RISKS OF INADEQUACIES OF INPUTS OF PRECONSTRUCTION ACTIVITIES TO DESIGN PHASE ON COST AND TIME OVERRUNS IN CONSTRUCTION PROJECTS

Leelanath Daluwatte

168040P

Degree of Doctor of Philosophy

Department of Civil Engineering

University of Moratuwa
Sri Lanka

March 2021

RISKS OF INADEQUACIES OF INPUTS OF PRECONSTRUCTION ACTIVITIES TO DESIGN PHASE ON COST AND TIME OVERRUNS IN CONSTRUCTION PROJECTS

Leelanath Daluwatte

168040P

Dissertation submitted in partial fulfilment of the requirement for the Degree of Doctor of Philosophy

Department of Civil Engineering

University of Moratuwa
Sri Lanka

March 2021

DECLARATION

“I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date:23-03-2021

The above candidate has carried out research for the PhD thesis Dissertation under my supervision.

Name of the supervisor: Professor Malik Ranasinghe

Signature of the supervisor: Date : 23-03-2021

ABSTRACT

Cost and Time overruns are common occurrences in construction projects completed in Sri Lanka. This research study was carried out to find the possible reasons for these overruns. The objectives of the study were to review, identify and analyze risks created by the inadequacies, correlations, coherence and accuracy of the input data of pre-construction activities to the design phase of construction projects and to develop and validate an industry best practice framework/model/guideline to minimize/eliminate cost and time overruns of construction projects due to risks of inadequacies, correlations, coherence and accuracy of the inputs of pre-construction activities to the design phase of the projects.

Initially, contributory factors for Cost and Time overruns of construction projects were identified. 'Design effects' was found to be the critical contributory factor. A study on 'Design effects' identified the pre-construction activities that are input to the design phase of construction projects. These pre-construction activities were used to examine 'Relevance of the activity' and 'Adequacy of the input of the activity' to the design phase in a construction project. Accordingly, a model, "$z = 100 - 2.6916e^{0.024x}$" where 'Inadequacy of the input to the design phase (z)' and 'Relevance of a pre-construction activity (x)' was derived for the input of a pre-construction activity to design phase of a construction project.

Pre-construction activities were expanded and analysed to assess the risks created by inadequate inputs from the pre-construction activities to the design phase of construction projects as follows. Scientifically developed questionnaires based on the mixed type of research method and where internal consistency was rated as 'excellent' were used for data collection. The probabilistic random sampling method confirmed that the sample of respondents selected for the study was adequate. One questionnaire was used to collect data from 32 projects to examine 'Relevance' and 'Adequacy' of input from pre-construction activities to the design phase of construction projects. The other questionnaire was used to collect data from 100 projects to examine the possibility of eliminating/minimising the Risk of Cost overruns and Risk of Time overruns by retaining services of a third-party independent designer to verify the adequacies of input from preconstruction activities to the design phase of construction projects. All respondents to the questionnaires were substantive experts actively involved in construction projects.

A structure to collect data was developed to identify and analyze risks from the input of respective pre-construction activities to the design phase of construction projects. The developed framework analysed risks using Risk Matrix, Relative Importance Index (RII), Severity Index (SI), Descriptive Statistics, Sampling Adequacy, Reliability, Validity, Correlation and Accuracy of data, Biases, Coherence of responses and Calibration of respondents.

Guideline for industry best practice was derived by using scientific techniques of data analysis for risks created by the inadequacies of input from respective pre-construction activities to the design phase of construction projects. Results from the analysis satisfied the limits set by each scientific technique used for the analysis. The analysis highlighted the ranks of preconstruction activities which with inadequate input to the design phase of construction projects increased the Risk of exceeding Cost, Risk of exceeding Time and minimising the Risk of exceeding Cost and Time. Risk interpretation revealed that top ranks of preconstruction activities were 'Likely' to induce Risk of exceeding Cost and Risk of exceeding Time of construction projects.

Guideline for industry best practice was validated through statistical methods and Case studies from the construction industry. The main conclusions of the study were that: i) Inadequacies of input from preconstruction activities to the design phase contributed towards Cost overruns and Time overruns in construction projects; ii) Risks created by the inadequacies, correlations, coherence and accuracy of the input data of pre-construction activities to the design phase of construction projects contributed towards Cost overruns and Time overruns in construction projects and iii) Verification of the input from preconstruction activities to the design phase of construction projects by a third party independent designer would minimise the Risk of exceeding Cost and the Risk of exceeding Time of Construction projects. In addition to the 3 main conclusions described above, there were 19 conclusions and 3 recommendations.

Key words: Cost overrun, Time overrun, Preconstruction activities, Risk, Independent designer

This dissertation is dedicated with warmest gratefulness to

my School

Ananda College, Colombo, Sri Lanka

and

my University

University of Moratuwa, Sri Lanka.

These two institutions paved the way for me to be what I am today.

ACKNOWLEDGEMENT

I express my heartfelt gratitude to Professor Malik Ranasinghe, my supervisor, who made the study stimulating and enjoyable. I greatly appreciate his availability for the study, almost at any time, prompt responses, guidance, advice, feedback and support from the inception of the study. I am blessed to have him as my supervisor.

I also thank Professor Asoka Perera and Dr S B Wijekoon, members of the review panel and Professor Saman Bandara for the valuable inputs given during the study. In addition, input to the study from Professor Kamal Premaratne, Dr. Asitha Seneviratne and Dr. Vasantha Abeysekara is deeply appreciated.

Further, noteworthy support to the study given by Mr. Namal Peiris, Mr. Sisira Weerabahu, Ms. Dinusha de Silva, Mr. Isuru Herath, Ms. Sashenka Kumarage, Ms. Dinusha Dissanayake, Mr. Thushara Perera, Mr. Darshana Weerabahu and Mr. Barnes Abeywardena is highly appreciated. Also, my appreciation goes to the experts who positively reacted to the requests for responses related to the study. In addition, I appreciate the relavant staff of the University of Moratuwa, specially from the Faculty of Graduate Studies for giving the best possible support to the study.

The encouragement given in either way to the study by my son, Randesh Daluwatte, was probably one of the highlights of the process of the study and I really appreciate his sincere efforts. Finally, I like to thank my family for standing by me.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

CHAPTER 1– INTRODUCTION

1.1 Background

Construction projects consume significant quantities of scarce resources (e.g. building materials, fossil fuels, machinery, human resources, etc.) irrespective of the magnitude of the project (EU Technical Report, 2014). Construction projects are expected to utilize these scarce resources to optimize both quantity and duration to effectively deliver project outputs. However, most construction projects do not optimally utilize resources or effectively deliver the project output (Shrestha, Burns and Shield, 2013). These shortcomings cause additional cost and time to achieve the scope of the project, resulting in lost opportunities to project stakeholders. Most construction projects in Sri Lanka face the above scenario, resulting in cost and time overruns of projects.

Daluwatte and Ranasinghe (2017) identified forty-two contributory factors for cost and time overruns in construction projects. Of these, design effects were found to be the most significant contributor. Moreover, cost and time overruns of construction projects could occur at any stage (Investigation, pre-design, design, implementation, operational and demolishing) of a construction project. This was evident from the findings of Daluwatte and Ranasinghe (2017). Further, Daluwatte and Ranasinghe (2018) highlighted thirty-eight pre-construction activities which provide inputs to the design phases of construction projects. In addition, a model was proposed for the relationship between the relevance and inadequacy of input of the pre-construction activity to the design phase of a construction project. Daluwatte and Ranasinghe (2019) showed that the risks of inadequacies of inputs of pre-construction activities to design phase lead to cost and time overruns in construction projects and stated that inadequate inputs to the design phase from pre-construction activities contributed to the risk of exceeding cost and time of construction projects.

