RISK ASSESSMENT OF FAST-TRACK CONSTRUCTION PROJECTS:

A SYSTEMS THINKING APPROACH

Thesis of

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has been accepted towards the partial fulfilment of the requirements for the degree of Masters of Science in Construction Engineering and Management

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This thesis is dedicated to my family and friends who kept me motivated even when I wanted to give up!

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

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ABSTRACT

Design and construction overlapping produces project complexity that levitates multifaceted risks. Modern risk management methods emphasize on the use of dynamic approaches for risk assessment procedure as a part of project planning of complex projects. The construction industry in developing countries, approaches risk management by using a set of practices that are out-dated, inefficient and limited which affect the success rate of project management. Traditionally risks are labelled as linear cause-effect relationships. They are assembled on a risk register, assessed and addressed independently but in complex systems this linear approach fails to reflect the actual risk situation

As an effort to address the complexity of fast-track projects, this research identifies interdependencies among significant risk factors and project objectives (cost, time, quality and safety). The study uses a combination of qualitative and quantitative research methods such as literature review, google survey and semi structured interviews. Literature review and online survey is used to identify fast-track related risks and to establish risk criticalities. Interviews are used to develop cause and loop diagram. Rework, design errors and change orders are found to be the top risk factors related to fast-track projects. Developed cause and loop diagram shows the complex interaction among variables which negate all the linear assessments. All the research findings are incorporated into a feedback loop mechanism which helps to understand the behaviour of risk factors and their chain effect. The application of systems thinking approach provides insight into system mechanisms which helps the assessor to foresee the compound impact of project risks and derive risk management strategies accordingly. The approach also provides a route for mobilization of numerical data in the developed feedback loop mechanism which can help to simulate the risk impact.

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LIST OF ABBREVIATIONS

CLD	Cause and Loop Diagram
CM	Construction-management
DB	Design-Build
EPC	Engineering-procurement-construction
FTP	Fast-track Project
SD	System Dynamic

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

In construction projects, reduced duration has always been a driving factor, which provides significant revenues for both the owner and the contractor (Austin et al., 2016; Khoramshahi et al., 2010; Rachid et al., 2018). Fast-tracking is one of the most common project acceleration techniques (Ballesteros-Pérez, 2017) used along with Design-Build (DB), Construction-Management (CM) and Engineering-Procurement-Construction (EPC) delivery systems (Chan et al., 2002; Cho et al., 2010). Contract with single entity provides greater coordination between designers and constructors which results in more buildable design and construction can commence prior design completion (Molenaar et al., 2001).

Fast-tracking involves overlapping of design, procurement and construction in order to shorten the project timeline (Pishdad-Bozorgi et al., 2016). Shortening of project duration does not only save project costs by reducing site overheads but also ensures early commissioning which can bring various benefits to the project parties. Cho et al. (2013) indicated a reduction in project time and cost up to 40.48% and 4.48%respectively, when compared fast-tracking to conventional construction methods. Fast-tracking methodology is particularly used in the public sector for emergency rebuilds, schools, hospitals and infrastructure projects (Austin et al., 2016) where early completion is required due to social pressure and political advantages. Whereas, in private sector early completion of project yields an opportunity to generate positive cash flows for the client (Cho et al., 2013).

Conversely, project acceleration with incomplete design information creates complexities accentuating project risks, such as numerous changes orders, design errors and rework (Dehghan et al., 2015; Hossain et al., 2014; Khoueiry et al., 2013). In a recent study (Hossain et al., 2014) it has been revealed that design errors and rework contribute 5% and 79% respectively towards cost overruns and also cause significant delays, which renders objectives of project acceleration. These impediments are not associated only with fast-track projects, but also affect conventional projects. However, tight schedule and partially completed design increases the complexity in such projects (Moazzami et al., 2011) by narrowing down the lag for correcting mistakes and effectively implementing variation orders (Cho et al., 2013). Consequently, a project can suffer cost overrun, low quality, and time delay.

Fast-tracked projects vary from traditional projects in many ways including their risk exposure which, poses more interconnected and cascading effect unlike traditional linear cause and effect relationship (Thamhain, 2013). The key to successfully managing such complex projects is to foresee project related risks as interconnected factors rather than independent events (Williams, 2017) and develop systematic risk management strategy different from the conventional project (Khoramshahi et al., 2010). Research has indicated that mega projects fail due to overlooking project risk management (Eriksson et al., 2017). Construction companies, particularly in developing countries, approach risk management by using a set of practices that are generally inadequate, inefficient, and limit the success of project management (Serpell et al., 2015). Globally, risk management has become a core part of project management; however, the currently prevailing traditional methods still reflect the dependency on risk registers (Powell et al., 2016; Thamhain, 2013) which treat risks as isolated events ignoring their interdependency and collective effect. Risks prevailing in fast-track projects are not greater than conventional projects but complexity of such projects escalates their interconnectedness and demand proactive management at a faster pace (Williams, 2017).

However, such proactive management must be supported by sound and reliable analytical tools and techniques (Park, 1999) rather than experience and intuition of the project manager. Among a few options available for investigating and exploring complex projects, Systems thinking is a comprehensive approaches to problem analysis, where influential elements are considered as interrelated rather than isolated components (Cattano et al., 2010; Goh et al., 2010; Sterman, 2000; Yang; et al., 2017). System thinking is a vastly used concept (Goh et al., 2010) to develop the interconnected structure of the system under consideration. This technique uses Causal Loop Diagram (CLD) to reveal underlying causal feedback mechanisms and their impact routes toward project objectives.

This study identifies and classify risk factors related to fast-track projects which are further ranked based on probability-impact assessment. The risk categories are analysed based on advanced and emerging economies to attain cluster weights. However, risk factors are assessed and shortlisted in view of developing countries for further analysis. Final risk assessment is based on systems thinking in which dynamic structure of fast-track construction risks is established and displayed as a feedback loop mechanism, which assists to gauge the cumulative risk impact. The CLD consists of risk cycles which are prioritised according to their strength and speed of impact in the system. The developed diagram identifies the most critical risk pathways and forms fundamentals of simulating model using robust tools such as system dynamics, which can help to conduct further investigation in the context of fast-track project performance. This technique highlights vigorous loops, resonant mechanisms which provide information of process within the system and helps to develop project management strategies.

1.2 PROBLEM STATEMENT:

Project completion within the expected time span has always been the most challenging task for construction companies, with many failing to deliver on the agreed schedule, cost and quality. The challenge is even greater with fast-tracked projects, where the schedule must be accelerated in order to cut project delivery time. FTPs can be less time consuming than a conventional project but also hold greater complications (Khoramshahi et al., 2010). FTP schedules often fail due to lack of effective risk management strategies causing immense cost and time overrun. Risk assessment is an important part of risk management which evaluates the impact of risks on project performance. The linear cause effect relationship is not enough to evaluate risk in such complex projects. Therefore, there is a need to develop a dynamic risk assessment model in the context of FTPs.

1.3 RESEARCH OBJECTIVES:

- To identify and categorise risk factors associated with the fast-track construction project
- To establish risk criticality in view of developing countries
- To develop interdependencies between risk factors using a systems thinking approach
- To conduct a causal loop analysis highlighting most critical risk parts in the system

1.4 SCOPE OF RESEARCH:

This research is limited to fast-track construction projects based on Design-Build and Construction Management delivery methods. The research reflects the problems associated with FTPs in emerging economies.

1.5 RESEARCH SIGNIFICANCE:

The dynamic risk assessment would provide a clear picture of a complex system which will help to identify most critical factors impacting project objectives. This will provide support to project managers in order to derive risk management strategies and enhance project success rate.

1.6 RELEVANCE TO NATIONAL NEEDS:

Construction and engineering services provide infrastructure, schools, healthcare facilities, sanitation facilities and many more to provide an economic uplift. The aggregate economy of

Pakistan is prominently influenced by the construction industry. Considering the significance, it is necessary to identify the major issues affecting the efficiency of the sector and take corrective action to reduce the number of project failures (Khan, 2008). Major infrastructure projects in Pakistan follow FT methodology and due to lack of systematic management techniques. These projects face time and cost overrun which leads to immense liquidated damages, claims and poor quality. It is imperative to understand the complexities in such project in order to evaluate a compound impact on project performance. A comprehensive risk assessment is a vital step before developing strategies to mitigate any risks.

1.7 THESIS OVERVIEW

This thesis has been arranged into five chapters.

