Adoption of Sustainable Supply Chain Management using System Dynamics for performance improvement in the construction industry

A thesis submitted in partial fulfillment of the requirements for the degree of

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by

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THESIS ACCEPTANCE CERTIFICATE

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This thesis is dedicated to my parents and my respected teachers!

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Abstract

Construction sector has a crucial role in the economy of a country. Construction industry is very diverse and unorganized in nature. Unlike manufacturing and production industry, the construction industry faces difficulty because of uniqueness of every construction project. The construction sector is highly fragmented with multiple stakeholders working at various interfaces. There is a need for integration among stakeholders in the supply chain on construction projects that would help greatly in reducing cost and time overruns. Supply chain comprises of all those entities and processes which are involved in accomplishing a customer order. More stakeholders are involved in management of resources, information, and processes. Sustainable Supply Chain Management (SSCM) involves managing of materials, information, cash flows, cooperation among companies along the supply chain incorporating goals of sustainable development. There is a need to adopt the principles and practices of SSCM. The adoption is not a straight forward process, creating complexity issues in terms of its adoption. System dynamics approach is used to simplify complexity in the adoption of sustainable SCM using feedback mechanism.

System Dynamics (SD) is an approach that is used to address complexity in the adoption of sustainable SCM using feedback mechanism. This research aims to determine challenges in the adoption of SSCM and to address the related complexity using system dynamics approach utilizing modelling and simulation techniques. The adoption of SSCM would lead to improved performance of the construction sector in the developing countries. The research consists of the following phases; identification of challenges from literature using content analysis and questionnaire surveys to determine causality among variables that led to the development of causal loop diagram (CLD). The CLD was used to develop the system dynamics model.

The research findings will help the practitioners to adopt sustainability principles in term of supply chain and will not only enhance productivity and performance, but will also help in minimization of delays, promote long term relations, reduce communication gaps and projects complexities.

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List of Abbreviations

SD	System Dynamics
SCM	Supply Chain Management
CLD	Causal Loop Diagram
SSCM	Sustainable Supply Chain Management
GSCM	Green Supply Chain Management

Introduction

1.1 Brief description/ abstract

Construction sector has a crucial role in the economy of a country. Construction industry is very diverse and unorganized in nature. Unlike manufacturing and production industry, the construction industry faces difficulty because of uniqueness of every construction project. Communication gap is seen among stakeholders (clients, consultants, contractors and suppliers) as they work together only on certain projects or a project and are then parted (Bal et al., 2013). This gap leads to increased delays, time and cost over runs in various construction projects that ultimately leads to reduced quality level (Jaffar et al., 2011).

Collaboration and communication is much necessary when construction supply chains are meant to make sure the social, environmental and economic performance, simultaneously on a project (Gold et al., 2010). The triple Bottom Line (TBL) perspective of sustainability includes economic (profit, cash flows, income), environmental (natural resources, energy conservation, land use) and social (education, equity, health , well-being , quality of life) performance (Ramaswamy, 2017).

Supply chain comprises of all those entities and processes which are involved in accomplishing a customer order. More stakeholders are involved in management of resources, information, and processes. Supply chain consists of sourcing, transformation, delivery, product use and recycle (Ramaswamy, 2017). The three pillars of sustainability i.e. social and environmental and economic are customary to characterize sustainable development in supply chains. (Boström, 2012).

Historically, the main focus of sustainability was on improvement of environmental issues, exclusively their interface with economic ones. Intermittently cited but rarely examined, the social perspective of sustainability has been considered as the least described and weakest pillar. Social sustainability assists the vulnerable workers and help suppliers in development of persisting relationships (Bal et al., 2013).

Sustainable Supply Chain Management (SSCM) involves the managing of materials, information and cash flows, collaboration amongst the companies along the supply chain incorporating sustainability dimensions (environmental and social and economic), resulting from consumer and participants necessities (Seuring, 2013). Likelihood of exploring a specific industry, classifying particular categories of sustainable activities and observing how the proposed theory on SSCM may or may not be applied remains accessible. Therefore, exploring a series of activities including operations, logistics and integration related design between sustainability and the supply chain should be explored (Fontes and Freires, 2018).

System dynamics approach is used to simplify complexity in the adoption of sustainable SCM using feedback mechanism. SD modeling has been used for strategic planning and policy analysis for more than forty years. In the early 1970s, began with two models developed at the Massachusetts Institute of Technology*,* called WORLD2 and WORLD3 (Fontes and Freires, 2018). SD models analyzed the durable socioeconomic interactions that caused and simultaneously resisted exponential growth of the world's population and industrial output. A system dynamics model is needed for adoption of SSCM for the enhanced performance of the construction industry.

1.2 Problem statement

In developing countries, construction sector is essentially labour intensive. There is an absence of environmental regulations (Galal and Moneim, 2016). Majority of researches concentrate on integration of economic and environmental aspect with a limited or no focus on social sustainability which covers labour rights, low wages, racism , lack of education, poverty etc (Weingaertner and Moberg, 2014). The supply chain management concept is quite innovative in construction sector.

Common problems such as political differences, communication gaps, unskilled workers, unreliable contractors, ever changing regulations, less finances, projects complexity, technology adoption, project delays, unpaid work, all affect the supply chain. These challenges have put the practitioners to opt sustainability principles in construction supply chains as traditional design and construction only target cost, time and quality and have a very little focus on social, economic and environmental impacts (Simchi-Levi et al., 2004).

In order to address all perspectives of sustainability in supply chains, minimize complexities and to cover all above mentioned challenges this research intents to make a SD model for performance improvement of the Construction industry (CI).

1.3 Level of research already carried out on the proposed topic

Papadopoulos et al. (2016) suggest construction companies having carried out an ample research on development of computer-based platforms to scrutinize the concepts of current supply chain management.

Majority of the researches in SSCM area primarily enlighten the environmental perspective, in comparison to social perspective of sustainability. There is not much information related to social issues of supply chain in the definition of Green SCM (Seuring and Müller, 2008b).

According to (Chen, 2016), problems regarding SSCM are still insufficiently managed. According to (Galal and Moneim, 2016) , an extensive research has been carried out on SSCM in developed countries but there is lack of research when it comes to developing countries. There are only a few measures opted for assessment of supply chains considering the concept of triple bottom line.

Discussing construction sector, especially, the constructor sector of developing countries there is an absence of research on SSCM. Some researches focus on GSCM but ignore the social perspective having major impact. Incorporating social aspect in supply chain concept will lead towards more sustainable supply chains.

This study will focus on the adoption of sustainable supply chain management practices using system dynamics model taking into consideration environmental, social and economic perspectives for performance improvement of the construction industry.

1.4 Reasons / justification for selection of the topic

Sustainable supply chain management is apprehended as the incorporation of sustainable development and supply chain management whereby sustainable development is most frequently explained as covering three dimensions that are incorporating environmental, social and economic concerns for human (Simões, 2014). As discussed earlier, construction sector is considered to be one of the major sources of economic growth and development. There are certain issues in our construction industry such as lack of sustainability in supply chains, inadequate efforts to incorporate social perspective of sustainability in supply chains. If proper network or any sort of system is adopted it will surely help in saving money, time and enhancement of quality. This study will provide construction industry a SD model that would increase efficiency of its supply chains whose adoption is much crucial now.

1.5 Objectives

- To identify the challenges in the adoption of sustainable supply chain management
- To determine the importance, interconnectivity and functionality amongst the identified factors
- To develop System Dynamics model to help address complexity issues in terms of adoption of SSCM in the construction sector

1.6 Relevance to national needs

The construction sector of developing countries is faced with issues such as fragmentation, lack of co-ordination, communication and trust among client, contactors, consultants and suppliers affecting the supply chain. Traditional contracting methods, lack of environmental regulations and a labour-intensive construction industry adversely affect productivity and performance. Therefore, there is a need to adopt the supply chain sustainability concept in construction industry. It is crucial as it will help in cost reduction, time reduction and boosting the quality of construction products by development of a system dynamics model to gain insight and understanding in the adoption of SSCM. This study will help in performance improvement of the construction industry.

1.7 Advantages

Proper alliance between construction project management practices and supply chain management is required and opportunities can be exploited to reduce cost, increase speed to market, mitigate risk, reduce delivery time, and enhance quality, waste minimization, and green procurement. There would be transparency, traceability, closed loop manufacturing, and strong communities (Ashby et al., 2012).

1.8 Areas of application

This study will help in:

- Increased communication and collaboration
- Enhanced efficiency, performance and productivity
- Reduced cost, improved quality and less wastage
- Increased integration among stakeholders
- Minimized delays and reduced resource consumption

Literature Review

2.1 Construction industry

Construction is the largest employment generating industry in a country and plays a key role in its economy (Isa et al., 2013, Maqsoom et al., 2013). There is a French saying:

"When the construction industry prospers everything prospers."

The major concern of construction industry is the enhancement of the social, economic and environmental sustainability indicators (Ullah et al., 2018). The engineering and construction industry faces menacing challenges such as low profit margin, continuous project overruns in budget and schedule, and is further bothered with claims and counter-claims (Yeo and Ning, 2002).

2.1.1 Characteristics of Construction sector

Construction industry is fragmented having issues such as communication gaps, design and construction separation, poor collaboration among various stakeholders (Albaloushi and Skitmore, 2008). Even though this sector is having a potential contribution in GDP of country, yet its full potential has never been exploited (Nawaz et al., 2013). This industry has to face challenges which include low profit margin, continuous project overruns in budget and schedule (Yeo and Ning, 2002). Issues include fragmentation, lack of coordination, communication and trust among various stakeholders of the supply chain, use of traditional contracting methods, lack of environmental regulations and a labour-intensive construction industry causing various problems (Albaloushi and Skitmore, 2008, Galal and Moneim, 2016). Common problems including political differences, communication gap, unskilled workers, unreliable contractors, ever changing regulations, document management, less finances, less qualified workers, projects complexity, safety, technology adoption, unfavorable contract terms, project delays, unpaid work, retirement of aging boomers, all of these effect the supply chain. Main issues regarding sustainability are social, environmental and economic (Ofori, 2000). Supply chain management is an implicit approach for the effective management of construction industry (Papadopoulos et al., 2016).

2.2 Supply chain management (SCM)

The **"supply chain",** term was first used in logistic literature as an inventory management approach (Cooper and Ellram, 1993), consist of a no of firms including supply (upstream) and distribution (downstream). The origin of supply chain management was initiated in the manufacturing industry (Christopher, 2016). Supply chain of a corporation comprises of merchants, internal functions of corporation, external suppliers and end users named as customers (Hervani et al., 2005, Choon Tan et al., 2002,(Mentzer et al., 2001).