1.2 Research Problem

The literature review highlighted that design effects, planning and controlling, and material issues were the key contributors to cost and time overruns of construction projects. Of these, design effects were identified as the most significant contributor to cost and time overruns of construction projects. The review also revealed that a possible relationship between the relevance and inadequacy of pre-construction activities exist.

Hence, risks created by the inadequacies of outputs of pre-construction activities as inputs to the design phase exist. In addition, risks due to correlation (factors and their interrelations) between input data to the design phase, accuracy and coherence (empirical validity of the current elaboration, based on a large number of cases) of the input data are possible factors that affect the relevance of the pre-construction activity. The ability to identify, quantify and manage the risks due to inadequacies, correlation, coherence and accuracy of input data would significantly improve the relevance of the input data to the design phase.

1.3 Research Aim

This research aims to develop a methodology to identify, quantify and manage and control risks created by inadequacies, correlation, coherence and accuracy of input data of pre-construction activities to the design phase of construction projects.

1.4 Research Objectives

To achieve the aim of this research study, the following research objectives are proposed.

1. Review, identify and analyze the risks created by the inadequacies, correlations, coherence and accuracy of the input data of pre-construction activities to the design phase of construction projects.
2. Develop industry best practice framework/model/guideline to minimize/eliminate cost and time overruns of construction projects due to risks of inadequacies, correlations, coherence and accuracy of the inputs of pre-construction activities to the design phase of the projects.
3. Validate the developed best practice framework/model/guideline as per Objective 2.

1.5 Main Findings

The literature review highlighted that inadequacies of input of preconstruction activities to the design phase of construction projects contributed towards Cost overruns and Time overruns in construction projects. The above finding was further confirmed by the extensive responses received from substantive experts in the industry to the structured questionnaires developed using accepted research methodologies. The data collected from a number of questionnaire surveys were analysed for correlations, coherence, accuracy, (ranking, internal consistency, validity and factor analysis) in the development of the best practice guideline. The analysed results from the developed best practice guideline were validated through both statistical validations and case studies.

The main conclusions of this research study were as follows.

1. Inadequacies of input from preconstruction activities to the design phase contributed towards Cost overruns and Time overruns in construction projects.

2. Risks created by the inadequacies, correlations, coherence and accuracy of the input data of pre-construction activities to the design phase of construction projects contributed towards Cost overruns and Time overruns in construction projects.
3. Verification of the input from preconstruction activities to the design phase of construction projects by a third party independent designer would minimise the Risk of exceeding Cost, the Risk of exceeding Time of construction projects.

1.6 Structure of the Thesis

The structure of this thesis is as follows.

Chapter 2 describes the literature review on, cost and time overruns, pre-construction phase and inadequacies of inputs to the design phase of construction projects. It reviews the risks and inadequacies, correlation, calibration of respondents, accuracy and bias of the inputs of pre-construction activities to the design phase of construction projects. It also reviews the relevance of data and activities, research methodology, Likert scale and substantive experts. The summary of the literature review demonstrates the gaps in knowledge that defines the research problem given in section 1.2.

Chapter 3 describes the research methodologies considered for the study. The qualitative research method, Quantitative research method and Mixed research method were the research methods considered for the study. Also, Questionnaire Surveys were utilized for the study.

Chapter 4 describes the development of the analysis framework to find the framework/model/guideline to minimize/eliminate the cost and time overruns of construction projects due to risks of inadequacy, correlations, coherence and accuracy of inputs of pre-construction activities of construction projects. The developed framework analyze possible risks created by the inadequacies of outputs of relevant pre-construction activities as inputs to the design phase of construction projects. Data for the development of the framework were obtained from substantive experts working in the field of civil engineering using two different Likert scale type questionnaires.

The developed analysis framework was based on the analysis of risks using several techniques. Techniques used for the analysis were Risk Matrix, Likert type scales, Relative Importance Index (RII), Severity Index (SI), Descriptive Statistics, Reliability of data, Validity of data, Correlation of data, Sampling Adequacy, Accuracy of data, Bias of responses, Coherence of responses and Calibration of respondents.

Chapter 5 describes the data collection utilising the developed analysis framework. It describes how questionnaires were developed for qualitative research and how the pilot survey, the main survey and the interviews were conducted to collect data on the inadequacies of the pre-construction activities and their effects on the design phase of construction projects. The suitable sample size for the studies was decided following methods reviewed during the literature review described in Chapter 2.

This Chapter also described the method of data collection, including i) identified contributory factors of cost and time overruns of construction projects (Daluwatte and Ranasinghe, 2017), ii) identified pre-construction activities that provide input to the design phase of construction projects (Daluwatte and Ranasinghe, 2018), iii) questionnaire to capture data for the thirty-eight relevant pre-construction activities (Daluwatte and Ranasinghe, 2018), and iv) questionnaire to capture data for the identified forty-nine relevant pre-construction activities to derive the framework for the study (Daluwatte and Ranasinghe, 2019).

Chapter 6 described the analysis of the input of pre-construction activities to the design phase of construction projects. It includes the analysis of input from thirty-eight relevant pre-construction activities to the design phase of construction projects. Based on the above analysis, a model was developed for the relationship between the 'Relevance to a pre-construction activity of a construction project' and 'Inadequacy of the input to the design phase of a construction project' (Daluwatte and Ranasinghe, 2018). Also, it described the analysis of the Risks created by the identified relevant forty-nine pre-construction activities. The analyses were carried out using the techniques described in Chapter 4 above.

Chapter 7 describes the validation of the developed best practice guideline through statistical (hypotheses) testing and case studies from the construction industry.

Chapter 8 describes the conclusions and recommendations of the study.

CHAPTER 2 - LITERATURE REVIEW

2.1 General

This chapter describes the literature review on cost and time overruns of construction projects (section 2.2), pre-construction phase of construction projects (section 2.3), inadequacies of inputs to design phase (section 2.4), risks and risks of inadequacies (section 2.5), correlation (section 2.6), calibration (section 2.7), coherence (section 2.8), accuracy (section 2.9), bias (section 2.10), accuracy and bias (section 2.11), research methodology (section 2.12), Likert scale (section 2.13) and substantive experts (section 2.14). The summary of the literature review which demonstrates the knowledge gap that defines the research problem is given in section 2.15.

2.2 Cost and time overruns of construction projects

The literature review revealed that previous research has identified the following areas (listed in sections 2.1.1 to 2.1.24) as contributing to cost and time overruns of construction projects.

2.2.1 Stakeholder Contribution

Buys (2015) stated the provision of all information to stakeholders as relevant would avoid doubts and conflicts and would lead to stakeholder satisfaction. However, (Doloi, 2013) claimed managing stakeholder responsibilities is a chronic problem in the Australian construction industry and how it can be managed successfully is unclear. Further, Olander (2007) stated analysis of stakeholder involvement includes evaluating the needs and expectations of stakeholders concerning the main objectives of the project.

AlNasseri & Aulin (2016) stated in the development of project plans and schedules, stakeholder's support was lacking. It was also observed that decisions made on the criticality of the activities and dependence on resources were poor. Bhatia & Apte (2015) concluded that advance actions required for the success of the project were not taken by any of the stakeholders involved.

