# Assessing Information Complexity and its Influence on Construction Quality Using Systems Thinking Approach

**Thesis of**

**Master's in Science**

**Construction Engineering and Management**

***By***

**Faizan Naveed**

2016NUSTMSCE&M0800000106125

**DEPARTMENT OF CONSTRUCTION ENGINEERING AND MANAGEMENT**

**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

**NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY**

**SECTOR H-12, ISLAMABAD, PAKISTAN**

**(2020)**

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Signature: ____________________________

Name of Supervisor: Dr. Khurram Iqbal Ahmed Khan

Date: ________________________________

Signature (HOD): ______________________

Date: ________________________________

Signature (Dean/Principal): ______________

Date: ________________________________

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**Assessing Information Complexity and its Influence on Construction Quality Using Systems Thinking Approach**

Submitted by

**Faizan Naveed**

2016NUSTMSCE&M0800000106125

has been accepted towards the partial fulfillment of the requirements for the degree of

**Master of Science in Construction Engineering and Management**

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**Dr. Khurram Iqbal Ahmed Khan**

Head of Department,

Department of Construction Engineering and Management,

School of Civil and Environmental Engineering (SCEE),

National University of Sciences and Technology (NUST), Islamabad

**ACKNOWLEDGEMENTS**

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.

I am in debt of gratitude to my research supervisor Dr. Khurram Iqbal Ahmed Khan for his guidance, motivation and constant encouragement throughout this journey. I appreciate the valuable time and personal support accorded by him.

I am incredibly grateful to all the volunteers and respondents for their valuable contribution to this research study. And at the end, I would like to pay my earnest and honest gratitude to my friends and family especially my parents, for their unconditional support, encouragement and patience.

# ABSTRACT

Construction sites are information-intensive environments. Huge amounts of information need to be communicated among various stakeholders during all phases of the construction lifecycle. The challenges faced in the transfer or exchange of information and data on construction projects have, however, led to information complexity. Above all, the success of any construction project relies upon the quality performance. Due to this complexity of information flow, the quality of construction projects has greatly suffered. To overcome this challenge, this paper investigates the causative relation between information complexity and construction quality by focusing on the factors that lead to information complexity on construction sites and describes how they subsequently influence the quality of construction. To demonstrate and address this complexity, qualitative systems thinking approach was used. This approach made use of six causal loop diagrams (CLDs) to provide an understanding of the information-flow mechanisms that influence project quality performance. The study finds ineffective communication, unclear details, changes in contract, information delays, unpleasant relationship between stakeholders and project complexity as the most critical factors. The CLDs were prioritized based on their strength and speed of influence in the system. This technique highlights the reinforcing loops which can help stakeholders to adopt proactive or reactive approaches in their projects by improving information flow or developing quality control measures respectively.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Study Background

Construction, as an industry, is certainly a complicated one. It includes involvement of several stakeholders each with their own interest and perspective (More *et al.*, 2017). It is reckoned to be a challenging business since multiple stakeholders that are involved require information, which includes, among others, plans, technical specifications, photos, letters, and drawings. The challenge, however, lies in timely communication and analysis of such information during all stages of the construction life cycle (Olanrewaju *et al.*, 2017). Hence, uninterrupted flow of information between the stakeholders is pivotal for success of projects in the construction industry. Breakdowns in communication and the flow of information however can add to various issues, for example, low quality and productivity. Since quality is termed as the principal element for customer satisfaction, it is significant to identify the challenges and barriers to communication and data transfer which result in information complexity and consequently lead to poor construction quality.

Information communication is of imperative significance to every stakeholder and participant influenced by, and involved in, projects (Emmitt, 2010). (Chin-Keng, 2011) cited inadequate information and ineffective communication as one of the key reasons, eventually laying grounds for the compromised quality in construction projects. According to (Olanrewaju *et al.*, 2017), well-communicated information between project participants helps in reducing the likelihood of the non-compliance of cost and schedule constraints. Moreover, such an approach can fairly enhance the sustainability as well as quality, thereby, improving the performance of the project. Accurate and timely dissemination of information during each phase of the construction life cycle also reduces delays, errors and rework while improving construction quality at the same time (Khan *et al.*, 2016).

Poor information and ineffective communication have been one of the major reasons of project failure (Gamil and Rahman, 2018). The barriers that hinder effective communication of information are very complex and varied due to the variation of the stakeholders involved (Pérez Gómez-Ferrer, 2017). Although the construction industry practitioners are fully familiar with the various benefits of maintaining quality in projects, they have failed to understand barriers to effective communication of information among project participants that has resultantly caused the construction quality to suffer, particularly among the third-world countries, like Pakistan (Hussain *et al.*, 2018). Since it is evident that challenges faced in the communication of information on projects have aggravated the need to understand information complexity, these projects necessitate an in-depth and holistic understanding of the influence that information complexity has on construction quality.

In such a case, among a couple of alternatives available for investigating complex situations, Systems Thinking (also known as qualitative systems dynamics) methodology as an analysis tool is a thorough approach to analyze problems, in which the influence of individual components is thought-out comprehensively in the whole system. This methodology makes use of Causal Loop Diagrams (also known as Influence Diagrams) to uncover basic mechanisms pertaining to collecting feedbacks and their influence on project objectives (Rasul *et al.*, 2019). ST can not only handle multiple variables at the same time, it can also provide linkages and interdependencies between them in a complex system. Since information complexity and construction quality constitute multiple dimensions and hence complicated relationships, ST is an appropriate approach to use in this study to understand and analyze the causal feedback relationships between various significant factors causing complexity of information flow and construction quality. Hence, this research aims to apply Systems Thinking to understand and analyze the causal feedback relationships among various factors causing complexity of information flow and provide an understanding as to how such mechanisms influence project quality. This study adds to the prevalent body of knowledge by facilitating the construction practitioners to understand the paradigm of information flow and data transfer. Not only this, it would also assist stakeholders to contemplate and analyze quality management procedures in their projects accordingly.

## 1.2 Problem Statement

The development of any industry, let alone the construction industry, is heavily reliant upon quality. There are quite a few studies originating from the developed world that have investigated the factors that lead to poor quality in the construction sector. This shows that the problem not only lies within developing nations but is also faced by the first-world countries. Although the literature identifies ineffective communication as one of the critical factors that affects performance of a construction project, not enough studies have been conducted that establish the direct relationship between poor communication and construction quality. A research carried out in the US states that around 7.5% of the total amount spent in the construction industry is lost due to ineffective communication. Similarly, a research conducted in Britain estimated that around £20 Billion are spent annually to correct defects caused due to ineffective communication.

The case of Pakistan is no different, poor quality categorizes as one of the major problems in both government and private sectors. With each passing day, increasing competition among different construction companies has put immense pressure on them to pay even more attention towards quality, not only to increase their profit margins but also to significantly aggrandize their reputation in the market. Numerous researches have already been carried out that assess various factors affecting the quality of construction projects. One factor however remains constant in majority of the studies i.e. efficient communication of information. As mentioned earlier, there have been quite a few researches on how communication might affect the overall performance of a project in the developed countries, however a little trend was seen towards the influence of ineffective information communication specifically on the quality of construction in developing countries such as Pakistan. Therefore, this study aim to address this research gap that will not only help mitigate quality related issues on construction sites but also help reduce adverse impacts on rest of the performance indicators such as cost, scope and schedule.

## 1.3 Research Objectives

**1.** To identify **a)** the factors that lead to information complexity on construction sites and **b)** key performance indicators of quality in the construction industry.

**2.** To determine the causative relation of complexity of information flow on the quality of construction projects using systems thinking approach.

**3.** To make recommendations in order to address information complexity leading to improved project performance.

## 1.4 Research Significance

The study undertaken would help our industry by educating the project stakeholders, decision makes and practioners about the factors that lead to information complexity on sites and its consequent influence on construction quality. The findings will help them focus on issues related to ineffective information and its communication as well as quality in their current or future projects. The research would indirectly help in reducing excessive amount of rework and cost overruns due to claims and non-conformity, while improving stakeholder integration, project feasibility and quality.

The utility of this study lies in the ability of Qualitative Systems Thinking to uncover the basic mechanisms of a system by gathering information and knowledge from a vast range of informants. The CLD, subsequently, provides closed cyclic structures/loops of causality that can educate project managers and decision-makers about the behavior of processes that occur within the system. There can be either of the two approaches; proactive and reactive. In the former approach, managers can aim to improve the flow of information on the project by focusing on the most critical causal factors of information complexity, whereas the latter approach would involve adopting quality control techniques and measures leading to improved quality performance of projects in the industry.

## 1.5 Advantages

In this study, the need for understanding of how particular dynamics regarding ineffective information flow can hinder the quality of a project will be highlighted. Some of the advantages are:

- Identify and mitigate the impacts of ineffective information and communication on construction projects of Pakistan
- Identify and rank factors affecting construction quality
- Reduce excessive amount of rework and cost overruns
- Improve project productivity and efficiency
- Improve flow of information on construction sites

## 1.6 Scope of Research

The scope of this research is limited not only to the construction sector but to all those industries that involve information flow as a communication medium and prioritize quality as a performance indicator. The Causal Loop Diagram developed in the study serves as tool that can assist project practitioners regarding the dynamics associated with quality in construction projects. Moreover, the findings of this study will have a broader area of application for both government and private sectors.

## 1.7 Thesis Organization

This research has been organized into five chapters. An overview of those chapters is given below;

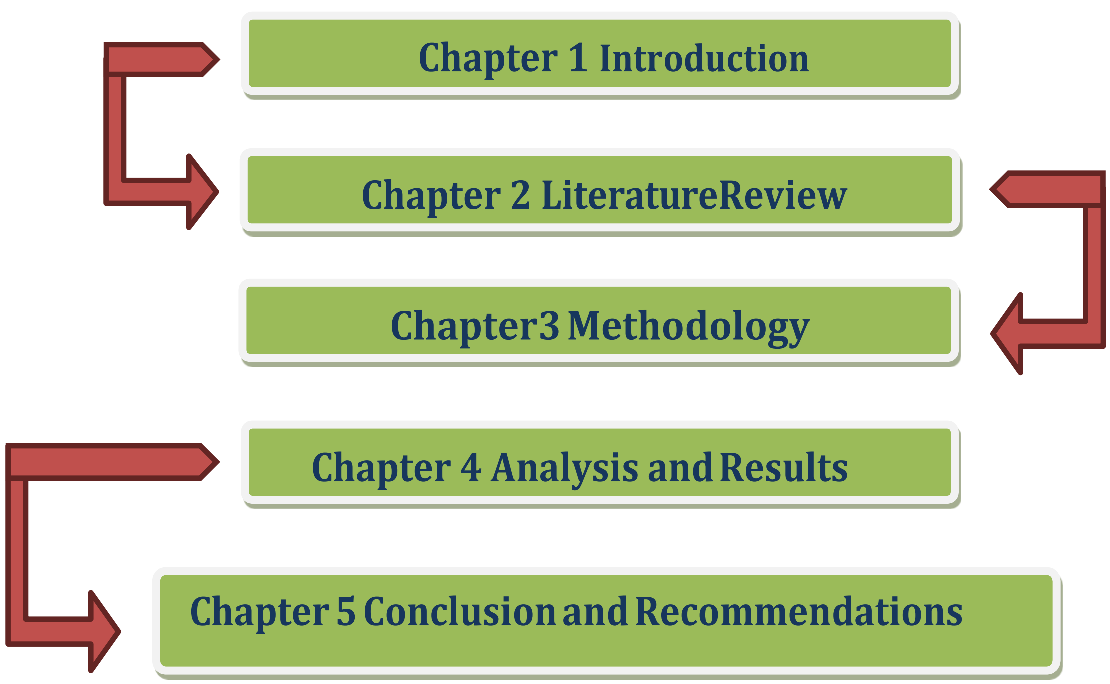


**Figure 1** Process Overview Map

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter presents a detailed review of the research studies already carried out on quality and its importance for construction project success. It further discusses in detail the literature on information and communication support activities and issues faced on the construction sites.

## 2.2 Characteristics of Construction industry

The construction industry is an important sector of the economy and plays a key role in national social and economic development (Ofori, 1990, Hillebrandt, 2000). The construction industry has peculiar features that need to be understood if it is to be able to perform effectively and efficiently (Ofori, 2015). The contribution of the construction industry to economic growth and long-term national development is widely acknowledged, highlighting its importance, particularly to developing countries. For the benefit of these countries, it is important to investigate the nature, essential characteristics and requirements of the construction industry and to use them to develop programmes for its improvement.

As the construction sector increasingly diversifies, the need for defining the industry becomes more apparent, with many traditional construction firms looking to broaden the scope of activities they participate in, thus putting more emphasis on the need for a broader definition, with well-defined boundaries.