2.2.1 Supply Chain Management –An introduction

Supply chain is a complete process or chain of dealing raw materials to delivery of goods to customer (Linton et al., 2007, Agrawal et al., 2002). Supply chain management (SCM) is a method to plan, implement and control the supply chain operations at its best level (Ballou, 2007a, Ballou, 2007b). Supply chain management targets to build trust and association among supply chain partners, which enhances inventory exposure and speed, and is an improvement that appears appropriate for construction projects (Lambert et al., 1998). Construction supply chain management helps in achieving integration among the chain stakeholders such as suppliers, designers, vendors, contractors, subcontractors and clients

(Papadopoulos et al., 2016). Sustainability is a multi-dimensional concept , a relationship among social, environmental and economic realities and constraints that constantly alter (Vanegas et al., 1995, Bruntland, 1987). The review highlights the importance of sustainable supply chain management and system dynamics approach in addressing the complexity issues in terms of adoption of SSCM.

2.2.2 SCM in the construction sector

Construction Supply Chain Management helps in achieving integration among the chain stakeholders such as suppliers, designers, vendors, contractors, subcontractors and clients (Papadopoulos et al., 2016). CSCM is a developed form of partnering, a number of construction organizations have started to opt the strategies of SCM for performance improvement (Aloini et al., 2012).

Construction is a global with many distinct features and comprises of projects of significantly different types, sizes and complexities whereas general supply chains should be simple. The realism in the construction industry is rather different, construction firms should assimilate countless construction supply chains and markets when the requisite is to deliver a solution to an end customer (Butkovic et al., 2016).

The four tiers of supply chain are:

- Supply
- Production
- Distribution
- Consumers (Beamon, 1998)

Process of supply chain management includes

- Supply of unprocessed materials
- Manufacturers
- Wholesalers
- Retailers
- Customers (Sheu et al., 2005)

2.3 Sustainable Supply Chain Management (SSCM)

Sustainable SCM is defined as the material, information and capital flows management ,collaborating among companies along the supply chain integrating goals from all three sustainability dimensions, i.e., economic, environmental and social. For supply chains to be sustainable it is crucial that the participants should fulfill the criteria of sustainability dimensions to stay within the supply chain (Seuring, 2013).

2.3.1 Sustainable Supply Chain Management –An introduction

SSCM is basically the integration of supply chain management and sustainable development where the sustainable development is the amalgamation of environmental, social and economic issues for the enhancement of industry (Simões, 2014). Although SSCM discipline is considered new, however interest in SSCM has been increasing at higher rate over the years. The enactment of sustainable supply chain management is critical for industries, needs cooperation from low or bottom line to top management of the firm (Carter and Liane Easton, 2011). Carter and Rogers (2008) view SSCM as the planned, clear integration and attainment of an organisation's social, environmental, and economic goals and objectives through the systemic coordination of key inter-organisational business processes in order to increase the lasting economic performance of the individual company and its supply chain (Seuring, 2013). Environmental and social standards have to be met by all members within the supply chain, in sustainable supply chains. However, it is believed that by fulfilling needs of customers and other relevant economic criteria competitiveness can be maintained (Seuring, 2013). Implementation of sustainable supply chain management is critical for industries, needs cooperation from bottom line to top management of the firm (Carter and Liane Easton, 2011).

Majority of the related research in the field of SSCM is mainly focused on the environmental dimension, in contrast to social dimension (Boström, 2012). Those dimensions can be geographically and industrially unique that is coming under social sustainability. Social sustainability in supply chains is about social interactions between the supply chain stake holders. As construction industry is labor-intensive hence it develops a standard in the social sustainability practices across the supply chains (Galal and Moneim, 2016). From the past two decades, the literature that has been published highlighted health and safety, child labor, conditions in which people are living, housing and equity problem, pressure from competition, consumer requirements and employee union pressures were determined as few key points whose consideration is need of time. Moreover, increase in efficiency in the social sustainability dimension of the supply chain is point of consideration (Sudusinghe et al., 2018). The social dimension is considered as the weakest pillar of sustainable development. Recently, much consideration has been given to social sustainability, the interaction between the ‘environmental’ and the ‘social’ although it is still an important unexplored terrain (Lehtonen, 2004).

2.4 Comparison of Sustainable and Green supply chain management:

Sustainable supply chain and Green supply chain are different from each other in many ways. SSCM and GSCM are not exactly one and the same, although they are closely linked together. Social sustainability is basically the maintenance and improvement of the well-being of existing and coming generations, social cohesion and veracity, social constancy, unbiased sharing of resources in social relations (Chiu, 2004). The role of is considered crucial in exertion of pressure on construction firms for the sustainability management (Mani and Gunasekaran, 2018). It is a need of time to identify the social issues that impart an effect on each level of the supply chain and stakeholders (Mani et al., 2018).

Objectives achieved through sustainable supply chain management are:

- Optimization or minimization of inventory
- Supply chain cost can be reduced
- Delivery time improvement
- Flexibility can be improved

Objectives achieved through green supply chain management are:

- Making eco-friendly oriented business
- Achieving viable benefit and extraordinary performance through GSCM practices.
- Assimilating the GSCM into corporate polices and strategy for smooth operation.
- Showing how significant it is to conserve environment

The following Table 2.1 shows a comparison between sustainable and green supply chain management:

Table 2.1: Differences between Sustainable and Green Supply Chain Management

Sr.#	Character	SSCM	GSCM	Source
i.	**Definition**	Practices that improve quality of life and address environmental issues.	Practices that address environmental issues often with the goal of reducing environmental impacts to zero	(Kadam et al., 2017)
ii.	**Consequences into account**	Social,Economic,Environmental	Environmental somewhat Economic	(Galal and Moneim, 2016)
iii.	**Objective and value**	Economic,ecological,social	Economic and Ecological	(Kadam et al., 2017)
iv.	**Supplier selection criteria**	Price switching supplier long term relation	Ecological aspect, short term relations	(Kadam et al., 2017)
v.	**Flexibility**	High	Low	(Kadam et al., 2017)
vi.	**Speed**	High	Low	(Kadam et al., 2017)
vii.	**Cost**	Low	High	(Kadam et al., 2017)
viii.	**Ecological optimization**	High integrated approach	Only ecological impact	(Ahi and Searcy, 2013)
ix.	**Stakeholders Management**	Yes	No	(Ahi and Searcy, 2013)

x.	**Risk**	High	Minimum	(Ahi and Searcy, 2013)
xi.	**Resource efficiency**	High	Moderate	(Ahi and Searcy, 2013)
xii.	**Prioritizes**	People,Planet,Profit	Planet	(Galal and Moneim, 2016)

2.5 SSCM in The Developed vs Developing Countries

In developing countries problems regarding SSCM are still insufficiently managed. Influencing factors of SSC incorporate internal management cognizance, government contribution, industry and customer pressure. The accustomed development mode for social and economic progress has caused crises and challenges due to which numerous countries have initiated an active exploration in sustainable development (Tiwari et al., 2014). Sikdar (2003) gave the definition of sustainability as :

"A wise balance among economic development, environmental stewardship, and social equity".

The principal driver for the prompt development of SCM has been economic sustainability, grounded on the foundation that a cohesive and well-organized supply chain aids in diminishing fiscal risks and surging revenues (De Angelis et al., 2018). Asia is profoundly accentuating sustainability regardless of the dissimilarity in opinions about corporate social responsibility and sustainability between Europe and Asia (Carter and Mol, 2006).

The **"House of Sustainable Supply Chain"** constructed on the three pillars of the Triple Bottom Line, that are observed as the necessary supports customary to keep the building in balance as proposed by Teuteberg and Wittstruck (2010) shown in fig below.

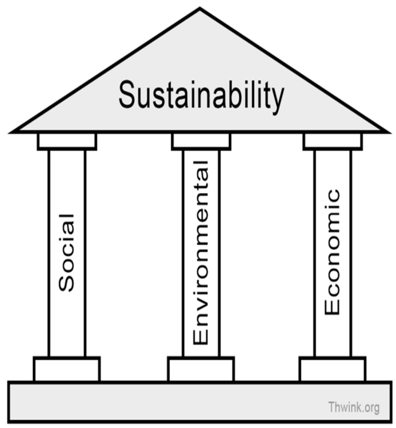

Figure2.1 House of sustainable supply chain

2.6 Challenges in sustainable supply chain management:

The following challenges were found from the review of literature and are shown in respective categories.

Table 2.2: Social Challenges

Sr.#	Social Challenges	Frequency	Source
1	Lack of training and education	13	(Al Zaabi et al., 2013) (Martens and Carvalho, 2017) (Dainty et al., 2001) (Elmualim et al., 2010)

			(Walker et al., 2008) (Adetunji et al., 2008) (Ravi and Shankar, 2005) (Akintoye et al., 2000) (Beske and Seuring, 2014) (Elmualim et al., 2010) (Govindan et al., 2014) (Nishat Faisal, 2010) (Mani et al., 2018)
2	Lack of top management commitment	14	(Walker and Brammer, 2009) (Nishat Faisal, 2010) (Ravi and Shankar, 2005) (Elmualim et al., 2010) (Akintoye et al., 2000) (Giunipero et al., 2012) (Beske and Seuring, 2014) (Ojo et al., 2014) (Govindan et al., 2014) (Walker and Jones, 2012) (Walker and Brammer, 2009) (Al Zaabi et al., 2013)

3	Suppliers human skills	1	(Ageron et al., 2012)
4	Suppliers top management commitment	6	(Akintoye et al., 2000) (Beske and Seuring, 2014) (Elmualim et al., 2010) (Govindan et al., 2014) (De Brito et al., 2008)
5	Suppliers firm culture	2	(Ageron et al., 2012) (Walker and Jones, 2012)
6	Suppliers firm size	3	(Ageron et al., 2012) (Walker et al., 2008) (Wognum et al., 2011)
7	Supply chain configuration	8	(Ageron et al., 2012) (Martens and Carvalho, 2017) (Gopalakrishnan et al., 2012) (Keating et al., 2008) (Svensson, 2007) (Swee et al., 2010) (Nishat Faisal, 2010) (Mani et al., 2018)
8	Maintaining environmental suppliers	2	(Negi et al., 2017) (Govindan et al., 2014)
9	Focal firms previous sustainability experiences	1	(Ageron et al., 2012)
10	Suppliers location	1	(Ageron et al., 2012)
11	Lack of resource (human)	6	(Negi et al., 2017) (Giunipero et al.,