To achieve information sharing with stakeholders, Buys (2015) suggested showing a timeline of progress, milestones, any problems encountered, and financial status to the stakeholders throughout the entire project duration would be effective.

2.2.2. Pre-construction Conditions

Craigie (2015), observing associated pre-construction service costs at various highway construction projects in Iowa, USA, suggested that each task at pre-construction process of construction projects be listed and the scope of work for each task be worked out. Costing such tasks would ensure the funding requirement of finance at the pre-construction stage of a construction project. Further, it was observed that inadequate fund allocation at the pre-construction stage had led to shortcomings of projects, such as ambiguities, design errors, and omissions, and these in turn had incurred more costs during the construction phase.

Jatarona, Yusof, Ismail & Saar (2016) reported under-performance in Malaysian public construction projects. This research shows that the ineffectiveness of early investigation and design are among the factors causing cost and time overruns in the said category of construction projects. Kaveen, Aleem & Thaarrini (2015) stated that deficiencies in the acquisition of land and planning and scheduling were among the most critical factors that caused cost and time overruns in major construction projects in India.

Azhar, Farooqui & Ahmed (2008) found, among other factors, the procedure of selecting the lowest bidder had contributed to cost overruns in Pakistani construction projects. Ojo & Odediran (2015) found that contract conditions were the most critical factor that generates significant risks in cost estimating in the construction industry in Nigeria.

Some of the associated risks in the pre-construction stage were identified as the bidding process, estimating process, finance and project design. Jackson (2000) stated client-driven design changes were found to generate the highest risk in cost overruns in construction projects and detailed information on designs at early stages would lead to more accurate budget estimates and in turn curtail possible cost overruns in construction projects.

Laufer, Tucker, Shapiria & Shenhar (1994) studied how construction planning was done in the pre-construction and pre-bid stage in the USA. Functional plans, participating parties and stages as three independent variables and involvement, effort, issuance and formats as planning measures were looked at. It was found that general scheduling was considered as the key in planning but successful projects consider it was only one of many planning aspects and effort for scheduling given is about $1/5^{th}$ of the total effort. Further, it was noted that the general planning process was carried out by a staff person assisted by a line manager whereas, in successful construction projects, the planning involved many parties, internal and external and involvement of parties were depended on the stage of the project.

Edwards, Bowen, Hardcastle & Stewart (2009) observed that communication of risks based on accurate risk statements was required for a project to be successful. A detailed work breakdown structure approach in the project implementation stage would be useful for the identification of possible risks in construction projects.

2.2.3. Finance

While Rahman, Memon, Nagapan & Latif (2012) stated that financial resource management was among the major contributors for cost and time overruns of construction projects in southern and central regions of the Malaysian peninsula, Craigie (2015) highlighted the importance of providing budget at the required amount for the services at the pre-construction phase of construction projects. This was evident at various highway construction projects in Iowa, USA.

Adam, Josephson & Lindahl (2017) suggested that financial issues in projects caused cost and time overruns in major public construction projects and Jackson (2000) found that accurate budget estimates can arrive through complete design information which in turn would curtail the risk of cost overruns of construction projects.

El-Kholy (2015) found that the financial condition of the owner was among the top 11 factors contributing to the cost overruns of construction projects in Egypt and Memon (2014) too stated that financial difficulties faced by the owner were a major factor causing time overruns in the construction industry in Malaysia. Shibani (2015) highlighted that financing delay caused time overruns (ranked fourth in factors causing time overrun) and constraints of financial budget caused cost overruns (ranked fourth in factors causing cost overrun) in construction projects in Egypt.

Desai, Pitroda, & Bhavsar (2015) stated change orders bring about a requirement of finance to the construction project and the design phase creates a higher requirement of finance than the construction phase of construction projects. Bekr (2015) concluded to facilitate regular periodic payments to the contractor and sufficient funding level should be determined at the inception of construction projects.

Larsen, J. K., Shen, G. Q., Lindhard, S. M. & Brunoe (2015) concluded lack of project funding was the most influential factor for time overruns in the USA. It was also stated there had been awareness among the construction industry, academics and politicians of the frequent cost and time overruns and reduced quality due to loss of financial resources. Morris (1990) stated inadequate funding leads to cost and time overruns in public sector construction projects in India. Also, it was concluded that the tendency to take up large numbers of projects and to short fund them was perhaps the most important factor in delays.

Kaveen, Aleem & Thaarrini (2015) stated mode of financing was an important factor that contributed to time overruns of construction projects and Okpala, & Aniekwu (1988) observed method of financing was one of the top three major reasons caused cost overruns in construction projects in Nigeria.

Vu, Wang, Min, Mai, & Nguyen (2016) summarised the risks faced in cost overruns in the highway construction projects in Vietnam, found capital and contract constraint risk within the top seven risks.

2.2.4. Approvals

Emam, Farrell & Abdelaal (2015) found long response time from utility agencies were among the top five causes contributing to time overruns in infrastructure construction projects in Qatar. It was also said contributory factors could vary from country to country and project to project and Mulla & Waghmare (2015) stated delay in getting clearances contributed to cost and time overruns of construction projects.

Mukuka, Aigbavboa & Thwala (2015) stated approval of major changes of scope of work and delays in getting permits from municipalities were among the major causes contributing to time overruns in construction projects in Gauteng, South Africa.

Kaveen, Aleem & Thaarrini (2015) claimed delay in the approval of design was an important factor that caused cost overruns in construction projects in India. After examining previous literature on cost and time overruns of construction projects El-Kholy (2015) stated delay in design and approval was one of the eleven critical factors that contributed to cost overruns in construction projects in Egypt. Memon, Rahman, & Azis (2011) claimed delay in the approval of drawings was among the most critical and common factors that caused cost overruns in the construction industry of Malaysia.

2.2.5. Project communication

While Adam, Josephson & Lindahl (2017) suggested ineffective communication contributed towards cost and time delay of construction projects and Priyadharshini & Kumar (2015) found inefficient communication or receiving and sending of information between the stakeholders of the projects was a key factor causing cost and time overruns in construction projects in India. Edwards, Bowen, Hardcastle & Stewart (2009) stated risks of a project need to be communicated effectively among the stakeholders and to facilitate the matter, accurate risk statements were required. Also, it was recommended workshops to be held during the pre-construction stage of construction projects to draw accurate risk statements of the project.

Ismail, Rahman & Memon (2013) studied factors contributing to cost and time overruns in all phases i.e. planning, design, construction and finishing of construction projects. Further, it was found, lack of communication between the parties was common in all four phases of the construction projects. Shibani (2015) stated poor communication and coordination between parties caused time overruns in Egyptian construction industry. This was the second most critical factor among the top five factors identified contributing to time overruns of such projects.

2.2.6. Contract conditions

Ojo & Odediran (2015) stated contract conditions were generating risks in construction cost estimating in construction projects in Nigeria. Also, it was observed, the size of the company was an influencing variable that can be considered in the management of risks in cost estimations in construction projects.

Vu, Wang, Min, Mai, & Nguyen (2016) stated contract constraint risk was one of the seven top risks involved in the cost overruns in highway construction projects in Vietnam. Further, it was claimed the Vietnam government departments should strengthen the management of supervision of bidding for construction projects.

2.2.7. Bid

Patel, Chaturvedi, Rao, Katta & Prasad (2015) stated limited time given for submission of proper bids contributed to time overruns of (some of them) infrastructure projects owned by the government of India. It was observed that even different tools were used (e.g. e-tendering) time overruns were occurring. Craigie (2015) stated that lack of funding for activities during the pre-construction stage, which includes bidding, generated problems at the construction stage which lead to extra cost during construction. This was found in highway projects in Iowa, USA.

