Contributing Factors for Implementation of Total Quality Management in Construction Sector: A System Dynamics Approach

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

in

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by

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Contributing Factors for Implementation of Total Quality Management in Construction Sector: A System Dynamics Approach

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This thesis is dedicated to my mother, friends, and my Family.

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In the name of Almighty Allah, the Most Merciful, the Beneficent. All praise is only for Allah, who created us and always planned the best for us. I am grateful to the Almighty Allah for His countless blessings and mercy bestowed upon me through the difficulties of life, and I seek His guidance and pray to Him for blessings and ease throughout this life and the life to come.

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ABSTRACT

Maintaining quality in construction projects is paramount to project success that is achieved through different techniques such as Total Quality Management (TQM). However, the key factors of TQM implementation in the construction industry of developing countries are not well explored. Accordingly, this paper evaluated the causative relationship and intricacies of TQM implementation in the construction sector of developing countries. A total of 28 key factors of TQM were captured through a literature review of data published in the last decade. Thereafter, 12 significant key factors were shortlisted through qualitative and quantitative analyses. Lack of top management commitment, poor customer/client satisfaction, inadequate quality of education regarding TQM, and ineffective organizational quality culture emerged as the most imperative impediments to implementing TQM in the construction sector. A novel methodology of systems thinking (ST) was used to develop a Causal Loop Diagram (CLD) that represented interrelations between the 12 shortlisted factors. The CLD encompassed four reinforcing and two balancing loops. Consequently, the system dynamics (SD) model was developed and simulated over five years. The simulation results of the developed SD model indicated an increase in TQM implementation over the period under the defined system. This exploration work provides a system of TQM implementation in the construction sector. The developed SD model can assist in developing strategic quality policies to improve the overall efficiency and performance of construction projects in developing countries.

Keywords: Total quality management (TQM), SDM, Systems thinking, CLD, Quality Performance, Construction Sector of developing countries.

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TQM	Total Quality Management
QA	Quality Assurance
QC	Quality Control
SDM	System Dynamics Modelling
OC	Organizational Culture
CI	Construction Industry
CS	Construction Sector
SPSS	Statistical Package for Social Sciences
ST	Systems Thinking
QS	Quality Survey
CLD	Causal Loop Diagram
SFD	Stocks and Flows Diagram
CS	Complexity Science
RII	Relative Importance Index
IM	Influence Matrix
PQ	Preliminary Questionnaire
PS	Pilot Surve

CHAPTER 1

INTRODUCTION

1.1. Study Background

The construction sector is complex and fragmented and causality is the key characteristic of the construction sector (Mohd Nawi *et al.* 2014).

Maintaining quality in the construction sector is the rudimentary element for strategic competitiveness, employee empowerment, employee involvement, customer repetition, diminishing rework and enhancing continuous improvement, increasing productivity, enhanced budget performance, and comparatively more desirable schedule performance (Sadikoglu and Olcay 2014).

The significant stumbling blocks in implementing total quality management in developing countries were found to be the absence of top management commitment, inadequate expertise, low bidding contract award concept, undervalued education and training, lack of workers involvement, lack of workers empowerment, rigorous attitude and behaviour, and rigid approach of executive towards quality management system (Subhash Erande and Pimplikar 2016).

The contributing challenges of total quality management related to the work environment are an unproductive quality system, excessive paperwork, inadequate knowledge of the process requirements, low bid subcontracting, and high cost to implement total quality management in the construction sector (Mohammed and Asmoni 2006).

Nevertheless, construction sectors in developing countries lag behind quality-oriented performance and as a result majority of construction projects are prematurely terminated or revised because of incompetent and ineffectual workmanship. The construction sectors of developing countries must map out a structural and strategic framework for the consideration of quality standards, quality assurance, quality control and enactment of total quality management to compete with their competitor developed countries.

Total Quality Management (TQM) is imperative for the success of the organization and implementing total quality management in the construction sector promises many benefits for developing organizations. This exploration work is aimed to investigate the contributing factors that are causing complexity in the implementation of total quality management in the construction sector of developing countries using a system thinking approach.

A preliminary and detailed questionnaire was developed using Google ® and floated to respondents in the construction sectors of developing countries. The data extracted from respondents further assisted in the statistical analysis and determination of shortlisted contributing factors and causal relationships among shortlisted contributing factors. The cumulative normalized score including literature and construction industry calculated and subsequently relative importance index (RII) of the contributing factors determined. Accordant with the relative importance index of screened out relationships and interrelation polarity either direct (+) or indirect (-) influence matrix mapped out.

The system dynamics modelling technique is a simulation-based approach for sorting out real-world intricacies by using causal relationships and polarity among variables. A system dynamics model using feedback mechanism through expert opinion developed for adoption and implementation of total quality management in the construction sector of developing countries. (Saavedra M. *et al.* 2018).

A system dynamics approach is used to develop stock and flow diagrams and causal loop diagrams on account of their causal relationship and system dynamics model developed using VENSIM® software. This approach is used to scrutinize and abridge complexity resulting from the implementation of total quality management in the construction sector of developing countries. This results in distinguish quality management system and improved overall project performance of construction sectors in developing countries. This approach uses a feedback mechanism and previously benefited for strategic quality planning and execution of quality policies over forty years (Saavedra M. *et al.* 2018).

1.2. Problem Statement

In developing countries, the construction sector is essentially labor-intensive, capable of creating jobs, and complex nature (Raftery, 1991).

The total quality management (TQM) concept is quite innovative, unconventional, novel in the construction sector, and already embraced in manufacturing and service industries to a large extent. There is a lack of quality management systems and regulations in developing countries' construction sectors (Tahir *et al.* 2021).

The construction industry is the major driver of developing countries' economies and contributes a significant portion to gross domestic product. The most common problems such as excessive paperwork, lack of contractors and suppliers' interest, low bidding subcontracting (Lahndt, 1999), inconsistent behavior of field employees regarding TQM, transient workforce, unique nature of construction, short term cost savings, political differences, communication gaps, unreliable contractors, fewer finances and project delays are contributing factors that are causing complexity in implementation of total quality management in the construction sector of developing countries.

The construction sector of several countries, especially developing countries, lags in ensuring quality management systems, quality assurance, and quality control practices (Martínez-Lorente *et al.* 1998).

Major reasons behind quality non-conformance are the absence of proper quality management and proper training systems and reluctance to on-site quality implementation. Many studies have been conducted to develop the comprehensive quality management framework for manufacturing and service industries, Still, very few efforts have been made to analyze the phenomenon of total quality management (TQM) in the construction sector of developing countries (Li *et al.* 2008).

The adaptation and implementation of TQM principles in the construction sector are an unconventional, unique, and novel concept and require commitment from top management on the operational level instead of the managerial level (Alofan *et al.* 2020).

Due to a lack of awareness of quality management systems and quality standards, construction projects are vulnerable to delays, cost overruns, and poor quality-oriented. These challenges have put the practitioners to opt for TQM principles in the construction sector that has very little focus on total quality management implementation in the construction sector compared to the manufacturing sector.

This study will provide developing countries with a fact-based system dynamics model that would increase efficiency and effectiveness for enacting total quality management in the construction sector of emerging developing countries.

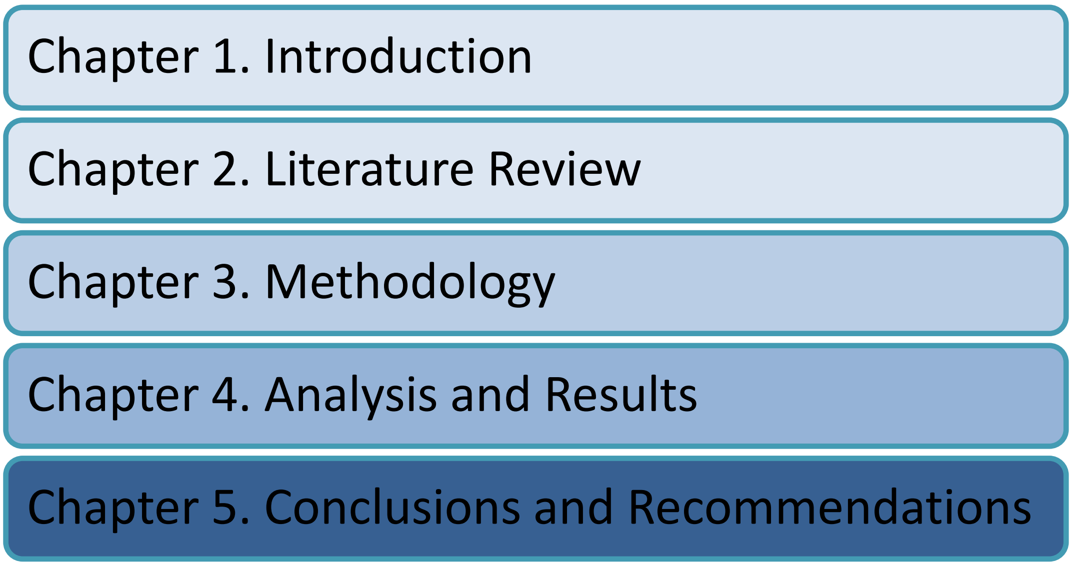
1.3. Overview of Study Approach

To fulfill the objectives set for this research, the subsequent research tasks are identified as:

- Precise literature review of the previous relevant exploration works and identifying the contributing factors, which impede the consideration of total quality management in the construction sector of developing countries. Using preliminary questionnaire survey barrier-impeding implementation of total quality management in the construction sector of developing countries shortlisted. The preliminary and detailed questionnaire survey form was generated using Google ®.
- To assess in detail, the methodology proposed, the contributing factors shortlisted using feedback mechanisms were analyzed using statistical tools.
- Obtained feedback from the target audience with the help of detailed questionnaire form and their causal relationship, interdependency, functionality, and polarity, either direct or indirect, also determined.
- Relative importance index of shortlisted contributing factors also determined from the data extracted from the detailed questionnaire.
- Influence matrix developed based on their causal relationship, polarity, and relative importance index (RII).
- System dynamics tools, including causal loop diagram (CLD), stock and flow diagram (SFD), and system dynamics model (SDM) made using feedback mechanism and filed expert opinion through VENSIM ® software. This model abridges complexities and uncertainties emerging from implementation of total quality management in construction sector of developing countries.
- Conclusion and Recommendations.

1.4. Organization of Thesis

This research is structured into five detailed chapters; the order and a brief description of these chapters are given below:



Chapter No. 1 Introduction

This chapter describes the study's background, problem statement, research objectives and, organization of the thesis.

Chapter No. 2 Literature Review

This chapter covers a thorough literature review comprising of different topics relevant to this research. It determines major contributing challenges in total quality management adoption implementation in the construction sector of developing countries. These contributing challenges shortlisted, analyzed, and cumulative normalized scores, including literature and industry determined using statistical tools.

Chapter No. 3 Research Methodology

This chapter covers tools (SPSS®), techniques (CLD), and methods (SDM) used to answer the research objectives.

Chapter No. 4 Analysis and Results

In this chapter, analysis is performed using different statistical techniques (SPSS®), and the results of this study have been presented and simulated using STELLA ® & VENSIM ® Software.