The construction sector is basically related to planning, construction, repairing, alteration and demolishing buildings, while involving other engineering works and structures. With each day passing, the competition within the construction industry is growing, with construction firms continuously reducing their profit margins to attract customers and remain engaged in this highly competitive market. This industry is also categorized by the individual nature of each construction work, a high proportion of temporary unskilled workers and a slow penetration of new technologies (dos Reis Almeida, 2011).

The typical construction process in the construction industry is explained using Juran's "Triple Roles" concept (Gunaydin, 1995). According to Juran (1988), the designer is the customer of the owner because the designer has to receive the project requirements from the owner in order to provide a feasible design. The designer supplies plan and specifications to the constructor; in this case the constructor is the designer's customer because the constructor uses the designer's plans and specifications, then conducts the construction process, and finally supplies the completed building to the owner. The owner is now the constructor's customer. Quality in each phase is affected by the quality in the preceding phases. The 'triple role' process in a typical construction project is shown below:

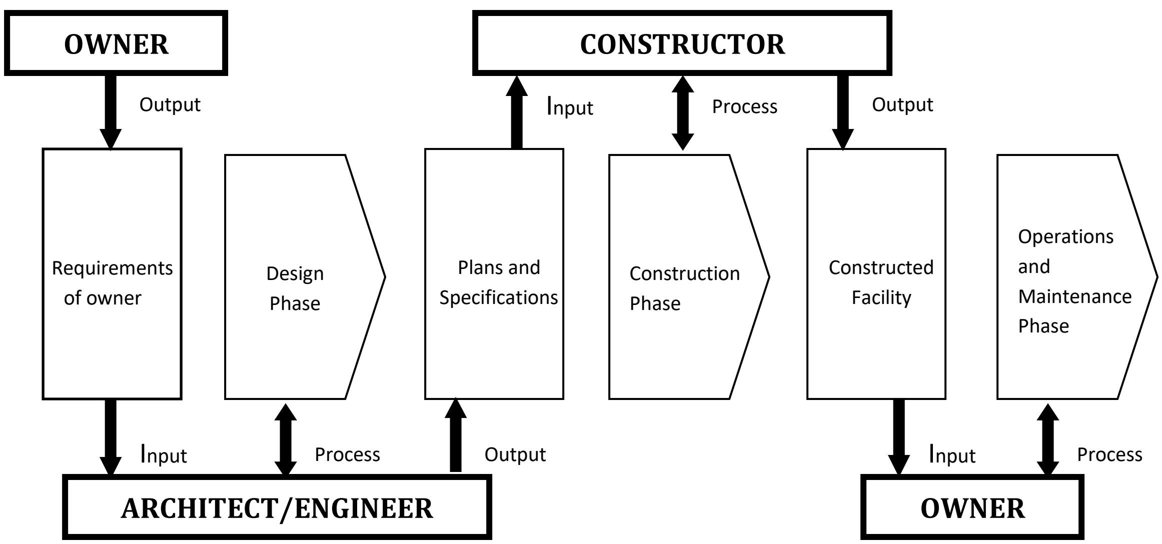


**Figure 2** Triple Role Process **Source:** (Juran, 1988)

### 2.2.1 Construction industry of Pakistan

The Pakistani Construction Industry offers immense economic and social significance to the country. According to Farooqui and Ahmed (2008), the Pakistani construction industry is now a growing market due to the recent rapid economic growth of the country. Recent (provisional) estimates published in the Economic Survey of Pakistan (2016-2017) show that the industry grew 9.1% in FY17 and contributed 2.7% to the country's gross domestic product (GDP).

Pakistan as a developing country is currently enjoying relatively strong growth in construction activities. Today, construction is the second largest sector in Pakistan's economy after agriculture. Roughly 30-35% of employment is directly or indirectly affiliated with the construction sector. As such, the construction sector in Pakistan has played an important role in providing jobs and facilitating revival of the economy (Farooqui and Ahmed, 2008).

The sector has also been an important recipient of foreign direct investment (FDI). This can be judged from the latest figures provided by the State Bank of Pakistan, which show that the construction industry received a net inflow of $35.7 million in August 2017. How attractive the industry is perceived to be for foreign investors can be gauged from the fact that in the current fiscal year from July-August FY17 the industry has received $55.7 million relative to $1.6 million in the same period of last year (Hussain, 2017).

According to a survey carried out of State Bank of Pakistan (2017), GDP from construction in Pakistan increased to PKR 320769 Million in 2017 from PKR 294154 Million in 2016. GDP from construction in Pakistan averaged PKR 239361.33 Million from 2006 until 2017, reaching an all-time high of PKR 320769 Million in 2017 and a record low of PKR 186380 Million in 2006.

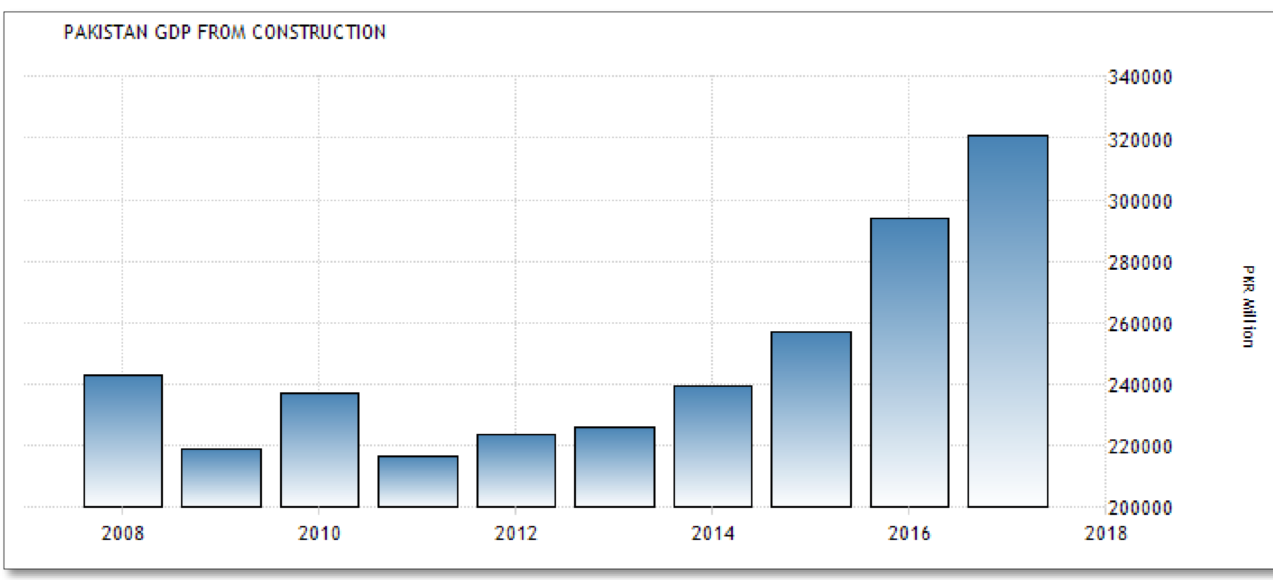


**Figure 3** Pakistan's GDP from Construction **Source:** Tradingeconomics.com | State Bank of Pakistan

In contrast to the prospective share of Pakistani construction in the local and global economic market, conversely, the development of the sector has not been at par with the market demands (Farooqui and Ahmed, 2008). During the first two decades of the 21st century, Pakistan's economy has seen its highs and lows. Growth rates of above seven percent were seen in the earlier years of the first decade, which however reduced to the lowest 0.39 percent in the FY 2009. The economy has ever been ever since growing, although slowly, in recent years to 5.79 percent in the FY 2018 (Economic Survey of Pakistan, 2017-18). This coupled with population growth rates of over 2.4 percent (Economic Survey of Pakistan, 2016-17), places an acute demand on basic and advanced infrastructure.

## 2.3 The Need for Information Mobility

The construction sector is looked upon as one of those industries that emphasize the most on information mobility (Anum ba *et al.*, 2008). Major construction projects and processes require transfer of information among the stakeholders, mainly the project team, in order to realize project objectives. According to (Sean and Li, 2018) effective project-related communication in simple terms is the correct information reaching the concerned party in the most economical way at the needed time. While communication is also defined as sharing, retrieval, and comprehension of information and data, the barriers that may occur in the transfer and exchange of this information often lead to information complexity.

In order to ensure success of a project, communication of information like any fundamental piece must be done in an effective and efficient way (Pérez Gómez-Ferrer, 2017). A study by (Nguyen, 2013) concluded effective information communication as one of the fundamental factors, out of four, contributing to a project's success. Similarly, as per (Knipe *et al.*, 2002), effective communication is a key element for ensuring integration within projects. Moreover, improved communication between project stakeholders may lead to timely dissemination of appropriate information, improved relationship among stakeholders, less failure, and technical solutions, that would ultimately positively influence the performance of a project. According to (Omale, 2011), completion of a project as per the triple constraints is a reflection of capability and efficacy, the credit of which can only be given to effective communication of relevant information during all phases of a construction project lifecycle.

On the contrary, since inflow of information in the construction industry is considered non-linear and dynamic in nature, ineffective communication of information among organizations and stakeholders leads towards non-completion of deliverables (Pozin *et al.*, 2018). (Tipili and Ojeba, 2014) suggest that over half of the projects are unsuccessful. They further state that poor and insufficient communication of information serves as a leading factor towards the failure of such projects. A publication by (PMI, 2013) emphasized such problems quoting that out of every US$ 1 Billion spent in the US construction industry, almost one-tenth is lost because of ineffective communication of information, asserting that many issues in the British construction industry are as a result of poor flow of information and data.

## 2.4 Communication and Its Role in Construction Projects

Communication is the process of acquiring all relevant information, interpreting this information and effectively disseminating the information to persons who might need it (Zulch, 2014). In construction, information is specially varied given the huge number of stakeholders involved in all the construction operations. Communication usually involves the transfer of information, a generic term that embraces meanings such as knowledge, processed data, skills and technology (Cheng *et al.*, 2001).

### 2.4.1 Information and its Communication in Construction

Communication and information management is a prime activity in construction. The entire construction process relies on vast quantities of information being generated, transmitted and interpreted to enable a project to be built, maintained, reused and eventually recycled. More specifically, construction industry participants are concerned with information exchange, dealing with drawings, specifications, cost data, programmes, plus other design and management information required for the successful completion of a building**.** Successful knowledge-based organizations have been shown to rely on the effective transfer of information (e.g. (Boist, 1998) and similarly good relations within a team or group are dependent on effective communication. Problems have been identified in relation to the ease and effectiveness of communications even in small ‘communication circles’ where the process is relatively simple and opportunity for interference is relatively low. In construction the information is usually prepared by individuals from diverse backgrounds, such as architects, engineers, sub-contractors and specialist suppliers, often using different terms and methods of graphical representation. Thus, verbal communication between two or more individuals is often concerned with resolving queries over the interpretation of the information provided.

### 2.4.2 The Importance of Effective Communication

Communication is a fundamental part of a construction project. Like any fundamental piece, it must be done in an effective way to ensure the success of the project (Pérez Gómez-Ferrer, 2017). It is needed to effectively communicate the areas of cost, scope and time, and quality, which are the results of the interrelationship between scope, cost and time (Zulch, 2014).

The efficiency and effectiveness of the construction process strongly depend on the quality of communication (Hoezen *et al.*, 2006). Communication is of vital importance to everyone involved in, and influenced by, projects (Emmitt, 2010). Ineffective communication can therefore also lead to misunderstanding in respect of construction projects. Inadequately defined tasks and critical processes, uncertainty regarding responsibilities, scope or objectives of construction projects may cause projects to fail (Zulch, 2014). As studied by Maslej (2006) poor communication during projects affects the schedule, the cost, the safety of workers and project quality. Similarly, improved communication by the project manager may lead to less failure, innovation and technical solutions, positively influencing the quality and leading to better decision making.

Any construction project that has a communication system to link its participants enjoys better flow of information and improved project functionality. Effective communication of information between project participants will ensure quick and accurate communication of technical information leading to easier decision making. It will improve teamwork, enhance quality, reduce conflicts and reworks, and then contribute to the project success (Yan *et al.*, 2006).

Berry and Verster propose that projects are run through effective communication. Cost, scope and time are the interrelated areas and change in one area affects the other two areas. Quality is the product of the interrelationship between scope, cost and time. Communication is the function that integrates cost, scope and time management to achieve a quality product. Communication is the area that integrates a project, and not solely integration, as illustrated in literature. Integration cannot be a trade-off between the areas without communication as support. Integration as an area cannot function without communication; thus, communication is seen as a more effective element that brings the areas together.