Ojo & Odediran (2015) stated risks associated with the estimation of the construction cost was found and included in the bidding procedure to control cost overruns of projects and Azhar, Farooqui & Ahmed (2008) found in the construction industry in Pakistan, procurement procedures based on the lowest bid was one of the top ten factors that caused cost overrun in construction projects.

Bekr (2015) recommended revising the bid documents (specifications, quantities take-off, drawings and design of the project) within the agreed schedule to minimise the overruns of construction projects.

2.2.8. Design

Design related issues were identified as the most problematic (Jatarona, Yusof, Ismail & Saar (2016); Craigie, 2015) and as significant (Memon, Rahman & Azis (2011); Jackson, 2000) in creating cost and time overruns of construction projects. Different aspects of the design were found to have contributed to cost and time overruns such as; design errors (Ojo & Odediran (2015); Vu, Wang, Min, Mai, & Nguyen (2016); Olawale & Sun, 2010), poor design (Memon, Rahman & Azis, 2011); Morris, 1990), delay in design (Memon, Rahman & Azis, 2011); Akinsiku & Akinsulire, 2012), design changes (Vu, Wang, Min, Mai, & Nguyen (2016); Olawale & Sun, 2010; Desai, Pitroda, & Bhavsar (2015), client driven design changes (Jackson, 2000; Desai, Pitroda, & Bhavsar (2015), change orders due to design changes (Desai, Pitroda, & Bhavsar (2015) failing to identify project risks at design stages (Edwards, Bowen, Hardcastle & Stewart (2009), erroneous design work/process including attitudes of the designer (Jackson, 2000; Desai, Pitroda, & Bhavsar (2015), design errors (Buys (2015); Desai, Pitroda, & Bhavsar (2015) and impacts of construction cost estimating (Ojo & Odediran (2015)).

Jackson (2000) stated more time invested in the early stages of design in view to clearly define the scope, assess the complexity of the projects and complete design information leads to more accurate budget estimates of construction projects. Edwards, Bowen, Hardcastle & Stewart (2009) found the work breakdown structure (WBS) approach to be a good `fall back' method for identifying project risks at the design stages.

Reviews of the following research publications highlighted how the effects of design have contributed to the cost and time overrun of projects. (Emam, Farrell & Abdelaal, 2015); Kaveen, Aleem & Thaarrini, 2015); Bekr , 2015); Sepasgozar, Razkenari & Barati (2015); El-Kholy, 2015; Akram, Memon, Ali and Siddiqui, 2015; Mahadik, 2015; Patel, Chaturvedi, Rao, Katta & Prasad (2015); Rahman, Memon, Nagapan & Latif, 2012; Memon, Rahman, Abdullah & Azis, 2010; Long, Ogunlana, Quang & Lam, 2004; Mukuka, Aigbavboa & Thwala (2015); Olawale and Sun 2010; Memon, 2014; and Azhar, Farooqui & Ahmed, 2008).

2.2.9. Planning

Shibani & Arumugam (2015) concluded efficient planning would be one of the ideal methods to reduce cost overruns of construction projects. Also, Bhatia & Apte (2015) and Rwakarehe & Mfinanga (2014), comparing the planned cost and time with actual cost and time found poor planning hampered the progress of the projects leading to cost and time overruns. Further, Rwakarehe & Mfinanga (2014), and Mulla & Waghmare (2015) observed cost and time overruns in construction projects were caused by poor planning. Also, Solís-Carcaño, Corona-Suárez & García-Ibarra (2015) found that there is a strong positive relationship between the timely completion of projects and effort invested in project schedule management to achieve timely completion of construction projects. Moreover, poor planning and controlling were found as a major factor for delay in projects. Further, Patel (2014) found a significant contribution to the cost overrun of construction projects was due to poor planning and coordination.

Laufer, Tucker, Shapiria & Shenhar (1994) observed planning process involved both internal and external parties to the construction company and some parties (e.g. project manager) get involved throughout the project period and involvement of other parties (e.g. specific sub-contractor) may vary. It was also noted that efforts in functional plans during the construction process were five times the effort in the preparation of the overall schedule.

Doloi (2013) stated in the perception of the clients, consultants, and contractors the highest impact on cost performance was deficiencies in planning and scheduling. Also, Kaveen, Aleem & Thaarrini (2015) identified by proper planning and scheduling cost overruns of the project could be curtailed. Further, Azhar, Farooqui & Ahmed (2008) found inaccurate planning of the contractors involved was rated in the top ten of cost overrun factors of construction projects. Also, Memon, Abdullah & Azis (2010) concluded there was a strong positive relationship with the inadequate experience of contractors with incorrect planning and scheduling which lead to a significant contribution in overruns of cost of construction projects.

Emam, Farrell & Abdelaal (2015) stated insufficient planning and scheduling was among the top factors which caused time overruns in projects. Also, it was found that projects need to use planning and scheduling systems to cater for their dynamic and changing nature. Further, Allahaim & Liu (2013) observed over the last few decades there was no significant reduction in cost overruns in construction projects and insufficient planning was listed as one of the four main contributors to the said cost overruns in construction projects.

Memon, Rahman & Azis (2011) stated construction cost overruns in construction projects was caused by ineffective planning and scheduling and was among the most common and significant factors causing cost overruns and AlNasseri (2015) concluded, despite the significance of causing cost overruns many construction companies appear to give inadequate consideration for project planning, including at the preplanning stage. Further, it was claimed that lack of knowledge and understanding of the area of project planning had contributed to cost and time overruns and a suggestion was made to stakeholders knowledgeable about front end planning as a possible solution.

Bekr (2015) found the effect of improper planning at the initial stages of construction projects manifests throughout the project and caused delay and cost overrun. It was also observed insufficient planning and scheduling was among the most important factors causing cost and time overruns of construction projects. KPMG – PMI study in India (2012) highlighted though planning was a controllable factor at the project level, improper planning had contributed to delays of most of the construction projects.

Fiedler & Schust (2015) found when construction started while planning was incomplete and planning and construction was done in parallel it caused cost and time overruns in construction projects. The study showed the Elbphilharmonie skyscraper project where planning and construction are done in parallel incurred a cost overrun of €513.3 million (from the planned value of €351.8 million) and a time overrun of seven years.

Also, a review of the following publications revealed how the effects of planning contributed to cost and time overruns of projects (AlNasseri & Aulin, 2016; Olawale & Sun, 2010; Mukuka, Aigbavboa & Thwala, 2015; Ojo & Odediran, 2015)

2.2.10. Workers

Memon, Rahman & Azis (2011) stated the relationship between management and labour was a significant factor inducing cost overruns in the construction industry in Malaysia and Bekr (2015) found delays caused by the shortage of skilled site workers was one of the important contributors to cost overruns in the construction industry in Jordan. Also, a KPMG study in India (2012) found the majority of infrastructure projects in India are delayed by severe skill shortage contributed to cost and time overruns.

Memon, Abdullah & Azis (2010) stated that one of the most severe factors in the construction industry in Malaysia is the shortage of site workers and this had led to cost and time overruns of construction projects. Also, Sepasgozar, Razkenari & Barati (2015) observed a shortage of labour was one of the top ten factors causing time overruns in construction projects in Iran.