Chapter No. 5 Conclusions and Recommendations

This segment concludes the results of research work comprehensively, and recommendations for future research work are also elaborated.

CHAPTER 2

LITERATURE REVIEW

2.1. Total Quality Management (TQM)

Quality as an expression, has extensive definitions and meanings. As elucidated by several authors, quality associated with meeting aesthetics, operative and licit conditions. Amidst, from the perception of construction sector it can be delineated as successful accomplishment of the deliverables accordant with specification of the project within the identified time and budget (Abas *et al.* 2015).

Quality is the excellence or fineness of any process, product or system and measured against recognized standards of merit for such items and the interests/needs of products, end-users, and other stakeholders. TQM is the outcome of revolution in quality management techniques and credit conferred to numerous people comprising Juran, Deming, and Crosby (Chang *et al.* 2009).

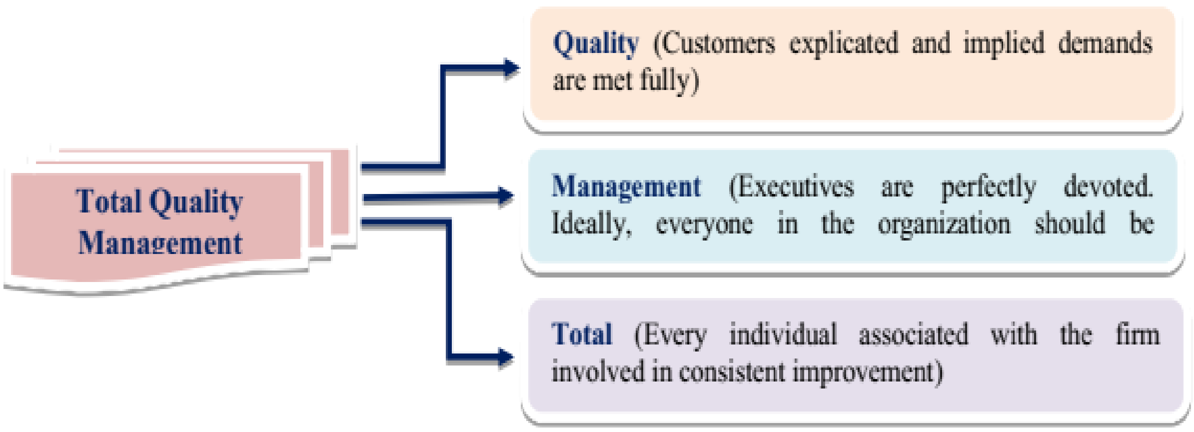


Figure 1: Total quality management meaning

Table I: An overview of existing definitions of TQM

Reference	Definitions of Total Quality Management
(Sadikoglu and Olcay 2014)	TQM is an integrative firm-wide management philosophy aimed at continuously improving the quality of the processes, products and services by focusing on meeting or exceeding customer expectations to enhance customer satisfaction and organizational performance.
(Bon and Mustafa 2013)	Total Quality Management (TQM) is a way of managing people and business processes to ensure complete customer satisfaction at every stage. It emphasizes a commitment to quality, communication of the quality message, and recognition of the need to change the culture of the organization to create total quality. Customer satisfaction is one of the main objectives of TQM, which directed organizational efforts towards the goal of TQM. TQM enhances innovative processes in an organization through continual improvement, thus ensuring sustainable development.
(Sinha and Dhall 2020)	Total quality management implementation has a momentous association with firms' performance.
(Jumah M.Th. Al-Dulaimy 2015)	TQM is defined as identifying and managing the necessary activities required attaining quality within an organization.

(Behnam Neyestani *et al.*, 2016)	TQM is a “systematic quality practice” for the management of the company to generate desirable change in the performance with the aim of promoting “quality, productivity, customer's satisfaction and profitability”.

Nevertheless, the concept of total quality management in construction sector is novel and intricacies pertaining to implementation of total quality management in construction sectors are not addressed and generic perspective explicated by predecessor authors (Rasha A. Al Salihi and Redvan Ghasemlounia 2021).

A conspicuous framework or system dynamics model required for prevailing contributing challenges causing complexity in the implementation of total quality management in construction sector.

2.2. Total Quality Management in Construction Sector

Total quality management in the construction sector is also evident that organization status improved, extensive market share achieved, and client satisfaction won (Mohamed *et al.* 2013a).

Construction total quality management bring forth a conducive work atmosphere where all employee indulged in the attainment of construction quality performance, pivoted on customer delight and strive to ameliorate the overall efficiency and productivity of the construction projects.

2.2.1. Benefits of Implementing TQM in the Construction Sector

Total quality management is considered as the well-regarded approach in managing the entire project to minimize nonconformity, complexity, nonlinearity, and achieve distinction. Rapid development and competition have made 'Quality' a strategic tool for profit margin and increased corporate profitability for businesses and companies around the globe (Hoonakker *et al.* 2010).

In pursuance of meeting customer demands and providing superior value to the customer through the company's operations, understanding, and responding to customers, the construction organization must promote total quality management initiatives. Several reports suggested total quality management as a means of strategic and competitive edge and increase construction sector productivity and efficiency (Eniola *et al.* 2019).

Organizations following total quality management principles gain a strategic market edge comparatively better than those organizations that are not following total quality management principles (Valmohammadi and Roshanzamir 2015). Since, the workers within the company exhibit excellent workmanship and higher quality-oriented work, if the company senior managers have a greater quality-oriented approach (Shibani *et al.* 2010).

The implementation of TQM in the construction sector committed various advantages such as enhanced budget efficiency, customer delight, better workers' job contentment, diminished rework, exquisite schedule and budget performance, better procurement, and greater participation in the bidding process (Chauhan 2014).

Quality is substantially considered as a criterion, which determines the superiority or inferiority of the construction product or service and means to understand how a construction product meets its desired specification.

(Valmohammadi and Roshanzamir 2015) identified the role of chief managers; expertise and client attention are key antecedents of the performance of the construction project.

With reference to the development of total quality culture in the construction sector of developing countries, one significant milestone is to create a construction team of suppliers, main contractors, the petty contractors who would be accountable for valuable quality practices and evolution of genuine quality management system (Clement *et al.* 2010).

2.3. Challenges in Implementing TQM in Construction Sector of Developing Countries

The construction sector is a complex, fragmented, nonlinear and dynamic sector and causality is the key characteristic of the construction sector. TQM is a structured determinant in the success of construction organizations. As far as most developed countries are concerned, TQM has become a significant exercise and preferred technique for enhancing quality in the construction sector.

Despite the advantages of this approach, Total quality management consideration in the construction sector is not simple due to complexities such as the absence of senior management interests, unskilled human resources, ineffective training, poor leadership support, and lack of technical workforce (Koh and Low 2010).

Construction sectors are embracing total quality management concepts to enhance their efficiency and minimize complexities but still, they lag behind other manufacturing and service industries. The primary impediments are their inability to evaluate client demands precisely and convert this knowledge into a complete facility (Haupt and Whiteman 2004).

There are several challenges and indicators for the adoption of total quality management in the construction sector of developing countries. The challenges related to working environment are low-bid subcontracting, improper communication channels among different stakeholders, high initial cost, poor organization quality culture, traditional quality policy, unclear strategic process quality management, lack of customer delight, discontinuous improvement of processed and techniques and lack of time to ensure quality control, quality assurance and quality management system (Ajayi, Oluwaseyi Osunsanmi, 2009).

The challenges related to human being are lack of attitude and behaviour towards TQM, lack of expertise, poor teamwork and workmanship, lack of superior management commitment, lack of employee training, lack of employee involvement and lack of employee empowerment (Mohammed and Asmoni 2006).

(Deepika *et al.* 2016) anticipated research model to scrutinized the influence of total quality management practices in construction projects.

Figure 2: Organization development research model (Deepika et al. 2016)

These above-revealed contributing challenges cause intricacy and complexity in the implementation of total quality management in the construction sector of developing countries. In view of enhancing the overall quality performance and productivity of construction projects, these contributing challenges must be considered and scrutinized to reduce uncertainty and intricacy throughout the life cycle of a construction project.

2.4. Systems Thinking and Complexity Science

System thinking is an idea for learning how feedbacks and causal relationships work in an everyday problem. It includes “systematic” or “holistic thinking” which is dependent upon learning relationships and interconnections between apparently scattered things. System analysis consists of a mental model illustration of the problem (conceptual model) whereas system dynamics comprises the mathematical recreation of the problem to elaborate the past and comprehend the future. System thinking and causal loop diagram analyzed the complex problem and drawn through feedback mechanism (Haraldsson and Ólafsdóttir 2003).

2.5. A System Dynamics Approach

The System Dynamics approach is a simulation technique for resolving real-life complications illustrating associations among variables in complex real systems. System dynamics method encompasses three elements namely: system, computer, and SD model in which the model originated from the system (which is the focus of study) and the computer runs the model through trial and error.

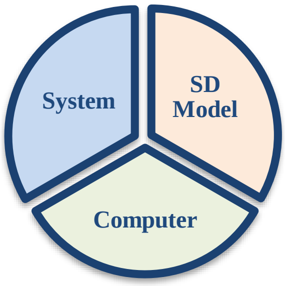


Figure 3: System dynamics component (Tahir *et al.* 2021)

Construction projects comprise multiple feedback loops including positive as well as negative loops. Positive feedback loops make the system away from realizing a certain goal while negative feedback loops have the characteristics of realizing that goal. Different constituents of construction projects have nonlinear behaviour, e.g., the productivity of labour over time (Tahir *et al.* 2021). A system dynamics model required for quality performance of the construction projects and adoption of total quality management in developing count

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Desk Study and Field Research

This exploration work pivoted on the implementation of total quality management for the effective and efficient performance improvement of the construction sectors by application of a system dynamics model. The diagrammatic representation for the methodology given below:

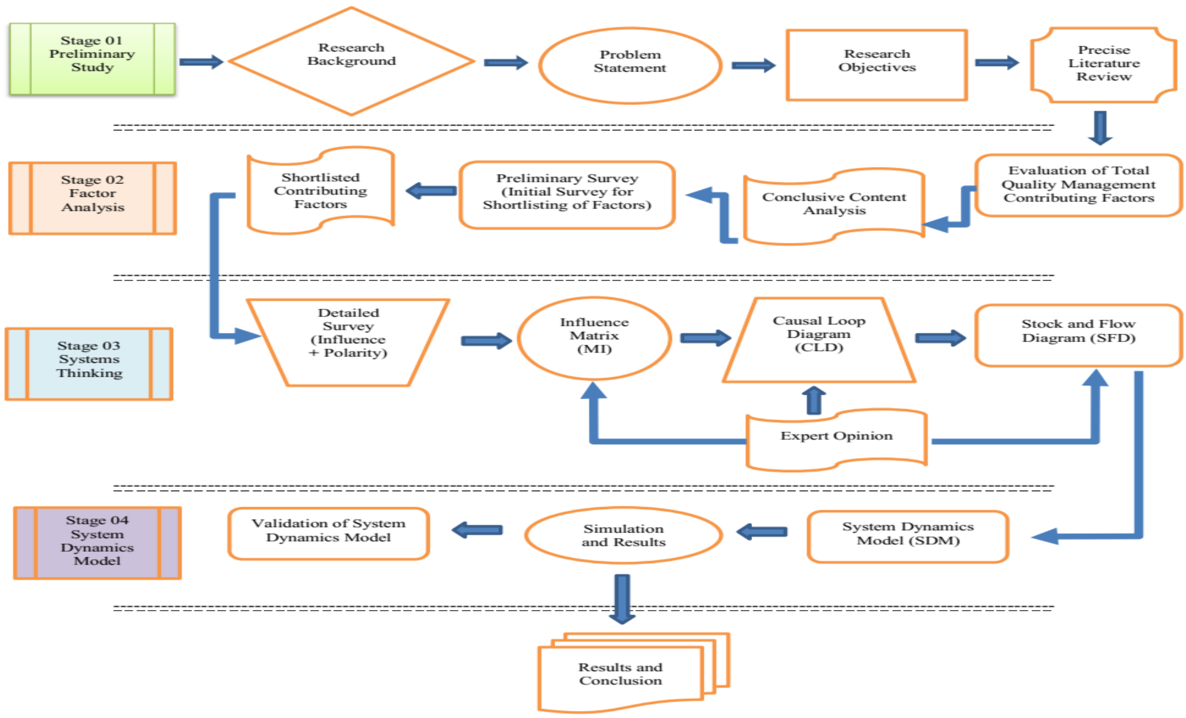


Figure 4: Research methodology

3.1.1 Phase 1: Identification of research objectives

This phase comprises key steps such as evaluating the research gap and research topic. The comprehensive scrutiny of literature was done from well-reputed journals articles, relevant books and high-impact conference papers for establishing this research gap. After the development of the problem statement, the objectives of the research were identified.

The objectives of this thesis research are:

- To identify and shortlist the contributing factors in the implementation of Total Quality Management (TQM) practices in the construction sector of developing countries.
- To evaluate the relative importance index, interconnectivity, and causal relationship among these shortlisted contributing factors.
- To develop a System Dynamics model to abridge complexities resulting from the implementation of Total Quality Management (TQM) in the construction sector of developing countries.

3.1.2. Phase 2: Literature Review and Preliminary Survey

The conclusive literature review from **28** recently published article was carried out to explore causative factors causing intricacy in the implementation of total quality management in the construction sector. Initially, 28 contributing factors (18 related to organization structure, 10 humans related) were extracted from literature and content analysis using **SPSS®** was conducted for screening out of least significant factors.

The following step was to conduct preliminary or pilot survey by using questionnaire form generated in **Google®** and **Likert scale** (Low=1, Medium=3, High=5) used for ranking of factor. The cumulative normalized literature score determined by dividing individual literature score of each contributing factor by the sum of the literature score. The shortlisted contributing challenges ranked on the basis of 60/40 ratio (40% literature score, 60% construction industry score) and twelve factors were finalist after preliminary survey (Naveed and Khan 2021).

3.1.3. Phase 3: Detailed Survey for Shortlisting of Interrelationship and Polarity

This phase explicitly pivoted on conduction of detailed questionnaire-based survey in line with the evaluation of contributing challenges causal interrelationships and polarity. During this phase, veteran opinions were also incorporated for development of influence matrix and causal loop diagram. Influence matrix formulated upon the basis of relative importance index **(RII)** of each contributing factor in the construction sector and polarity of each relationship either direct **(+)** or indirect **(-)** determined. The following step was to map out causal loop diagram in conformity with finalist causal relationships to make it consequential and meaningful to construction sector (Tahir *et al.* 2021).

3.1.4. Phase 4: Development of System Dynamics Model

This is the far-reaching and decisive phase of this exploratory work. During this phase, a system dynamics model (SDM) generated on the strength of stock and flow diagram (SFD) and causal loop diagram (CLD) to mitigate intricacies in implementation of total quality management (TQM) in the construction sector. The intent of this simulated model was to elevate quality performance of construction projects exclusively in developing countries

CHAPTER 4

RESULTS AND DISCUSSIONS

Two surveys were conducted. The explication of each is as follows:

4.1. Preliminary Questionnaire Survey (Phase 1)

A preliminary questionnaire-based survey was conducted for which a questionnaire form was developed in **Google®** and constitute of two sections. Respondents were entreated about the significance of each factor on a Likert scale. **PARETO analysis** used for shortlist the factors having a **60%** impact score and twelve contributing factors finalized through 60/40 ratio (Sami Ur Rehman *et al.* 2020).

4.1.2. Ranking of Factors based upon Field Score + Literature Score

Industry normalized score and literature score were combined to get the final ranking of contributing factors. The ratio used in this respect is 60/40 (60% score dedicated to industry and 40% to literature);

Table II: Ranking based on total cumulative normalized score by using 60/40 ratio

Sr. No.	Contributing Factors of Total Quality Management	Total Score 60/40	Cumulative Normalized Score	Reference
1.	**Top Management Commitment**	0.0732	0.0732	(Othman, Norfarahhanim Mohd Ghani and Woon Choon, 2019); (SHOSHAN and ÇELİK 2018); (Singh *et al.* 2018);(Ajayi, Oluwaseyi Osunsanmi, 2018); (Nouban and Abazid 2017);(Subhash Erande and Pimplikar 2016);(Deepika *et al.* 2016);(Ephantus *et al.* 2015);(Shibani *et al.* 2010)
2.	**Customer Satisfaction**	0.0649	0.1381	(Singh *et al.* 2018); (SHOSHAN and ÇELİK 2018); (Ajayi, Oluwaseyi Osunsanmi, 2018); (Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Deepika *et al.* 2016);(Chauhan 2014);(Neyestani and Juanzon 2016);(Jumah M.Th. Al-Dulaimy 2015);(Mohamed, Ibrahim and Mohamed Khodeir, 2013)
3.	**Quality of Education Regarding TQM**	0.0511	0.1893	(SHOSHAN and ÇELİK 2018); (Singh *et al.* 2018); (Ajayi, Oluwaseyi Osunsanmi, 2018); (Neyestani and Juanzon 2016); (Shibani *et al.* 2010)
4.	**Organization Quality Culture**	0.0470	0.2363	(Mohamed, Ibrahim and Mohamed Khodeir, 2013); (SHOSHAN and ÇELİK 2018); (Singh *et al.* 2018); (Neyestani and Juanzon 2016); (Ephantus *et al.* 2015); (Shibani *et al.* 2010)

5.	**High Initial Cost**	0.0449	0.2813	(Ajayi, Oluwaseyi Osunsanmi, 2018); (Deepika *et al.* 2016); (Neyestani and Juanzon 2016)
6.	**Continuous Improvement**	0.0449	0.3262	(Mohamed, Ibrahim and Mohamed Khodeir, 2013); (Subhash Erande and Pimplikar 2016); (Chauhan 2014); (Neyestani and Juanzon 2016); (Jumah M.Th. Al-Dulaimy 2015)
7.	**Employee Training**	0.0445	0.3707	(Singh *et al.* 2018); (Ajayi, Oluwaseyi Osunsanmi, 2018); (Subhash Erande and Pimplikar 2016); (Deepika *et al.* 2016); (Neyestani and Juanzon 2016); (Ephantus *et al.* 2015); (Shibani *et al.* 2010);
8.	**Employee Involvement**	0.0430	0.4138	(Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Deepika *et al.* 2016); (Chauhan 2014); (Neyestani and Juanzon 2016); (Shibani *et al.* 2010);
9.	**Employee Empowerment**	0.0438	0.4577	(Singh *et al.* 2018); (Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Chauhan 2014); (Neyestani and Juanzon 2016); (Shibani *et al.* 2010);
10.	**Appropriate Communications Medium**	0.0408	0.4985	(Singh *et al.* 2018); (Nouban and Abazid 2017); (Deepika *et al.* 2016); (Neyestani and Juanzon 2016); (Ephantus *et al.* 2015); (Shibani *et al.* 2010)
11.	**Attitude and Behavior Towards TQM**	0.0346	0.5331	(Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Neyestani and Juanzon 2016); (Jumah M.Th. Al-Dulaimy 2015); (Shibani *et al.* 2010)

12.	**Low Bid Subcontracting**	0.0339	0.5671	(Nouban and Abazid 2017); (Chauhan 2014); (Neyestani and Juanzon 2016)
13.	**Leadership**	0.0325	0.5997	(SHOSHAN and ÇELİK 2018);(Singh *et al.* 2018); (Nouban and Abazid 2017); (Neyestani and Juanzon 2016);
14.	**Supplier Quality Management**	0.0317	0.6314	(Singh *et al.* 2018); (Subhash Erande and Pimplikar 2016); (Neyestani and Juanzon 2016);
15.	**Process Improvement**	0.0290	0.6605	(Ajayi, Oluwaseyi Osunsanmi, 2018); (Subhash Erande and Pimplikar 2016); (Chauhan 2014); (Neyestani and Juanzon 2016);
16.	**Human Resource Management**	0.0290	0.6896	(Singh *et al.* 2018); (Chauhan 2014); (Neyestani and Juanzon 2016); (Ephantus *et al.* 2015); (Shibani *et al.* 2010);
17.	**Supplier Relationship**	0.0284	0.7180	(SHOSHAN and ÇELİK 2018); (Singh *et al.* 2018); (Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Chauhan 2014); (Neyestani and Juanzon 2016);
18.	**Expertise & Resources**	0.0284	0.7464	(Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Neyestani and Juanzon 2016)
19.	**Employee Satisfaction**	0.0271	0.7736	(Ajayi, Oluwaseyi Osunsanmi, 2018); (Subhash Erande and Pimplikar 2016); (Chauhan 2014); (Neyestani and Juanzon 2016); (Jumah M.Th. Al-Dulaimy 2015); (Shibani *et al.* 2010)

20.	**Benchmarking**	0.0271	0.8008	(Ajayi, Oluwaseyi Osunsanmi, 2018); (Chauhan 2014); (Neyestani and Juanzon 2016);
21.	**Strategic Quality Improvement**	0.0271	0.8280	(Singh *et al.* 2018); (Subhash Erande and Pimplikar 2016); (Deepika *et al.* 2016); (Neyestani and Juanzon 2016);
22.	**Excessive Paper Work**	0.0269	0.8549	(Ajayi, Oluwaseyi Osunsanmi, 2018); (Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Neyestani and Juanzon 2016); (Jumah M.Th. Al-Dulaimy 2015)
23.	**Process Quality Management**	0.0263	0.8813	(Singh *et al.* 2018); (Nouban and Abazid 2017); (Subhash Erande and Pimplikar 2016); (Neyestani and Juanzon 2016);
24.	**Quality Policy**	0.0259	0.9072	(Ajayi, Oluwaseyi Osunsanmi, 2018); (Nouban and Abazid 2017); (Neyestani and Juanzon 2016)
25.	**Time to Implement TQM**	0.0253	0.9326	(Nouban and Abazid 2017); (Chauhan 2014); (Neyestani and Juanzon 2016); (Ephantus *et al.* 2015); (Shibani *et al.* 2010)
26.	**Teamwork**	0.0247	0.9573	(SHOSHAN and ÇELİK 2018); (Singh *et al.* 2018); (Ajayi, Oluwaseyi Osunsanmi, 2018); (Neyestani and Juanzon 2016)
27.	**Resources**	0.0242	0.9816	(Singh *et al.* 2018); (Neyestani and Juanzon 2016); (Ephantus *et al.* 2015)
28.	**Financial Management**	0.0193	1	(Nouban and Abazid 2017); (Chauhan 2014); (Neyestani and Juanzon 2016);

4.1.3. Shortlisted Factors – Contributing Factors of TQM

The contributing factors finalist and coded pertaining to 60% of the cumulative normalized as the break off point and twelve contributing factors unearthed possessing cumulative normalized score under 60% (Ahmad *et al.* 2018).