			2012) (Walker et al., 2008) (Govindan et al., 2014) (Ojo et al., 2014) (Walker and Brammer, 2009)
12	Lack of technical expertise	3	(Negi et al., 2017) (Elmualim et al., 2010) (Govindan et al., 2014)
13	Fear of failure	2	(Negi et al., 2017) (Govindan et al., 2014)
14	Lack of customer awareness	3	(Negi et al., 2017) (Govindan et al., 2014)
15	Perception of out of responsibility zone	2	(Negi et al., 2017) (Govindan et al., 2014)
16	Lack of awareness about reverse logistics	4	(Negi et al., 2017) (Elmualim et al., 2010) (Govindan et al., 2014) (Walker and Brammer, 2009)
17	Lack of corporate social responsibility	5	(Negi et al., 2017) (Seuring and Müller, 2008a) (Govindan et al., 2014) (Ojo et al., 2014) (Svensson, 2007)
18	Lack of information sharing between construction firms and suppliers	4	(Negi et al., 2017) (Govindan et al., 2014) (Diabat and Govindan, 2011) (Ojo et al., 2014)

19	Lack of trust	4	(Dainty et al., 2001) (Elmualim et al., 2010) (Akintoye et al., 2000) (Swee et al., 2010)
20	Resistance to change	1	(Elmualim et al., 2010)
21	Unwillingness to share risks and rewards	1	(Elmualim et al., 2010)
22	Cross functional conflicts	1	(Elmualim et al., 2010)
23	Inadequate performance measurement	2	(Elmualim et al., 2010) (Giunipero et al., 2012)
24	Lack of awareness	5	(Giunipero et al., 2012) (Walker et al., 2008) (Seuring and Müller, 2008a) (Ravi and Shankar, 2005) (Nishat Faisal, 2010)
25	Poor supplier commitment	1	(Al Zaabi et al., 2013) (Walker and Jones, 2012)
26	Employee involvement	1	(Walker and Jones, 2012)
27	Vendor selection	2	(Seuring and Müller, 2008a)
28	Organizational culture	7	(Martens and Carvalho, 2017) (Walker and Jones, 2012) (Walker and Brammer,

			2009) (Ahmad et al., 2017) (Gopalakrishnan et al., 2012) (Abbasi and Nilsson, 2012) (Govindan et al., 2014)
29	Resistance to change to reverse logistics	1	(Ravi and Shankar, 2005)
30	Reluctance of the support of dealers, distributors, and retailers	1	(Ravi and Shankar, 2005)
31	Lack of strategic planning	2	(Ravi and Shankar, 2005) (Keating et al., 2008)
32	Low commitment of partners	1	(Akintoye et al., 2000)
33	Frequent meetings	1	(Akintoye et al., 2000)
34	Closer links between demand and supply	1	(Akintoye et al., 2000)
35	Reliability of supply	1	(Akintoye et al., 2000)
36	Initial burden on suppliers	1	(Giunipero et al., 2012)
37	Lack of legitimacy	1	(Walker and Jones, 2012)
38	Supplier commitment	1	(Walker and Jones, 2012)
39	Poverty	1	(Mani et al., 2018)
40	Health and safety	6	(Martens and Carvalho, 2017) (Walker and Brammer, 2009) (Mani et al., 2018)

			(Galal and Moneim, 2016) (De Brito et al., 2008) (Keating et al., 2008)
41	Philanthropy	3	(Martens and Carvalho, 2017) (Mani et al., 2018) (Walker and Brammer, 2009)
42	Child labor and forced labor	3	(Martens and Carvalho, 2017) (Mani et al., 2018) (Keating et al., 2008)
43	Discrimination	3	(Mani et al., 2018) (Keating et al., 2008)
44	Wages	1	(Mani et al., 2018)
45	Labor practices	3	(Martens and Carvalho, 2017) (Seuring and Müller, 2008a) (Mani et al., 2018)
46	Unethical practices	1	(Mani et al., 2018)
47	Human rights	3	(Martens and Carvalho, 2017) (Mani et al., 2018) (Walker and Brammer, 2009)
48	Sustainable sourcing	1	(Mani et al., 2018)
49	Local sourcing	1	(Mani et al., 2018)
50	Employment creation	2	(Mani et al., 2018)

			(Galal and Moneim, 2016)
51	Gender inequality	2	(Galal and Moneim, 2016) (Keating et al., 2008)
52	Stakeholder engagement	5	(Martens and Carvalho, 2017) (Seuring and Müller, 2008a) (Elmualim et al., 2010, Mani et al., 2018) (Keating et al., 2008)
53	Collaboration with suppliers	1	(Diabat and Govindan, 2011)
54	Collaboration with customers	1	(Diabat and Govindan, 2011)
55	Company policies	5	(Negi et al., 2017) (Ravi and Shankar, 2005) (Govindan et al., 2014) (Wognum et al., 2011) (Keating et al., 2008)
56	Supplier lack resources	1	(Negi et al., 2017, Giunipero et al., 2012)
57	Disbelief about environmental benefits	3	(Govindan et al., 2014) (Ojo et al., 2014)
58	Problems in maintaining environmental suppliers	1	(Walker et al., 2008)

Table 2.3: Environmental Challenges

Sr.No	Environmental challenges	Frequency	Source
1	Complexity to design,reuse,recycle product	10	(Al Zaabi et al., 2013) (Wognum et al., 2011) (Gopalakrishnan et al., 2012) (Govindan et al., 2014) (Diabat and Govindan, 2011) (De Brito et al., 2008) (Ojo et al., 2014) (Svensson, 2007) (Negi et al., 2017)
2	Green induced changes	2	(Ageron et al., 2012) (Diabat and Govindan, 2011)
3	Product quality	2	(Ravi and Shankar, 2005) (Beske, 2012)
4	Lack of effective environmental measures	2	(Negi et al., 2017) (Govindan et al., 2014)
5	Less involvement in environmental related programs and meetings	4	(Negi et al., 2017) (Diabat and Govindan, 2011) (Seuring and Müller, 2008a) (Govindan et al., 2014)

6	Lack of government support to adopt environmental friendly policies	2	(Negi et al., 2017) (Govindan et al., 2014)
7	Environmental performance	5	(Walker and Brammer, 2009) (Walker et al., 2008) (Swee et al., 2010) (Beske, 2012) (Keating et al., 2008)
8	Usage of renewable materials	1	(Negi et al., 2017)
9	Waste minimization	1	(Martens and Carvalho, 2017)
10	Eco-efficiency	1	(Martens and Carvalho, 2017)

Table 2.4 Economic Challenges

Sr.#	Economic Challenges	Frequency	Source
1	Financial cost / financial constraints	10	(Ageron et al., 2012) (Negi et al., 2017) (Dainty et al., 2001, Ravi and Shankar, 2005) (Elmualim et al., 2010) (Abbasi and Nilsson, 2012) (Govindan et al.,

			2014) (Mani et al., 2018, Wognum et al., 2011) (Walker and Brammer, 2009)
2	High cost for waste disposal Wastes	4	(Govindan et al., 2014) (Giunipero et al., 2012) (Negi et al., 2017) (Al Zaabi et al., 2013)
3	Return on investment	4	(Ageron et al., 2012) (Negi et al., 2017) (Martens and Carvalho, 2017) (Govindan et al., 2014)
4	Product price	2	(Ageron et al., 2012) (Seuring and Müller, 2008a)
5	Economic uncertainity	2	(Giunipero et al., 2012) (Abbasi and Nilsson, 2012)

6	Cost of third part certification	2	(Adetunji et al., 2008, Beske and Seuring, 2014)
7	Availability of funds	2	(Abbasi and Nilsson, 2012) (Nishat Faisal, 2010)
8	Eco-friendly packaging cost	1	(Al Zaabi et al., 2013)
9	Cost of sustainability and economic conditions	1	(Al Zaabi et al., 2013)
10	Green investments	1	(Ageron et al., 2012)
11	Non availability of bank loans	1	(Giunipero et al., 2012)
12	Cost concern hinders	1	(Walker et al., 2008)
13	Distribution of cost benefits	1	(Adetunji et al., 2008)
14	Initial buyer and supplier investment	1	(Giunipero et al., 2012)

These challenges are ranked as shown in Table 2.3 according to their literature score obtained through content analysis where the impact of each challenges (high, medium, low) is assessed through detailed review of literature. A quantitative number is assigned to each impact (**High as 5, Medium as 3, and Low as 1)** and the highest frequency impact is selected for each barrier. Equation 1 shows the calculation of literature score, where A is the highest possible score, N is the total no of papers which were considered for the identification of the challenges, frequency shows the repetition of challenges in papers.

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

(Equation 2.1)

The next step was to convert this literature score into normalized score by dividing individual literature score of each challenge with the sum of literature score. Normalized score is then arranged in descending order and cumulative score is calculated. This technique is used for elimination of less significant factors (Ullah et al., 2018).