Shibani (2015) stated low productivity of the labourers was one of the five critical causes for cost and time overruns in construction projects in Egypt while Mulla & Waghmare (2015) stated one of the main reasons for cost and time overruns in construction projects in India was low productivity of resources. Further, Mukuka, Aigbavboa & Thwala (2015) found low productivity level of workers, risky behaviour on sites by the workers and a shortage of skilled equipment operators were three of the major factors of time overruns in construction projects in Gauteng, South Africa.

2.2.11. Material

Mahadik (2015) stated reduction of cost and time overruns can be achieved through the availability of material during the implementation of construction projects while Adam, Josephson & Lindahl (2017) found material related issues that caused time overruns in major public construction projects.

El-Kholy (2015) found an increase in material cost due to inflation significantly contributes to cost overruns in construction projects in Egypt and also Patel (2014) concluded an increase in the cost of construction material caused significant cost overruns in construction projects in India. Further, Shibani (2015) stated fluctuation of material prices is one of the factors contributing to cost overruns in the construction industry in Egypt.

Kaveen, Aleem & Thaarrini (2015) identified escalation of cost of material as an important factor in causing cost overruns in construction projects while Patil & Bhangale (2013) found escalation of material prices and change in material specifications were among the five most critical factors contributing to cost overruns in construction of high-rise buildings in India. Also, Ameh, Soyingbe, & Odusami (2010) observed that the high cost of imported material ranked second in construction-related factors contributing to cost overruns in Telecommunication infrastructure projects in Nigeria.

Memon, Rahman & Azis (2011) claimed late delivery of material and equipment was among the significant and common factors resulting in cost overruns in the construction industry in Malaysia and Mukuka, Aigbavboa & Thwala (2015) stated delays in material delivery caused time overruns in construction projects in Gauteng, South Africa. They also said it was among the major causes that contributed to delay in projects.

Rahman, Memon, Karim, & Tarmizi (2013) said fluctuation of the cost of material was one of the most critical factors affecting cost overruns in large construction projects in Malaysia and Azhar, Farooqui & Ahmed (2008) found fluctuation in the prices of raw material caused cost overruns in construction projects.

Desai, Pitroda, & Bhavsar (2015) stated change in quantities of material and substituting material through change orders could contribute to the cost and time overruns in construction projects and Sepasgozar, Razkenari & Barati (2015) identified deficiency in the material caused time overruns in construction projects in Iran. Further, Buys (2015) stated inadequate and inappropriate procurement contributed to cost and time overruns of construction projects and also Mulla & Waghmare (2015) found a delay in the client supplied material caused time overruns in construction projects in India.

The following publications in the area of effects of material that contributed to cost and time overruns of projects were reviewed too. (Rajguru & Mahatme, 2015; Shibani & Arumugam, 2015).

2.2.12. Management

Rahman, Memon, Nagapan & Latif (2012) stated deficiencies in finance management and project management were critical factors and caused cost and time overruns in construction projects in the southern and central regions of Malaysia and Ojo & Odediran (2015) observed management of cost estimating process of construction projects were very important as it formed the backbone of the forecasting of the costs.

Mahadik (2015) observed that strategies applied during project implementation were important to save cost and time of construction projects.

Long, Ogunlana, Quang & Lam (2004) observed that poor change management contributed to cost and time overruns of construction projects in Vietnam. Also, Rwakarehe & Mfinanga (2014), and Memon, Rahman & Azis (2011) stated the relationship between management and labour and poor site management were among the most common and significant factors that caused cost and time overruns in the construction industry in Malaysia.

Morris (1990) and Rwakarehe & Mfinanga (2014), claimed inconclusive decision making by the bureaucrats causes costs and time overruns of the public sector construction projects in India and Choi, Oliveira, Stephen, Mulva & Kang (2016) suggested a framework and ten input measures; Planning, Organizing, Leading, Controlling, Design efficiency, Human resources, Quality, Sustainability, Supply chain and Safety, for measuring project management in capital projects.

2.2.13. Contract Management

Okpala, & Aniekwu (1988) found the high cost of construction occurred due to poor contract management and Buys (2015) stated cost and time overruns of construction projects was a result of faulty contract management. Also, Ojo & Odediran (2015) found conditions of contracts caused time overruns and Rahman, Memon, Nagapan & Latif (2012) stated contract administration issues were among the major contributors to cost and time overruns of the construction projects.

Wilks (2015) stated that poor contract management generated disputes and failure to administer contracts properly caused disputes which generated additional costs and Shibani (2015) recommended checking and revising contract documents (duration, clauses etc.) in view to avoid possible overlooked loopholes to control cost and time overruns in construction projects.

Also, the following publications on the effects of poor contract management were reviewed; (Mulla & Waghmare, 2015; Memon, Rahman & Azis, 2011; Mahadik, 2015).

2.2.14. Site conditions

Azhar, Farooqui & Ahmed (2008) found poor project site contributed to cost overruns in the Pakistani construction industry and Adam, Josephson & Lindahl (2017) stated site conditions were a reason to incur cost and time overruns of major public construction projects. Besides, Allahaim & Liu (2013) claimed poor site conditions was a major factor that contributed to cost overruns in infrastructure projects in Saudi Arabia. It was also stated that their findings could be used in the early stage to mitigate issues.

Memon (2014) in a publication following a study for Construction Industry Development Board of Malaysia stated unforeseen ground condition was a major causative factor for cost overruns in construction projects in Malaysia.

2.2.15. Site management

Doloi (2013) stated according to clients, consultants and contractor's site management was a critical factor contributing to cost overruns in the Australian construction projects and Shibani & Arumugam (2015) claimed proper site management and supervision of the project would be ideal to avoid cost overruns of construction projects.

Rahman, Memon, Karim, & Tarmizi (2013) found poor site management and supervision as a critical factor that caused cost overruns in large construction projects in Malaysia and Azhar, Farooqui & Ahmed (2008) stated poor site management was one of the main reasons that caused cost overruns in the Pakistani construction industry. Further, Memon, Rahman & Azis (2011) and www.springer.com observed poor site management and site supervision were among the most significant and common factors in cost overruns in the Malaysian construction industry.

Emam, Farrell and Abdelaal (2015) identified though the time overruns of construction projects vary according to the country, the project and the locality, effective control of progress could minimise such overruns in construction projects in Qatar and Shibani (2015) stated contractors were advised to be responsible about their work to prevent cost and time overruns in Egyptian construction projects.

Lee (2008) found delay during construction was listed as a critical factor that caused cost overruns in road, rail, airport, and port construction projects in Korea. Also, Adam, Josephson & Lindahl (2017) suggested management as causative in inducing cost and time overruns of major public construction projects.

2.2.16. Delay in decisions

Memon (2014) stated delay in decision making was a significant contributor to time overruns in construction projects in Malaysia and also Bhatia & Apte (2015) found delays in decision making as a critical factor that caused cost and time overruns of construction of private residential properties in Pune, India.

Mukuka, Aigbavboa & Thwala (2015) claimed slowness in the decision making process was a major contributing factor in time overruns in construction projects in Gauteng, South Africa and Morris (1990) observed bureaucratic indecision was one of the critical factors contributing to cost and time overruns in public sector projects in India.

2.2.17. Payments to Contractor

Okpala, & Aniekwu (1988) identified delay in payments for completed work was a major reason for high costs in construction and Mulla & Waghmare (2015) stated a major reason for the delay was settling running account bills. Further, Memon, Abdullah & Azis (2010) stating cash flow and financial difficulties faced by contractors was among the most severe factors for cost overruns of construction projects.