Chapter 1 Introduction: It comprises an overview of the research, problem statement, objectives and scope of the study. It delivers a general introduction to the research.

Chapter 2 Literature Review: It enlightens the previous studies carried out related to the research topic, providing essential information and guidelines to manage fast-track projects.

Chapter 3 Research Methodology: It describes how the research has been conducted to obtain our objectives.

Chapter 4 Results and Discussion: It covers the analysis of data and discussion of results.

Chapter 5 Conclusions and Recommendations: Presents the summarized conclusions and recommendations.

Chapter 2

LITERATURE REVIEW

2.1 DIMENSSIONS OF FAST-TRACKING:

Fast tracking is a time focused process which requires concurrency between engineering, procurement and construction activities. Earliest definition of construction fast-tracking implies design and construction overlapping (Fazio et al., 1988) however many authors have used the term in design activity overlapping or construction activities overlapping. Some exclusive approaches such as use of precast components have also been identified as fast-track construction strategies. It is possible to customize fast-tracking strategy, according to project type and desired schedule goals. A literature review to evaluate variance dimensions of fast-track was is conducted to find the most frequently used term. Results are presents in Table 1 which indicated that design-construction overlapping is most frequently used term.

2.2 RISK IN FAST-TRACK PROJECTS:

Fast-tracking compresses the project schedule by overlapping design and construction activities which otherwise are performed in a sequence (Khoueiry et al., 2013). This schedule compression based on incomplete design information creates project complexity which leads towards more design errors, rework and short time to implement and rectify these changes and mistakes (Eastham et al., 2002). Vidal et al. (2011) defines project complexity as *"the property of a project which makes it difficult to understand, foresee and keep its overall behaviour under control, even when given reasonably complete information about the project system".* This suggests that complexity is a multi-dimensional theory, involving uncertainties at different levels and of various categories. There are several dimensions of complexity including structural, socio-political, environmental, technical, financial and schedule (Hass et al., 2008). In fast-track projects, high level of uncertainty in design and scope induces

Table 1: Fast-track strategies

No.	Researchers	Title of research	Type of overlapping			
			Design-Design	Design-Construction	Construction-construction	Exclusive approach
1	(Ballesteros-Pérez, 2017)	Modelling the boundaries of project Fast-tracking	X	X	X	
2	(Dehghan et al., 2015)	Optimization of overlapping activities in the design phase of construction projects	X	X	X	
3	(Austin et al., 2015)	Identifying and Prioritizing Best Practices to Achieve Flash Track Projects		X		
4	(Hossain et al., 2014)	Overlapping design and construction activities and an optimization approach to minimize rework		X		
5	(Pawar et al., 2014)	Risk in Fast-track construction		X		
6	(Dehghan et al., 2013)	Model of Trade-off between Overlapping and Rework of Design Activities	X	X		
7	(Khoueiry et al., 2013)	An optimization-based model for maximizing the benefits of Fast-track construction activities	X	X	X	
8	(Srour et al., 2013)	A methodology for scheduling overlapped design activities based on dependency information	X	X	X	
9	(Alhomadi et al., 2011)	The predictability of Fast-track projects				X

10	(Khoramshahi et al., 2010)	A framework for evaluating the effect of Fast-tracking techniques on project performance		X		X
11	(Cho et al., 2010)	Partnering Process Model for Public-Sector Fast-Track Design-Build Projects in Korea	X	X	X	
12	(Bogus et al., 2006)	Strategies for overlapping dependent design activities	X	X	X	
13	(Kasim et al., 2005)	Improving material Management practices on Fast-track construction projects	X	X	X	
14	(PMI, 2004)	A guide to project management body of knowledge	X	X	X	
15	(Eastham et al., 2002)	The fast-track manual : A guide to schedule reduction for clients and contractors on engineering and construction projects	X	X	X	
16	(Prasad, 1996)	Concurrent engineering fundamentals	X	X	X	
17	(Russell et al., 1991)	Decision framework for fast-track construction: A deterministic analysis		X		
18	(Fazio et al., 1988)	Design impact of construction fast-track		X		
		Total	11	17	10	2

multiple risks and time pressure intensifies the impact of these factors which eventually mutilates the project objectives (Khoramshahi et al., 2011). Uncertainties resulted by overlapping activities make projects more unstable and complex, which creates non-value adding iterations (Park, 2002).

In fast-track projects downstream activity starts with incomplete information from upstream activity which holds a huge risk of rework if prior incomplete information changes (Srour et al., 2013). Since project design, scope and specifications keep evolving during construction, it becomes challenging to estimate accurate project cost and time which becomes the reason of legal complications (Moazzami et al., 2011). Complicated schedule compression amplifies many risks in construction project that disturb project goals. In complex projects, risks that cause project failure are not individual, separate risks, but rather a combination of risks in causal chains (Thamhain, 2013; Williams, 2017). These risks may initiate a chain reaction which is facilitated by management actions and team reactions, building up “vicious circles” of disruption. Risks have been primarily assessed using linear methods that ignore risks in their causal networks, but for a holistic risk assessment model a system thinking approach is required to identify casual chains of risks and understand the compound effect of potential risk factors (Cavallo, 2014).

It is not only essential to understand and assess complexity, but the visualisation of complex interactions between complexity induced risks and objectives is also important to prioritise critical risks and select optimal risk mitigation strategies (Qazi et al., 2016). Additionally to achieve the best outcomes, fast-tracking should not only be facilitated by selection of the right materials, methods and accurate designs (Hossain et al., 2012; Kasim et al., 2005) but ensuring effective risk management is also vital (Wang et al., 2017).

2.3 RISK MANAGEMENT IN FAST-TRACK PROJECTS:

Risk management as a course of identifying, assessing risks, and to apply methods to decrease it to a tolerable degree (Perera et al., 2014). It is a step by step procedure which begins with risk recognition and an effective assessment (likelihood of occurrence and impact) method before moving towards mitigation, control and consequence management (Moteff, 2010). Risk identification and assessment are the crucial steps in risk management process (Powell et al., 2016; Wang et al., 2017) whether related to disaster risk reduction, supply chain management, construction projects or banking and finance as it forms the foundations for further analysis and management reforms.

Fast-track projects are very dynamic and can benefit from dynamic risk management (Dey, 2000). However, the construction industry in developing countries approaches risk management by using a set of practices that are generally inefficient and limited affecting project management success (Serpella et al., 2014). Fast-track projects carry complexities that require systematic up-to-date risk management techniques. Thamhain (2013) states that risks occurring in a complex environment are found to be more interconnected and thus their impact is amplified. Hence, the project management team should be able to perceive the accumulated effect of project risks rather than setting strategies for individual risk.

PMI (2017) has mentioned two-levels of risk, covering both single risk and overall project risk. However, construction risk management processes still only address the former level and there is little advice on how to address the overall risk. The modern research indicates that linear risk assessment is a major flaw in risk management of complex project (Wang et al., 2017; Williams, 2017). Thamhain (2013) states that risks are usually labelled as linear cause-effect relationships. They are assembled on a risk register, assessed and addressed independently. However, in complex systems this kind of approach fails to reflect the actual risk situation. In complex projects, apparently unrelated systems fail as a result of chain reactions. The cascading effect of one failure my effect the other highly interconnected systems (Helbing, 2013). There is an obvious need to utilise scientific and systematic tools and techniques to assess and analyse risks as interconnected systems.

Researchers have used various techniques for capturing interdependency between project risks. Well-cited methods include Soft System Methodology (SSM) (Wang et al., 2015); Network Theory (Fang et al., 2012); Analytical Network Process (ANP) (Boateng et al., 2015) and Causal Mapping (Ackermann et al., 2014). However, systems thinking technique is linked to system dynamic (Coyle, 1996; Goh et al., 2010) which provides means to mediate between qualitative expressions of dynamic mechanism and possible quantitative representations of the systems (Sterman, 2000). This technique deploys graphical influence diagrams known as CLD to form the basic structure for numerical simulations. Sytem dynamic models are more robust (Sterman, 2000) however, CLD forms the structure of the system which is crucial in the simulations and these structures have the ability to provide insight to those dynamic mechanisms that are important in generating system outputs (Powell et al., 2016).