Effective communication is essential for the functioning of any organization. Breakdowns in communication contribute to a group of problems that result in low productivity and quality (Al-Reshaid and Kartam, 1999). The importance of communication can be assessed from the fact that it has been referred to as the lifeblood of a project by many practitioner (Awati, 2010). According to Olanrewaju *et al.* (2017) well-communicated information on project locations, type of projects, class of projects, and type of clients preempts overruns on both cost and time, would help to improve the project performance in terms cost, time, quality, sustainability, and comfort. Poor communications legitimate, problematize, and exacerbate change order, reworks, variations, and claims. Similarly, relationships among the parties to construction contracts can be improved with effective communication. Poor communication also affects ordering and payment with material suppliers.

Armstrong (2001) concisely summarizes the importance of communication in team projects:

- ***Achieving coordinated results*** – construction projects function by means of the collective actions of actors, but independent actions lead to outcomes incongruent with the project objectives. Coordinated outcomes, therefore demand effective communications.
- ***Managing change*** – most construction projects are subject to continuous change. This, in turn, affects their teams. Acceptance and disposition to embrace change is possible only if the reasons for this change are well communicated.
- ***Motivating workforces*** – the degree to which an individual is motivated to work effectively in the construction project is dependent upon the responsibility they have and the scope for achievement afforded by their role. Feelings in this regard will depend upon the quality of communications from senior managers within their projects.
- ***Understanding the needs of the workforce*** – within team projects, to be able to respond effectively to the needs of their employees, it is vital that they develop an efficient channel of communication. This two-way channel must allow the feedback from the workforce on organizational policy in a way that encourages an open and honest dialogue between employees at all levels, even at the top-level managers of the team.

Good communication is therefore a key piece and critical in achieving better cooperation and coordination across organizations in the business world. In construction the project team consisting of the owner, contractors, designers, and other parties all need to work together to achieve common goals. The project team needs to communicate over the life cycle of the project efficiently and effectively.

However, it is also important to understand the challenges and barriers to communication and data transfer that restrict project information and its effective communication among project participants which resultantly give rise to information complexity. These challenges and barriers are listed in the subsequent section in the form of factors affecting communication of information on projects.

### 2.4.3 Factors Leading to Complexity of Information Flow on Construction Sites

Information Complexity is a term contrary to Information Mobility and as mentioned earlier, it is defined as the barriers or challenges to communication and the flow of information and data. As fundamental good communication is to the entire construction process, the research conducted on communication as a whole is scarce in the construction industry (Gorse and Emmitt, 2003). The first part of this research aims at finding these barriers and challenges using literature and studies already conducted in this field of work. In the study carried out by (Olanrewaju *et al.*, 2017) various sources of communication problems were identified after surveying the Malaysian construction industry as well as through literature and experience. Similar study was carried out by Yan *et al.* (2006) to identify the factors that lead to complexity of information flow on construction sites. Many of these causative factors have been gathered through extensive literature review and presented irrespective of their ranks in Table 1 on the following page.

**Table 1** Factors leading to information complexity

| Sr No. | Causative Factors of Information Complexity | Sources |
|---|---|---|
| **1** | Lack of incorporation between stakeholders due to poor management | (Nipa *et al.*, 2019, Khan *et al.*, 2016, Bandulahewa, 2015) |
| **2** | Lack of integration among stakeholders to frequently share information | (Khan *et al.*, 2016, Khurana *et al.*, 2011) |
| **3** | Absence of formal platforms to address and manage information | (Khan *et al.*, 2016, Hoezen *et al.*, 2006) |
| **4** | Lack of effective communication between stakeholders | (Gamil and Rahman, 2018, Kamalirad *et al.*, 2017b, Dansoh *et al.*, 2017, Emuze and James, 2013) |
| **5** | Ineffective reporting system | (Sean and Li, 2018, Ejohwomu *et al.*, 2017) |
| **6** | Inadequate pre-planning by the sub-contractors | (Khan *et al.*, 2016, Murray *et al.*, 2007) |
| **7** | Lack of provision of clear and detailed information to the contractor by the design consultant | (Lee and Bernold, 2008) |
| **8** | Unclear or inadequate drawing details | (Rad and Kermanshachi, 2018, Bandulahewa, 2015) |
| **9** | Poor quality of the information content | (Ejohwomu *et al.*, 2017, Dansoh *et al.*, 2017) |
| **10** | Lack of appropriate communications medium | (Olaniran, 2015, Günhan *et al.*, 2012a, Murray *et al.*, 2007, Hoezen *et al.*, 2006) |
| **11** | Having more than required information at a time than can be utilized | (Doloi *et al.*, 2012) |
| **12** | Unclear classification of the information | (Rad and Kermanshachi, 2018, Liu *et al.*, 2006) |
| **13** | Lack of document management | (Khan *et al.*, 2016, Murray *et al.*, 2007) |
| **14** | The Project organizational structure | (Günhan *et al.*, 2012, Tai *et al.*, 2009) |
| **15** | Not getting the needful information at the right time | (Abdullahi A.H, 2016, Khurana *et al.*, 2011, Lee and Bernold, 2008, Liu *et al.*, 2006) |
| **16** | Frequent changes in project contract | (Nipa *et al.*, 2019, Kamalirad *et al.*, 2017, Laihonen *et al.*, 2014, Khurana *et al.*, 2011, Murray *et al.*, 2007) |
| **17** | Misinterpretation of instructions | (Olanrewaju *et al.*, 2017, Tipili and Ojeba, 2014) |
| **18** | Poor communication skills | (Gamil and Rahman, 2018, Olanrewaju *et al.*, 2017, Mohammed *et al.*, 2016) |
| **19** | Unclear channels of communication | (Sean and Li, 2018, Olaniran, 2015, Tipili and Ojeba, 2014, Tai *et al.*, 2009, Murray *et al.*, 2007) |
| **20** | Delay in accessibility to accurate information | (Abdullahi A.H, 2016, Olaniran, 2015, Khahro and Ali, 2014, Khurana *et al.*, 2011) |

| | | |
|---|---|---|
| **21** | Lack of uniform standards for construction information | (Günhan *et al.*, 2012) |
| **22** | Lack of communication procedure and training | (Khahro and Ali, 2014, Tipili and Ojeba, 2014) |
| **23** | Selective listening e.g. workers only tend to listen to what interests them or only listen to their favorite seniors | (Olanrewaju *et al.*, 2017, Hoezen *et al.*, 2006) |
| **24** | Slow flow of information between parties | (Laihonen *et al.*, 2014, Khurana *et al.*, 2011) |
| **25** | Absence of support for advanced communication technologies | (Nipa *et al.*, 2019, Kamalirad *et al.*, 2017, Emuze and James, 2013) |
| **26** | Unpleasant relationship between the stakeholders | (Sean and Li, 2018, Mohammed *et al.*, 2016, Doloi *et al.*, 2012, Murray *et al.*, 2007) |
| **27** | Different information needs of the participants related to the different project activities and different project stages | (Kamalirad *et al.*, 2017, Liu *et al.*, 2006) |
| **28** | Complexity of the project | (Ejohwomu *et al.*, 2017, Emuze and James, 2013, Günhan *et al.*, 2012, Murray *et al.*, 2007, Liu *et al.*, 2006) |

## 2.5 Defining Quality in Construction

Quality, as a term, has enormous meanings and definitions. As explained by Mallawaarachchi and Senaratne (2015), quality pertains to fulfilling the legal, functional and aesthetic requirements. Albeit, from the perspective of the construction industry it can be defined as successful completion of the deliverables as per the scope of the project, within the specified budget and time (Abas *et al.*, 2015). This implies that the definition of quality is dependent upon the perspective of the person defining it; some people view it as ‘Conformance to Specifications’, while others consider it ‘Value for Money’ (Reid and Sanders, 2007).

Quality is considered not only a desirable characteristic by stakeholders, but it is also a critical performance indicator that contributes to the success of construction projects and helps achieve expectations of clients and project participants (Khan *et al.*, 2008).

### 2.5.1 The Importance of Efficient Quality Performance on Construction Projects

In spite of quite a few performance indicators for a project, the development of the construction industry particularly is heavily dependent upon quality (Ashokkumar, 2014). In order to compete in the present market and to develop better relations with the stakeholders, it is important for the contractors to provide consistency in the quality of their work. Talking about consistency, improving quality should be one of the most important aims of the project since poor quality could add to project costs for the organization (Mallawaarachchi and Senaratne, 2015). Measuring costs of poor quality is one way of showing how it can financially affect an organization and why periodic improvements in quality need to be done (Josephson *et al.*, 2002). Poor quality cost refers to the failure, appraisal and prevention costs that stand as the three major categories connected with poor quality (Rodchua, 2006). As per (Love *et al.*, 2017), quality failure costs in the construction industry lie in the range between 1 % to one-fifth of a project's original contract amount. Apart from that, poor quality can also result in a loss of productivity, added costs in the form of rework and finally being put out of business (Jha and Iyer, 2006).

In previous studies, it has been found that successfully achieving all project objectives direct towards quality of the final product. However, various studies have discussed the reasons behind the lack of achievement of quality on construction projects such as (Hussain *et al.*, 2018). The author classified Stakeholder related factors such as poor relationship among project team, absence of contractor supervision, lack of management commitment and site-related factors such as lack of skilled workers, improper coordination between on-site project team, and inadequacy of experienced project managers as the basic factors affecting construction quality in Pakistan. Likewise, the Chinese construction industry is also facing quality problems. A study by (Gan *et al.*, 2017) observed Chinese construction projects and determined that absence of design criteria, lack of quality management principles and lack of coordination and communication between different groups of designers were the most influential factors that affect project quality in China. Similarly, a study by (Joy, 2014) highlighted empirical research in India that incomplete design, poor communication and lack of support from upper management were the top three most contributing factors. A study was carried out by (Farooqui and Ahmed, 2008) on analyses of the

Pakistani construction industry. The authors found out that escalation, selection of material and low-level communication were the prime factors that influence quality.

The importance of performing work to the expected quality level has been recognized by practitioners and project stakeholders in the construction industry since long. Some of its prominent benefits are;

- Improved employee job satisfaction
- Improved relationship with architects/engineers/clients
- Repeated customer engagement
- Improved schedule performance
- Reduced defects and rework
- Absence of claims
- Higher productivity

Having gone through similar literature on construction quality, most of the content suggested that the key factor affecting construction project quality is poor communication and information flow among project participants. Therefore, the second part of this research aims to determine the causative relation of information complexity on construction quality by identifying quality issues caused due to ineffective flow of information on project sites.

## 2.5.2 Factors Affecting Construction Project Quality

As mentioned earlier, quality is a key performance indicator like time and cost and is therefore important for all construction projects (Abas *et al.*, 2015). Among many key factors that affect the quality of a project, ineffective communication is considered an essential one. Results of various researches regarding factors affecting construction quality are mentioned in Table 2 on the following page:

**Table 2** Factors affecting construction quality

| | | |
|---|---|---|
| **1.** | **(Abas *et al.*, 2015)** | ▪ Continuous improvement<br>▪ Joint working<br>▪ Communication<br>▪ Technical person availability<br>▪ ISO Certification<br>▪ Procurement unit of contractor |
| **2.** | **(Joy, 2014)** | ▪ Design<br>▪ Lack of communication<br>▪ Conformance to codes and standards<br>▪ Co-operation of parties<br>▪ Top management support<br>▪ Financial issues<br>▪ Contract documents. |
| **3.** | **(Said and Usman, 2013)** | ▪ Lack of technical person availability<br>▪ Lack of awareness about quality management system<br>▪ Lack of trained workers |
| **4.** | **(Farooqui and Ahmed, 2008)** | ▪ Material Price Escalation<br>▪ Inflation<br>▪ Procurement<br>▪ Selection of Material<br>▪ Lack of Communication<br>▪ Poor on-site supervision |
| **5.** | **(Bezelga and Brandon, 2006)** | ▪ Management<br>▪ Improper Planning<br>▪ Carelessness<br>▪ Lack of training<br>▪ Improper use of materials |
| **6.** | **(Jha and Iyer, 2006)** | ▪ Bad weather condition<br>▪ Communication Problem<br>▪ Lack of project management skills<br>▪ Low Bids due to excessive competition |
| **7.** | **(Rustom and Amer, 2006)** | ▪ Availability of construction materials<br>▪ Political environment<br>▪ Site staff experience<br>▪ Proper documentation |
| **8.** | **(Chan and Tam, 2000)** | ▪ Project Client involvement<br>▪ Effective project management<br>▪ Building effective construction team<br>▪ Project environment |
| **9.** | **(Arditi and Gunaydin, 1998)** | ▪ Continuous improvement<br>▪ Training of employees<br>▪ Effective communication<br>▪ Building an effective project team |
| **10.** | **(Samuels, 1994)** | ▪ Lack of trust with supplier<br>▪ Poor training system<br>▪ Communication gap among project participants |

Quality is an essential element for sustainability and customer satisfaction. The need for achieving quality of the finished product is therefore very important. It is evident from the table that along with numerous other factors affecting quality, effective communication of information is identified by majority of researchers that conclude ineffective information flow as one of the major reasons affecting construction project quality.