2.2.18. Change order requests

Desai, Pitroda, & Bhavsar (2015) observed that change orders had a critical impact on cost, time and quality of construction and stated that change orders were associated with changes arising from the process of construction and these changes were usually due to the complexity of the projects. Also, it was concluded that change orders averaged a 10% to 15% increase of the contract value and the higher the change higher the loss of productivity (loss of 10% to 20%) and cost of the project. Further, it was observed that change of mind by the owner, change in material and design omissions were the main reasons for change orders which caused not only disputes among the parties and cost and time overruns of construction projects.

Jackson (2000) found clients were the main party that imposed changes and client-driven design changes caused the critical risks that generate cost overruns of construction projects in the UK and Patel (2014) concluded when client issued change orders in exceeding quantities during construction it contributed to the cost overruns in the construction industry in India.

2.2.19. Contractor inexperience

Memon, Abdullah & Azis (2010) found inexperienced contractors induced erroneous planning and scheduling in the implementation of construction projects and inadequate contractor experience was among the main factors contributing towards the cost overruns in the construction industry in Malaysia. Similarly, Ameh, Soyingbe, & Odusami (2010) found a lack of contractor experience on telecommunication projects was a significant factor that caused cost overruns in telecommunication projects in Nigeria.

Kaveen, Aleem & Thaarrini (2015) observed nonperformance of subcontractors and inadequacy of contractor's resources were critical contributory factors in cost and time overruns of construction projects in India and also Olawale & Sun (2010) found despite the availability of various software for project control, the output from the subcontractors was poor and critically contributed to cost and time overruns in construction projects in the USA.

Long, Ogunlana, Quang & Lam (2004) concluded incompetent contractors caused cost and time overruns in large construction projects in Vietnam and also Vu, Wang, Min, Mai, & Nguyen (2016) stated cost overrun of highway projects in Vietnam indicated capacity to manage, including the human resource factor, such work during construction was a risk factor contributing to cost overruns.

Larsen, J. K., Shen, G. Q., Lindhard, S. M. & Brunoe (2015) concluded errors or omissions in construction work was the most significant factor affecting the quality of construction work in the USA.

Bekr (2015) identified most of the projects were awarded to the lowest bidder and the contractors' capabilities lack the requirements needed to perform the project satisfactorily. Further, the local contractors were hardly successful in producing efective plans project start. All these issues and construction mistakes and defective works lead to cost overruns in the construction industry in Jordan.

2.2.20. Changes by Client

Jackson (2000) stated the greatest risk in cost overruns was caused by client-driven design changes in construction projects in the UK. It was also observed that the clients being the party who does the majority of changes, should take account of themselves rather than blaming the inefficiencies of the industry.

Patel (2014) found change orders issued due to expanding requirements by the client caused substantial contribution to cost overruns in building construction projects in India and Kaveen, Aleem & Thaarrini (2015) stated too many change orders from the owner was a major contributory factor for cost and time overruns in construction projects in India. Also, Shibani (2015) stated additional works by the owner or the client caused cost and time overruns in construction projects in Egypt.

Also, Desai, Pitroda, & Bhavsar (2015) stated the main source of change orders arise from the change in plans by the client which generated from a change in mind. These changes have a critical impact on project cost, time and quality and similarly, Bekr (2015) observed changes, additional works and change in the scope of work initiated by the client contributed to cost overruns in construction projects in Jordan.

Sepasgozar, Razkenari & Barati (2015) found owner attributes was one of the key factors that contributed to time overruns in construction projects in Iran. Also, El-Kholy (2015) observed retention of the risk for variation of quantities by the client was a major cause for cost overruns in construction projects in Egypt.

Adam, Josephson, & Lindahl (2014) identified although the contractors' role was examined, the role of the client organization had often been overlooked in analyzing cost and time overruns of major public construction projects in Sweden.

2.2.21. Changes in Scope

Emam, Farrell & Abdelaal (2015) found changes in the scope of the project was a critical factor that incurred cost and time overruns and also Memon, Abdullah & Azis (2010) concluded that changes in the scope of the project were among the most severe factors affecting the cost of construction projects. Further, Shibani (2015) stated additional works by the owner and change orders during work and Kaveen, Aleem & Thaarrini (2015) identified too many change orders generated by the owner as a critical factor that caused cost and time overruns in construction projects.

Buys (2015) stated that change of scope and Jackson (2000) observed client-driven design changes caused a great risk of cost overruns in construction projects. Bekr (2015) studying on time delays of the projects, found additional works and changes done by the owner as one of the most important causes for time overruns in the project. Further, Desai, Pitroda, & Bhavsar (2015) identified variations in the scope of work and Patel (2014) found expansion of client's requirements during construction significantly contributed towards cost overrun of construction projects.

Following publications on the changes in the scope of construction projects was reviewed too. (El-Kholy, 2015; Adam, Josephson & Lindahl (2017); Azhar, Farooqui & Ahmed (2008); Memon, 2014; Ismail, Rahman and Memon, 2013; Allahaim & Liu (2013); Lee, 2008)

2.2.22. Construction methods

Shibani & Arumugam (2015) claimed to avoid cost overruns in construction projects by the use of proper methods for construction and contributions from the contractors at an early stage of the project were critical. Also, Mahadik (2015) observed cost-effective construction techniques and the development of innovative technologies and methodologies were useful for cost reduction in construction projects. Besides, Jatarona, Yusof, Ismail & Saar (2016) claimed the closing stages of construction were among the most critical factors that caused time overruns in construction projects.

Memon, Abdullah & Azis (2010) researching with project management consultants stated that inadequate contractor experience was among the major factors contributing to cost overruns in construction projects in Malaysia and Mukuka, Aigbavboa & Thwala (2015) found reworks due to errors during construction was among the critical factors contributing to time overruns in construction projects in Gauteng, South Africa. Also, Adam, Josephson & Lindahl (2017) stated process-related factors in construction projects influenced and contributed to cost and time overruns in major construction projects in India.

2.2.23. Construction Technology

Sepasgozar, Razkenari & Barati (2015) concluded that a decrease in project duration and an increase in productivity can be achieved by effective use of construction technology. Further, it was noted the use of older construction technology was a major factor for time overruns in construction projects in Iran. Similarly, Mahadik (2015) stated cost and time could be saved by employing cost-effective construction techniques during the construction phase of the project.

Long, Ogunlana, Quang & Lam (2004) observed that improper techniques used at construction induced cost and time overruns in construction projects and Ojo & Odediran (2015) stated lack of technological requirements in construction projects induced overruns cost and time. Also, Mukuka, Aigbavboa & Thwala (2015) found lack of skilled operators for equipment and errors in construction leading to rework were among critical contributing factors in time overruns in construction projects in Gauteng, South Africa and Kaveen, Aleem & Thaarrini (2015) observed time taken in the erection of equipment at construction projects had contributed to time overruns in the construction industry in India.

2.2.24. Government policies

Azhar, Farooqui & Ahmed (2008) stated the unsupportive government policies among the top ten factors causing cost overruns in the Pakistani construction industry and Allahaim & Liu (2013) stated uncertainties in regulations caused cost overruns in infrastructure projects in Saudi Arabia.

2.3 Pre-construction phase of construction projects

Further, the findings of the literature review regarding the pre-construction phase of construction projects are described below in sections 2.3.1 to section 2.3.5.

2.3.1 Pre-construction approach

Al-Reshaid, Kartam, Tewari & Albader (2005) suggested pre-construction approach enables the executors of projects in carrying out professional monitoring and controlling of two of the most important aspects necessary for the success of any construction project, i.e. schedule and budget of projects. It was also stated such a proactive approach rather than a reactive approach carries significant importance to the construction industry as it highlights the areas that ample scope of improvement would be possible.