2.4 RISK IDENTIFICATION AND RANKING:

A number of studies have identified many risk factors induced in the successful delivery of fast-track projects. In this context, research articles published during the period 2010-2017 were analysed for the identification of fast-track project related risks. Thirty four (34) identified risk factors from the different research articles are summarised in the Table 2. Since there is no standard classification of risk and various methods for risk classification are reported with most common classification based on the nature of risk (Hwang et al., 2017; Qin et al., 2016; Yang et al., 2016). Thus, all the identified risks were categorised into six categories; environmental, financial, legal, managerial, social and technical as classified by Chien et al. (2014). Furthermore, a two-part content analysis was performed on the identified risks to achieve their ranking. In the first part, frequency of appearance (a quantitative score) and in the second part, contextual importance (as a qualitative score) were considered. The frequency of each factor was simply noted and accumulated, and the qualitative importance was assessed on a 3 point Likert scale (high=5, medium=3 and low=1) by using the impact of a factor as described in the paper. A product of qualitative score and frequency were used to assign a literature score to each risk factor. Finally the literature score was normalized before ranking the risk factors as presented in Table 2 in literature review section.

The risk factors in fast-track and conventional projects may be common but their significance based on probability of occurrence and impact makes them specific to selected construction method. The identified risks are by-products of activity overlapping and are highlighted as critical in the context of fast-track projects, whereas same factor might not be much prevalent in traditional construction.

Frequency analysis shows that rework is found to be the most critical risk that results from commencing construction with partially developed design (Hossain et al., 2014). Design errors and omission are second most critical risks caused by compressed timeline (Moazzami et al., 2011) as schedule pressure affects the reliability of design which further leads towards more change orders. Other key risk factors in fast-track projects include unrealistic and inaccurate schedule goals (Dehghan et al., 2011), numerous change orders (Austin et al., 2016), changing project scope and specifications (Cho et al., 2010), delay damages (Moazzami et al., 2011), low quality work (Alhomadi et al., 2011) and use of improper methods and equipment contrary to fast-tracking (Pawar et al., 2014).

Table 2: Risk Identification and ranking via literature review

Risks Factors	Ballesteros-Pérez (2017)	Williams (2017)	Austin et al. (2016)	Pawar et al. (2014)	François Berthaut (2014)	Khoueiry et al. (2013)	Srour et al. (2013)	Hossain et al. (2012)	Alhomadi et al. (2011)	Dehghan et al. (2011)	Moazzami et al. (2011)	Cho et al. (2010)	NLS	Rank
1- Environmental risks														
ER1-Latent site conditions	-	-	-	-	-	-	-	-	-	x	-	-	0.011	30
ER2-Incomplete environmental assessment	-	-	-	x	-	-	-	-	-	-	-	-	0.007	33
ER3-Weather conditions	-	-	-	-	x	-	-	-	-	x	-	-	0.021	23
2- Financial & economical risks														
FR1-Late payments	-	-	-	-	x	-	-	-	-	x	-	x	0.021	22
FR2-Unavailability of funds	-	-	-	-	x	-	-	-	-	-	-	-	0.011	28
FR3-Appropriate fund & resource allocation	-	-	-	x	-	-	-	-	-	x	-	x	0.034	10
FR4-Higher purchasing cost	-	-	-	x	-	-	-	-	-	-	-	-	0.011	26
3- Legal risks														
LR1-Absence of contractual risk liability	-	-	x	-	-	-	-	-	-	-	x	-	0.023	11
LR2-Delay damages	-	x	x	x	x	-	-	-	-	-	x	-	0.041	6
LR3-Delay in legal approvals	-	-	-	x	-	-	-	-	-	-	-	x	0.023	13
LR4-Contract change/modification	-	-	-	x	-	-	-	-	x	x	-	-	0.014	25
4- Managerial risks														
MR1-Project team conflict	-	x	-	-	-	-	-	-	x	x	-	x	0.014	24
MR2-Poor site management	-	-	-	-	-	-	-	-	-	x	-	x	0.023	19
MR3-Delayed procurement	-	-	-	-	-	-	-	-	-	-	-	x	0.011	31
MR4-Incompetent representatives	-	-	-	-	-	-	-	-	-	x	-	x	0.023	18
MR5-Contractor's productivity	-	-	-	x	-	-	-	-	x	x	-	-	0.034	7
MR6-Slow decision making	-	-	-	-	-	-	-	-	-	x	-	x	0.023	17
MR7-Unrealistic schedule	-	-	x	x	x	-	x	-	-	x	x	-	0.069	3

MR8-Key stakeholder conflicts	-	-	x	-	-	-	-	-	-	-	x	-	0.023	12
MR9-Overlooked work	-	-	-	-	-	-	-	-	-	x	-	-	0.007	34
MR10-Construction accidents	-	-	-	x	x	-	-	-	-	x	-	x	0.057	5
MR11-Unclear scope & specification	-	x	-	-	-	x	-	-	-	-	-	-	0.023	15
MR12-Changing stakeholders	-	x	x	x	-	-	-	-	-	-	-	-	0.021	20
5- Social risks														
SR1-Political influence	-	-	-	x	-	x	-	-	-	-	-	-	0.023	14
SR2-Adverse organizational culture	-	x	-	-	-	-	-	-	-	-	-	-	0.011	27
6- Technical risks														
TR1-Low quality work	-	-	-	-	x	-	-	-	-	-	-	-	0.034	9
TR2-Selection of Methods and equipment	-	-	-	x	-	-	-	-	-	x	-	x	0.034	8
TR3-Rework	x	-	x	x	x	x	x	x	x	x	x	-	0.115	1
TR4-Design errors	x	-	x	x	x	x	-	x	x	-	x	x	0.103	2
TR5-Lack of fast-track project experience	-	-	-	x	-	-	-	-	-	-	-	-	0.007	32
TR6-Shortage of material/equipment	-	-	-	x	-	-	-	-	-	x	-	-	0.023	16
TR7-Late change request	-	-	-	x	-	-	-	-	x	-	-	x	0.021	21
TR8-Lack of technological advances	-	-	-	-	-	-	-	-	-	x	-	-	0.011	29
TR9-Numerous change orders	x	-	x	-	-	-	x	x	x	-	x	-	0.069	4

"X" = Presence of risk variable in corresponding literature sourc

RESEARCH METHODOLOGY

This research focuses on risk assessment of fast-track projects using a systems thinking approach and the process is divided into three stages as presented in Figure 1.

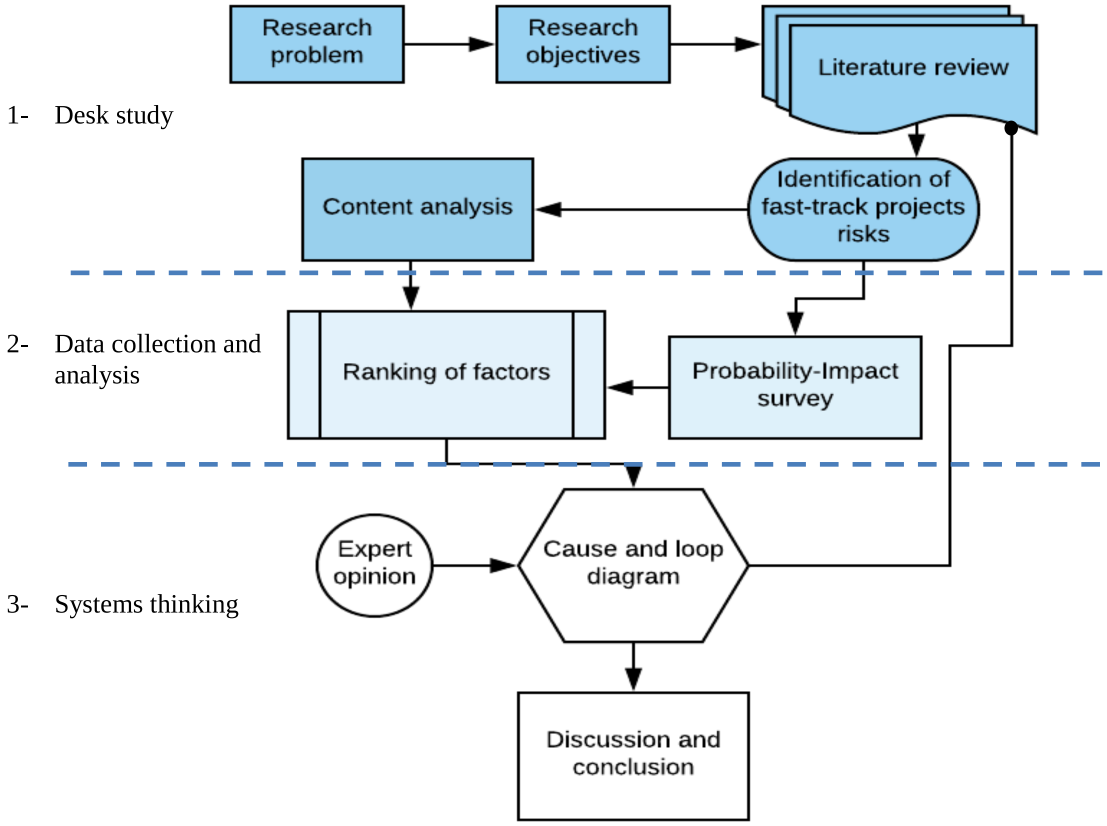

Figure 1: Schematic presentation of research design

3.1 DESK STUDY

In stage one, research problem was identified through critical review of relevant literature. After setting up research objectives, an extensive literature synthesis was carried out to identify risk factors specific to fast-track projects. As presented in Table 2, thirty four risk factors were extracted, categorized and ranked as explained earlier in the literature review.