Table 2.5 : Ranked challenges via literature review

	Identified factors	Literature Score	Normalized Score	Cumulative Score
1	Lack of top management commitment	0.4516	0.0713	0.0713
2	Lack of training and education	0.4194	0.0662	0.1375
3	Complexity to design,reuse,recycle product	0.3226	0.0509	0.1884
4	Financial cost / financial constraints	0.3226	0.0509	0.2393
5	Supply chain configuration	0.2581	0.0407	0.2800
6	Organizational culture	0.2258	0.0356	0.3157
7	Health and safety	0.1935	0.0305	0.3462
8	Lack of awareness	0.1613	0.0255	0.3717
9	Company policies	0.1613	0.0255	0.3971
10	Environmental performance	0.1613	0.0255	0.4226
11	Lack of trust	0.1290	0.0204	0.4430
12	Less involvement in environmental related programs and meetings	0.1290	0.0204	0.4633
13	High cost for waste disposal wastes	0.1290	0.0204	0.4837
14	Return on investment	0.1290	0.0204	0.5041

15	Suppliers top management commitment	0.1161	0.0183	0.5224
16	Lack of resource (human)	0.1161	0.0183	0.5407
17	Lack of corporate social responsibility / lack of demand	0.0968	0.0153	0.5560
18	Child labor and forced labor	0.0968	0.0153	0.5713
19	Discrimination	0.0968	0.0153	0.5866
20	Human rights	0.0968	0.0153	0.6018
21	Stakeholder engagement	0.0968	0.0153	0.6171
22	Lack of awareness about reverse logistics	0.0774	0.0122	0.6293
23	Suppliers firm culture	0.0645	0.0102	0.6395
24	Inadequate performance measurement	0.0645	0.0102	0.6497
25	Vendor selection	0.0645	0.0102	0.6599
26	Lack of strategic planning	0.0645	0.0102	0.6701
27	Employment creation	0.0645	0.0102	0.6802
28	Gender inequality	0.0645	0.0102	0.6904
29	Green induced changes	0.0645	0.0102	0.7006
30	Product quality	0.0645	0.0102	0.7108
31	Lack of effective environmental measures	0.0645	0.0102	0.7210
32	Lack of government support to adopt environmental friendly policies	0.0645	0.0102	0.7312
33	Product price	0.0645	0.0102	0.7413
34	Economic uncertainty	0.0645	0.0102	0.7515
35	Cost of third part certification	0.0645	0.0102	0.7617
36	Availability of funds	0.0645	0.0102	0.7719
37	Suppliers firm size	0.0581	0.0092	0.7811
38	Lack of technical expertise	0.0581	0.0092	0.7902

39	Lack of customer awareness	0.0581	0.0092	0.7994
40	Disbelief about environmental benefits	0.0581	0.0092	0.8086
41	Philanthropy	0.0581	0.0092	0.8177
42	Labor practices	0.0581	0.0092	0.8269
43	Maintaining environmental suppliers	0.0387	0.0061	0.8330
44	Fear of failure	0.0387	0.0061	0.8391
45	Perception of out of responsibility zone	0.0387	0.0061	0.8452
46	Suppliers human skills	0.0323	0.0051	0.8503
47	Resistance to change	0.0323	0.0051	0.8554
48	Unwillingness to share risks and rewards	0.0323	0.0051	0.8605
49	Cross functional conflicts	0.0323	0.0051	0.8656
50	Employee involvement	0.0323	0.0051	0.8707
51	Resistance to change to reverse logistics	0.0323	0.0051	0.8758
52	Low commitment of partners	0.0323	0.0051	0.8809
53	Reliability of supply	0.0323	0.0051	0.8859
54	Poverty	0.0323	0.0051	0.8910
55	Wages	0.0323	0.0051	0.8961
56	Unethical practices	0.0323	0.0051	0.9012
57	Sustainable sourcing	0.0323	0.0051	0.9063
58	Local sourcing	0.0323	0.0051	0.9114
59	Collaboration with suppliers	0.0323	0.0051	0.9165
60	Collaboration with customers	0.0323	0.0051	0.9216
61	Usage of renewable materials	0.0323	0.0051	0.9267
62	Waste minimization	0.0323	0.0051	0.9318
63	Eco-efficiency	0.0323	0.0051	0.9369

64	Eco-friendly packaging cost	0.0323	0.0051	0.9420
65	Cost of sustainability and economic conditions	0.0323	0.0051	0.9470
66	Green investments	0.0323	0.0051	0.9521
67	Non availability of bank loans	0.0323	0.0051	0.9572
68	Distribution of cost benefits	0.0323	0.0051	0.9623
69	Initial buyer and supplier investment	0.0323	0.0051	0.9674
70	Lack of information sharing between construction firms and suppliers	0.0258	0.0041	0.9715
71	Poor supplier commitment	0.0194	0.0031	0.9745
72	Reluctance of the support of dealers, distributors, and retailers	0.0194	0.0031	0.9776
73	Closer links between demand and supply	0.0194	0.0031	0.9807
74	Problems in maintaining environmental suppliers	0.0194	0.0031	0.9837
75	Initial burden on suppliers	0.0194	0.0031	0.9868
76	Lack of legitimacy	0.0194	0.0031	0.9898
77	Supplier commitment	0.0194	0.0031	0.9929
78	Cost concern hinders	0.0194	0.0031	0.9959
79	Focal firms previous sustainability experiences	0.0065	0.0010	0.9969
80	Suppliers location	0.0065	0.0010	0.9980
81	Supplier lack resources	0.0065	0.0010	0.9990
82	Frequent meetings	0.0065	0.0010	1.0000
		6.3355		

2.7 System dynamics approach

System dynamics (SD) approach is used to simplify complexities in the adoption of sustainable SCM using feedback mechanism (Thompson and Bank, 2010). It is an iterative modelling process. Jay Wright Forrester, Professor at Massachusetts Institute of Technology (MIT), gave System Dynamics (SD) idea during the 1950s. The main objective of SD methodology was to help industrial processes where variables are connected to a system which is dynamic in nature. System dynamics is mainly designed for complex, huge socio-economic systems (Forrester, 1997). System dynamics (SD) modeling is a beneficial approach for the comprehensive evaluation of a complex system (Xu and Coors, 2012). System dynamics is an iterative modeling process. SD incorporates the use of stocks, flows, feedback loops, table functions and time delays (Coyle and Coyle, 1977). A causal loop diagram (CLD) is developed to determine relationship among variables, balancing and reinforcing feedback loops in the holistic system (Nguyen and Bosch, 2013). Every pair of variables in SD models has a cause and effect showing that the variables can move in the same or opposite direction. Polarities among links only predict what would happen if there is a change, they don't show the behavior of variables (Sterman, 2000).

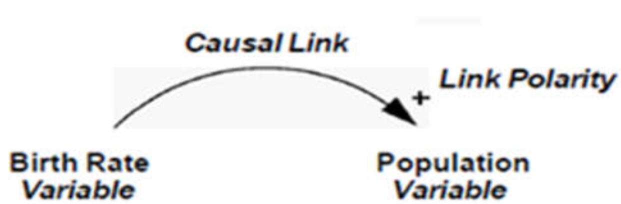

Figure2.2: Causal link and polarity

Polarity is determined by tracing effects of the variable as it propagated around the loop. A positive loop is represented by **"R"** depicts the actions that produce a result and arise further action producing more results in same direction while a negative loop is represented by **"B",** aims to generate state of system in opposite direction (Coyle, 2000).

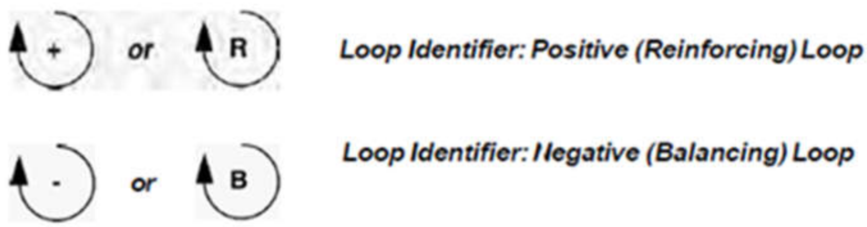

Figure 2.3: Positive and Negative loops

An important feature of system dynamics approach is that it tracks and interprets a given system over a time period, combining different theories philosophies and techniques that help in providing useful framing, understanding the behavior shown by management system (Forrester, 1997). All SD models are composed of variables of three types: stock, flow and auxiliary and flows of two types, physical/material and information both of which could interact and respond to others. Variables, simultaneously with stock flows are part of essential formation of stock-flow diagram in which feedback loops plays a crucial role in simulation of model. The representation of the system dynamics model, in terms of stocks and flows of energy, gives a highly perceptive understanding of the principles. An important feature of system dynamics approach is that it tracks and interprets a given system over a time period, combining different theories philosophies and techniques that help in providing useful framing, understanding the behavior shown by management system (Forrester, 1997).

For the economic and social progress of a country construction activities are an important index. Recently, an exceptional growth in terms of quantity, size and difficulty of large projects has been seen in many developing countries. System dynamics approach is opted for better understanding of organizational dynamics and to deal with all the complexities involved in any project (Ogunlana et al., 2003).

2.8 Summary:

Construction sector plays an important role in a country's economy. Communication gap is seen among stakeholders (clients, consultants, contractors and suppliers) as they work together only on certain projects or a project and are then parted (Bal et al., 2013). This gap leads to increased delays, time and cost over runs in various construction projects that ultimately leads to reduced quality level (Jaffar et al., 2011).

Collaboration and communication is much necessary when construction supply chains are meant to ensure economic, environmental and social performance, simultaneously on a project (Gold et al., 2010). Triple Bottom Line (TBL) perspective of sustainability includes economic (profit, cash flows, income), environmental (natural resources, energy conservation, land use) and social (education, equity, health ,well-being, quality of life) performance (Ramaswamy, 2017). SSCM involves the managing of materials, information and capital flows, cooperation among companies along the supply chain incorporating goals of sustainable development (economic, environmental and social),derived from customer and stakeholder requirements (Seuring, 2013). System dynamics approach is used to simplify complexity in the adoption of sustainable SCM using feedback mechanism. In order to address all perspectives of sustainability in supply chains, minimize complexities and to cover all above mentioned challenges this research intents to make a SD model for performance improvement of CI.

Research Methodology

3.1 Introduction

This study focuses on the adoption of sustainable supply chain management for the performance improvement of the construction industry using a system dynamics model. The research is carried out in various phases. The diagrammatic representation for the methodology of this study is presented in figure 3.1.