2.3.2 Pre-construction activities

Gidado (2004) concluded that the implementation of the proposed system of pre-construction planning contributed to capture knowledge and experience and to produce consistency and reliability in practice, and thus produce innovation. Further, the following pre-construction activities were identified; Social attitudes, Legal, Programming, Scheduling, Organising, Controlling, Social expectations, Customers, Refining Plans, Controlling, Suppliers, Culture, Implementation, Globalisation, Policies, Space People, Materials, Plant Information, Access, Energy, Time, Money, Quality Plans, Cost Plans, Time Plans, Safety Plans, Planning, Shareholders, Trade barriers, Monitoring, Subsoil constraints, Project Objectives (fulfilling the business case & project brief - in time to budget right quality and safely and Availability of skills.

Al-Reshaid, Kartam, Tewari & Albader (2005) stated three-step sequential route was carried out during the planning or pre-design phase: 1) Initial concept and scope of the work, 2) Professional evaluation of the project feasibility report and 3) Appropriate data collection. It was also observed each step must be thoroughly analyzed and comparatively reviewed with similar data, preferably of similar origin of work. Further, the collection of data essentially covered the following five areas of information: 1) Project statistical information, 2) General environmental information, 3) Technical information, 4) Financial information and 5) Statutory authorities' information.

Muller (1986) stated pre-construction activities were predominantly analytical and administrative but were especially important since they would set the framework of cost and schedule control of the project. Also, it was observed that the pre-construction activities were set into four subsets; 1) Job setup 2) Purchasing 3) Performance model and 4) Job startup.

Perry & Hayes (1985) stated risks of cost and time overruns in construction projects aroused from the following pre-construction activities; non-availability of information, nonstandard suppliers, temporary design; quality, responsibility and supervision, the capability of professional staff, ground conditions, inadequate site investigations, the relationship of professional staff, delay in obtaining information from designers, poor design and shop drawings and extension of the bid validity period.

2.3.3 Pre-construction planning

Gidado (2004) concluded it was important to highlight that comprehensive pre-construction planning at tender/contract stages could only be brought to fruition if the client was to demand the information required as a part of the bid requirement. However, the general approach may need to be replaced by 1) Adequate time to be given to enable the main or prime contractors to carefully collaborate with their subcontractors, consultants and suppliers to effectively carry out the pre-construction planning required at this stage of the project.

Kreitler (2011) stated knowing how pre-construction planning affects cost savings and how these methods promote sustainability is valuable information to investors and owners and Anderson & Rosenberg (2012) stated pre-construction planning had claimed to be a major determinant for project success. It was also identified that pre-construction planning had three major aspects; 1) Project characteristics 2) Site manager's abilities and 3) Assigned resources.

Al-Reshaid, Kartam, Tewari & Albader (2005) stated constant review of Terms of References during the planning process of similar projects should be carried out and incorporate lessons learnt from similar executed projects.

2.3.4 Design and pre-construction phase

Al-Reshaid, Kartam, Tewari & Albader (2005) observed during the design phase that the budgets of various projects were prepared by keeping in mind that two important ingredients, i.e. inflation and contingencies.

Gidado (2004) concluded the client needs to understand that comprehensive pre-construction planning often produces economies in time and cost of construction projects by eliminating non-value-adding activities at a very early stage. It was also stated that pre-construction planning of a project was most cost-effective to change methods, procedures or even design of construction projects.

2.3.5 Project control in pre-construction phases

Al-Reshaid, Kartam, Tewari & Albader (2005) stated that when pre-construction planning was done, slippage of project schedules and overruns of the project costs could be mitigated to a great extent, if not eliminated.

2.4 Inadequacies of inputs to design phase

Kajtazi (2012) found an initial outline of information inadequacy at least in three dimensions;

(i) Further development of the content that represents information inadequacy, i.e. factors and their interrelations,

(ii) The empirical validity of the current elaboration, based on a very large number of cases and

(iii) The research objectives.

2.5 Risks and risks of inadequacies

2.5.1 Overview

Aven (2015) concluded risk assessment and management was established as a scientific field 30 to 40 years ago and principles and methods were developed for how to conceptualize, assess and manage risk. Also, it was stated that there are risks in all functions, processes and systems (International Standard Organisation - ISO 9001:2015).

Dumbravă & Icob (2013) observed any activity performed by individuals that are registered as risky, involves incidents or accidents generating damages which sometimes lead to loss of human lives.

Adam, Beck, Loon, & Loon (2000) established risk as sociological agenda and brought together a range of issues centring on the environment, health, and personal risk. The risks were further referred to technologies, communication, generic, reproductive and nuclear.

Construction projects are subject to uncertainties and risks are induced due to the complex nature of the projects. Each construction project is unique with different objectives, duration and financial constraints. Therefore, there are several project-specific risk sources (Kiral and Comu, 2014).

Possible risks of inadequacies induced due to inadequate inputs of pre-construction activities to the design phase of construction projects would be captured analyzed and responded through risk management (risk identification, risk quantification, risk response and risk management) during the research.

2.5.2 Risk identification

Risk identification is the often neglected first step in the risk management process: potential problems specific to the project must be identified before quantification of the magnitude of the risk, or consideration of prevention or mitigation actions (Batson, 2009).

Identification of risk at the design phase is extremely important for an effective contingency estimation of a project cost (www.nap.edu). Risk assessment at the pre-project stage in construction was concluded as one of the main sub-processes (Haponawa & Al-Jibouri, 2009).

The defective design was identified as a critical factor by the contractors as creating risk in the construction industry (Hameed and Woo, 2007). Sihombing (2016) concluded changes due to design errors is a factor creating rework and noted as an acceptable risk in affecting cost overruns in the construction industry.

Although it is generally recognized that the risk should be transferred to the party which is in the best position to deal with it, contractors are often made responsible for most of the risks (Hameed and Woo (2007).

2.5.3 Risk Quantification

Meyer (2015) concluded that the projects should be set up for the Quantification of Risk Assessment (QRA) from the initial stages. When this was done correctly it is easy to determine where risks could impact the project, as well as to quantify that impact.

Meyer (2015) stated quantitative risk management is the process of converting the impact of risk on the project into numerical terms. After considering many models following model was presented by Meyer (2015) for QRA (see Figure 1).

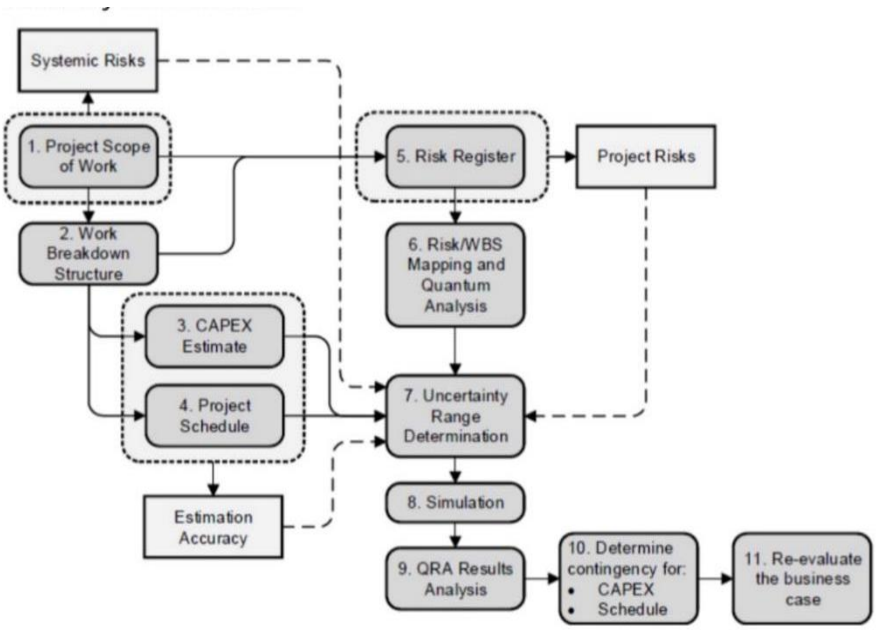

Figure 1 - Adapted from "Quantifying risk: measuring the invisible" by W.G. Meyer, 2015, *PMI Global Congress, 2015*.