### 2.5.3 Cost of Poor Quality

Construction projects are always expected to create a balance between cost, time and quality. Even though, improving quality is not always the major objective of the project; the poor quality could create cost to organization (Mallawaarachchi and Senaratne, 2015). Measurement of these costs are one way of finding out how poor quality can influence an organizations' performance and why periodic improvements in quality are necessary (Josephson *et al.*, 2002). There is reported in several studies that costs of poor quality may be in the size of 25-30% of the organization's turnover (e.g. (Sörqvist, 1998). Despite being aware of the facts, some organizations tend to ignore the systematic measurement of costs of poor quality which could otherwise lead to actions to reduce them. The cost of poor quality refers to all costs that are incurred due to provision of poor-quality service or product. These costs can be categorized into three major categories as costs due to failure, appraisal and prevention (Rodchua, 2006). Costs that are incurred due to prevention activities or reduction of errors are called prevention costs. Appraisal costs could incur while measuring, evaluating or auditing to assure the quality conformance. Finally, failure cost could be occurred as internal or external failures. Internal failure cost could include rework, scrap, re-inspection, re-testing, re-design, material review etc. While external failure costs include processing customer complaints, customer returns, warranty claims and repair costs, product liability and product recalls (dos Reis Almeida, 2011).

Quality failure costs in construction have been reported to range from less than 1 to over 20% of a project's original contract's value (OCV) (Love *et al.*, 2018). Hall and Tomkins (2001) sought to quantify the total quality related costs in the construction of an office development of low technical complexity in southern England. The site staff was responsible for recording the failures detected during construction in "log sheets". The total cost of quality failures was 5.84% of the contract sum while prevention and appraisal activities accounted for 12.68%. The cost of failures was almost entirely the cost of resources (labour, materials and plant) used in their correction. The largest portion of the cost of failures was caused by “suppliers”, being responsible for 55.03% of these costs. This category also includes the failures attributed to subcontractors. Prevention and appraisal costs were obtained by the review of document sources, specially the bill of quantities. The research team evaluated the cost of the delays arising from failures in activities in the project critical path. This exercise showed that delays cost 1.11% of the project cost. Since delays are a subset of quality failures, the direct cost of failures was 4.73% of the contract sum (dos Reis Almeida, 2011).

### 2.5.4 Key Performance Indicators for Quality in the Construction Industry

When compared to performance measurement indicators such as cost and schedule, quality usually does not take a priority in the project lifecycle (Song *et al.*, 2004). There is a consensus among professionals of the construction industry that the solution to this problem lies in forming quality management at all levels of design, procurement and construction (Sodangi *et al.*, 2010). Providing better quality of work is increasingly becoming a way for companies to differentiate themselves from their competitors as well as win more projects. However as pointed out earlier, cost and time are the most commonly implied indicators for performance measurement that in isolation do not provide a balanced view of a construction company’s efficiency. In order to meet this challenge, the companies must devote their efforts in identifying ways to measure quality performance through performance indicators that are enough to comprehensively assess the effectiveness of a construction project. Therefore, in this research, key performance indicators for measuring quality performance have been established through literature. These indicators will provide way to determine how information complexity factors have an influence on the quality outcomes of a project. For this purpose, KPIs of Quality in the construction industry are listed in Table 3. It also includes normalized literature score of each indicator obtained by qualitatively scoring it based on the indicator’s frequency and ranking in respective research articles.

**Table 3** Identification of KPIs of quality via literature

| Sr. No | Key Performance Indicators of Quality | Sources |
|---|---|---|
| **1** | Conformance to specifications | (Leong *et al.*, 2014, Yeung *et al.*, 2013, Ali and Rahmat, 2010, Sodangi *et al.*, 2010, Song *et al.*, 2006) |
| **2** | Value for money | (Ali *et al.*, 2013, Takim and Akintoye, 2002, Rad and Khosrowshahi, 1998) |
| **3** | Fit for purpose | (Shaikh and Darade, 2017, Leong *et al.*, 2014, Ali and Rahmat, 2010, Takim and Akintoye, 2002, Rad and Khosrowshahi, 1998) |
| **4** | Stakeholder satisfaction | (Leong *et al.*, 2014, Yeung *et al.*, 2013, Ali *et al.*, 2013, Ali and Rahmat, 2010, Radujković *et al.*, 2010, Takim and Akintoye, 2002, Kagioglou *et al.*, 2001, Rad and Khosrowshahi, 1998) |
| **5** | Customer engagement | (Leong *et al.*, 2014, Sodangi *et al.*, 2010, Ali and Rahmat, 2010, Song *et al.*, 2006) |
| **6** | Defects and quality errors | (Sibiya *et al.*, 2015, Ali *et al.*, 2013, Radujković *et al.*, 2010, Sodangi *et al.*, 2010, Takim and Akintoye, 2002, Kagioglou *et al.*, 2001) |
| **7** | Rework | (Ali *et al.*, 2013, Yeung *et al.*, 2013, Radujković *et al.*, 2010, Song *et al.*, 2006) |
| **8** | Wastage and scrap | (Ali *et al.*, 2013, Sodangi *et al.*, 2010) |
| **9** | Incidents (Health and Safety) | (Sibiya *et al.*, 2015, Leong *et al.*, 2014, Yeung *et al.*, 2013, Radujković *et al.*, 2010, Takim and Akintoye, 2002) |
| **10** | Schedule and budgetary performance | (Yeung *et al.*, 2013, Ali *et al.*, 2013, Ali and Rahmat, 2010, Radujković *et al.*, 2010) |
| **11** | Warranty claims and disputes | (Ali *et al.*, 2013, Yeung *et al.*, 2013, Radujković *et al.*, 2010, Ali and Rahmat, 2010, Takim and Akintoye, 2002) |
| **12** | Implementation of Quality Management Plan and Improvement Techniques | (Ali *et al.*, 2013, Yeung *et al.*, 2013, Ali and Rahmat, 2010, Sodangi *et al.*, 2010, Takim and Akintoye, 2002) |

## 2.6 System Thinking Approach for Addressing Information Complexity

The concept behind Systems Thinking (ST) is to comprehend the basic structure of the system by reliably deducing about its behavior (Richmond, 1994). Senge (2006) suggested that systems thinking is concerned with the relationship between elements. Since variables of a system have complicated relationships among them, systems thinking approach aids in studying the feedback behavior of each variable and its effect on other variables. However, while deriving these relationships, this approach focuses on the whole system rather than taking a partial view of the project and is therefore a viable and efficient method to understand as well as address complexity within a system (Khan *et al.*, 2016).

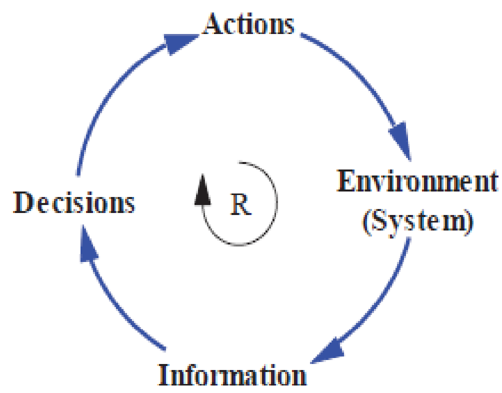

**Figure 4** SD Feedback Mechansim

Systems thinking is concerned with a feedback mechanism of information-decision-action and influence on the environment as shown in the figure (Olaya, 2012). This feedback mechanism provides the dynamic hypothesis with the power to diagnose the problems and visualize the behavior of the system under different scenarios (Sterman, 2000). Since a complex system constitutes of several variables and hence multiple relationships, this approach can help analyze the cause-and-effect relationship between all those variables and hence is a suitable approach towards understanding a complex system. Figure 5 below best describes this approach.

In this research, Qualitative Systems Thinking principles will be applied to understand and analyze causal feedback relationships among various factors. This will be done by establishing causality between information complexity and quality performance indicators leading to the identification of quality issues caused due to ineffective information and its communication. The study will assist project managers and leaders by providing them a ground to comprehend the management of complexity of information flow in their projects and develop mechanisms to evaluate possible solutions to problems. This will also enable project stakeholders to take appropriate on-site decisions to reduce the influence of information complexity and, at the same time, improve construction project quality.

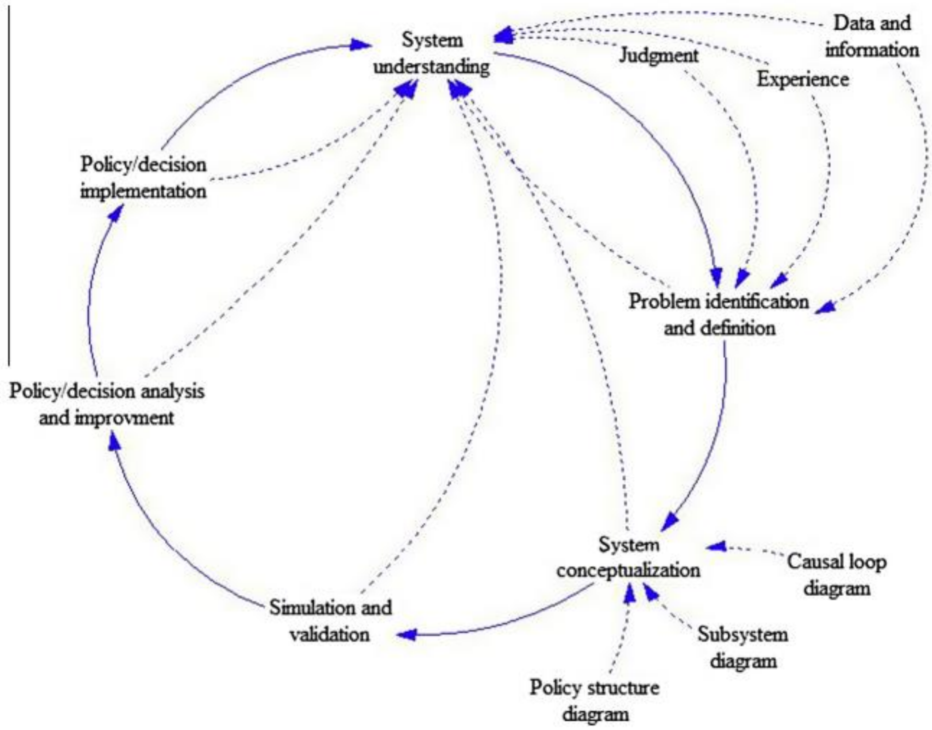


**Figure 5** Qualitative System Dynamics Approach **Source**: (Aslani *et al.*, 2014)

## CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Introduction

The research undertaken is a 'Desk and Field Research' meaning that some of the information is obtained indoors via literature while some is collected through questionnaires and interviews. The research phase is comprised of a four-stage process as shown in Figure 6.

## 3.2 Research Problem Statement

The intent and direction for the collection and treatment of data is very well defined by posing research questions. Following questions are the main drivers that address research issues:

1) What factors lead to information complexity on construction sites?
2) What are the ill-effects or influence of information complexity on construction quality?
3) How to improve flow of information on construction projects leading to improved quality performance?

Responses to the above research questions will not only help understand relation between information complexity and quality of construction but also help in proposing a viable solution to the problem that results in improved quality performance for construction industry.

## 3.3 Research Objectives

1. To identify **a)** the factors that lead to information complexity on construction sites and **b)** key performance indicators of quality in the construction industry.

2. To determine the causative relation of complexity of information flow on the quality of construction projects using systems thinking approach.

3. To make recommendations in order to address information complexity leading to improved project performance.

## 3.4 Research Design

The research phase comprised of a four-stage process as shown in Figure 6.