3.2 DATA COLLECTION AND ANALYSIS

Keeping in mind that content analysis uses secondary data and represents the trend of past research on fast-track projects, primary data collection found necessary. Thus, to attain recent and reliable primary data, a probability-impact survey consisting identified risks was carried out. The survey helped to examine risk categories in view of the developed and developing economies. The considered economies were segregated based on the inclusive development index set by World Economic Forum (2018). The variations in the results of two economies were briefly discussed and data from developing countries were used for further analysis.

For this purpose, a two-section questionnaire was developed using Google ™ Docs (Shen et al., 2017; Wong et al., 2016). The first section contained questions regarding general information about the respondents such as company type, respondent designation, qualification, experience, etc. In the second section, the respondents were required to rate the probability and impact of identified factors using a Likert scale of 1-5 (1=very low and 5=very high). Respondents were also given an option to add other related risk factors.

In this study, no fixed population was used for sampling, so the sample was a non-probability sample (Limsila et al., 2008). As a generally accepted rule, the central limit theorem is satisfied with a sample size of 30 or above (Chan et al., 2018) and representative is ensured with a sample size of 96 or above (Dillman, 2011). This survey was floated globally to targeted respondents having experience in fast-track construction projects through online professional communities like LinkedIn®, social networking sites like Facebook® and research network sites like ResearchGate®.

After collection of data, its reliability and normality were checked by basic statistical tests on SPSS®. Subsequently, risk score was taken as a product of probability and impact which was then converted into a Relative Importance Index (RII) of risk. The RII is a statistical method to determine the ranking of different factors (Hossen et al., 2015; Muneeswaran et al., 2018).

The Equation 1 was used to determine RII for risk score of six categories and each factor, where W is risk score, A is the highest possible score and N is the total number of respondents. The greater the value of RII, more important the factor or category is.

$$\boldsymbol{RII} = \frac{\sum \boldsymbol{w}}{\boldsymbol{A * N}} \qquad \text{Equation 1}$$

In field data analysis, cluster weights were applied to all the corresponding RII risk values to attain a weighted risk score. Weighing factors compensates risk elements for perceived advantages. Multiplying group weights to risk score creates more variance among RII and ranks become more distinguishable. Afterward, the results of primary (field) and secondary (literature) data were given 60% and 40% weights respectively before combining them to achieve a collective risk ranking. Using Pareto analysis, top 14 risk factors having above 50% cumulative impact were shortlisted for further analysis (Ahmad et al., 2018).

3.3 SYSTEMS THINKING

Stage three involves data collection from field experts in two parts. In first step, most immediate causal links among shortlisted factors and project's key objectives were developed thorough semi structured interviews of experts with significant experience of fast-track projects and further validated by a literature review. The interviews provided significant information regarding polarity and strength of causal links among selected factors and project objectives. Data were utilised to develop a cause and loop diagram to present selected risk factors as a complex system indicating significant loops. In the second part, the same experts classified feedback loops according to strength and speed of impact they carry. The loop classification was used to identify most critical loops in the system.

The experts represented a diverse set of individuals covering different roles within the organizations such as project directors, contract engineers, project managers, planning engineers and site engineers. To determine the sample size in interview based research, concept of sample saturation was used (Mason, 2010). Sample saturation was achieved on eleventh interview however, to increase certainty, thirteen experts were interviewed.

The standard methodology of systems thinking process is to use a blend of tool based methods and visual examination to detect critical loops. A robust software VENSIM® was used to develop a graphical representation of the established causal links. Development of CLD was an iterative process where connections among variables were chronologically perceived and arranged using professional judgment. Additional risk variables such as *profit loss*, *time overrun* and *cost overrun* were included in the top fourteen factors to make the model more comprehensible. Risk variables such as cost overrun, time overrun, low quality work, and site accidents were used as indicators of key project objectives (time, cost, quality and safety).

In the CLD, selected variables were connected via arrows in the direction of impact. Each arrowhead carries a negative (-) or positive (+) polarity and negative connections were shown as dotted lines. The negative symbol indicates an inversely proportional relationship (i.e., if independent variable increases, the dependent variable decreases or vice versa) where positive symbol stands for a directly proportion relationship among the factors (i.e., if independent variable increases, the dependent variable also increases or vice versa). Closed chains of cause and effect are called feedback loops (Sterman, 2000) and each loop was defined as reinforcing or balancing. Finally, discussion and conclusion were developed in view of the analysis and research objectives.

RESULTS AND DISCUSSION

4.1 FIELD DATA:

4.1.1 Regional distribution of responses:

The survey collected 151 responses out of which 64% were international and remaining 36% were national. Major countries to participate in the survey were Pakistan, USA, UK, UAE, Canada, South Africa, Australia and Saudi Arabia, as shown in Figure 2. All the responses were segregated into developing and developed countries resulting into 54% responses from developing economies and 46% from developed economies.

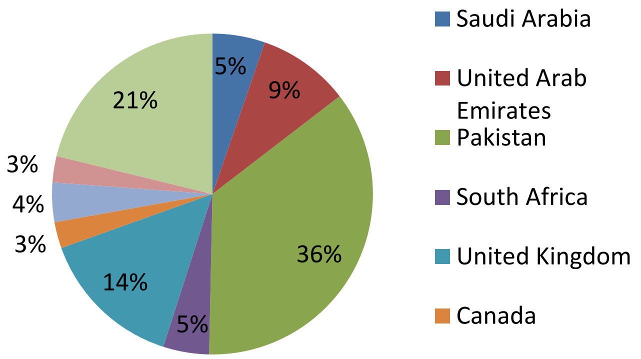

Figure 2: Regional distribution of responses

4.1.2 Respondent’s profile:

A variety of construction professionals were targeted, including construction manager, designer, site manager, contract administrator, project director and many more. However largest responses were received from construction managers (24%). Cumulatively, 74 respondents had more than ten years of construction experience indicating that 49% of responses came from highly experienced professionals. Only 21 respondents reported less than 2 years’ experience which is 14% of the total sample.

Qualification wise, 52% M.Sc. holders and 7% PhD holders responded indicating that altogether, 59% of responses came from highly qualified professionals. A respectable 32% of responses were from B.Sc./BEng graduates and mere 9% of total feedback was from B.Tech holders. The majority of professionals completing the questionnaire held high qualification which verifies the reliability of their opinion. Information on the knowledge of risk management in the construction industry is important as it reflects whether the project parties are conscious about fast-track project risks. The results reveal a moderate to exceptional understanding of risk management by more than 63% of respondents which reinforces the confidence in the quality of data. Table 3 provides insight to respondent profiles.

Table 3: Frequency distribution of responses

Profile	**Frequency**	**Percentage**
Total responses = 151		
Job title		
Construction manager	36	24%
Project engineer	27	18%
Contract engineer	8	5%
Site manager	12	8%
Designer	8	5%
Project manager	30	20%
Project director	14	9%
Others	17	11%
Years of Experience		
0 to 2 years	21	14%
3 to 5 years	27	18%
6 to 10 years	29	19%
11 to 20 years	45	30%
Above 20 years	29	19%
Education		
B-tech	14	9%
B.Eng./ B.Sc.	11	32%
Ms/M.Sc.	78	52%
PhD/D. Eng.	48	7%
Understanding of risk management		
No understanding at all	2	1%
Slight	17	11%
Moderate	95	63%
Exceptional	37	25%

4.1.3 Probability-Impact analysis

The questionnaire gathered information related to the rate and severity of occurrence for each risk and risk category. Microsoft® Excel was used to create spread sheets of the data for further calculations.