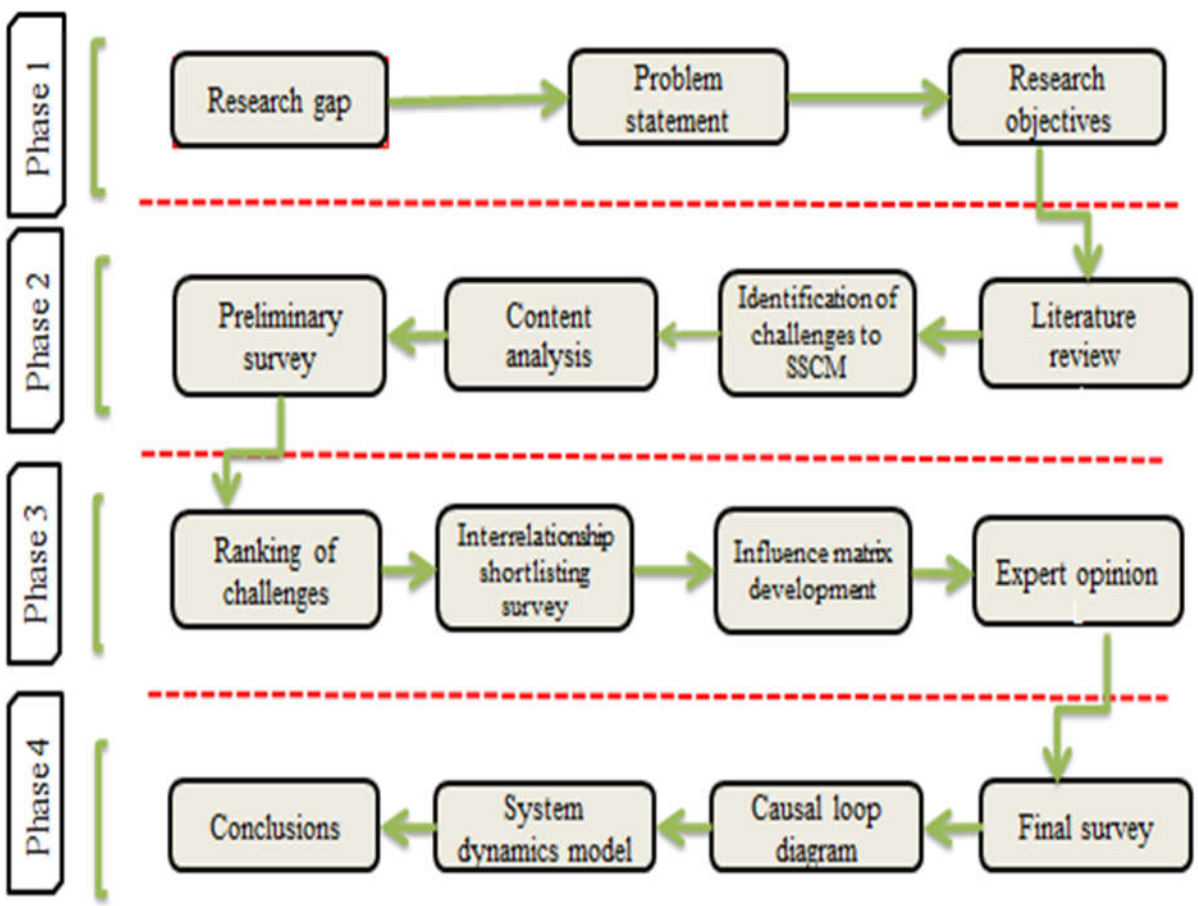

Figure 3.1 : Flow chart of Research Methodology

3.1.1 Phase 1: Identification of research objectives

This phase involved basic steps such as finding research gap and research topic. The scrutiny of literature was done from research articles, books and conference papers for establishing this gap. After the development of problem statement, objectives of research were identified. This helped in answering certain questions such as work already done on this topic? Why is this research carried out? What would be its benefits to construction industry? What will be its relevance to national needs?

3.1.2 Phase 2: Literature review and preliminary survey

Literature review was carried out to find challenges causing hindrance in the adoption of sustainable supply chain management in the construction industry. 31 research papers were reviewed for the identification of challenges related to adoption of sustainable supply chain management. Data analysis revealed 82 challenges (58 social, 14 economical, 10 environmental) in the adoption of SSCM. Content analysis was conducted for selection of most important challenges. This was carried out using literature score and field survey. The identified challenges from literature were ranked according to their literature score obtained through content analysis where the impact of each challenge (high, medium, low) was assessed through detailed review of literature. A quantitative number was assigned to each impact (high as 5, medium as 3 and low as 1) as described in the study. The highest frequency impact was selected for each barrier.

The next step was to convert this literature score into normalized score by dividing individual literature score of each challenge with the sum of literature score. Normalized score was then arranged in descending order and cumulative score was calculated. This technique is used for elimination of less significant factors (Ullah et al., 2017).

3.1.3 Phase 3: Interrelationships shortlisting survey

Data was collected through questionnaires, a weightage of 60/40 was selected, Pareto analysis was used and then most important challenges were considered and rest were discarded from the list. In this phase, expert opinion was acquired for which a questionnaire survey was circulated (for shortlisting interrelationships among challenges and determination of polarity) that helped in development of influence matrix. Further these experts were asked about the root cause of each challenge.

3.1.4 Phase 4: Development of System Dynamics Model

This is the most important phase of this research. In this phase, final survey was conducted to determine impact of one challenge on the other for the development of equations of the system dynamics model. Causal loop diagram was made followed by a System Dynamics model to address challenges in adoption of sustainable supply chain management for enhancing the performance of construction industry. The end of this phase is followed by the most important part of the research i.e. discussion, conclusions and recommendations for future research.

Results and Discussions

4.1 Surveys:

A total of 3 surveys were conducted. The description of each is as follows:

4.1.1 Preliminary Survey

A preliminary survey was conducted for which a questionnaire was developed in Google® Forms consisting of two sections. Respondents were asked about the importance of each challenge on a scale of 1 (having very low impact) to 5 (having a very high impact). The ratio of 60/40 (60 percent respondent's normalized score and 40 % literature's normalized score) was selected.

PARETO analysis was used to shortlist the factors having 50% impact score (Ahmad et al., 2018). Based on the collective score of the field and literature data, final ranking of challenges was established, as presented in table below. Response rate for this survey was 30. Top thirty (30) factors were shortlisted. The descending list of top thirty factors is as below:

Table 4.1: Ranking on basis of literature and field score in view of developing countries

Sr.#	Challenges	60R/40L	Cumulative Score
1	Lack of top management commitment	0.03459	0.03459
2	Lack of training and education	0.03458	0.06918
3	Complexity to design,reuse,recycle product	0.02847	0.09765
4	Financial cost / financial constraints	0.02847	0.12613
5	Supply chain configuration	0.02237	0.14850
6	Organizational culture	0.02034	0.16884
7	Health and safety	0.01830	0.18714

8	Lack of awareness	0.01829	0.20543
9	Company policies	0.01829	0.22372
10	Environmental performance	0.01626	0.23999
11	Lack of trust	0.01625	0.25624
12	Less involvement in environmental related programs and meetings	0.01625	0.27250
13	High cost for waste disposal	0.01625	0.28875
14	Return on investment	0.01625	0.30501
15	Suppliers top management commitment	0.01544	0.32045
16	Lack of resource (human)	0.01544	0.33589
17	Lack of corporate social responsibility	0.01422	0.35011
18	Child labor and forced labor	0.01422	0.36432
19	Stakeholder engagement	0.01422	0.37854
20	Product quality	0.01421	0.39275
21	Lack of awareness about reverse logistics	0.01300	0.40575
22	Discrimination	0.01219	0.41794
23	Human rights	0.01219	0.43013
24	Suppliers firm culture	0.01218	0.44231
25	Inadequate performance measurement	0.01218	0.45449
26	Lack of strategic planning	0.01218	0.46667
27	Gender inequality	0.01218	0.47885
28	Lack of government support to adopt environmental friendly policies	0.01218	0.49104
29	Product price	0.01218	0.50322
30	Economic uncertainty	0.01218	0.51540

4.1.2 Survey for shortlisting interrelationships:

A second survey was conducted in two phases. Respondents were asked about the existence of interrelationships among the identified challenges and in addition the polarity among these in phase 1. This resulted in 95 relationships which helped in development of influence matrix as shown in figure 4.1. Respondents were asked about the root cause of each challenge in phase 2. It is worthy to note that taking into account all influences rather than immediate causes among variables reflects the past behavior of a system and does not represent the structure of the system (Sterman, 2000). Thus, influences with no direct effect were dropped from further analysis and only those relationships were considered that capture the underlying causal structure of the system keeping the feedback loops closed and meaningful. A total of 24 relationships were shortlisted that helped in development of the causal loop diagram. The responses were collected from experts (7 in no) in sustainability and construction management field having experience more than 5 years.

Table 4.2: Coding

Code	Explanation
C1	Top management commitment
C2	Training and education
C3	Supply chain configuration
C4	Organization culture
C5	Health and safety
C6	Awareness
C7	Company policies
C8	Trust
C9	Suppliers top management commitment
C10	Resource (human)
C11	Corporate social responsibility
C12	Child labour and forced labour
C13	Stakeholder enagagement
C14	Awareness about reverse logistics

C15	Discrimination
C16	Human rights
C17	Suppliers firm culture
C18	Gender inequality
C19	Strategic planning
C20	Inadequate performance measurement
C21	Financial constraints
C22	Return on investment
C23	High cost for waste disposal
C24	Product price
C25	Economic uncertainty
C26	Complexity to design,reuse,recycle product
C27	Environmental performance
C28	Government support to adopt environmental friendly policies
C29	Less involvement in environmental related programs and meetings
C30	Product quality

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

Figure 4. 1 :Influence matrix

4.1.3 Final survey:

On the basis of 24 relationships the next step was to determine the impact of one challenge on the other using a bi-section questionnaire developed in Google® Docs (Wong et al., 2016, Shen et al., 2017). The head section was having questions regarding general information about the respondents such as, qualification, experience, job title etc. The second section comprised of the Likert scale from 0 to 5 where 0 shows no impact and 5 shows a very high impact. The questionnaire survey was circulated to various developing countries through online sources including official email, professional networks such as LinkedIn, and social networks such as Facebook. Above 1500 researchers and field personnel were contacted and a total of 125 responses were obtained. These responses were received from 20 countries with major responses from Pakistan, India, Iran, Qatar, South Africa, Morocco, Malaysia, and UAE.