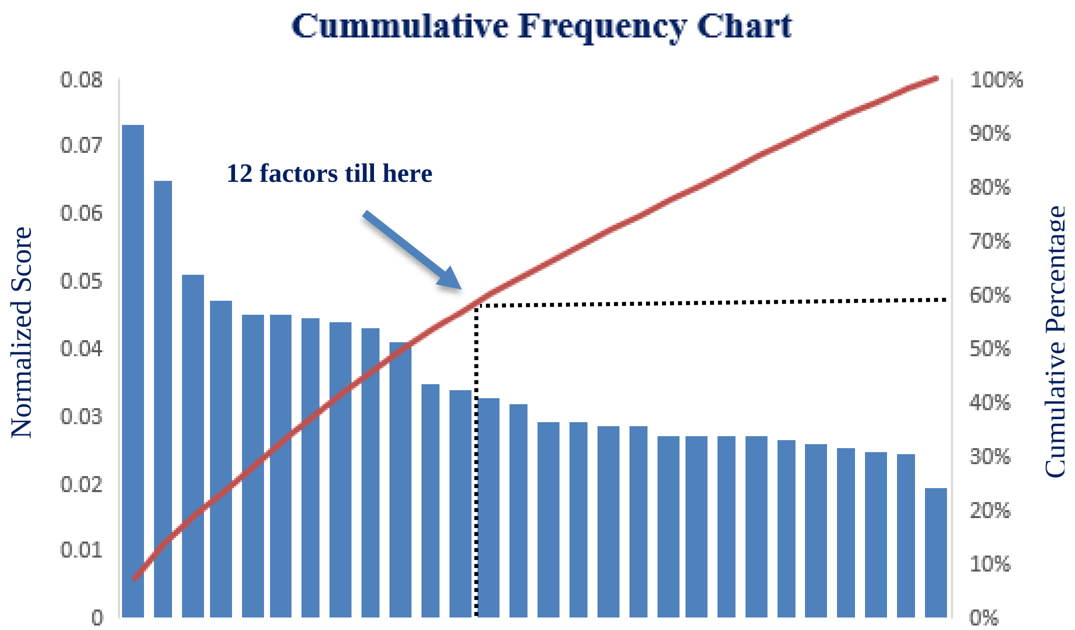


Figure 5: Cummulative frequency chart for contributing factors of total quality management

Table III: ranking of factors derived from industry + literature normalized score

Code	Contributing Factors of TQM In Construction Sector	Normalized Literature Score	Normalized Industry Score	Total Score 60/40	Cumulative Normalized Total Score	Rank (40/60 Ratio)
F1	Top Management Commitment	0.11363	0.04629	0.0732	0.07323	1st
F2	Customer/ Client Satisfaction/Focus	0.09297	0.04629	0.0649	0.13819	2nd

F3	Quality of Education Regarding TQM	0.07231	0.03703	0.0511	0.18934	3rd
F4	Organization Quality Culture	0.06198	0.03703	0.0470	0.23636	4th
F5	High Initial Cost	0.05681	0.03703	0.0449	0.28131	5th
F6	Continuous Improvement	0.05681	0.03703	0.0449	0.32626	6th
F7	Employee Training	0.05578	0.03703	0.0445	0.37079	7th
F8	Employee Involvement	0.05268	0.03703	0.0430	0.41385	8th
F11	Employee Empowerment	0.04028	0.04629	0.0438	0.45775	9th
F12	Appropriate communications medium	0.04648	0.03703	0.0408	0.49856	10th
F14	Attitude and Behavior Towards TQM	0.03099	0.03703	0.0346	0.50718	11th
F18	Low Bid Subcontracting	0.01549	0.04629	0.0339	0.50716	12th

4.2. Detailed Questionnaire Survey (Phase - 2)

A substantial and conclusive questionnaire composed of 132 causal relationships originated through Google® coupled with polarities. Veteran respondents enjoined to rank causal relationships on Likert scale in conjunction with polarity either direct or indirect. Accordant with the extensive nature of the detailed questionnaire, veteran respondents were requested to give their feedback in a grid format (combined level of influence and polarity) to enable their prompt response.

4.2.1. Sample Size

The optimum sample size was evaluated through equation imparted by (Ephantus *et al.* 2015);

$$\mathbf{n} = \mathbf{N} / \mathbf{1} + \boldsymbol{N}(\mathbf{e})^{\mathbf{2}} \qquad \textbf{Eq. 1}$$

$$n = 174/1+174(0.05)^2 = 121$$

Here n = the anticipated sample size, e = probability of error (i.e., the desired precision, 0.05% for 95% confidence level), N= 174, the estimated responses from valuable respondents) required minimum sample size comes out to be 121 (Ephantus *et al.* 2015).

4.2.2. Respondents Detail

Data was accumulated from 174 respondents, out of which 53 were invalid, and 121 factual responses were contemplated for the analysis (Tahir *et al.* 2021). With regard to qualification, 34% were bachelors in civil engineering, whereas 61% of the respondents conferred master degrees and leftover 5% of the respondents had a doctorate degree. The professional experience of 64% of the respondents ranging from 1-5 years and 22% of the respondents had 6 to 10 years of experience. Similarly, 6% of proficient had 11 to 15 years of extensive experience and 8% of informant had equal or greater than 20 years of professional experience.

With reference to designation of respondents, majority of the respondents had exposure of construction management and project management and rest of the respondents were from quantity survey, construction design, architects and consultancy domain

Table IV: Frequency distribution of responses

Profile	Frequency	Percentage
Total responses = 121		
Title of Job		
Project Management	20	16%
Construction Management	35	29%
Site In-charge/Execution	5	4%
Architect	12	10%
Construction Design Consultant	25	21%
Quantity Surveyor	14	12%
Consultancy	10	8%
Qualification		
Bachelors (B.Eng./B.Sc.)	41	34%
Master (M.Sc.)	74	61%
Doctorate (PhD/D.Eng.)	6	5%
Professional Experience		
0 to 5 years	75	64%
6 to 10 years	27	22%
11 to 15 years	8	6%
16 to 20 years	6	4%
21 and above	5	4%

4.2.3. Organization Type

With the connection to organization type, 35% of the respondents were from contractor organization while 15% were from client domain. Likewise, 35% of the respondents were from the consultant side while 2% were from specialty or petty contractors. The remaining 13% were from the academic domain and 3% were project managers.

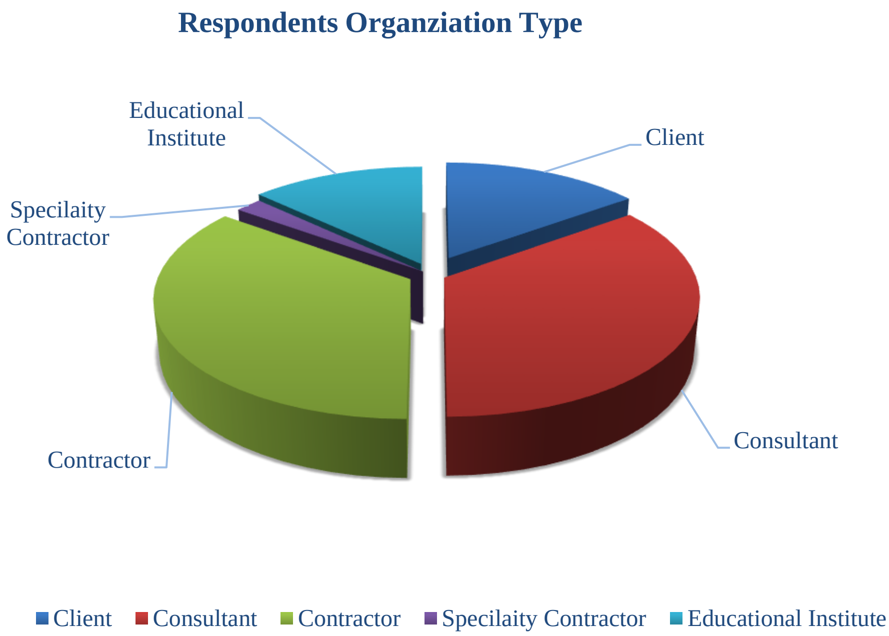


Figure 6: Organization type

4.2.4. Region of Respondents

With reference to statistics, 62 of the respondents were from Pakistan, 11 were from India, 6 from Bangladesh, 2 from Qatar, 6 from South Africa, 5 from Iran, 4 from Algeria, 2 from Azerbaijan, 2 from Tanzania and 3 from Iran and 1 from Siri Lanka etc.

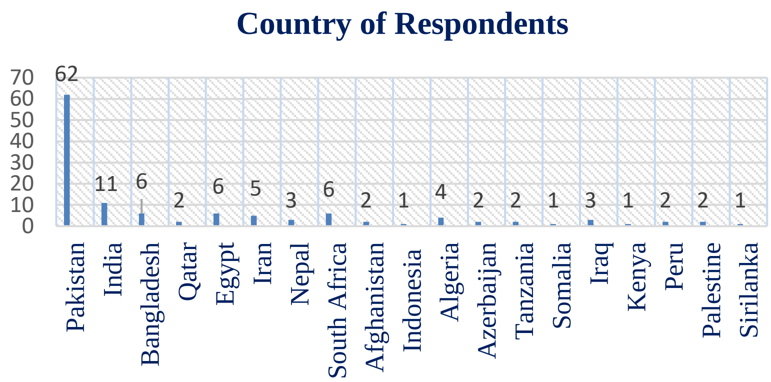


Figure 7: Regions of respondents

4.2.5. Normality and Reliability Check

To check the reliability and internal consistency of data, Cronbach's Alpha test is conducted and its benchmark value is 0.7, higher the value, the more data is reliable and internally consistent as shown in Figure. Cronbach's Alpha value came out to be 0.981, which indicated that data is sufficiently reliable and internal consistent (Tavakol and Dennick 2011)

Table V: Cronbach's Alpha Benchmark values

The Relationship between the Cronbach's alpha Value and Internal Consistency	
Cronbach's alpha Value (α)	***Internal Consistency***
α ≥ 0.9	Excellent
0.9> α ≥ 0.8	Good
0.8>α ≥ 0.7	Acceptable
0.7>α ≥ 0.6	Questionable

Table VI: Reliability statistics

Cronbach's Alpha	***N of Items***
0.98	132

4.2.6. Influence Matrix for Causal Loop Diagram

Influence matrix mapped out in consonance with consequential results, interpretation and analysis of pilot and detailed questionnaire survey. Values in the lower half of the matrix demonstrated data taken through veteran opinions, which assisted in the modification of the causal loop diagram.

