynamic model all the contributing variables evaluated through conclusive literature review and cross-checked by veteran in building sector. The resultant causal loop diagram mapped out through finalist causal relationships and polarities and further modified through veteran opinions. Therefore, the system dynamic model is meaningful, apprehensive, logical and meticulously characterizing certain building industry system. This practice is in compliance of effort carried out by Qudrat-Ullah and Seong (Qudrat-Ullah and Seong 2010).

Parameter verification test extrapolated that the mathematical functions incorporated in system dynamic model were generated relied on two essentials; causal strength and polarity of interrelations. Both causal strength and polarity of finalist interrelations were evaluated through veteran building professionals.

During **extreme condition test,** the entire exogenous variables assigned unity value and simulated under extreme conditions. The outcomes demonstrated that model behavior is logical as total quality management (convergence point of all three stocks) amplified exponentially under given mechanism as illustrated in figure (Tahir et al. 2021).

Chapter 5

Conclusions & Recommendations.

The aim of this exploration work was to identify the barriers of sustainable construction in Pakistan and the interrelationship of these barriers. System thinking approach was used to simplify intricacy resulting from interaction of these barriers in building sector by development of system dynamics model that led towards the identification and recognition of important barriers.

A detailed literature review was conducted and twenty seven (27) barriers in the adoption of sustainable construction were identified. Preliminary or pilot surveys and detailed surveys were conducted to and cumulative normalized literature and industry score determined by statistical tools. A pilot survey was initiated to determine the most profound challenges in relation to the construction industry of Pakistan .Detailed survey was conducted to determine their causal relationship and polarity either direct or indirect.

A preliminary survey was conducted by circulating questionnaire form developed through **Google®** and respondents were asked to rank contributing factors on Likert scale and detailed survey was conducted to evaluate causal relationship strength, polarity either direct (+) or indirect (-) and subsequently relative importance index (RII) of each shortlisted relationship determined. The influence matrix (MI) illustrated by causal interrelationship of impacted factors and impacting factors having a mean value ranging from **3.75<=m<=5**.

Higher initial cost, Lack of public awareness, Lack of legislation, Lack of incentives, Lack of expertise, Lack of government interest, Lack of client understanding, Lack of knowledge, Lack of client demand, Lack of Training, Lack of integrated design were recognized as the top most barriers of the Pakistani construction Industry.

The causal loop diagram (CLD) was created in accordance with sessions with building field experts and significant shortlisted interrelationships. Veteran opinions and valuable suggestions were also incorporated to make the causal loop diagram more significant and relevant to the building sector's need and demand. Stock and flow diagram (SFD) developed with the connection of causal relationships and polarity and subsequently turned out in the development of the system dynamics model. **Lack of Government Interest and Lack of Integrated design** were specified as two notable stocks of this system dynamics model. The third stock termed **Sustainable Construction** incorporated and all two existing stocks that were converged on it in order to comprehend their combined effect.

The combination of influence matrix, causal loop diagram and stock and flow diagram assisted in development of system dynamics model through **VENSIM® Software.** This model was simulated over a tenure of 100 months. The values of exogenous variables (Lack of client understanding) was kept constant i.e., one throughout the simulation. The existing two stocks under the impact of reinforcing interrelationships illustrated ascending behavior over the course of time.

Subsequently, the **Sustainable Construction** graph illustrated descending behavior over the period as all two stocks were converged on that point. This reflected the fact that Sustainable Construction will decrease over the course of time in the construction industry of Pakistan if Lack of Government interest and Lack of integrated design continues to exhibit an increasing trend.

The causal loop diagram and system dynamics model holistically explicated the adoption of Sustainable Construction through systems thinking approach. The findings of this exploration work strengthen the way for creating a strategy/policy which is more feasible for adoption of Sustainable Construction Practices in the Construction Industry of Pakistan.

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