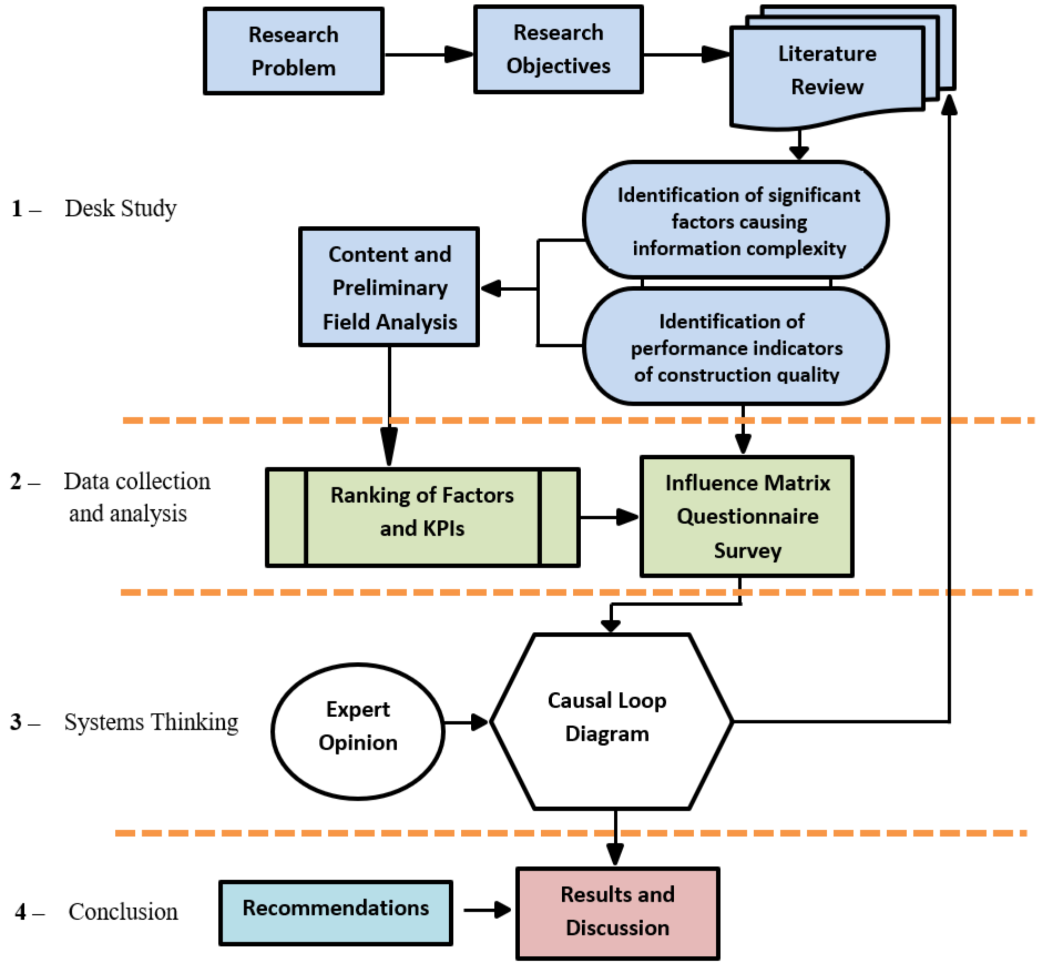


**Figure 6** Schematic representation of research methodology.

In stage one; the problem statement was identified by carrying out a critical review of literature followed by conceiving the research objectives of the study. Using these objectives as the basis of this study, an extensive literature review was conducted. For the same purpose, research articles published between the years 2005-2019 (except a few published earlier ) were studied by consulting Google Scholar, Scopus, Taylor and Francis, Emerald Insight, American Society of Civil Engineers and various other libraries and conference proceedings by using the key words "construction management", "information management", "construction quality", "information complexity" and "key performance indicators". By doing so, 25 relevant articles were retrieved that helped identify significant factors causing complexity of information flow on construction sites (see Table 1) while 11 articles were extracted that helped determine key performance indicators of construction quality (see Table 3).

Since there is relatively very little literature in terms of Pakistan, the importance of factors and indicators reported in the literature could not be assumed to be the same as that of local context. Therefore, a content analysis was conducted that included a) a two-part literature analysis based on relevant articles, and b) a preliminary pilot survey to calculate and assign literature and industry scores to both factors and indictors. In the first part of the literature analysis, frequency of occurrence of each factor and indicator in literature was observed and accumulated, while in the second part, contextual significance i.e. qualitative score relatively assessed in the form of qualitative importance by the respective authors was considered on a three-point Likert scale (1=Low, 3=Medium and 5=High) . Thereafter, a literature score was assigned to each factor and indicator by simply obtaining the product of its accumulated frequency and qualitative score. Prior to ranking them in a descending order, these literature scores were normalized. Furthermore, to improve the contextualization and promote local context, a preliminary pilot survey was performed. Two different preliminary questionnaire surveys were formulated and circulated to 30 experts having an average experience of over 10 years in the field of project management and construction quality to signify the factors causing information complexity in the construction sector and signify performance indicators of construction quality respectively. Based on expert feedback, normalized industry scores were calculated by using mode values against all responses obtained from the survey and subsequently ranked in descending order. The detail of the preliminary surveys is shown in Table 4.

**Table 4** Preliminary Survey Respondent's demographics

| **Organization Type** | **No. of responses** | **Years of experience** | **Total No.** | **Education Level** | **Total No.** |
|---|---|---|---|---|---|
| Client | 14 | 0-5 | 20 | Diploma | 1 |
| Contractor | 9 | 6-10 | 10 | Bachelors | 15 |
| Consultant | 11 | 11-15 | 3 | Masters | 21 |
| Subcontractor/ Specialist contractor | 1 | 16-20 | 5 | Doctorate | 3 |
| Designer | 2 | 21 & above | 2 | | |
| Academia | 3 | | | | |
| **Total** | **40** | | | | |

## 3.5 Data Collection and Analysis

The second stage of research phase involved screening out factors and indicators of lesser importance through simple additive weighting method (Ahmad *et al.*, 2018) and ranking the most important ones accordingly. By using the literature and industry scores calculated earlier, both the factors and performance indicators were assigned cumulative scores by following different weighting distributions (Literature/Industry) e.g. 30/70, 40/60 and 50/50. Then a statistical check (One-Way ANOVA) was performed to see if there is any statistically significant variation between the ranks of different variables when assessed through different weighting distributions. The p-value of 0.85 suggested non-significant difference, and so giving respective thought to the industry experts and hence the 40/60 weighting distribution, 14 significant causative factors of information complexity (see Table 5) and 6 key performance indicators of quality (see Table 6) were selected based on 60% commutative score to encompass maximum influence. The details of the factors with their ranking along with cumulative normalized scores are shown in Table 5, while similar details for KPIs are shown in Table 6.

**Table 5** Assessed causative factors of information complexity

| Description of Factor | Normalized Score | Cumulative Score | Rank |
|---|---|---|---|
| Lack of effective communication between stakeholders | 0.070 | 0.070 | 1 |
| Absence of formal platforms to address and manage information | 0.051 | 0.121 | 2 |
| Lack of appropriate communications medium | 0.050 | 0.171 | 3 |
| Absence of support for advanced communication technologies | 0.047 | 0.218 | 4 |
| Not getting the needful information at the right time | 0.045 | 0.263 | 5 |
| Delay in accessibility to accurate information | 0.044 | 0.307 | 6 |
| Poor quality of the information content | 0.043 | 0.350 | 7 |
| Poor communication skills | 0.043 | 0.393 | 8 |
| Unclear or inadequate drawing details | 0.041 | 0.434 | 9 |
| Complexity of the project | 0.040 | 0.474 | 10 |
| Frequent changes in project contract | 0.040 | 0.514 | 11 |
| Unpleasant relationship between the stakeholders | 0.038 | 0.552 | 12 |
| Unclear channels of communication | 0.037 | 0.589 | 13 |
| Slow information flow between parties | 0.036 | 0.625 | 14 |

**Table 6** Assessed key performance indicators of quality

| Description of Performance Indicator | Normalized Score | Cumulative Score | Rank |
|---|---|---|---|
| Conformance to specifications | 0.132 | 0.132 | 1 |
| Stakeholder satisfaction | 0.118 | 0.250 | 2 |
| Defects and quality errors | 0.105 | 0.355 | 3 |
| Rework | 0.093 | 0.448 | 4 |
| Implementation of quality management plan and improvement techniques | 0.092 | 0.540 | 5 |
| Value for money | 0.079 | 0.619 | 6 |

Since content analysis represents past research trends using secondary data, primary data collection was considered necessary. The objective of primary data collection was to explore the part played by information complexity in quality performance of a construction project. Thus, a need was felt to carry out an international survey to ensure and improve the reliableness and effectiveness of this research that involved collecting data from developing nations to be used for further analysis. In order to select these countries, Inclusive Development Index (IDI) was considered that measures progress of the countries set by World Economic Forum (2018).

To begin with the data collection, an influence matrix questionnaire was prepared through Google™ Docs platform (Rasul *et al.*, 2019). It comprised of two sections; the first section inquired personal information from respondents such as country of occupation, qualification, experience, organization role etc. The second section that followed required the respondents to identify the influence of each causative factor of Information Complexity on Key Performance Indicators of Quality using a 3-point Likert Scale (1=Low, 3=Medium and 5 =High).

As generally acknowledged, a sample size of 96 or above is required to ensure a representative sample (Dillman, 2011). Therefore, in order to obtain relevant and rational data, a total of 180 experts were selected by evaluating their profiles and relevance to the construction quality and management field through LinkedIn and other research network sites such as Research Gate. These experts belonged to both multi-national and local construction firms and the four major internal stakeholder categories i.e. client, contractor, consultant and designer. The reason for considering only these stakeholders was their contractual obligation and legal association with the project (Irfan *et al.*, 2019).

The survey was conducted between the months of June-August 2019, and in result, 109 responses were gathered giving a 61% response rate. Once the data was collected and before proceeding on to draw inferences from the data, responses were evaluated using basic statistical tools to check for the reliability, consistency and normality of the responses through IBM™ SPSS® Statistics. For measuring the data's reliability and consistency, Cronbach's coefficient alpha method was implied while Shapiro-Wilk test was used for the measurement of normality. Minimum acceptable alpha value for reliability is 0.7 (Wang *et al.*, 2019). The collected data had Cronbach's alpha value of 0.813 that ensured that the data was reliable as well as highly consistent. Similarly, Shapiro-Wilk test is used for evaluation of data distribution for a sample size less than 2000 (Zahoor *et al.*, 2016). The results indicated that the data was not normally distributed since all 84 Likert Scale inquiries had significance values less than 0.05, which necessitated the use of non-parametric analysis. Thereupon, Kruskal-Wallis test was performed to look for disparities in the distributions of data among groups. The results showed that only 14 inquiries had p-value less than 0.05 which suggested that the respondents had perception differences regarding only 14 of the total inquiries.

After having evaluated the responses using basic statistical tools, an analysis technique to rank the likert-scale data was required. Usually during the questionnaire development stage, one can decide what type of analysis is required for Likert items (Boone and Boone, 2012). Since the questionnaire for this research was prepared based on combined measurement of factors, therefore Relative Importance Index (RII) method was implied to rank the deduced relations using importance indices, as distinguished by respondents. Data collection through questionnaires revealed 84 relations between the causative factors of information complexity and KPIs of quality that are shown in Table 7 below.