Veteran suggestions were incorporated to make the causal loop meaningful and validate feedback loops are moving in the same direction. Subsequently, directions of a few interrelations were changed through expert opinions and the ameliorated influence matrix (MI) illustrated below.

Causal loop diagrams derived from significant causal relationships and influence matrix elicited from relative importance index of finalist factors. Causal relations showing RII value greater or equal to **0.75** or having mean value **3.75<=m=<5** is taken for further analysis (Chong *et al.* 2017).

Table VII: Influence matrix established from correlation of impacting factor and impacted factors

	V1	***V2***	***V3***	***V4***	***V5***	***V6***	***V7***	***V8***	***V9***	***V10***	***V11***	***V12***
V1	1	0.80	0.77						0.78	0.86		
V2		1			-0.82							

V3			1	-0.75		0.76						
V4				1							-0.78	
V5					1							-0.79
V6						1	0.81	0.78				
V7	0.84						1					
V8	0.78							1				
V9						0.75			1			
V10						0.78				1		
V11											1	0.75
V12	-0.76											1

V1: Top Management Commitment V2: Customer Client Satisfaction/focus V3: Quality of Education Regarding TQM V4: Poor Organization Quality Culture V5: Initial Cost V6: Continuous Improvement V7: Employee Training V8: Employee Involvement V9: Employee Empowerment V10: Appropriate Communication Medium V11: Attitude and Behavior Towards TQM V12: Low Bid subcontracting

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

4.3. Causal Loop Diagram

A causal loop diagram (CLD) is developed in conformity with interrelationships having the mean influence value ranging from 3.75=<m<=5. It consists of four reinforcing and two balancing loops. The CLD is ameliorated in harmony with veteran construction professionals holding experience more than ten years to make it less intricate, meaningful. The following step was to make certain that feedback loops are revolving in the same direction and some of the interrelations were overlooked which were going away from the system (Dhirasasna and Sahin 2019). The CLD constituted of four reinforcing and two balancing loop and each loop elaborated blow by blow.

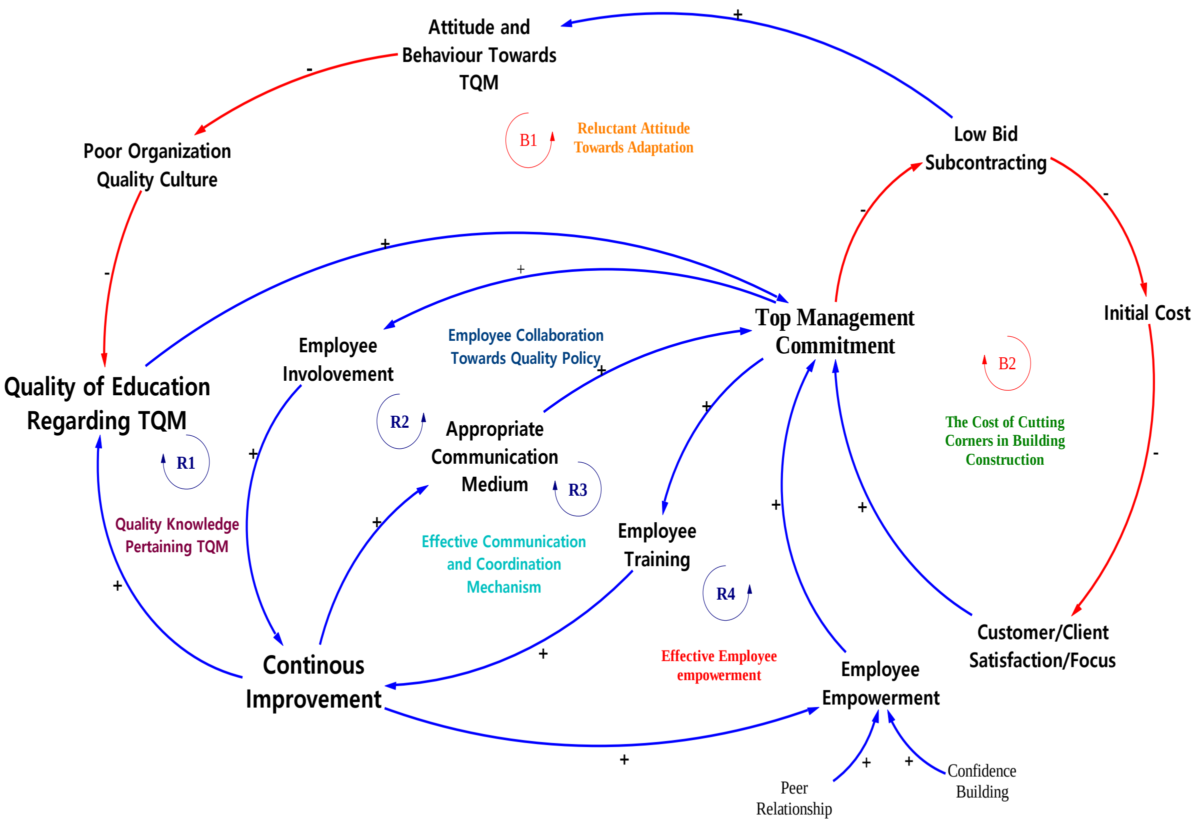


Figure 8: Causal loop diagram (CLD)

4.3.1. Quality Knowledge pertaining TQM (Reinforcing Loop R1)

Reinforcing loop R-1 extrapolated that as top management commitment amplifies, it led towards encouraging employee involvement and strongly influence continuous amelioration of construction project. Since due to concurrent ceaseless improvement and refined quality of knowledge regarding TQM, quality performance of construction organizations improvised immediately, thus this loop bolster prompt and robust influence and marked as reinforcing loop R-1.

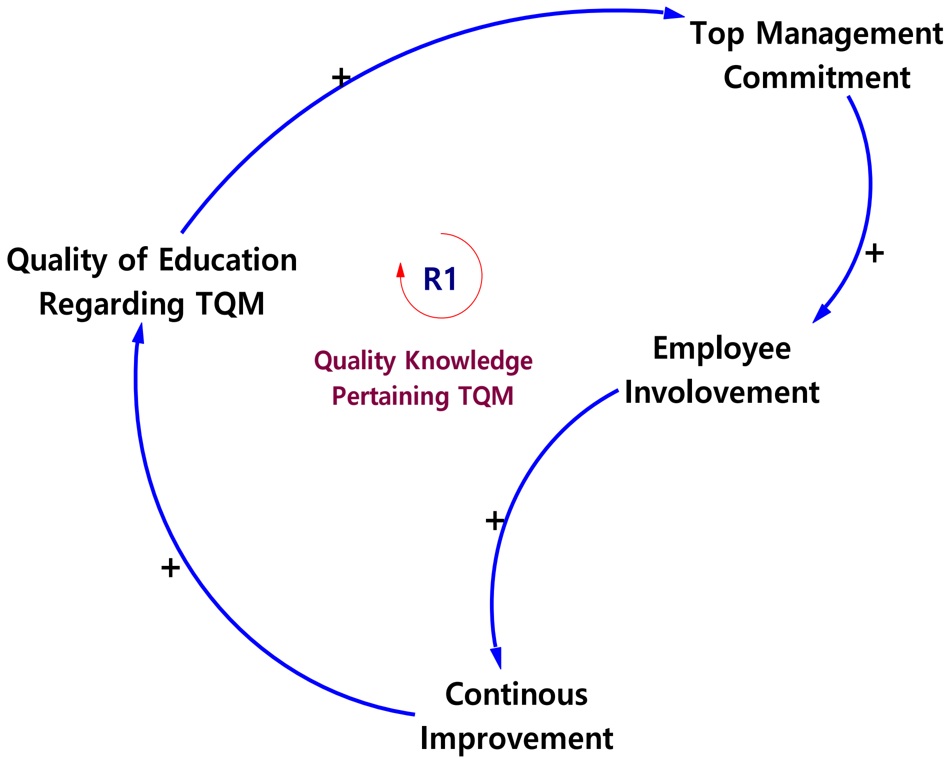


Figure 9: Reinforcing loop R-1

4.3.2. Employee Collaboration Towards Quality Policy Making (Reinforcing Loop R2)

Reinforcing loop R-2 deduced that increase in senior management commitment coupled with employee participation in policy/decision making lead towards relentless improvement of construction projects. As continuous improvement progressively escalates, communication channel among dominant stakeholders i.e., client, consultant, contractor improvised, thus quality performance of construction projects and total quality management implementation spontaneously bumped up.

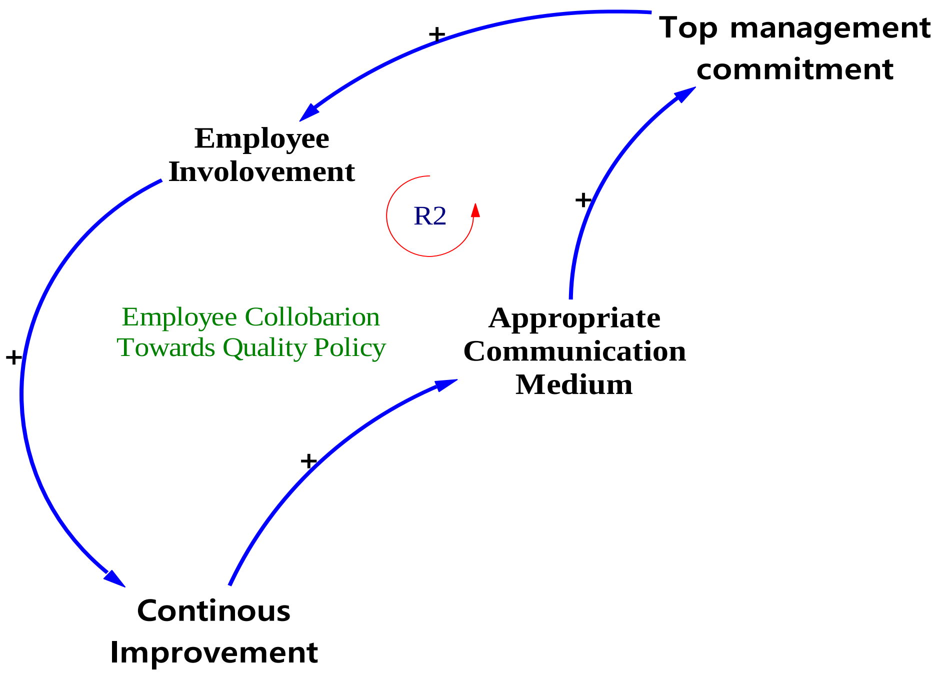


Figure 10: Reinforcing loop R-2

4.3.3. Effective Communication and Coordination Mechanism (Reinforcing Loop R3)

Reinforcing loop R3 implies that a significant uplift in executive management commitment leads towards boom in employee professional training and development of technical expertise, thus continuous improvement can be influenced positively. Appropriate communication medium has a pivotal role in the success or failure of any booming construction organization. To certify quality-oriented performance and underpinning of total quality management in construction sector, it is indispensable prerequisite to reveal the most appropriate channels of communication within a construction project. As effective communication and coordination mechanism developed, quality performance of construction project tremendously straighten out. Therefore, this loop is thought to have volatile, robust but reinforcing impact.