Table 4. 3: Polarity and Normalized impact score among Challenges

Relation	Polarity	Impact score	Normalized score
How much impact does "Lack of top management commitment" has on "Supply chain configuration" ?	+	3.808	0.045
How much impact does "Lack of top management commitment" has on "Financial constraints" ?	+	4.072	0.048
How much impact does "Lack of training and education" has on " Lack of awareness" ?	+	3.888	0.046
How much impact does "Supply chain configuration" has on " Lack of training and education" ?	+	3.152	0.037
How much impact does "Organizational culture" has on "Lack of corporate social responsibility" ?	+	3.648	0.043
How much impact does "Health and safety" has on " Lack of top management commitment " ?	+	3.424	0.040
How much impact does "Lack of government support to adopt environmental friendly policies" has on "Health and Safety " ?	-	3.120	0.037
sHow much impact does "Lack of awareness" has on "Lack of strategic planning" ?	+	3.768	0.044
How much impact does "Lack of strategic planning" has on "Inadequate performance measurement " ?	+	3.648	0.043
How much impact does "Lack of awareness" has on"Complexity to design,reuse,recycle product" ?	+	3.544	0.042
How much impact does "Company policies" has on	+	3.544	0.042

"Organization culture" ?			
How much impact does "Lack of trust" has on "Lack of top management commitment" ?	+	3.560	0.042
How much impact does "Inadequate performance measurement" has on "Lack of trust" ?	+	3.568	0.042
How much impact does "Lack of corporate social responsibility" has on "Child labour and forced labour" ?	+	3.728	0.044
How much impact does "Discrimination" has on "Lack of corporate social responsibility " ?	+	3.560	0.042
How much impact does "Lack of corporate social responsibility" has on "Top management commitment " ?	+	3.312	0.039
How much impact does "Child labour and forced labour" has on "Discrimination " ?	+	3.448	0.041
How much impact does "Financial constraints" has on "Child labour and forced labour" ?	+	3.384	0.040
How much impact does "Financial constraints" has on "Economic uncertainty" ?	+	3.712	0.044
How much impact does "Return on investment" has on "Lack of top management commitment" ?	+	2.840	0.033
How much impact does "Complexity to design ,recycle,reuse product" has on "Environmental performance" ?	-	3.424	0.040
How much impact does "Environmental performance" has on "Lack of government support to adopt environmental friendly policies " ?	+	3.376	0.040
How much impact does "Economic uncertainty" has on "Return on investment" ?	-	3.416	0.040

How much impact does "Lack of top management commitment" has on "Company policies" ?	-	4.112	0.048
		∑= 85.056	

4.2 Data demographics

The survey collected 125 responses with the demographic details given in table below:

Table 4. 4: Respondents Demographic Details

Respondent Demography		**Frequency**	**Percentage**
Qualification	Diploma Holders	7	6%
	Graduation	53	42%
	Post-Graduation	54	43%
	PhD	11	9%
Organization type	Government	30	24%
	Semi-government	10	8%
	Private	85	68%
Experience(years)	0-5	55	44%
	6-10	27	22%
	11-20	21	17%
	>20	22	18%
Understanding of sustainable supply chain management	No understanding at all	5	4%
	Slight	24	19%
	Moderate	77	62%
	Exceptional	19	15%
Job Title	CEO	5	4%

Project Director	6	5%
Project Manager	12	10%
Construction Manager	9	7%
Assistant Manager	12	10%
Project Engineer	22	18%
Planning Engineer	15	12%
Site Manager	4	3%
Architect/Designer	6	5%
University Professor	10	8%
Others	24	19%

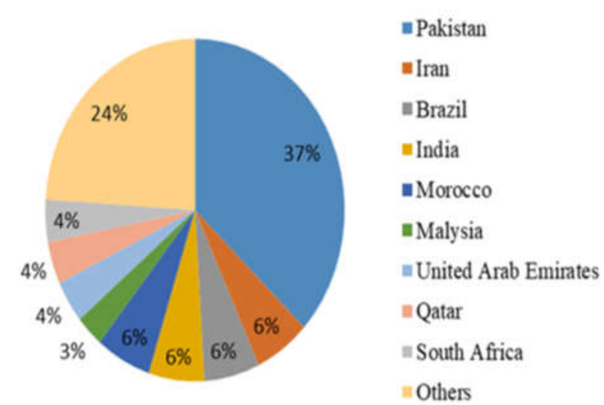

Figure 4. 2: Regional Distribution of respondent

4.3 Reliability and Normality check

For checking the reliability of the data collected on Likert scale Cronbach's Alpha method was used. If the value comes to be greater than 0.7, the data is considered reliable (Gliem and Gliem, 2003). Further, if the value comes to be greater than 0.9, the data is highly consistent for use. (Tavakol and Dennick, 2011) have interpreted Alpha value as excellent if found greater than 0.90. The value of Cronbach's Alpha came out to be 0.98 in this data set which shows that the data is reliable for further analysis.

Shapiro-Wilk test was also conducted on the collected data, to determine the normality, as it is the most powerful test for all types of distribution and sample sizes ranging from 10 to 2000. After running the test, outcome indicated significance values less than 0.05 which predict that data is not normally distributed means the data is non-parametric.

4.4 Causal loop framework development

The causal loop diagram illustrates 6 important reinforcing and balancing loops as described below:

4.4.1 Reinforcing loop R1

Figure 4.3 shows if there is an increase in lack of top management commitment, there would be an increase in issues in the supply chain configuration leading to an increase in lack of training and education. The increased lack of training and education will lead to an increase in lack of awareness which shows increased complexities to design, reuse, recycle product. An increase in complexities to design, reuse, recycle product will lead to decreased environmental performance which shows a decrease in lack of government support in adoption of environmental friendly policies. This decrease would lead to an increase in health and safety issues which leads to an increase lack of top management commitment.

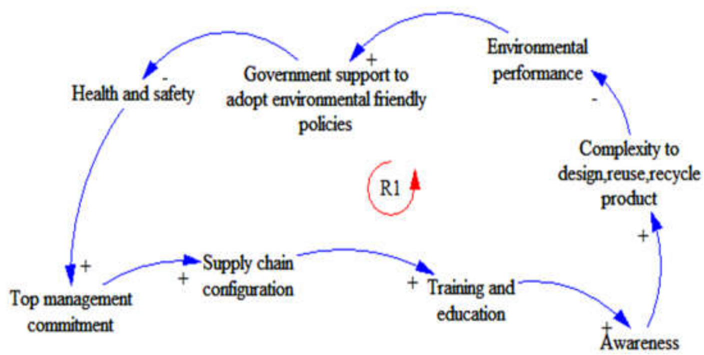

Figure 4. 3: Reinforcing loop R1

4.4.2 Reinforcing loop R2

Figure 4.4 shows if there is an increase in lack of top management commitment, there would be increase in issues in the supply chain configuration leading to an increase in lack of training and education. The increased lack of training and education will lead to an increase in lack of awareness; increase in lack of awareness will lead to increase in lack of strategic planning which leads to increase in inadequate performance measurement due to which there would be an increase in lack of trust. The increase in lack of trust will lead to an increase in lack of top management commitment.

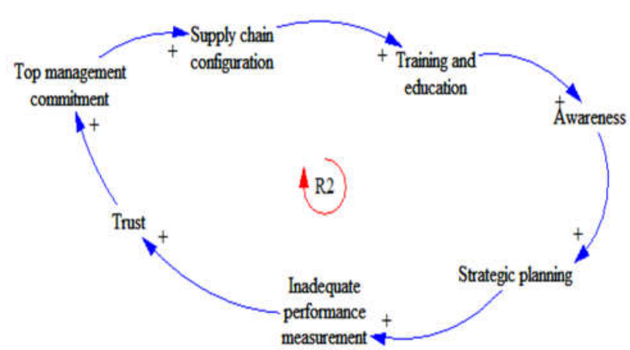

Figure 4. 4: Reinforcing loop R2

4.4.3 Reinforcing loop R3

Figure 4.5 shows an increase in lack of corporate social responsibility will lead to an increase in child labour and forced labour which increases discrimination which again leads to an increase in lack of corporate social responsibility.

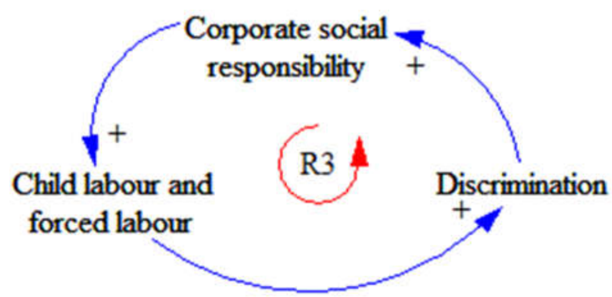

Figure 4. 5: Reinforcing loop R3

4.4.4 Reinforcing loop R4

An increase in lack of top management commitment leads to increase in financial constraints that lead to an increase in child labour and forced labour (as shown in Figure 4.6). An increase in child labour and forced labour leads to increase in discrimination that leads to increase in lack of corporate social responsibility that again leads to increase in lack of top management commitment.

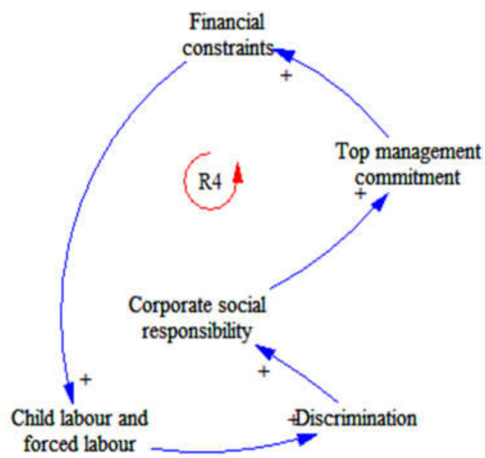

Figure 4. 6: Reinforcing loop R4

4.4.5 Balancing loop B1

An increase in lack of top management commitment would lead to an increase in financial constraints which promotes economic uncertainty (as shown in Figure 4.7). Increased economic uncertainty will lead to decreased return on investment which leads to a decrease in lack of top management commitment.

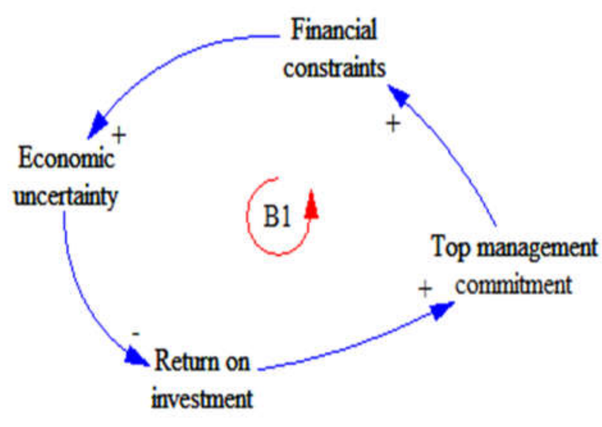

Figure 4. 7: Balancing loop B1

4.4.6 Balancing loop B2

Considering balancing loop B2 (as shown in Figure 4.8), increase in lack of top management commitment would lead to a decrease in company policies which will affect (decrease) organisation culture which leads to a decrease in lack of corporate social responsibility which leads to a decrease in lack of top management commitment.

Figure 4.8: Balancing loop B2

Figure 4.9 is a consolidated diagram of all loops. The causal loop diagram has been fed into the system dynamics model.