**Table 7** RII Scores for information complexity factors affecting construction quality

| Sr. No | Key Performance Indicators of Quality | Causative Factors of Information Complexity | Weighted RII Score |
|---|---|---|---|
| 1 | **Conformance to Specifications** | Lack of effective communication between Stakeholders | 0.818182 |
| | | Lack of formal systems and platform to manage information | 0.664646 |
| | | Lack of appropriate communications medium | 0.753535 |
| | | Lack of support for advanced communication technologies | 0.620202 |
| | | Not getting the needful information at the right time | 0.842424 |
| | | Delay in accessibility to accurate information | 0.818182 |
| | | Poor quality of information content | 0.806061 |
| | | Poor communication skills | 0.70101 |
| | | Insufficient drawing details/inexperienced interpretation of working drawings | 0.894949 |
| | | Complexity of the project | 0.656566 |
| | | Frequent changes in project contract | 0.741414 |
| | | Unpleasant relationship between stakeholders | 0.652525 |
| | | Unclear channels of communication | 0.705051 |
| | | Slow information flow between parties (Client and Consultant/Contractor) | 0.765657 |
| 2 | **Stakeholder Satisfaction** | Lack of effective communication between Stakeholders | 0.846465 |
| | | Lack of formal systems and platform to manage information | 0.713131 |
| | | Lack of appropriate communications medium | 0.70101 |
| | | Lack of support for advanced communication technologies | 0.583838 |
| | | Not getting the needful information at the right time | 0.69697 |
| | | Delay in accessibility to accurate information | 0.668687 |
| | | Poor quality of information content | 0.729293 |
| | | Poor communication skills | 0.810101 |
| | | Insufficient drawing details/inexperienced interpretation of working drawings | 0.684848 |
| | | Complexity of the project | 0.721212 |
| | | Frequent changes in project contract | 0.757576 |
| | | Unpleasant relationship between stakeholders | 0.886869 |
| | | Unclear channels of communication | 0.713131 |
| | | Slow information flow between parties (Client and Consultant/Contractor) | 0.725253 |
| 3 | **Defects and Quality Errors** | Lack of effective communication between Stakeholders | 0.822222 |
| | | Lack of formal systems and platform to manage information | 0.713131 |
| | | Lack of appropriate communications medium | 0.753535 |
| | | Lack of support for advanced communication technologies | 0.680808 |

| | | | |
|---|---|---|---|
| | | Not getting the needful information at the right time | 0.870707 |
| | | Delay in accessibility to accurate information | 0.866667 |
| | | Poor quality of information content | 0.842424 |
| | | Poor communication skills | 0.717172 |
| | | Insufficient drawing details/inexperienced interpretation of working drawings | 0.874747 |
| | | Complexity of the project | 0.737374 |
| | | Frequent changes in project contract | 0.761616 |
| | | Unpleasant relationship between stakeholders | 0.644444 |
| | | Unclear channels of communication | 0.725253 |
| | | Slow information flow between parties (Client and Consultant/Contractor) | 0.769697 |
| **4** | **Rework** | Lack of effective communication between Stakeholders | 0.761616 |
| | | Lack of formal systems and platform to manage information | 0.664646 |
| | | Lack of appropriate communications medium | 0.749495 |
| | | Lack of support for advanced communication technologies | 0.620202 |
| | | Not getting the needful information at the right time | 0.846465 |
| | | Delay in accessibility to accurate information | 0.814141 |
| | | Poor quality of information content | 0.789899 |
| | | Poor communication skills | 0.652525 |
| | | Insufficient drawing details/inexperienced interpretation of working drawings | 0.907071 |
| | | Complexity of the project | 0.705051 |
| | | Frequent changes in project contract | 0.806061 |
| | | Unpleasant relationship between stakeholders | 0.668687 |
| | | Unclear channels of communication | 0.729293 |
| | | Slow information flow between parties (Client and Consultant/Contractor) | 0.789899 |
| **5** | **Implementation of Quality Management Plan and Improvement Techniques** | Lack of effective communication between Stakeholders | 0.806061 |
| | | Lack of formal systems and platform to manage information | 0.777778 |
| | | Lack of appropriate communications medium | 0.69697 |
| | | Lack of support for advanced communication technologies | 0.688889 |
| | | Not getting the needful information at the right time | 0.680808 |
| | | Delay in accessibility to accurate information | 0.680808 |
| | | Poor quality of information content | 0.648485 |
| | | Poor communication skills | 0.737374 |
| | | Insufficient drawing details/inexperienced interpretation of working drawings | 0.664646 |
| | | Complexity of the project | 0.80202 |
| | | Frequent changes in project contract | 0.644444 |
| | | Unpleasant relationship between stakeholders | 0.753535 |
| | | Unclear channels of communication | 0.705051 |

| | | | |
|---|---|---|---|
| | | Slow information flow between parties (Client and Consultant/Contractor) | 0.676768 |
| 6 | **Value for Money** | Lack of effective communication between Stakeholders | 0.765657 |
| | | Lack of formal systems and platform to manage information | 0.749495 |
| | | Lack of appropriate communications medium | 0.721212 |
| | | Lack of support for advanced communication technologies | 0.729293 |
| | | Not getting the needful information at the right time | 0.793939 |
| | | Delay in accessibility to accurate information | 0.753535 |
| | | Poor quality of information content | 0.737374 |
| | | Poor communication skills | 0.705051 |
| | | Insufficient drawing details/inexperienced interpretation of working drawings | 0.834343 |
| | | Complexity of the project | 0.818182 |
| | | Frequent changes in project contract | 0.842424 |
| | | Unpleasant relationship between stakeholders | 0.781818 |
| | | Unclear channels of communication | 0.713131 |
| | | Slow information flow between parties (Client and Consultant/Contractor) | 0.741414 |

However, the following formula of RII was used to establish importance indices for each relation (Azman *et al.*, 2019), and identify the most significant/immediate causative factors of information complexity that affect the quality of construction projects.

$$\text{Relative Importance Index}(RII) = \frac{\sum W}{A * N}$$ , where

w = weights assigned in Likert Scale (ranging between 1 and 5)

A = maximum weight assigned in the scale (i.e. 5 in this study),

N = total number of respondents (i.e. 109 for this study), and

The RII has a minimum and maximum value of 0 and 1 respectively.

It is important to note that considering all influences rather than immediate causes do not represent the structure of the system (Sterman, 2002). Studies carried out by Rooshdi *et al.* (2018), Rajgor *et al.* (2016), Megha and Rajiv (2013) and Kikwasi (2012) revealed that a criteria had to be formulated to categorize the responses according to importance levels obtained from respective RII scores. In this research a criteria similar to Rooshdi *et al.* (2018) was adopted that categorized RII scores ranging from 0 to 0.2 as 'Very Low', 0.2 to 0.4 as 'Medium-Low', 0.4 to 0.6 as 'Medium', 0.6 to 0.8 as 'Medium-High' and 0.8 to 1 as 'Very High'. In order to reduce the data set to a smaller set of summary variables, relationships having RII scores >= 0.8 were weighed as most important or most immediate, and hence considered for further analysis using Systems

Thinking. Table 8 shows the most immediate factors of information complexity that affect the quality of construction projects.

**Table 8** Immediate factors of information complexity based on RII scores

| Sr. No | Key Performance Indicators of Quality | Causative Factors of Information Complexity | Weighted RII Score |
|---|---|---|---|
| **1** | Conformance to Specifications | Slow information flow | 0.806061 |
| | | Lack of effective communication between Stakeholders | 0.818182 |
| | | Unclear or inadequate drawing details | 0.894949 |
| **2** | Stakeholder Satisfaction | Unclear channels of information flow | 0.810101 |
| | | Lack of effective communication between Stakeholders | 0.846465 |
| | | Unpleasant relationship between stakeholders | 0.886869 |
| **3** | Defects and Quality Errors | Lack of effective communication between Stakeholders | 0.822222 |
| | | Delay in accessibility to accurate information | 0.866667 |
| | | Unclear or inadequate drawing details | 0.874747 |
| **4** | Rework | Frequent changes in project contract | 0.806061 |
| | | Delay in accessibility to accurate information | 0.814141 |
| | | Unclear or inadequate drawing details | 0.907071 |
| **5** | Implementation of Quality Management Plan and Improvement Techniques | Complexity of the project | 0.802020 |
| | | Lack of effective communication between Stakeholders | 0.806061 |
| | | Unpleasant relationship between stakeholders | 0.810101 |
| **6** | Value for Money | Complexity of the project | 0.818182 |
| | | Unclear or inadequate drawing details | 0.834343 |
| | | Frequent changes in project contract | 0.842424 |

## 3.6 Systems Thinking

Stage three was carried out in two phases that involved data collection in the form of expert opinion to develop a cause and loop diagram showing influence of information complexity factors on quality performance indicators as a complex system. In the first phase, interviews were conducted from experts to establish polarities of the most immediate causal links that are listed in Table 8. This data was utilized to develop a CLD that indicated significant loops. In the second phase, while feedback loops are based on closed chains of cause and effect (Sterman, 2002), the same experts were asked to classify each feedback loop based on its strength and speed of influence. Using this loop-based classification the most critical loops in the system were identified. The respondents in this interview were industry experts having average experience of over 21 years occupying different positions in construction organizations such as project manager, construction manager, planning engineer and structural engineer. The concept of sample saturation (Bernard and Bernard, 2013) was used to determine the sample size for the interviews. The author stated that the number of interviews required to reach data saturation could not be quantified, but it was what the researcher could take. Sample saturation was however achieved at the 11th interview.

In order to establish a graphical depiction of the causal links, an extensive software called VENSIM® was utilized. The CLD was developed using a chronological process that involved chronologically perceiving connections among variables (Rasul *et al.*, 2019). In the diagram, arrows were used to connect the variables directing their impact. All arrowheads were assigned a polarity that shows the nature of relationship between the two variables. A negative polarity (-) indicates an inversely proportional relationship (i.e. Increasing the independent variable decreases the dependent variable and vice versa) whereas a positive polarity (+) depicts directly proportional relationship between the two (i.e. Increasing the independent variable increases the dependent variable and vice versa.). This subsequently led to discussion and development of conclusions considering the project objectives and analysis conducted.

## 3.7 Demographics of Survey

The purpose of the primary survey was to target construction industry professionals including general managers, project managers, construction managers, contract specialists, design engineers as well as academicians serving in different parts of the world. Majority of the respondents had master's as minimum education (35%) while Diploma (4%) was the least found education among the respondents. Most of them were experienced in the range 6 to10 years (26%) where senior professionals having experience exceeding 21 years also constituted the mix (14%). Majority of the respondents worked in Consultant organizations (28%) while professionals from Client (22%) and Contractor organizations (26%) were also found in abundance. One of the questions asked each respondent about their level of understanding of the topic, to which majority of the results revealed moderate to advanced understanding, which corroborates the quality of data. Table 9 provides information regarding respondent profiles.

**Table 9** Frequency distribution of responses

| Profile | Frequency | Percentage |
|---|---|---|
| **Total No. of Responses = 109** | | |
| **Education** | | |
| Diploma | 04 | 04% |
| Bachelors | 31 | 28% |
| Masters | 38 | 35% |
| Doctorate | 35 | 23% |
| Post-doctorate | 11 | 10% |
| | | |
| **Experience** | | |
| 0 to 5 years | 17 | 16% |
| 6 to 10 years | 28 | 26% |
| 11 to 15 years | 22 | 20% |
| 16 to 20 years | 26 | 24% |
| 21 & above | 16 | 14% |
| | | |
| **Role of Organization** | | |
| Client | 24 | 22% |
| Contractor | 28 | 26% |
| Consultant | 31 | 28% |
| Sub-contractor/Specialist contractor | 05 | 05% |
| Designer | 04 | 04% |
| Academia | 17 | 15% |
| | | |
| **Understanding of Study** | | |
| No understanding | 01 | 01% |
| Slight understanding | 15 | 14% |
| Moderate understanding | 67 | 61% |
| Advanced understanding | 26 | 24% |

## 3.7.1 Regional categorization of responses

Total 109 survey responses were gathered that included 48% national whereas 52% international responses. Major countries that participated in the survey include Pakistan, India, Turkey, Malaysia, Brazil, Ghana, Sri Lanka, Saudi Arabia, Jordon, Indonesia, Iran, Iraq, UAE, Egypt, Nepal and others as shown in Figure 7. All the responses were collected from third-world economies.

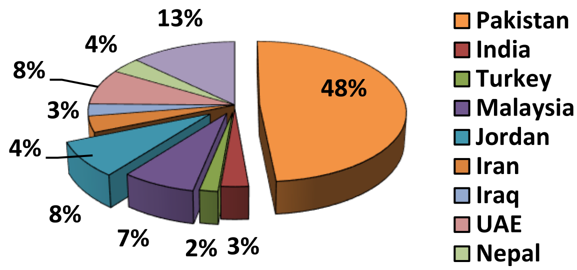


**Figure 7** Regional distribution of responses

### 3.7.2 Academic Qualifications

Responses were made by construction professionals having different academic backgrounds. Fig. 8 explains the respondents' highest academic qualification: Construction professionals having professional engineering degree were 53 (48%), with further masters were 38 (35%). Moreover, those having doctorate level of engineering education were 13 (12%) while those having post doctorate level of engineering education were only 1 (1%). The construction professionals at senior positions but with only Diploma of Civil Engineering numbered 4 (4%) of the total 109 respondents.

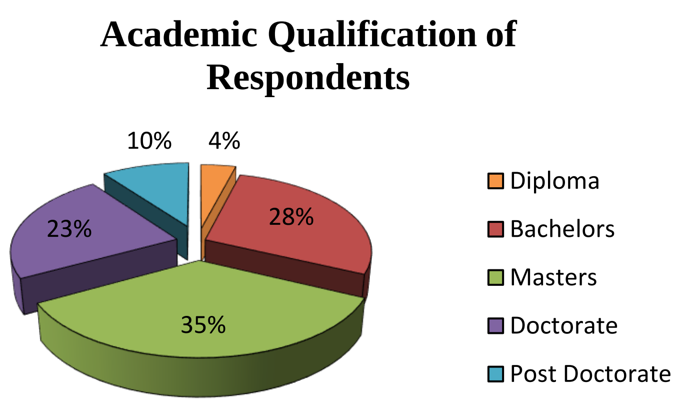


**Figure 8** Academic Qualifications of Respondents

### 3.7.3 Professional Experience

The respondents had varying years of professional experience. Fig. 9 demonstrates that 51 (47%) of respondents carried up to 5 years of experiences, while the next majority 28 (26%) had between 6-10 years of experience. Moreover, 11 (10%) respondents had 11-15 years, 6 (5%) respondents had 16-20 years, and 13 (12%) respondents had more than 20 years of professional experience in the construction industry.