4.1.3.1 Reliability and Normality check

Internal consistency and reliability of Likert scale data is measured using Cronbachs Alpha, which is a numerical value between 0 and 1. Internal consistency defines the degree to which all the items in a test measure the similar concept, therefore it is linked to the inter-relatedness of the items within the test. To ensure validity, internal reliability of data must be examined before conducting further investigations (Tavakol et al., 2011). Statistical analysis of collected data calculated a value of 0.98 for Cronbach's Alpha. Tavakol et al. (2011) has interpreted Alpha value as excellent if found greater than 0.90. Author also stated that a high level of alpha may indicate a high correlation between items in the test. However, Alpha is sensitive to the quantity of items in a test. A large number of items can produce a larger α value and too few items may result in a smaller Alpha.

Shapiro-Wilk test was also conducted on the collected data, to determine the normality. Test outcome indicated significance values less than 0.05 which indicates that data is not normally distributed, which means that for further analysis of such data, non-parametric test would be required.

4.1.3.2 Cluster weights:

The field survey included questions about the significance of each identified risk class (Financial, Legal, Technical, Management, Environmental, & Social). Results are presented in Table 4. These cluster weights indicate the significance of the respective categories in a project and are used to determine more realistic risk factor loads.

Table 4: Cluster weights

Risk categories	Developing Economy				Developed Economy			
	RII				RII			
	Probability	**Impact**	**Rate**	**Rank**	**Probability**	**Impact**	**Rate**	**Rank**
Financial	0.684	0.788	**0.539**	1	0.665	0.706	0.469	2
Legal	0.602	0.663	**0.399**	4	0.612	0.679	0.416	4
Technical	0.636	0.694	**0.441**	3	0.644	0.682	0.440	3
Management related	0.672	0.716	**0.481**	2	0.674	0.700	0.471	1
Environmental	0.569	0.660	**0.375**	5	0.603	0.626	0.378	5
Social	0.581	0.646	**0.375**	6	0.494	0.550	0.272	6

Results indicate that in view of developing economies, financial risks have the highest significance. Whereas, management and technical risks are ranked second and third, followed by legal, environmental and social risks. It is obvious that financial and management risks have main variance in ranking. Developing economies selected financial risks as the most critical risk category, while advanced countries prioritize management related risk factors.

Within the context of developing economies financial risk in construction industry have been identified as most influential risks (Iqbal et al., 2015) which was confirmed by a number of studies conducted in Nigeria(Mansfield et al., 1994), Iran (Ghoddousi et al., 2012), Kuwait (Kartam et al., 2001), Malaysia (Goh et al., 2013), Vietnam (Le-Hoai et al., 2008) and Pakistan (Choudhry et al., 2013). Financial risk are attributes of economic and political instability, fluctuations in currency and interest rates and a shortage of material and equipment, which are typical problems in developing countries (Baloi et al., 2003). The situation is aggravated by deficient financial facilities and the supplementary complex supply chains in such countries (El-Gohary et al., 2013). Construction industry in developing countries suffers from management related risks and the main reasons for this includes a lack of advanced management strategies and dependence on intuition of construction manager (Wang et al., 2004). On the other hand advanced countries keep the development and implementation of project management strategies as top of their agenda (Kang et al., 2018) and therefore, management risks are valued higher in established economies.

4.1.3.3 Factor ranking and shortlisting:

Based on the collective risk score of the field and literature data, final ranking of factors was established, as presented in Table 5. Top fourteen factors were shortlisted using Pareto analysis as presented in Figure 3. The descending list of top fourteen factors include; rework/modifications (TR3), design errors (TR4), numerous change orders (TR9), unrealistic schedule goals (MR7), construction accidents (MR10), delay damages (LR2), contractor delays (productivity) (MR5), methods and equipment contrary to fast-tracking (TR1), low quality work (TR2), appropriate fund and resource allocation (FR3), stakeholder collaboration (MR8), unclear project scope and specifications (MR11), decision making time (MR6) and late payment (FR1).

Table 5: Collective risk score and ranking in view of developing economies

		Field data from developing economies (60% weight)			*Literature data (40% weight)*	*Merging of data*	
Cluster weights	**ID**	**Probability**	**Impact**	**Weighted RII of risk**	**Relative literature score**	**Collective score**	**Final Rank**
Environmental risks (0.375)	ER1	2.964	3.434	0.153	0.1	0.132	32
	ER2	3.265	3.819	0.187	0.06	0.136	31
	ER3	3.048	3.482	0.159	0.18	0.168	27
Financial risks (0.539)	FR1	3.008	3.434	0.223	0.18	0.206	14
	FR2	2.145	3.982	0.184	0.1	0.150	29
	FR3	3.072	3.094	0.205	0.3	0.243	10
	FR4	2.867	3.542	0.219	0.1	0.171	26
Legal risks (0.399)	LR1	3.564	3.422	0.195	0.2	0.197	17
	LR2	3.92	3.482	0.218	0.36	0.275	6
	LR3	3.169	3.386	0.171	0.2	0.183	20
	LR4	3.578	3.687	0.211	0.12	0.174	24
Managerial risks (0.481)	MR1	3.096	3.578	0.213	0.12	0.176	23
	MR2	2.801	3.566	0.192	0.2	0.195	19
	MR3	3.589	3.759	0.260	0.1	0.196	18
	MR4	3.048	3.53	0.207	0.2	0.204	16
	MR5	3.012	3.874	0.225	0.3	0.255	7
	MR6	3.169	3.47	0.212	0.2	0.207	13
	MR7	3.233	3.554	0.221	0.6	0.373	3
	MR8	3.229	3.711	0.231	0.2	0.218	11
	MR9	3.157	3.639	0.221	0.06	0.157	28
	MR10	3.036	3.834	0.224	0.5	0.334	5

	MR11	3.229	3.627	0.225	0.2	0.215	12
	MR12	3.145	3.663	0.222	0.18	0.205	15
Social risks (0.375)	SR1	3.108	3.542	0.165	0.2	0.179	21
	SR2	3	3.349	0.151	0.1	0.130	33
Technical risks (0.441)	TR1	3.4	3.713	0.223	0.3	0.254	8
	TR2	3.472	3.486	0.214	0.3	0.248	9
	TR3	3.625	3.614	0.231	1	0.539	1
	TR4	3.723	3.386	0.222	0.9	0.493	2
	TR5	2.819	3.241	0.161	0.06	0.121	34
	TR6	2.819	3.301	0.164	0.2	0.178	22
	TR7	2.904	3.289	0.168	0.18	0.173	25
	TR8	2.867	3.301	0.167	0.1	0.140	30
	TR9	3.88	3.229	0.221	0.6	0.373	4