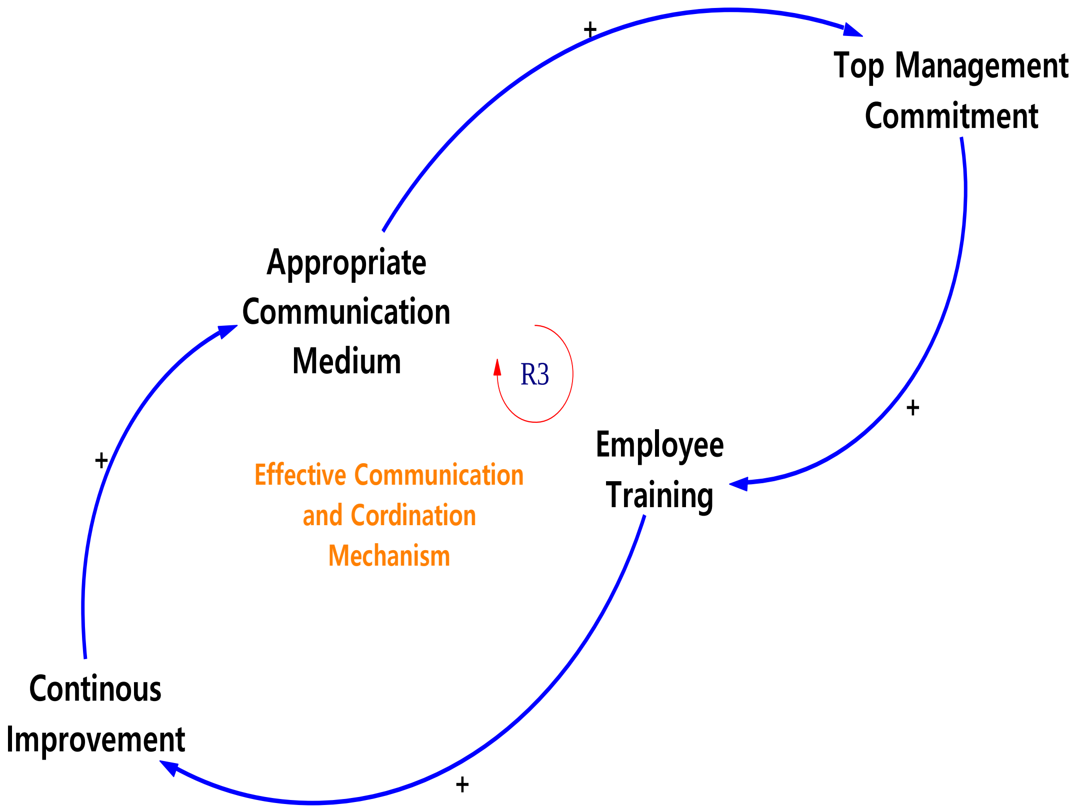


Figure 11: Reinforcing loop R-3

4.3.4. Effective Employee Empowerment (Reinforcing Loop R4)

Reinforcing loop R4 inferred that an amplification in superior management commitment leads towards boosting employee professional training, quality-oriented character construction and uninterrupted improvement of construction projects. Continuous improvement of any construction organization is directly proportional to employee empowerment. As continuous improvement of construction procedures and operations increase, employee quality focused attitude and morale boost up that lead towards deceleration of rework and foster total quality management concept. Hence, this loop carried slow but strong impact and identified as a reinforcing loop.

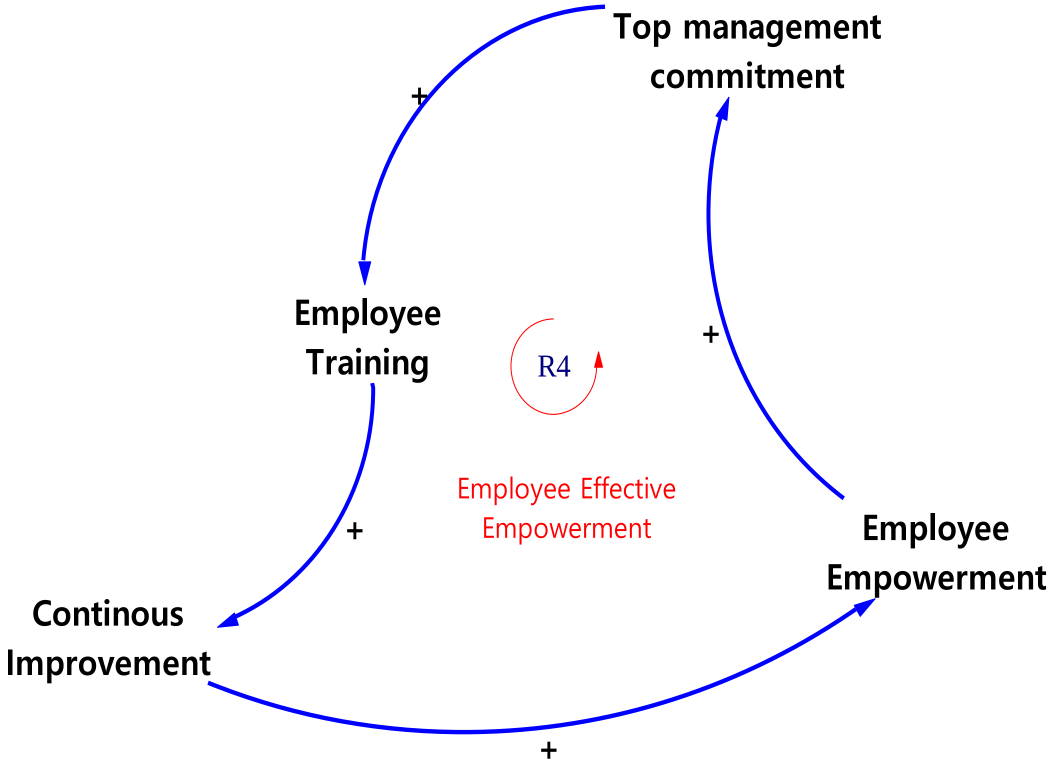


Figure 12: Reinforcing loop R-4

4.3.5. Reluctant Attitude Towards Adaptation (Balancing Loop B1)

Balancing loop B2 concluded that top management has an inverse relationship along with low bid subcontracting, as top management commitment increases low bid subcontracting decreases gradually. Low bid subcontracting is actually corner cutting contract awarded mechanism based on lowest cost vendor preference, while compromising the overall quality of the project. As low bid subcontracting dwindled attitude and behavior of client/customer towards TQM amplified and poor organization quality culture decline respectively. As poor organization quality trend reduced quality of education, training, quality practices pertaining the implementation of TQM increases. Hence, loop B1 carries a strong and fast influence that is identified to be self-balancing.

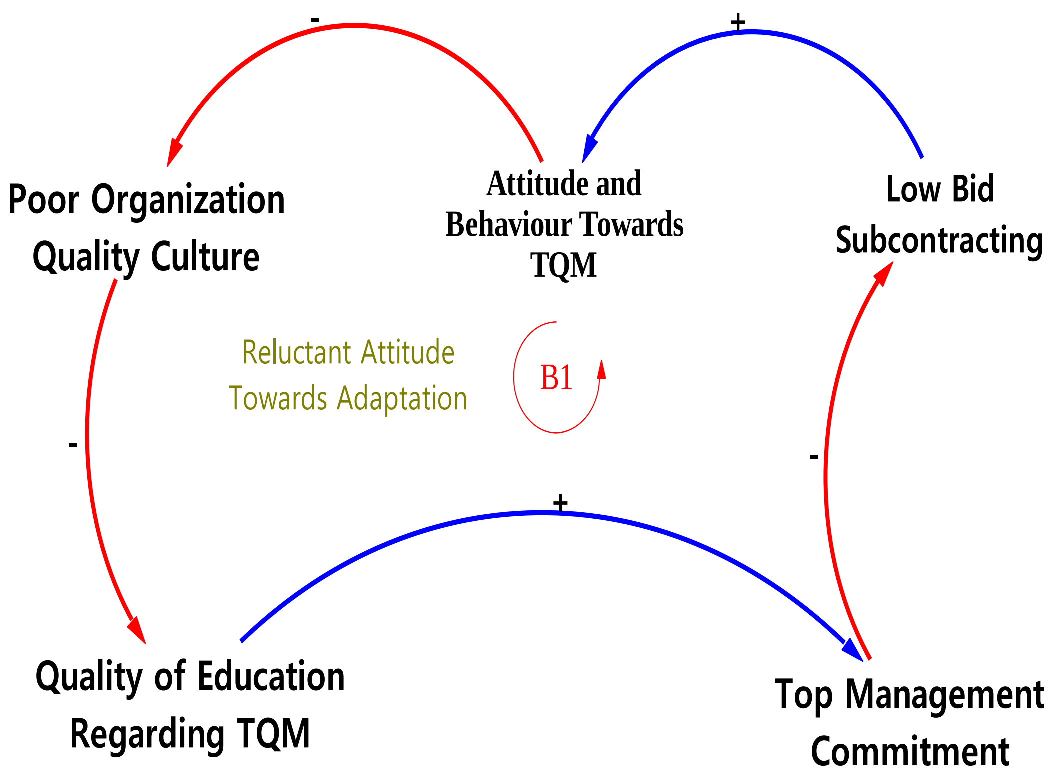


Figure 13: Balancing loop B-1

4.3.6. The Cost of Cutting Corners in Construction (Balancing Loop B2)

Self-balancing loop B2 deduced that as top management commitment increases low bid subcontracting decreases that lead towards the high initial cost of project. As upfront cost increases customer satisfaction and focus decrease. Customer delight can be achieved if anyone in the organization from either the lowest position or highest position takes part wholeheartedly for successful completion of the project while optimizing cost and taking time management into account. Since, top management commitment is directly proportional to customer delight, as top management commitment increases customer client satisfaction and interest pertaining TQM increases. Consequently, loop B2 carries a strong and fast influence that is identified to be self-balancing.