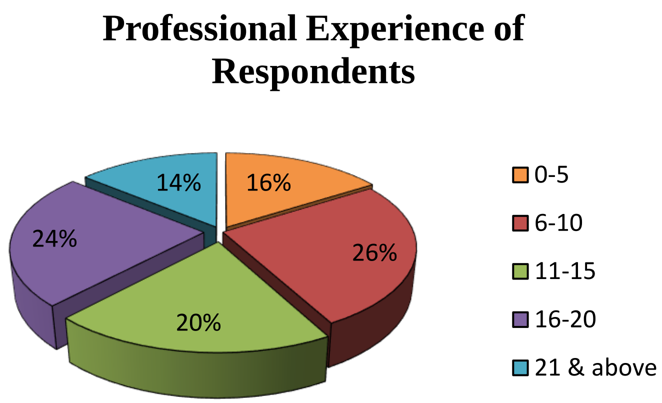


**Figure 9** Professional Experience of Respondents

### 3.7.4 Organization Role of Respondents

Another classification considered for the 109 respondents was their organization's role in the construction industry. Fig 10 shows that 24 (22%) respondents belong to client organizations, 31 (28%) to consultant, and 28 (26%) to principal contractor organizations. Remaining respondents are designers (4%), sub-contractors/specialist contractors (4%) and academicians (16%).

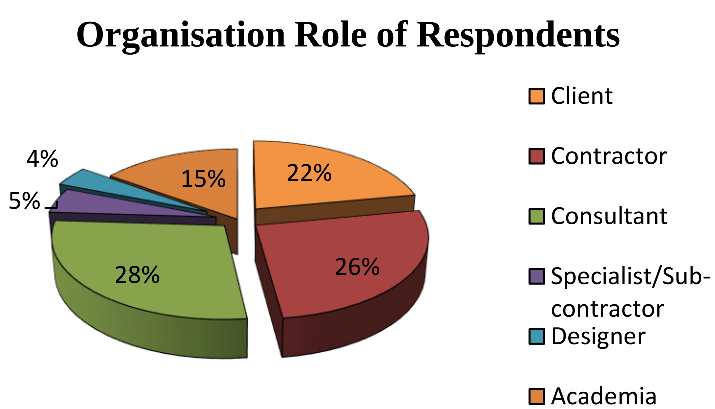


**Figure 10** Organization role of Respondents

### 3.7.5 Subject Understanding of Respondents

The respondents were asked about their understanding of information complexity and quality performance in the construction industry. Out of 109 respondents, 26 (24%) stated that they had advanced knowledge about the subject, 67 (61%) checked moderate, 15 (14%) checked slight while only 1 (1%) respondent stated that he had no understanding of the subject.

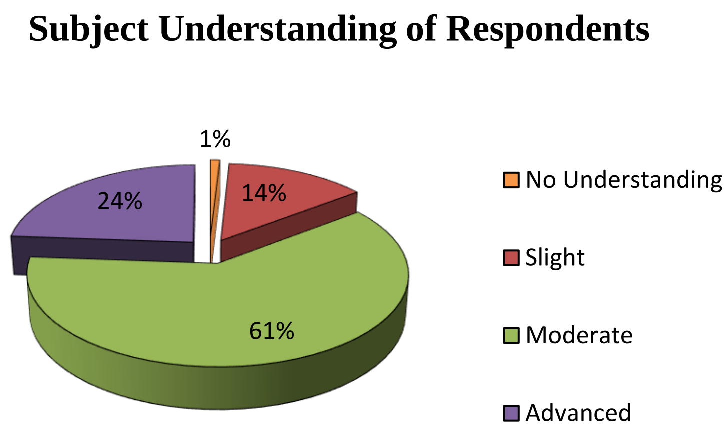


**Figure 11** Subject Understanding of Respondents

# CHAPTER 4

# RESULTS AND ANALYSIS

## 4.1 Effects of information complexity on project quality performance

As much as information mobility is crucial for the success of any project, challenges or impediments to the flow of information specifically in the construction industry may affect project performance and can lead to poor quality. Therefore, efficient information flow holds prime importance in construction projects. This requires delving deeper into the inter-dependencies that exist between various factors of information complexity to make better judgment of their influence on project quality performance. In order to assess these interactions qualitatively, a useful appraisal can be made by employing Causal Loop Diagrams that make it easy to identify the root cause of the problem being studied through representation of the loop structure (Hirsch *et al.*, 2007). A developed CLD shown in figure 12 facilitates a better comprehension as to how project quality is driven within a system. It, moreover, represents the chains of causality between two types of variables; information complexity and quality performance.

The CLD consists of six major loops, each representing the causality of information complexity on one of the quality indicators. The reinforcing or positive loops generate change in the same direction (increasing or decreasing) and are denoted by the letter 'R' whereas balancing or negative loops move variables in the opposite direction (i.e. counter change in every cycle) and are denoted by the letter 'B'. This CLD consists of two balancing loops and four reinforcing loops that provide an understanding of how quality performance is influenced within a system. It now helps us visualize the system with all its constituents and their interactions. So, by capturing these interactions, the causal loop diagram can help us understand not only the structure of the system but also the nature of these relationships. All loops are identified and explained below.

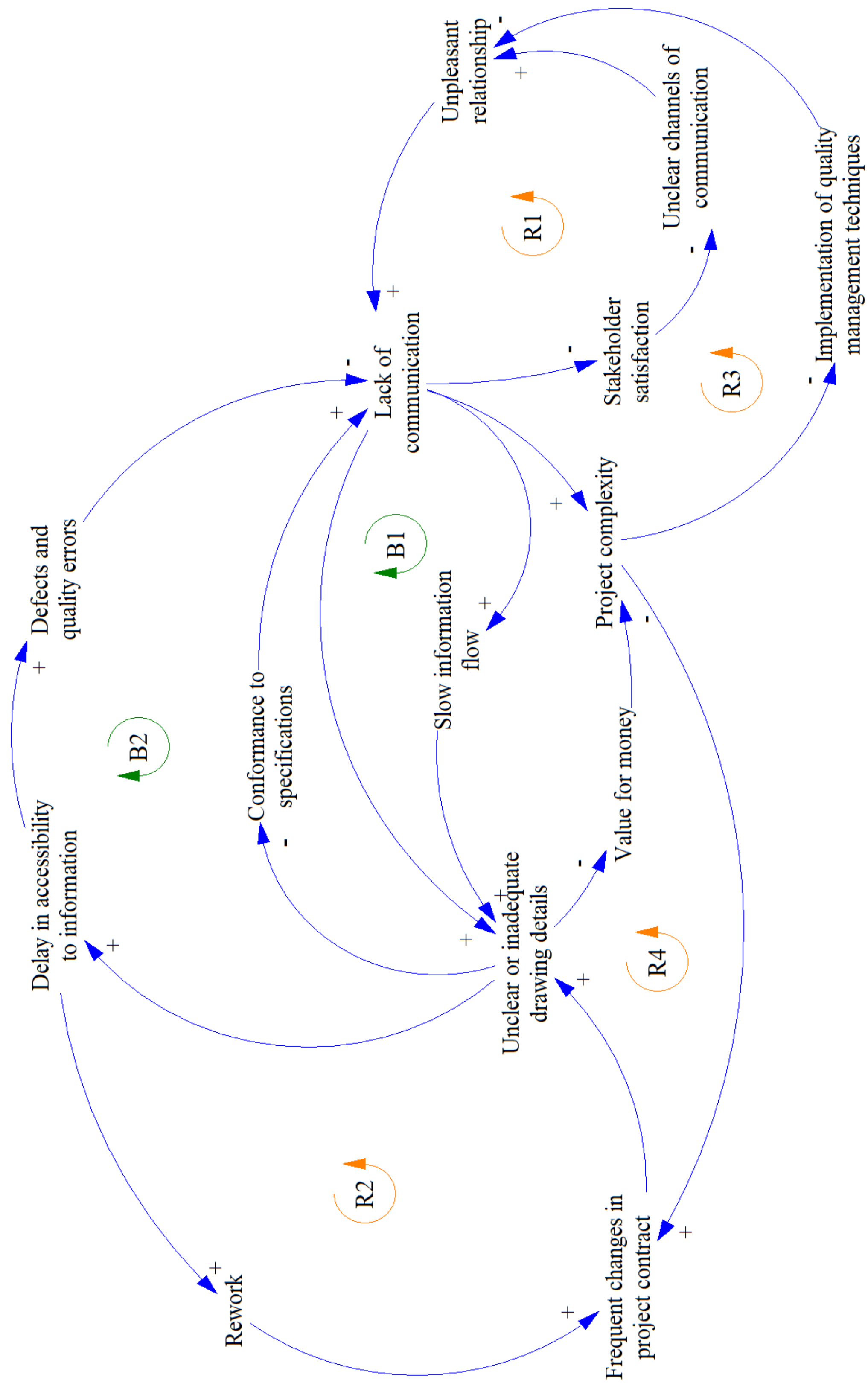


**Figure 12** The CLD of information complexity and project quality

### 4.1.1 Loop B1 - conformance to specifications

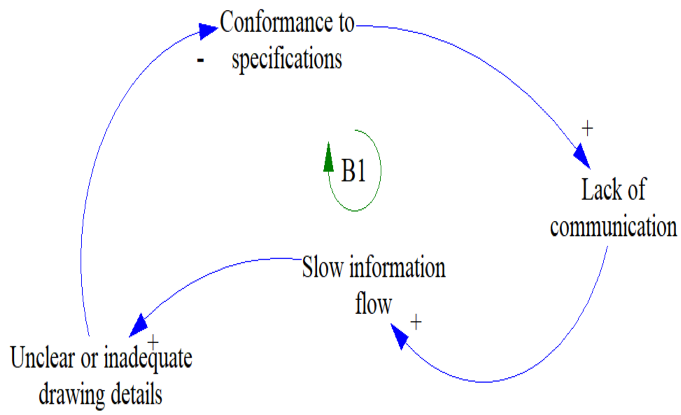


**Figure 13** Loop B1

Loop B1 in Figure 13 shows that if lack of communication between project stakeholders is not catered, it will cause a decrease in conformance to specifications. Flow of information is critical to any organization. When there is lack of effective communication between consultants in a construction project, information flow tends to be slow and irregular. Slow information flow means lack of integration between them to share information which results in unclear and inadequate details and specifications in drawings. Since drawings and specifications are holistically followed on construction sites, unclear or inadequate details will result in a decrease in conformance to specifications. However, impacts of non-conformance to specifications can be seen immediately and in order to put project quality back on track, managers tend to decrease the lack of communication between project parties through increased coordination. Therefore, loop B1 carries a strong and fast influence that is identified to be self-balancing.

### 4.1.2 Loop R1 - stakeholder satisfaction

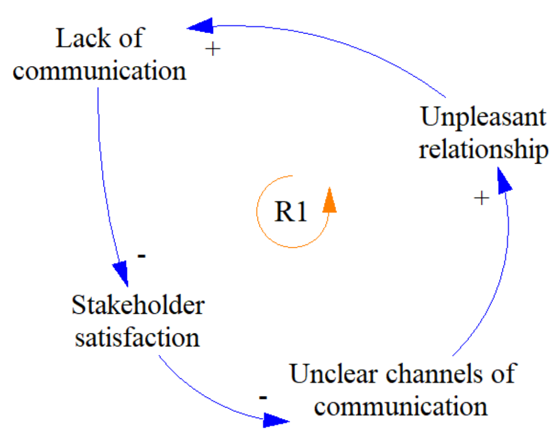


**Figure 14** Loop R1

Loop R1 in Figure 14 indicates that an increase in unclear channels of communication in a project results in a decrease in stakeholder satisfaction. Communication is the key to all healthy and productive relationships in an organization. To ensure smooth and effective communication within construction industry, it is critical to determine the most appropriate channels of communication within a project. Most consultants prefer emails as most appropriate channel to communicate and share information, while some stick to traditional channels such as mobile phones. Therefore, the use of different channels of communication among the stakeholders often leads to unpleasant relationship between them. Since every stakeholder has difference in preference, the loop shows that unclear channels of communication between project stakeholders ultimately lead to an increase in miscommunication. This is followed by a noticeable reduction in the stakeholder satisfaction. As satisfaction decreases, prime stakeholders may choose to show least interest which would deteriorate the communication procedures even further. Since stakeholder satisfaction is often assessed at the end of a project, this loop is acknowledged to carry a slow yet strong influence that is reinforcing in nature.