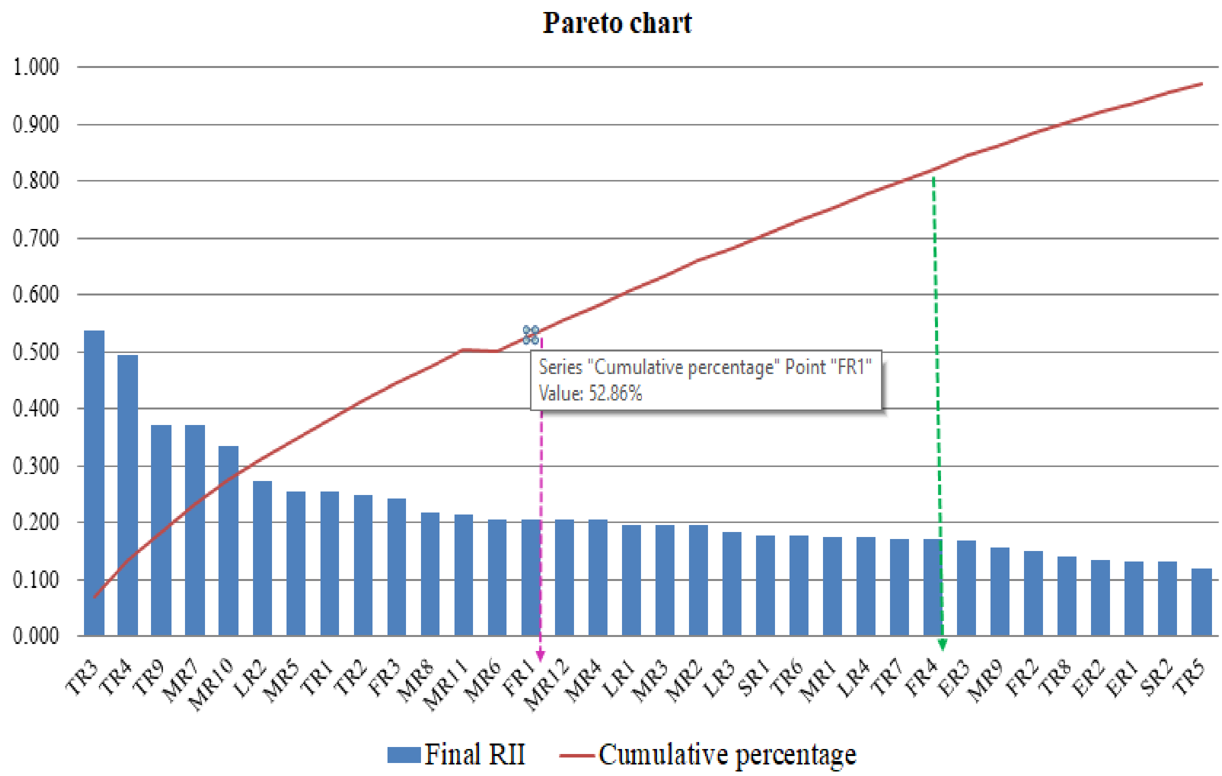

Figure 3: Shortlisting of factors using 50% impact

4.2 DEVELOPMENT OF THE FEEDBACK LOOP MECHANISM (CLD):

Fast-track construction projects are complex systems consisting interrelating components which influence each other. For example, profitability depends on cost, which is influenced by the quality and schedule performance, both of which are affected by multiple other variables. This interaction must be considered when assessing risk. CLD presented in Figure 4 provides a better understanding of what drives the system behaviour. The diagram graphically presents the interdependencies between the risk factors and key project objectives (time, cost, quality and safety) which are validated from literature and presented in Table 6. Change in scope and specifications, late payments, slow decision making and key stakeholder conflict are written off as owner related risks. The owner related risks are set as exogenous variable that are not given a high importance as they do not form part of the system and are kept out of the scope.

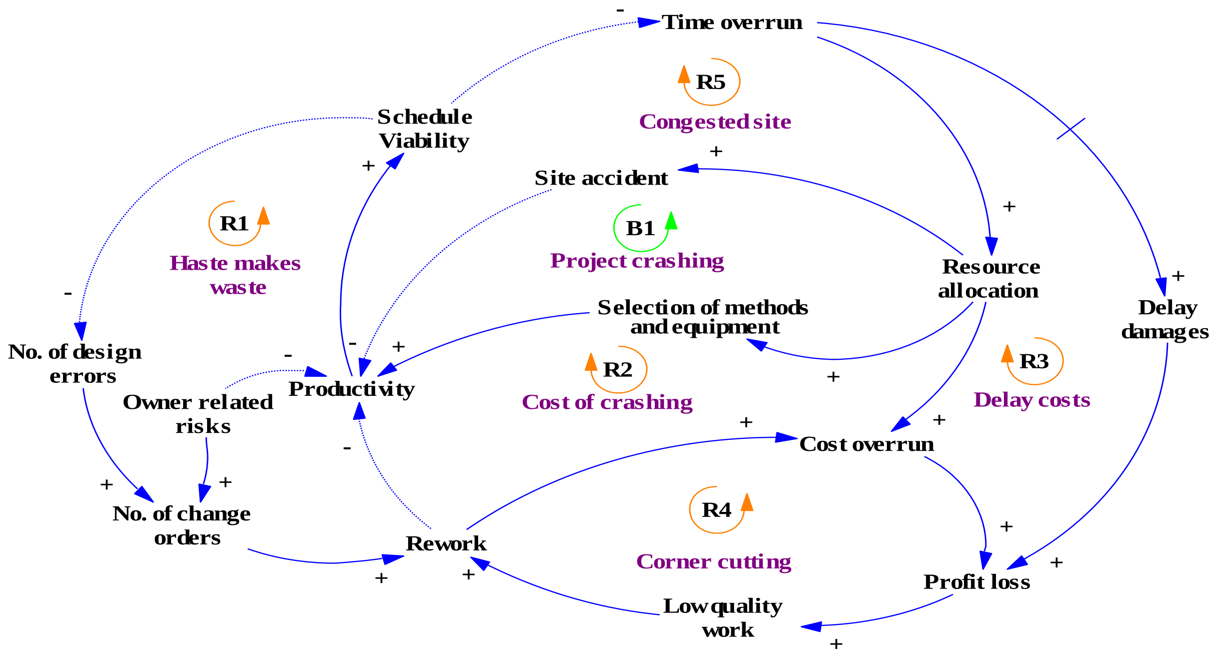

Figure 4: The CLD of fast-track project risks and objectives

Table 6: Correlations between variables in the CLD

Impacting variable	Polarity	Impacted Variables	Sources
Quality	-	Rework	(Pheng et al., 2004)
No. of change orders	+	Rework	(Alhomadi et al., 2011; Moazzami et al., 2011)
Schedule viability	-	Design errors	(Moazzami et al., 2011)
Owner interference	+	Scope change	(Zou et al., 2009)
Scope change	+	No. of change orders	(Moazzami et al., 2011)
Design errors	+	No. of change orders	(Khoueiry et al., 2013; Moazzami et al., 2011)
Fast-track method and equipment	+	Productivity	(Dozzi et al., 1993)
Resource allocation	+	Productivity	(Dozzi et al., 1993)
Time overrun	+	Delay Damages	(Moazzami et al., 2011)
Rework	-	Productivity	(Alhomadi et al., 2011; Leon et

			al., 2018; Zhi, 1995)
Resources allocation	-	Selection of equipment/methods	(Nilesh D. Chinchore, 2014)
Time overrun	+	Project crashing/ additional resource allocation	(Ballesteros-Pérez, 2017; Nilesh D. Chinchore, 2014)
Productivity	+	Schedule viability	(Leon et al., 2018)
Project crashing	+	Cost overrun	(Ballesteros-Pérez, 2017)
Delay damages	+	Profit loss	(Eriksson et al., 2017; Khoueiry et al., 2013)
Rework	+	Cost overrun	(Alhomadi et al., 2011; Eriksson et al., 2017; Khoueiry et al., 2013)
Schedule viability	-	Time overrun	(Leon et al., 2018; Rachid et al., 2018)
Cost overrun	+	Profit loss	(Leon et al., 2018; Myers, 2016)
Profit loss	-	Quality	(Alchimie, 2004; Love et al., 2011)
Owner related risks	+	Scope change, Late payments, slow decision making and key stakeholder conflicts	(Enshassi et al., 2010; Haseeb et al., 2011; Khoueiry et al., 2013; Moazzami et al., 2011; Zou et al., 2009)

Six major loops were identified through visual inspection. There are two canonical forms of feedback loops depending on their performance. The reinforcing loops or positive loops have an ever increasing (or decreasing) effect. On the other hand, balancing or negative loops are goal seeking that counter a change in every cycle. B1 is the only balancing loop in the developed CLD that shows how additional resources may alter the situation by increasing productivity and reducing time delays. There are five reinforcing loops in the system (R1, R2, R3, R4 and R5) which make the entire system rather volatile. As mentioned earlier, positive feedback loops are self supporting, which means they have a high potential for either a quick descending or a quick ascending trend in project performance.

The CLD was broken down into feedback loops which were discussed with experts regarding their impact on the system. Altogether six loops were identified and analysed as described below.

4.2.1 Balancing loop B1 (Project crashing)

B1 shown in Figure 5 implies that as the time overrun increases, project team tends to increase resource allocation (Ballesteros-Pérez, 2017; Nilesh D. Chinchore, 2014) to meet the deadline, and avoid prolongation cost and legal claims. Improved resources improve selection of construction equipment and methods (Nilesh D. Chinchore, 2014). As the resource allocation and selection of equipment/methods improve, overall productivity improves (Dozzi et al., 1993) which eventually enhances time performance. Fast-track projects are time focused and additional resources are the only logical way to cater for a time loss. This balancing loop has a strong impact because additional resources improve productivity immediately. Contractors use this approach as need based strategy to reduce delays very often during the project. Hence loop B1 has a *strong, fast and balancing* impact.