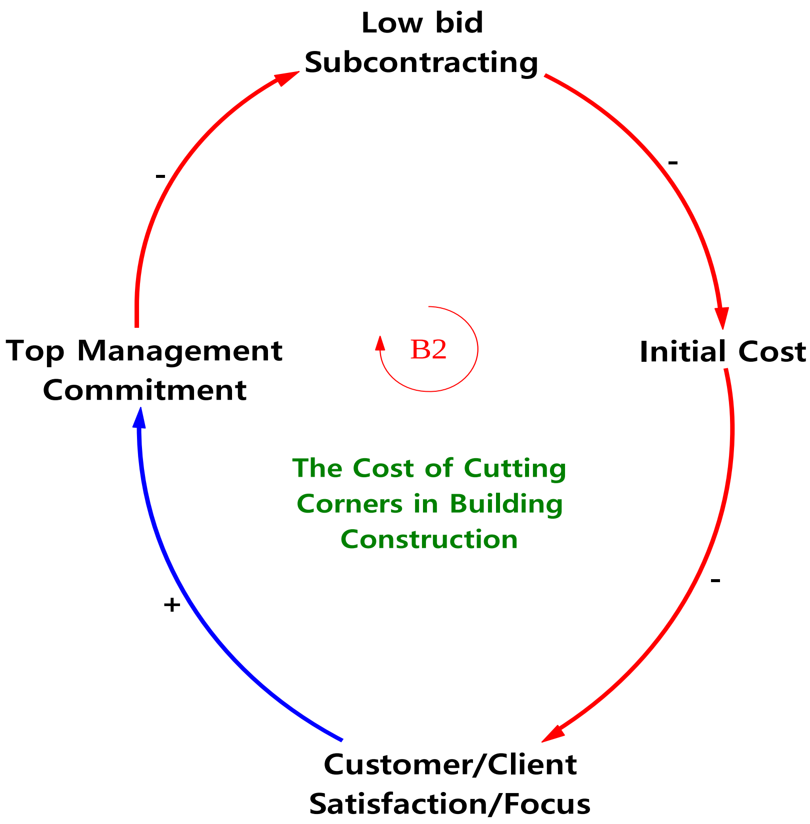


Figure 14: Balancing loop B-2

4.4. Stock and Flow Diagram

Stock and flow diagram originated from causal loop diagram. Top management commitment, quality of education regarding TQM, and continuous improvement were three stocks recognized and additional stock was also incorporated in the model expressed as total quality management to observe the convergence of the existing three stocks.

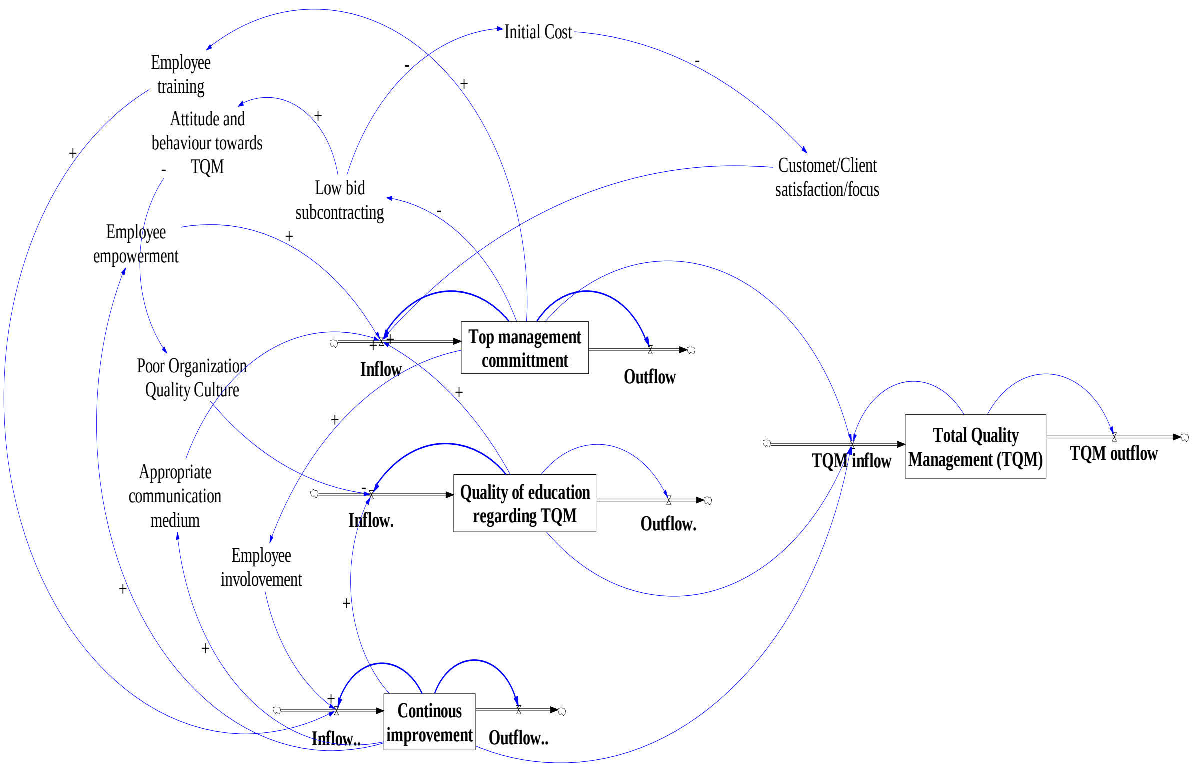


Figure 15: Stock and flow diagram (SFD)

4.5. System Dynamics Model

The relative importance index is measured depending upon the mean value, afterward the nature of queries was not unique and unrelated hence mean value was chosen over the mode value (Tahir *et al.* 2021). Consequently, 17 causal relationships clinched having RII greater or equal to 0.75.

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

Eq.2

Table VIII: Correlation, polarity and relative importance index of finalist causal relationship

Sr. No.	Impacting Factor	Impacted Factor	Mean	RII	N. RII	Polarity
1	Client Satisfaction/Focus	Top Management Commitment	3.99	0.80	0.060	Direct
2	Low bid subcontracting	Initial Cost	3.96	0.79	0.059	Indirect
3	Quality of Education Regarding TQM	Top Management Commitment	3.84	0.77	0.057	Direct
4	Poor Organization Quality Culture	Quality of Education Regarding TQM	3.76	0.75	0.056	Indirect
5	Low bid subcontracting	Attitude and Behavior Towards TQM	3.76	0.75	0.056	Direct
6	Initial Cost	Customer/Client focus/Satisfaction	4.12	0.82	0.062	Indirect
7	Continuous Improvement	Quality of Education Regarding TQM	3.78	0.76	0.057	Direct
8	Employee Training	Continuous Improvement	4.04	0.81	0.061	Direct
9	Top Management Commitment	Employee Training	4.19	0.84	0.063	Direct
10	Top Management commitment	Low Bid Subcontracting	3.81	0.76	0.057	Indirect
11	Employee Empowerment	Top Management Commitment	3.90	0.78	0.058	Direct
12	Employee Involvement	Continuous Improvement	3.88	0.78	0.058	Direct

13	Top Management Commitment	Employee Involvement	3.90s	0.78	0.058	Direct
14	Continuous Improvement	Employee Empowerment	3.76	0.75	0.056	Direct
15	Appropriate Communications Medium	Top Management Commitment	4.32	0.86	0.065	Direct
16	Continuous Improvement	Appropriate Communications Medium	3.88	0.78	0.058	Direct
17	Attitude and Behavior Towards TQM	Poor Organization Quality Culture	3.90	0.78	0.058	Indirect

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

1. **Top Management Commitment inflows** = 0.06*V2 + 0.057*V3 + 0.058*V9 + 0.065* V10 + 1*V1 **Eq. 3**
2. **Top Management Commitment outflow** = 1*V1 **Eq. 4**
3. **Quality of Education Regarding TQM inflow** = -0.056*V4 + 0.057*V6 + 1*V3 **Eq. 5**
4. **Quality of Education Regarding TQM outflow** = 1*V3 **Eq. 6**
5. **Continuous Improvement inflow** = 0.058*V8 + 0.061*V7 + 1*V6 **Eq. 7**
6. **Continuous Improvement outflow** = 1*V6 **Eq. 8**
7. **TQM inflow** = V6 + V3 + V1 + 1.00 * Total quality management **Eq. 9**
8. **TQM outflow** = 1.00 * Total quality management **Eq. 10**

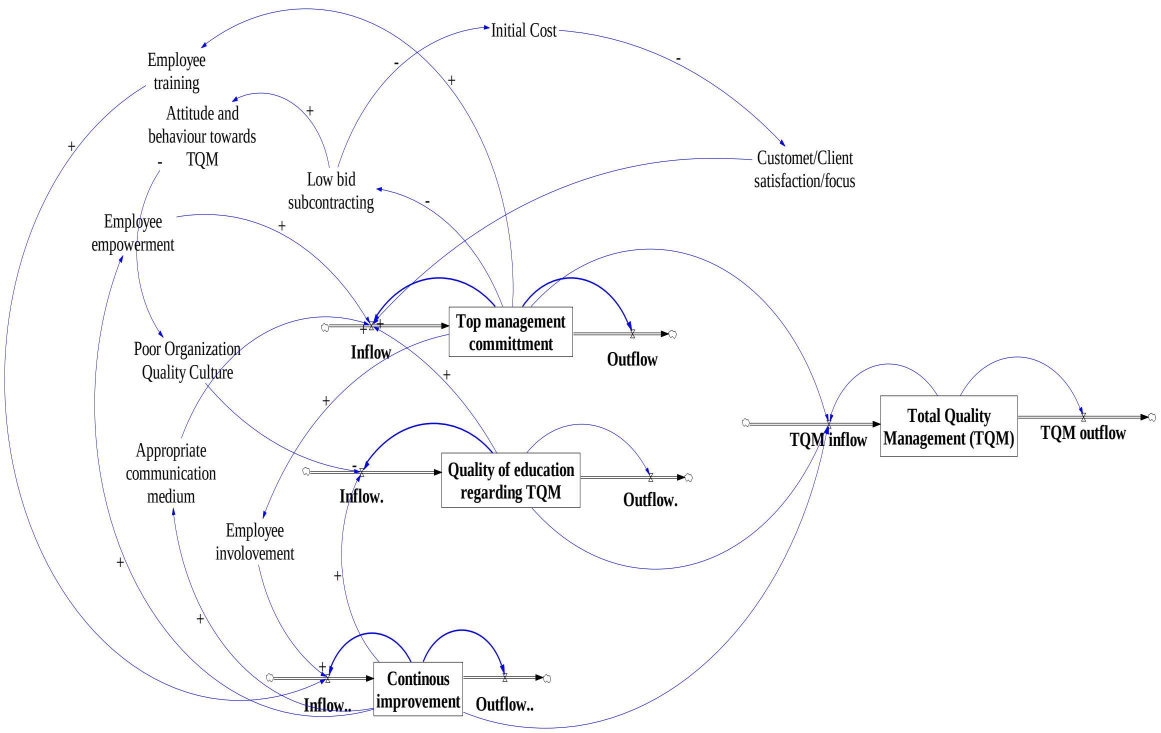


Figure 16: System dynamics model

4.5.1. Simulation and Results

This simulation represented the behavior of the complex integrated system and three stocks termed as top management commitment, quality of education regarding TQM and continuous improvement were simulated distinctly over the period of five years. Subsequently, an additional stock expressed as total quality management was also simulated to deduce the impact of all three stocks, which were converged on it.