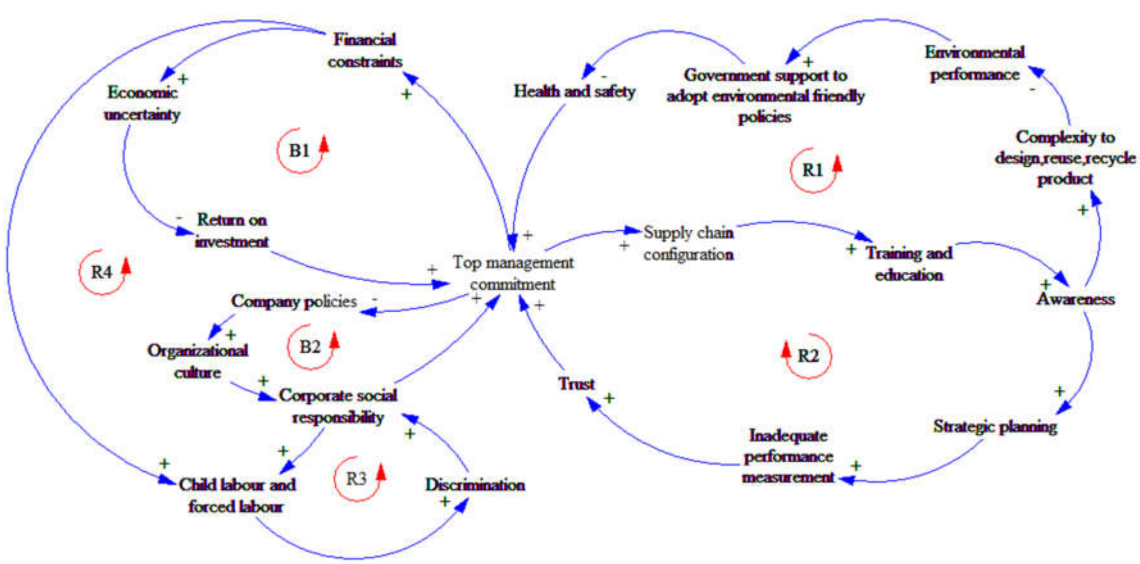

Figure 4.9: Feedback causal loop diagram

4.5 System dynamics model

After development of the causal loop diagram that describes the feedback mechanism, it was converted to stock and flow diagram which was finally converted to system dynamics model using VENSIM®. The model consists of three stocks, **"Top management commitment", "Corporate social responsibility", "Project performance"**, governed by inflows and outflows. The data collected in final survey also helped in development of equations in the model. The top management commitment and corporate social responsibility were selected as stocks as they were showing accumulation since these were the two challenges which were having the most of the interrelationships with other challenges. Thus, are showing the combined effect of variables in connection with them, influencing upon the project performance. The data collected in final survey also helped in development of equations in the model.

$$\text{Inflow of top management commitment} = (0.04 * C11) + (0.04 * C5) + (0.033 * C22) + (0.042 * C8)$$

(Equation 4. 1)

$$\text{Outflow of top management commitment} = (1 * C1)$$

(Equation 4. 2)

$$\text{Inflow of corporate social responsibility} = (0.042 * C15) + (0.043 * C4)$$

(Equation 4. 3)

$$\text{Outflow of corporate social responsibility} = (1 * C11)$$

(Equation 4. 4)

$$\text{Performance} = (C1 * C11 * \text{Project performance})$$

(Equation 4. 5)

$$\text{Project progress} = (1 * \text{Project performance})$$

(Equation 4. 6)

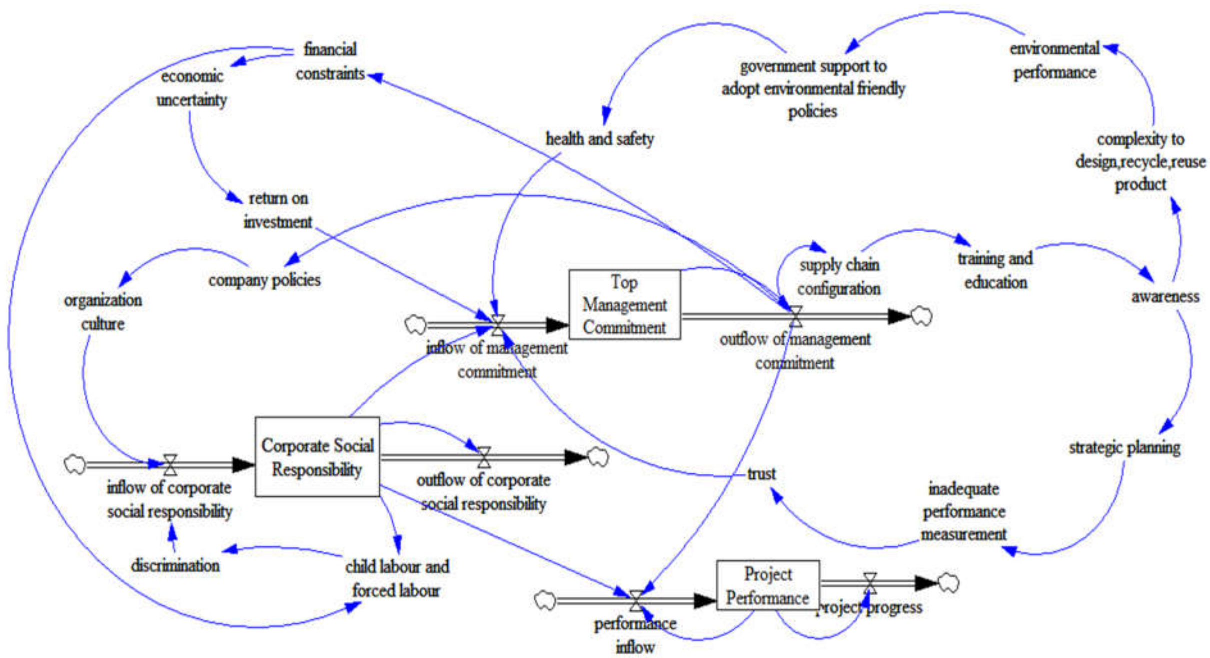

Figure 4. 10: Quantitative SD Model

4.6 Simulation results and discussion:

The simulation represents the behavior over a time period of 5 years. The simulation represents the behavior over a time period of 5 years. The decrease in curve of the following simulation graph with the passage of time shows how various endogenous variables (such as discrimination, company policies, child labour and forced labour etc.) effect the corporate social responsibility. An increase in lack of top management commitment would cause a decrease in company policies which will effect organization culture which leads to an increase in lack of corporate social responsibility which leads to an increase in lack of top management commitment. An increase in lack of corporate social responsibility will increase child labour and forced labour which increases discrimination which again increases lack of corporate social responsibility. An increase in lack of top management commitment leads to increase in financial constraints that leads to increase in child labour and forced labour.An increase in child labour and forced labour leads to increase in discrimination that leads to an increase in lack of corporate social responsibility that causes an increase in lack of top management commitment.

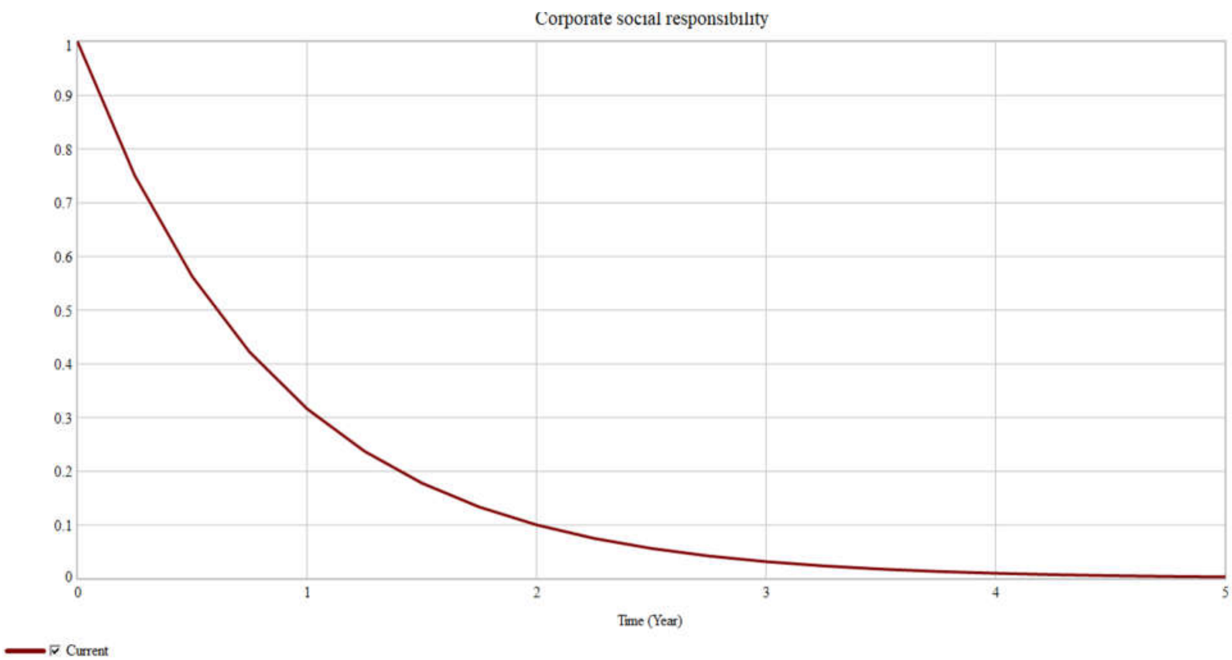

Figure 4. 11: Simulation Graph (Corporate social responsibility)

The graph presents that if there is lack of top management commitment, there would be flaws in supply chain configuration leading to an increase in lack of training and education. The increased lack of training and education will lead to an increase in lack of awareness which shows increased complexities to design, reuse, recycle product. An increase in complexities to design, reuse, recycle product will lead to decreased environmental performance which shows lack of government support in adoption of environmental friendly policies. This lack would lead to a decrease in health and safety which again leads to an increase in lack of top management commitment. Also if there is an increase in lack of top management commitment, there would be flaws in supply chain configuration leading to an increase in lack of training and education. The increased lack of training and education will lead to an increase in lack of awareness; increase in lack of awareness will lead to an increase in lack of strategic planning which leads to increase in inadequate performance measurement due to which lack of trust would be increased which leads to an increase in lack of top management commitment.

An increase in lack of top management commitment would lead to an increase in financial constraints which promotes economic uncertainty. Increased economic uncertainty will lead to a decreased return on investment which shows an increase in lack of top management commitment. An increase in lack of top management commitment would cause a decrease in company policies which will effect organization culture which leads to an increase in lack of corporate social responsibility which causes an increase in lack of top management commitment.