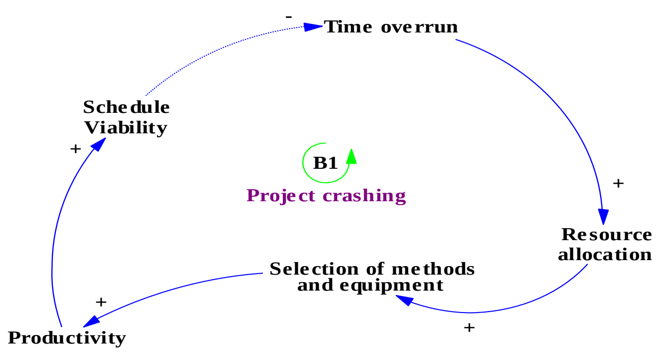

Figure 5:Loop B1

4.2.2 Reinforcing loop R1 (Haste makes waste)

R1 implies that schedule pressure creates a need to achieve tasks quickly which amplifies probability of design errors as shown in Figure 6. Over ambitious contractor may over compress schedule which reduces the viability and project may suffer drastically. This might be caused by the significance of market timing but also due to social and political issues especially in developing countries (El-Sayegh, 2008). It becomes hard to retain design reliability when working under pressure with overlapping activities. Over compressed timeline builds schedule pressure which increases number of design errors (Moazzami et al., 2011), leading to change orders and rework (Khoueiry et al., 2013), which ultimately decreases the productivity. Furthermore, this low productivity translates into reducing the schedule viability even more and the cycle repeats.

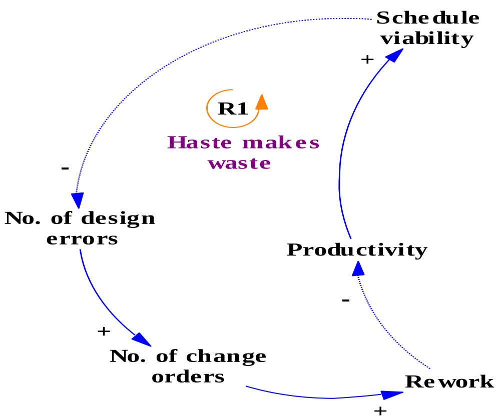

Figure 6: Loop R1

The overall impact of this loop is strong because during parallel design and construction activities, design error can cause major delays on site. Design errors also lead to rework which strongly affect schedule and cost of project. Again, due to concurrent design and construction activities, impact of design errors can be seen immediately, thus this loop carries a quick impact. Loop R1 is identified to carry *strong, fast and reinforcing* influence.

4.2.3 Reinforcing loop R2 (Cost of crashing)

Figure 7 shows that project cost increases as project is crashed (Ballesteros-Pérez, 2017) and project cost impacts profitability by contributing to the profit margins (Leon et al., 2018; Myers, 2016). Since profitability is the main focus of a contractor, a loss in profit leads to corner cutting and low quality work (Alchimie, 2004; Love et al., 2011) which may lead back to rework (Pheng et al., 2004), productivty loss and delays. It can also be deduced that the key project objectives (time, cost, quality and safety) are highly interrelated and variation in one goal may disturb the remaining. Fast-track projects may achieve reduced timelines but cost increase and quality compromise becomes consequential (Alhomadi et al., 2011). Delays in early execution phase can be catered with less additional resources and contractor may adjust extra costs by managing resources accordingly at a later stage. Quality compromise is avoided to achieve regular and whole payments. The issue arises when delays have built up throughout the project and resources are increased intensely. Heavy allocation of additional resources for longer periods impact project cost significantly and that is when quality is compromised, which usually happens towards the end of the project. Therefor, this loop is thought to have *strong, slow but reinforcing* impact.

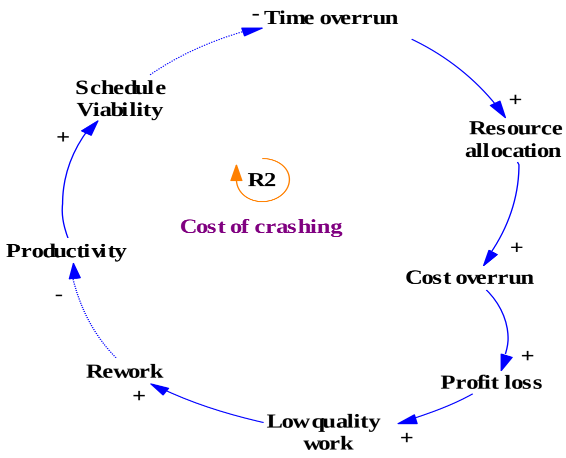

Figure 7:Loop R2

4.2.4 Reinforcing loop R3 (Delay costs)

Figure 8 shows that if time overrun in fast-track projects is not catered, it will cause an increase in the delay damages which relatively reduces the profit margins (Eriksson et al., 2017; Khoueiry et al., 2013) and affect the quality of work. The low quality work enhances the amount of rework and reduces the overall productivity. Similarly, the low productivity translates into reduced schedule viability which contributes to time overrun. Hence, to reduce delay impact, quality is compromised.

A considerable 33% of fast-track projects go through claims compared to 7% of conventional projects (Moazzami et al., 2011). Because fast-track projects are time oriented, delays would lead to significant amount of legal costs. Contractors may lose huge amounts in terms of delay damages thus this route is strongly avoided by the project team. Delay damages are usually summed up towards the end of the project and carry slow speed impact. However, a contractor may perceive the upcoming losses and start cutting corners to save some money. But this impact would occur more towards the end of the project when contractor has failed to reduce project delays. Thus loop R3 is acknowledged as a *strong, slow and reinforcing* loop.

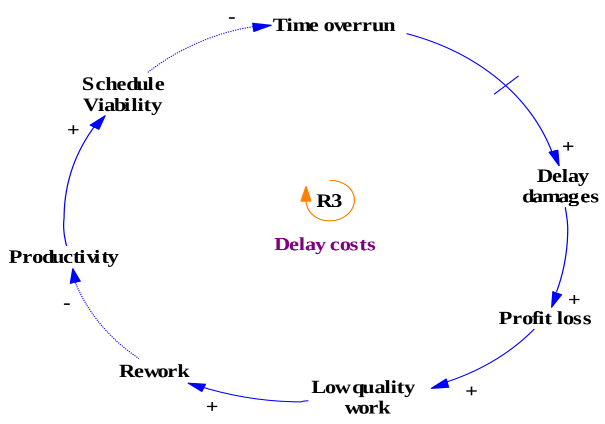

Figure 8:Loop R3

4.2.5 Reinforcing loop R4 (Corner cutting)

Shown in Figure 9, loop R4 implies that rework, which is the largest risk factor faced by fast-track projects, directly impacts project cost. As the amount of rework increases, the direct costs increase (Alhomadi et al., 2011; Eriksson et al., 2017; Khoueiry et al., 2013). Increased costs lead to an increase in profit loss which causes reduced quality requiring rework and the cycle goes on. Rework strongly and immediately impacts projects costs and contractor would react to save money by corner cutting. Thus, R4 is classified to have *strong,fast and reinfrocing* impact.

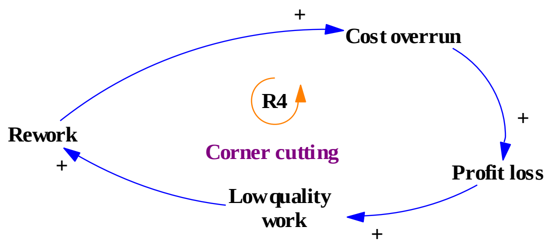

Figure 9:Loop R4

4.2.6 Reinforcing loop R5 (congested sites)

Figure 10 shows that project delay requires allocation of additional resources which improves selection of fast construction equipment and methods. However, the excessive resources on site also make the site prone to accidents (Shapira et al., 2009). In fast-track projects, safety is given least priority (Koehn et al., 1995) especially in the construction indutry of developing countries. The causation of more accidents on site reduces the overall productivity of the project. Likewise, the low productivity converts into lower schedule viability, which leads to time overrun and the effect is reinforced in each cycle.