### 4.1.3 Loop B2 - defects and errors

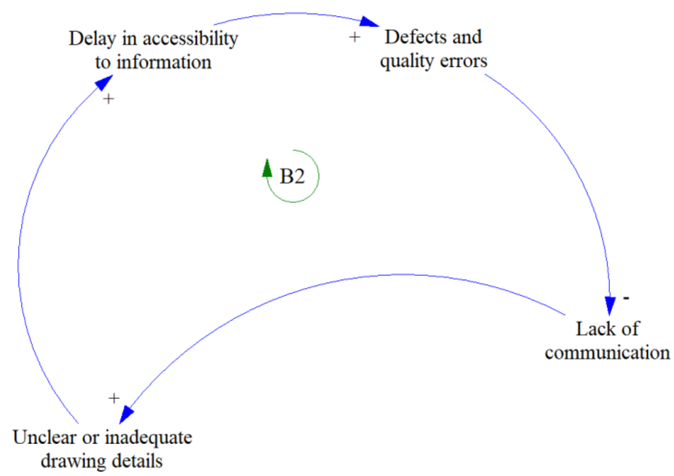


**Figure 15** Loop B2

Communication involves transfer of information between parties. While effective communication is crucial for project success, lack of communication can result in poor construction quality in the form of defects and quality errors. This is shown by loop B2 in Figure 15 which implies that as lack of communication between project stakeholders increases due to which design consultants are not regularly let in on project details, the chances of getting unclear or incomplete drawings increase. Since every project encompasses involvement of multiple stakeholders each with their own demands and requirements, unclear and inadequate details and specifications in drawings may lead to increased delays in accessibility to accurate information. While increased delays are hazardous to the budgetary and schedule performance of a project, they also have an increasing effect on defects and quality errors in the project. Considering the loop, increased defects and errors in the project may lead to dissatisfaction among the stakeholders who may impose penalty on contractors that ultimately leads to a decrease in lack of communication between them. Since design and construction go together, defects and errors can be seen almost immediately, hence the loop bears a fast and strong influence that is again self-balancing.

### 4.1.4 Loop R2 – rework

The loop R2 indicates that an increase in change orders, unclear details and/or delay in project information leads to an increase in rework that significantly influences the quality of construction. Frequent changes in the project contract conditions are usually known as change orders that have a crucial role in the construction industry since they largely impact the schedule, cost and quality of a project. With lots of change orders being generated on a project, the consultant tends to issue shop drawings with details that keep on changing with each change order that is issued. Resultantly due to unclear or repeatedly changing details in drawings, the contractor is likely to wait for final drawings that result in delay in accessibility to accurate information on site. While delays can result in disputes, contractors eventually must start with little details they have to avoid any claims but end up having to re-do the work. Again, delays in getting accurate information leading to rework can be instantly observed and recorded, thus this loop, shown in Figure 16, carries a strong and fast influence that is reinforcing in nature.

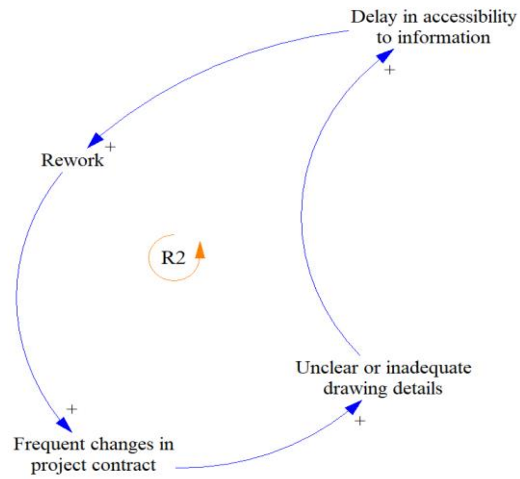


**Figure 16** Loop R2

### 4.1.5 Loop R3 - quality management

This loop shown in Figure 17 implies that an increase in poor relationship among stakeholders leads to a decrease in implementation of quality management principles and improvement techniques in construction projects. Identification of key stakeholders at the start of a project and addressing their needs and requirements often contributes to creating of a relatively fitter environment and a basis for project success. However, poor relationship between them can trigger a series of actions that can cause deterioration in achieving project objectives. Unpleasant relationships between stakeholders may lead to minimal or restricted communication between them. Ineffective communication

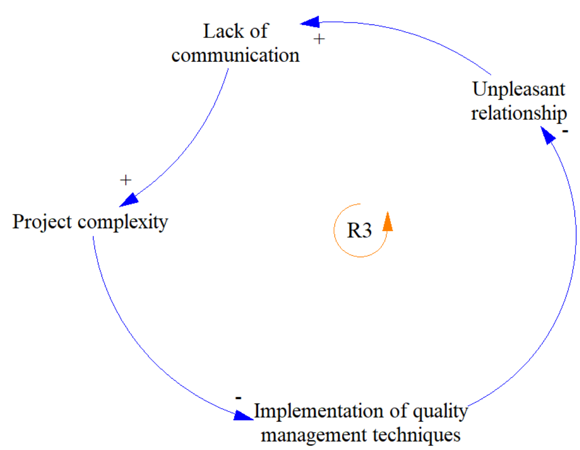


**Figure 17** Loop R3

between project stakeholders is however one of the most notable reasons behind the addition to the complexity. Since projects involving complexity are relatively more time and resource consuming, contractors tend to deliberately miss out on the implementation of quality management principles and improvement techniques. Findings of Ajayi and Osunsanmi (2018) have also identified project complexity as a challenge and constraint to implementing TQM in the construction industry. To counter this, site managers will tend to introduce vigorous and extensive techniques to ensure quality of the project that will ultimately stress out the contactors and lead to increased adverse relationship between them as shown. Since the implementation of quality principles and techniques can be assessed instantly, this loop also bears a fast and strong influence that is reinforcing in nature.

### 4.1.6 Loop R4 - value for money

The loop implies that increase in project complexity and hence change orders may reduce value for money of a project. In terms of construction, the degree of complexity determines the approach, tools and techniques, and the resources to be employed in the project. A fast-track construction project might show complexity when only a minor portion of design is completed at the start of construction which would lead to incomplete design information for the contractor. As well as resulting in frequent changes in contract and issuance of change orders, project complexity further leads to unclear or insufficient drawing details on part of the consultant. If complex projects are not properly managed and change orders administered, incomplete or insufficient design details may lead to defects, rework and ultimately reduced value for money. Reduced value for money would contribute to the use of extensive quality control techniques to achieve customer satisfaction that would eventually increase complexity of the project. Since value for money can only be realized as the project moves towards completion, the loop, as shown in Figure 18, exhibits a strong but slow influence that has a reinforcing nature.

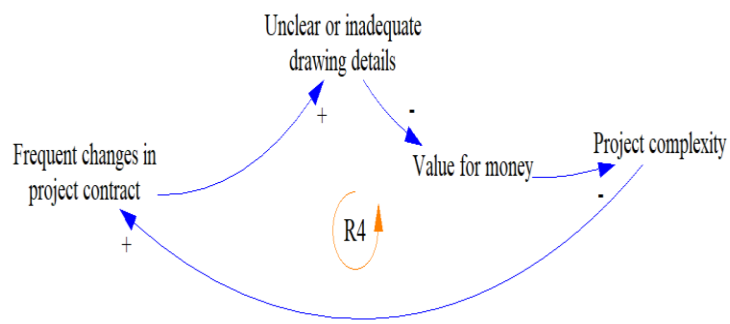

**Figure 18** Loop R4

## 4.2 Loop analysis and Validation:

The speeds and strength of influence on system outputs provide a comprehensive criterion for categorization of loops. This categorization acts as a filtering mechanism that facilitates prioritization of important actions. The influences of all loops in the CLD were therefore identified for their strength and speed based on expert interviews and were given priority in the following order; fast - strong, fast - weak, slow - strong, slow - weak (Powell *et al.*, 2016). Table 10 below summarizes these results for each feedback loop including directly influenced quality performance indicators. This can assist decision-makers and stakeholders by assisting them on how to manage complexity of information flow in their projects and provides an extensive analysis of the factors having influence on the operating mechanisms of the system i.e. project quality performance.

Reinforcing loops have a resonating influence which exhibits a continuing effect, while balancing loops have decaying effect which exhibit decaying change over time. Loops R2 and R3 are therefore considered critical since they carry a strong, fast and reinforcing influence, whereas B1 and B2 are less crucial followed by R4 and R1.

Before proceeding on to draw conclusions from the study, confirming the credibility of results, and hence validation of the causal loop diagram was ensured using member checking technique (also known as respondent validation) (Birt *et al.*, 2016). The CLD was shared back with the participants of expert opinion session for verification and to assess if the dependencies still resonate with their practical experiences. Each participant was involved in the interpretation of data where they validated the relationships as were perceived by them during the initial interview sessions which further enhanced trustworthiness of the results.

**Table 10** Loop analysis results

| | Influenced Quality Performance Indicators | | | | | | Loop Prioritization | | |
|---|---|---|---|---|---|---|---|---|---|
| **Loop** | Conformance to specifications | Stakeholder satisfaction | Defects and quality errors | Rework | Implementation of quality management principles and improvement techniques | Value for money | **Speed of Influence** | **Strength of Influence** | **Nature of Influence** |
| R1 | | x | | | | | Slow | Strong | Reinforcing |
| R2 | | | | x | | | Fast | Strong | Reinforcing |
| R3 | | | | | x | | Fast | Strong | Reinforcing |
| R4 | | | | | | x | Slow | Strong | Reinforcing |
| B1 | x | | | | | | Fast | Strong | Self-balancing |
| B2 | | | x | | | | Fast | Strong | Self-balancing |

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

The CLD developed in this research is a representation of a complex system comprising of six feedback loops that help apprehend the mechanisms that influence project quality performance. Lack of effective communication between stakeholders, unclear or inadequate drawing details, frequent changes in project contract, delay in accessibility to accurate information, unpleasant relationship between stakeholders and project complexity are the most critical barriers to information communication that are also mutual factors among various loops. R2 and R3 are the most crucial feedback loops based on their prioritization. These loops provide insight into mechanisms which contribute to a reduction in project quality performance through increased rework on sites and decreased implementation of total quality management. Loops B1 and B2 act as goal-seeking loops that resist change by acting as a self-constructive and corrective cycle. Loops R1 and R4 follow similar mechanism but are not critical due to slow speeds of influence. All these feedback loops in the CLD interact with each other in a complex manner rather than behaving as independent cycles to transfer the influence of information complexity on construction quality. This complex interaction overshadows linear assessment of project quality usually made at construction sites by project stakeholders. This research while adding to the existing body of knowledge assists practitioners and project stakeholders regarding the dynamics associated with quality in construction projects.

The utility of this study lies in the ability of Qualitative Systems Thinking to uncover the basic mechanisms of a system by gathering information and knowledge from a vast range of informants. The CLD, subsequently, provides closed cyclic structures/loops of causality that can educate project managers and decision-makers about the behavior of processes that occur within the system. There can be either of the two approaches; proactive and reactive. In the former approach, managers can aim to improve the flow of information on the project by focusing on the most critical causal factors of information complexity, whereas the latter approach would involve adopting quality control techniques and measures leading to improved quality performance of projects in the industry.

The CLD provides a logical way to perceive the linkages and interdependencies between various causal factors of information complexity and how each one of them attempts to influence performance indicators of construction quality. It is a common observation that there are numerous challenges and barriers to efficient flow of information in a construction project that ultimately lead to information complexity. However, the CLD is based upon only eight causal factors of information complexity that were scrutinized based on immediate causality. While the combined effect of these eight causal factors on construction quality performance lead to the development of a comprehensive model, the use of all factors would lead to an extensive number of variables and hence hundreds of loops that would make the model complex to understand. Thus, only the most critical factors based on immediate causality were selected.

Qualitative system dynamics or systems thinking provide an understanding of managerial issues not by calculations but rather by deduction of behavior of the system represented. The approach in this research purposely dismisses the utilization of numerical information. The qualitative SD approach, as a matter of fact, isn't restricted in its analysis by the absence of numerical data, although it allows the use of such data where it is available. Hence, further work in this area establishes ways to simulate quality performance of a project by introducing numerical data on the established mechanism. However, it must be understood that qualitative or quantitative models only facilitate the decision-making process by allowing relationships and interdependencies to explain the behavior of complex systems, they in no context provide specific project-related advices to practitioners. For that purpose, it is necessary that the model be conjoined with case-based or expert systems to advise the project team on real-time problems occurring in construction projects.

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