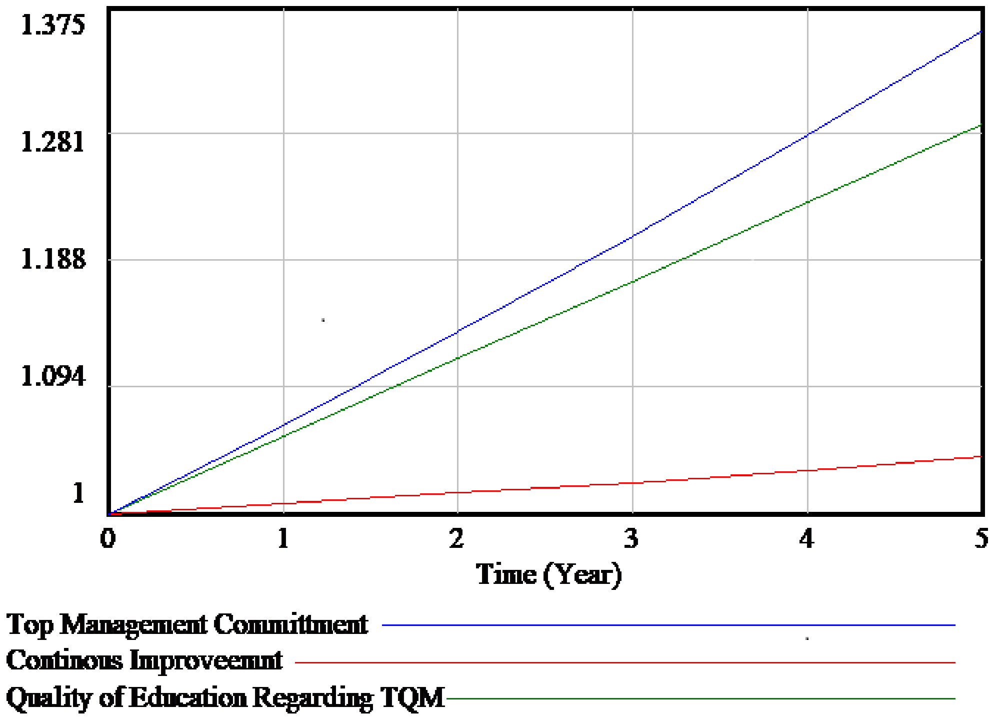


Figure 17: Simulation graph (behaviour of stocks)

This graph inferred that total quality management implementation amplifies as top management commitment, continuous improvement and quality knowledge pertaining TQM bolster up. As top management commitment increases employee integrity and allegiance towards continuous improvement of quality performance magnify. Top-tier commitment is directly proportional to constant improvement of project and quality of education pertaining TQM reinforce fact-based decision making and process amelioration of construction projects. This overwhelming trend explicated in graph leads towards exponential improvement and implementation of total quality management in construction sector.

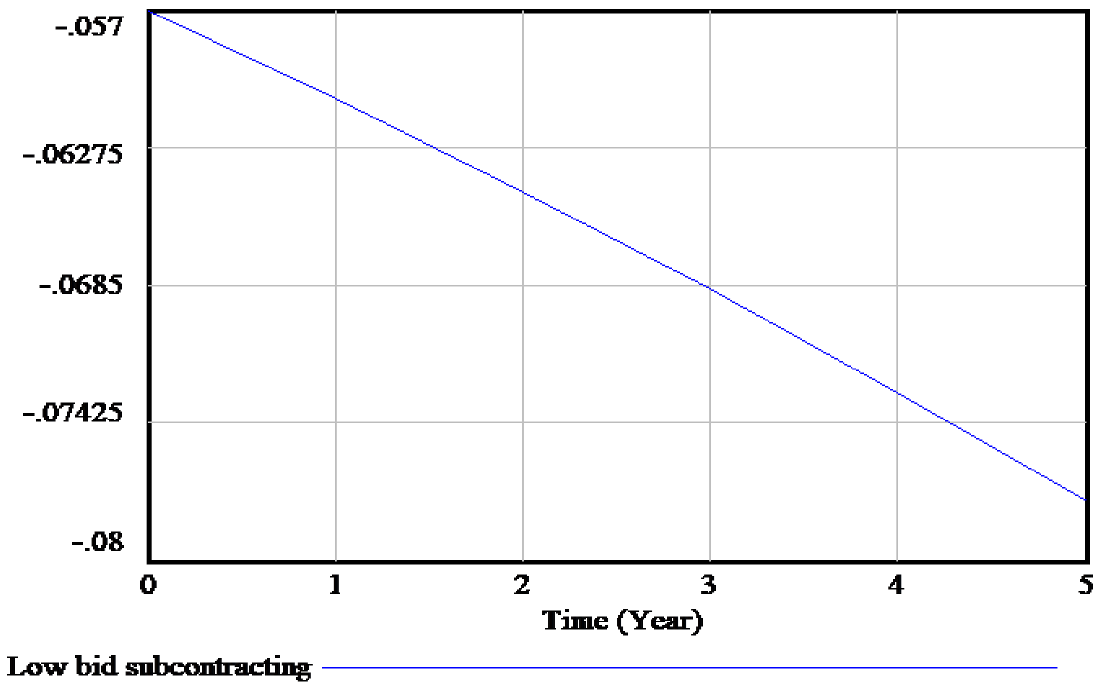


Figure 18: Simluation graph (low bid subcontracting)

This graph implies that low bid subcontracting decelerates as top management commitment accelerate as low bid subcontracting is inversely proportional to senior management commitment. Since, the concept of low bid subcontracting cut corners and ultimately jeopardized quality of the construction project. As top-tier commitment amplified, constancy of purpose and organization wide process improvement inevitably achieved, thus as a consequence customer delight and pursuit of construction quality performance conquered. Consequently, the simulation graph of low bid subcontracting and high initial cost extrapolated declining behavior over the course of five years.

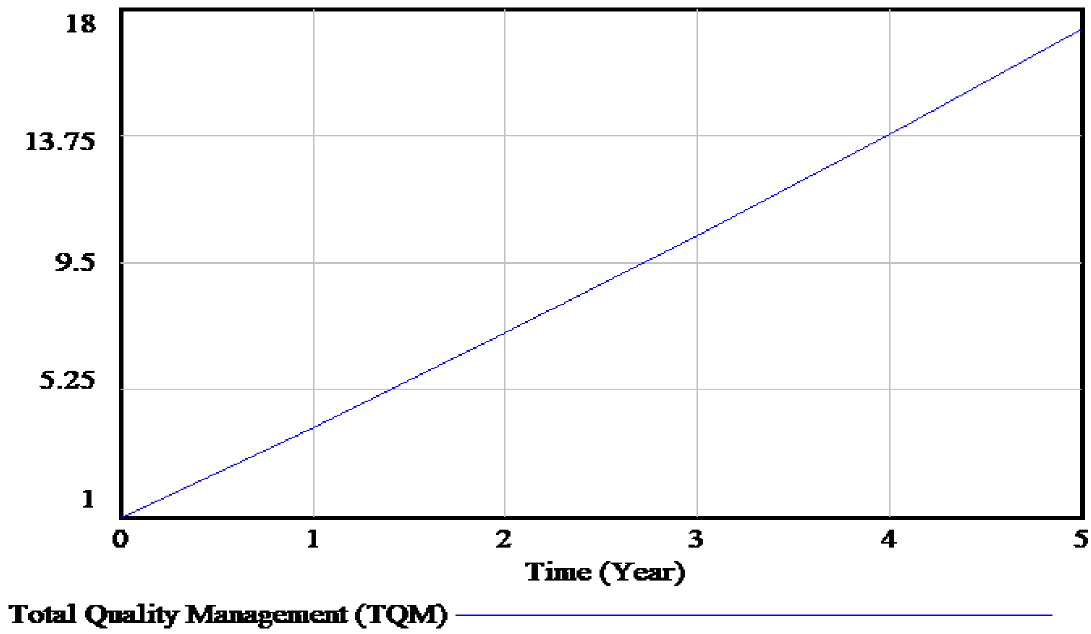


Figure 19: Simulation graph (behaviour of total quality management over the course of five years)

This graph deduced that implementation of total quality management in the construction sector of developing countries inevitably magnified over the course of five years. The employee mutual reciprocity, training and collaboration led towards relentless improvement and influence the overall project quality performance of construction projects. The profound knowledge pertaining TQM contributed towards construction process improvement, revamping quality policy, fact-based decision making, employee prerogative, preeminent quality culture, averting cut corners ethos and pulling off customer delight.

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 construction 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 was conducted to endorse three constituents, whether all significant insights are endogenous to system or not, whether the behavior of model change is significant when boundary conditions are changing and whether policy recommendations change when the boundary is extended. All variables are endogenous in present model except two which are exogenous i.e., peer relationships and confidence construction. Consequently, after simulation the behavior of the model and policy recommendations does not alter when boundary conditions are altered.

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 construction 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, cognizant, logical and meticulously representing certain construction 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 construction 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

CONCLUSION

Despite diversity and novelty of each construction projects, most of the total quality management practices and conceptual frameworks were developed for the manufacturing and services industry. The aim of this exploration work was to abridge the intricacy and causality resulting from the implementation of total quality management in the construction sector, especially in developing countries. System thinking approach was used to simplify intricacy resulting from adoption of total quality management in construction sector by development of system dynamics model that led towards distinguishing quality management system and quality-oriented performance of construction projects.

A precise and conclusive literature review was conducted and twenty-eight contributing challenges were extracted for the implementation and adoption of total quality management concept in the construction sector. 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 screen out least significant contributing factors and 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**.

Top management commitment, customer/client satisfaction, quality of education regarding TQM, organization quality culture and high initial cost were considered the top five contributing factors of total quality management.

Accordant with sessions conducted with construction field expert and significant shortlisted interrelationships the causal loop diagram (CLD) mapped out. Veteran opinions and valuable suggestions were also incorporated to make causal loop diagram more significant and relevant to need and demand of construction sector.

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. ***Top management commitment, continuous improvement and quality of education regarding TQM*** were specified as three notable stocks of this system dynamics model. The fourth stock termed ***total quality management*** incorporated and all three existing stocks were converged on it with connection 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 five years. The values of exogenous variables were kept constant i.e., one throughout the simulation. The existing three accumulated stocks under the impact of reinforcing interrelationships illustrated ascending behavior over the course of time.

The graph of contributing factors including ***low bid subcontracting, poor organization quality culture, and initial cost*** exhibited descending trend over the course of time as these are negatively complemented by attitude and behavior towards total quality management. Subsequently, the *total quality management* graph illustrated ascending behavior over the period as all three stocks were converged on that point. This reflected the fact that total quality management implementation increased as the years passed under a well-defined system and so as construction project efficiency and overall performance improved.

The causal loop diagram and system dynamics model holistically explicated total quality management implementation through systems thinking approach. The findings of this exploration work strengthen the way for creating a strategy/policy or quality-oriented environment, which is more feasible for total quality management implementation and enhanced quality performance of construction project.

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APPENDICES

Appendix 1: Preliminary Questionnaire

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Appendix 2: Detailed Questionnaire

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