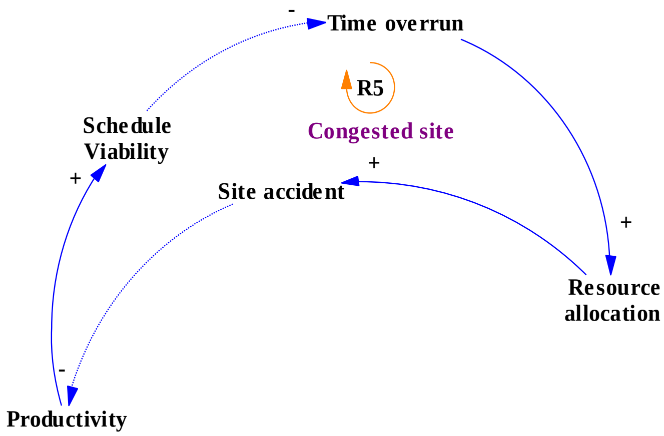

Figure 10:Loop R5

The impact of additional resources on site accidents could be contextual as it depends on site location, size and implemented safety measures. However, factor of human error is most critical in site accidents (Pinto et al., 2011) and increasing manpower means increasing the chances of safety breach and accidents. However, if site accidents happen, they impact labour productivity intensely. Site causalities may halt work and create an overall demotivation in workers for days. The risk of accidents increases as soon as the additional resources approach the site. Thus, it has a quick impact and therefore R5 carries *strong, fast and reinforcing* impact.

The identified loops were prioritised in the preferred sequence of fast+strong, slow+strong, fast+weak, and slow+weak. Reinforcing loops have a resonating impact while the effect of balancing loops decays overtime. Thus, reinforcing loops are comparatively more critical (Powell et al., 2016). Loops R1, R4 and R5 are the most critical loops having strong, fast and reinforcing impact, whereas, R2 and R3 are less crucial, followed by B1.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

The CLD reflects a complex interacting system where six loops provide an insight into mechanisms that impact project performance. Construction rework, productivity, time overrun, resource allocation, cost overrun and quality of work are the most critical and mutual factors among various loops. R1, R4 and R5 were prioritised as vicious cycles of risk which contribute to budget and schedule failure, which require the attention of project team when setting risk mitigation measure. Whereas, B1 is the only balancing loop that counter changes the risk impact in each cycle. This loop behaves as a self-constructive and corrective cycle. However, it initiates cost and safety related risks. Loops do not behave as independent cycles, but they interact with each other to transfer risk impact. This complex interaction as illustrated in CLD negates linear assessment of risk in fast-track projects as usually practiced by project managers.

Fast-track construction has become a standard procedure in advanced economies due to advanced technology and research efforts. In contrast, the construction industry in developing countries is still struggling without modern construction project management strategies. The CLD provides a more logical way to perceive project risks which can improve overall project management practice in emerging economies, increasing project success rate.

Following features of systems thinking approach and CLD for fast-track projects can help project managers in many ways. Project team can foresee causes and effect of critical risks which helps to analyse the actual risk situation and facilitates risk mitigation process. The project manager can observe that mere focusing on project schedule and budget will lower quality and safety performance, which will negatively impact time and cost of the project. Thus, all key objectives must be kept in balance while planning a project. Project managers must consider if system is dominated by reinforcing or balancing feedback loops which helps to predict potential consequences of remedial measures. Balancing feedback loops are likely to have a systematic resistance to disruptions within the system, including to management actions taken to improve project outcomes which require multiple changes in multiple locations. Reinforcing feedback loops, on the other hand, is likely to have a high degree of instability, such that disruptions can lead quickly to major changes in project performance. Implementation of changes in a positive feedback system, therefore requires a cautious approach and monitoring.

5.1 LIMITATIONS AND RECOMMENDATIONS

This study contributes to the body of knowledge by assisting project managers to understand the dynamics of fast-track project risks. The model provides an understanding of vicious risk cycles which can support project teams to realize and predict system behaviour and assign risk management strategies accordingly.

Alternatively, it is recognized that construction projects contain several risks, whereas the CLD is only based upon top fourteen risks which reduce the coverage of risk model. However, it must be acknowledged that a large number of variables in dynamic systems would form thousands of loops which will make the model complex to understand. Also, numerous meaningless and repetitive loops carrying low impact compromise the integrity of the model. Therefore, the most critical factors were selected.

The research appears to intentionally discard the application of numerical data. As a matter of fact, the system thinking methodology permits the induction of numerical data at a later stage, but is not incomplete in its analysis by the absence of it. The developed mechanism achieves the aim of the research which was to find interrelations among risk factors and identify critical loops that provide the perception of complex systems in fast-track projects.

The tools and techniques used in this research provide flexibility for mobilization of numerical data on the established mechanism which can be used to simulate project performance as a further study. However, qualitative or quantitative models on their own do not provide operational support and specific advice to project manager. Instead, they facilitate decision making process by increasing the perception of interdependencies and behaviour of complex systems. The model must be used in collaboration with case-based or expert systems to provide comprehensive predictive advice to project team.

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APPENDICES

6.1 APPENDIX I: GOOGLE SURVEY

"Probability-Impact assessment of risk factors in Fast-Track Construction Projects (FTCPs)"

6.2 APPENDIX II: INTERVIEW

"Causal relationship between critical risk factors in Fast-track Projects"

Organisation	
Designation	
Years of experience	
No. of Fast-track Projects	

Fast-track projects are time focused endeavours. In such projects, construction begins with partially completed design documents to avail the maximum time benefit. Design and construction activities are overlapped to compress the project timeline which creates complexities within the project. The semi-structured questionnaire is designed to find out the causal relationships among listed factors. Please indicate accordingly whether any of the factors "i" can cause factor "j".

Risk factors are described on subsequently for the ease of understanding.

Critical fast-track project risk factors and their description

S No.	Risk Factors	Description
1	Rework	Defective or low quality product requiring modifications or rework
2	Design errors	Errors in design and drawings
3	Schedule viability	The practicality of schedule (Sometimes the schedule is over compressed due to client pressure or political influence)
4	Change orders	Design changes during project execution
5	Safety	Accident and injuries during construction
6	Delay Damages	Monetary claims for late completion of work as agreed upon in the contract
7	Resource allocation	Apportionment of finance, manpower, equipment and facilities for each project phase and activity
8	Productivity	Contractor’s adherence to established schedule
9	Quality	Level of work in accordance to specifications
10	Construction equipment/methods	Use of proper construction equipment/methods supporting fast-tracking
11	Key stakeholder collaboration	Constructive involvement of the main project partners
12	Change in the specification/scope	Change in project specification & scope according to client requests, cost & time constraints, and political influence
13	Decision making time	Slow decision making process before and during execution of the project
14	Timely payments	Adherence to payment schedules
15	Time delay	Nonconformity to established timeline
16	Cost overrun	Cost deviation from set budget

	S No.	Factors (i)		Factor (j)	Does any factor (i) causes Factor (j)? Yes/No
1	2	Design errors	→	Rework	
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
2	1	Rework	→	Design errors	
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
3	1	Rework	→	Schedule viability	
	2	Design errors	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		

	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
4	**1**	Rework	→	Change orders	
	2	Design errors	→		
	3	Schedule viability	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
5	**1**	Rework	→	Constructio n safety	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
6	**1**	Rework	→	Delay Damages	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		

	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
7	**1**	Rework	→	Resource allocation	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
8	**1**	Rework	→	Productivity	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
9	**1**	Rework	→	Quality	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	10	Construction equipment/methods supporting fast-tracking	→		

	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
10	**1**	Rework	→	Construction equipment/ methods supporting fast-tracking	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
11	**1**	Rework	→	Key stakeholder collaboration	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
12	**1**	Rework	→	Change in the specification/scope	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods	→		

		supporting fast-tracking			
	11	Key stakeholder collaboration	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
13	**1**	Rework	→	Decision making time	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	14	Timely payments	→		
	15	Time delay	→		
	16	Cost overrun	→		
14	**1**	Rework	→	Timely payments	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	15	Time delay	→		
	16	Cost overrun	→		
15	**1**	Rework	→	Time delay	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		

	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	16	Cost overrun	→		
16	**1**	Rework	→	Cost overrun	
	2	Design errors	→		
	3	Schedule viability	→		
	4	Change orders	→		
	5	Construction safety	→		
	6	Delay Damages	→		
	7	Resource allocation	→		
	8	Productivity	→		
	9	Quality	→		
	10	Construction equipment/methods supporting fast-tracking	→		
	11	Key stakeholder collaboration	→		
	12	Change in the specification/scope	→		
	13	Decision making time	→		
	14	Timely payments	→		
	15	Time delay	→		

Appendix - I

Google Survey