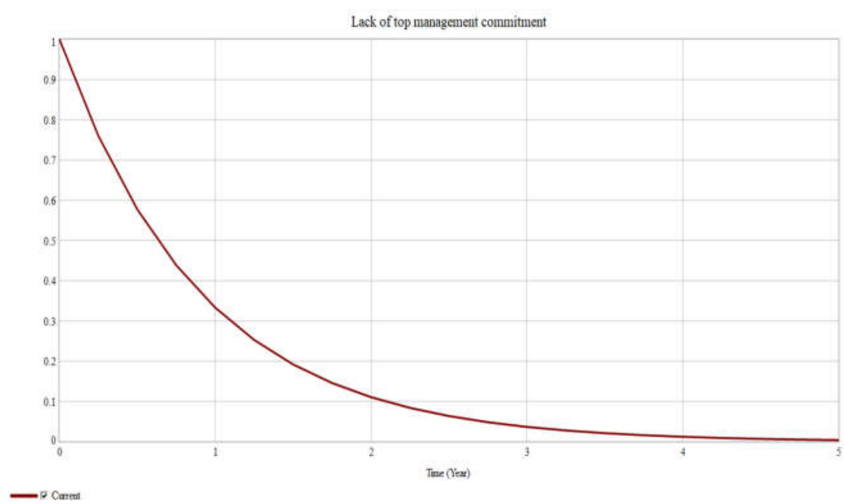

Figure 4. 12: Simulation Graph (Lack of top management commitment)

The decrease in curve of the following simulation graph with the passage of time shows how various endogenous variables (such as supply chain configuration, lack of trust, financial constraints, return on investment etc.) effect the top management commitment.

The following simulation graph signifies that due to a decrease in corporate social responsibility and top management commitment projects performance gradually decreases. The simulation results predict that due to decrease in lack of corporate social responsibility there would be a decrease in lack of top management commitment which effects the performance of project which gradually decreases to a minimum level.

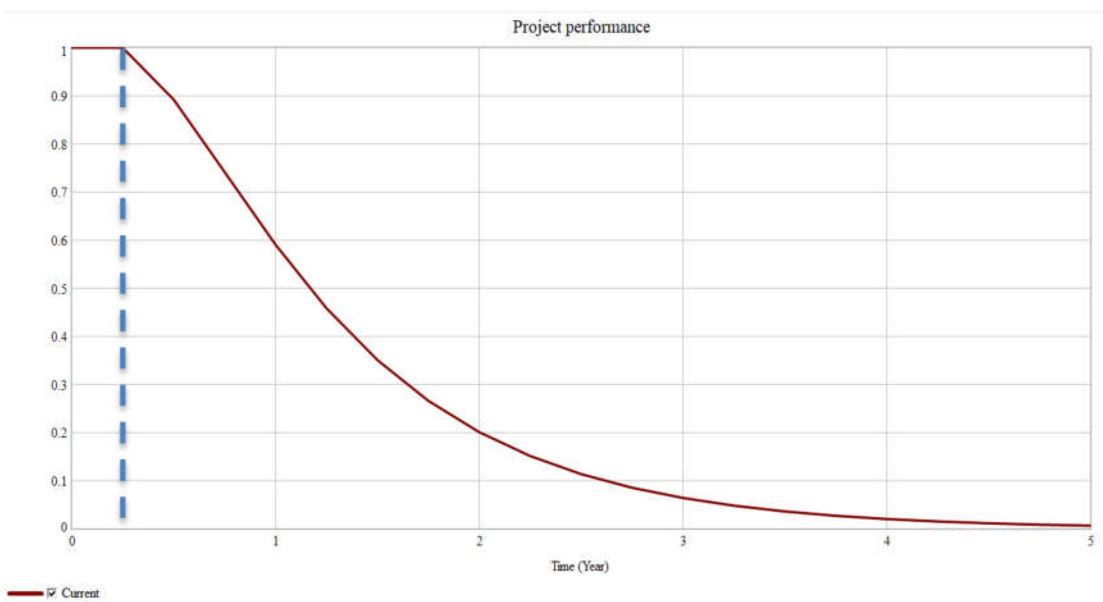

Figure 4. 13: Simulation Graph (Project performance)

The overall simulation results predict that due to increase in lack of corporate social responsibility (decrease in corporate social responsibility) there would be an increase in lack of top management commitment (decrease in top management commitment) which affects the performance of project decreasing gradually decreases to a minimum level i.e zero.

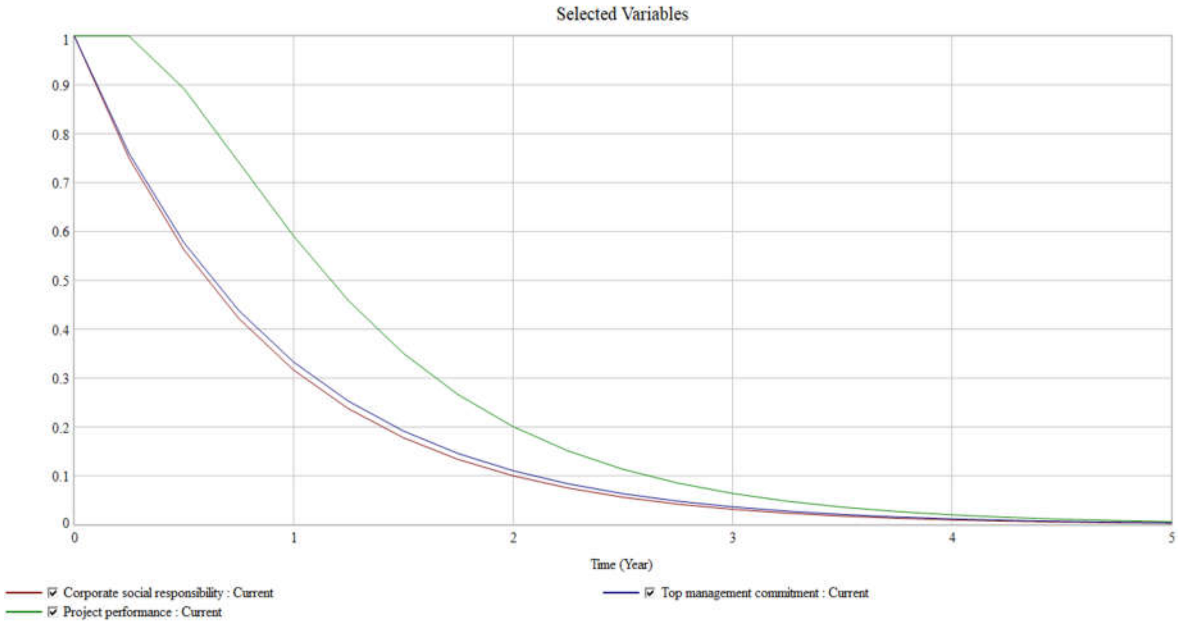

Figure 4. 14: Simulation Graph (Combined effect)

The developed model shows the effect of challenges on “Corporate Social Responsibility” and “Top Management Commitment”, which eventually impart an effect on performance of project. The simulation results predict that due to lack of corporate social responsibility and lack of top management commitment, project performance decreased gradually to zero after a certain period of time. Thus, if the top management commitment and corporate social responsibility are addressed then project performance would get better as these two are having most of the interrelationships.

4.7 Model validation:

A SD model addresses a particular issue, not a general, and the confidence in placing model to help analyze the given problem should not depend upon whether the model can address other problems (Richardson and Pugh, 1981). In this regard, the model validity depends on the purpose for which the model is developed (Sterman, 2000).

As described above, the essence of developed SD model is to help address complexities in adoption of sustainable supply chain management in construction industry. Therefore, the validation of model structure is the first step of validating SD model.Qudrat-Ullah and Seong (2010) listed following tests that are used for structural validity of an SD model.

4.7.1. Boundary adequacy test:

Sterman (2000) explained three purposes of this test; whether all the important concepts in addressing the problem are endogenous to the model, if the behaviors of the model change significantly when boundary assumptions are relaxed and whether the policy recommendations change when the model boundary is extended. After examining all the variables in the SD model, it is found that each of these variables is crucial, as all the variables have been identified from literature and cause hindrance in adoption of sustainable supply chain management. All of the challenges are endogenous such as supply chain configuration, health and safety, financial constraints, discrimination contributing to sustainable supply chain management.

4.7.2 Structure verification test:

This step of validation is of immense significance and the aim is to check whether the model structure is consistent with relevant descriptive knowledge used in the model. The developed CLD is based on variables identified from the literature and then field professionals provided with the influencing interrelations amongst all variables. Therefore, the model structure is logical and closely represents the actual system in the industry. So, this is in line with the methodology followed by (Qudrat-Ullah and Seong, 2010).

4.7.3 Parameter verification:

The mathematical functions developed to link the variables are based on responses from field experts that ensure empirical and theoretical foundations

Conclusions and Recommendations

The nature of the construction industry is such that it does not support a coherent supply chain. The supply chain consisting of stakeholders such as clients, consultants and contractors are mostly working in silos, in particular, the construction industry of the developing countries. There are a lot of issues associated with the supply chain including environmental, social and economic constraints. There exists a huge challenge, creating complexity, in terms of adoption of sustainable supply chain management (SSCM) in the construction industry, in particular, the construction industry of the developing countries.

The aim is to address all perspectives of sustainability in supply chains, minimizing the complexities in terms of adoption of SSCM; this research identifies the significant challenges causing hindrance in its adoption. The uniqueness of this study lies in the development of system dynamics model model.

A total of 82 challenges were extracted from literature. Data was later collected from industry on the extracted challenges to present the industry trends about their perceived criticality in view of various developing countries. After combining the industry and literature scores, using Pareto analysis the top 30 challenges were incorporated into influence matrix. Out of 95 relationships field experts confirmed 24 relationships which were then used to develop a CLD depicting a clear picture of interconnections among the identified challenges.

The developed causal loop diagram comprises of four reinforcing and two balancing loops, which further led to development of System Dynamics Model. The developed model shows the effect of challenges on "Corporate Social Responsibility" and "Top Management Commitment", which eventually impart an effect on performance of project.

The simulation results predict that due to lack of corporate social responsibility and lack of top management commitment, project performance decreased gradually to zero after a certain period of time. Thus, if the top management commitment and corporate social responsibility are addressed then project performance would get better as these two are having most of the interrelationships. The research findings will help the practitioners to adopt sustainability principles in term of supply chain and will not only enhance productivity and performance, but will also help in minimization of delays, promote long term relations, reduce communication gaps and projects complexities.

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Appendices (i-iv)