2.5.4 Risk Matrix

A risk matrix displays the basic properties, "consequence" and "likelihood" of an adverse event and aggregate notion of risk. It uses discrete categories of consequence, likelihood, and risk to describe the uncertainty of an event (Duijm, 2015). The risk matrix is an effective educational tool to illustrate the importance of risk management strategies (Alexander and Marshal, 2006) and is a method of evaluating both the probability and severity of a specific action or inaction that is expected or anticipated to occur (Safeopedia.com/ Dictionary).

Some examples of Risk metrics/descriptions (Aven, 2016) are:

1. The combination of probability and magnitude/severity of consequences.

2. The triplet (s_i, p_i, c_i), where s_i is the i^{th} scenario, p_i is the probability of that scenario, and c_i is the consequence of the i^{th} scenario, i =1, 2 …N.

3. The triplet (C', Q, K), where C' is some specified consequences, Q a measure of uncertainty associated with C' (typically probability) and K the background knowledge that supports C' and Q (which includes a judgement of the strength of this knowledge).

4. Expected consequences (damage, loss), for example, computed by:

i. Expected number of fatalities in a specific period or the expected number of fatalities per unit of exposure time.

ii. The product of the probability of the hazard occurring and the probability that the relevant object is exposed given the hazard, and the expected damage given that the hazard occurs and the object is exposed to it (the last term is a vulnerability metric).

iii. Expected disutility.

Duijm (2015) claimed risk matrices are widely used for risk management and are also used as formal corporate risk acceptance criteria. Risk matrices have been implemented throughout the oil and gas industry and are used extensively in risk-management contexts. This is evidenced by numerous publications by the Society of Petroleum Engineers (SPE) documenting Risk matrices as the primary risk-management tool (Thomas, Bratvold & Bickel 2014).

Risk matrices are widely used in the assessment and monitoring of risks in the construction projects in Sri Lanka too. Risk assessment was made essential for construction projects in Sri Lanka with a project value of SLR 150 million or above when the ISO 9001:2015 Quality Management System for the Construction industry in Sri Lanka was made mandatory (Guidelines of Construction Industry Development Authority, Sri Lanka).

2.5.5 Risks in projects

During a project, it may appear different threats is usually placed either in the account of human resources or the funding account. However, they are not the only threat. In achieving successful designs, its management must take into account sudden changes in the environment (natural disasters), the political and the socio-economic (armed conflicts, strikes, new regulations). Completion of a project may also be threatened by labour incidental, movement and more. Thus, difficult situations or risk management is of key importance in project management. Proper management of the threats of the type listed involves a more precise prediction of the effects that could be caused by events considered at risk (Dumbravă & Icob, 2013).

2.5.6 Risk Response

Risk response uses the collective information in the analysis stage and to decide on how to improve the possibility to complete the project within time, cost and performance (Naji & Ali, 2018).

Focusing on the risks of the most significant contributors can shift the odds in favour of project success. Early in project development, activities and information may seem chaotic, coming to the project from multiple directions and multiple sources. Risk management provides a structured and disciplined way to document, evaluate, and analyze the information, so we emerge with a well-organized and prioritized list of project risks. This prioritization can be used to direct project risk management resources most effectively (Washington State Department Project Risk Management Guide, 2018).

2.5.7 Risk Management

Goral (2007) identified the importance of risk assessment and management of risks in different phases of the building projects, especially in the conceptual design phase. Further, Eldash, Abd-Raboh & El-Dars (2006) contended the risk management in the design phase of large-scale construction projects. Iqbal, Choudhry, Holschemacher & Ali (2015) claimed there are two types of risk management techniques: preventive techniques which can be used before the start of a project to manage risks that are anticipated during the project execution; and remedial techniques that are used during the execution phase once a risk has already occurred. Also, it was stated, the contractor was responsible for the management of most risks occurring at sites during the implementation phase, such as issues related to subcontractors, labour, machinery, availability of materials and quality, while the client was responsible for the risks such as financial issues, issues related to design documents, changes in codes and regulations, and scope of work. Further, it was noted, proper schedule by getting updated data of the project and guidance from previous similar projects were the most effective preventive risk management techniques while close supervision and coordination within projects were the most effective remedial risk management techniques.

2.5.8 Proactive approach in managing risk

The construction industry in Sri Lanka is regulated by the Construction Industry Development Authority (CIDA) which was established by the Construction Industry Development Act No 33 of 2014. According to CIDA regulations for all the construction companies of CIDA registration Grade C3 and above (i.e. for CIDA registration Grades C3, C2, C1, CS1 and CS2) required to certify for ISO Quality Management System, ISO 9001:2015. CIDA registration Grading has a minimum project value of SLR 150 million (for Grade C3) and a maximum project value of more than SLR 3 billion (for Grade CS2) (Guidelines of Construction Industry Development Authority, Sri Lanka). Even for a construction project with an equal or above comparatively low project value of SLR 150 million has to implement risk management as a mandatory requirement as per ISO Quality Management System, ISO 9001:2015 and most of the construction companies use Risk matrices for risk management in the projects.

ISO 9001:2015 is established on an approach of risk-based thinking. It applies proactive methods and allows to find action needed to minimise unacceptable outcomes at an early stage. Risk-based thinking ensures the risks in functions, processes and systems are identified, considered and controlled throughout the design and use of the quality management system. When risk-based thinking is used, consideration of risk will be for the entire scope. Then achieving objectives will be more likely and customer loyalty could be improved (ISO 9001:2015).

ISO 9001:2015 certified companies/organizations are required to implement the following in the execution of construction projects. The organization is required to determine its QMS processes and to address its risks and opportunities (Clause 4); the top management is required to Promote awareness of risk-based thinking and determine and address risks and opportunities that can affect product /service conformity (Clause 5); the organization is required to identify risks and opportunities related to QMS performance and take appropriate actions to address them (Clause 6); the organization is required to determine and provide necessary (Clause 7); the organization is required to manage its operational processes (risk is implicit whenever "suitable" or "appropriate" is mentioned) (Clause 8); the organization is required to monitor, measure, analyse and evaluate the effectiveness of actions taken to address the risks and opportunities (Clause 9); and the organization is required to correct, prevent or reduce undesired effects and improve the QMS and update risks and opportunities (Clause 10).

It is evident by having the certification for ISO Quality Management System (ISO 9001:2015) that a substantial number of Sri Lankan construction projects are implemented considering the risk-based thinking and with a proactive approach to risk (Risk-based thinking in ISO 9001:2015).

2.6 Correlation

According to Merriam-Webster dictionary correlation is a relation existing between phenomena or things or between mathematical or statistical variables which tend to vary, be associated, or occur together in a way not expected based on chance alone. It also explains the types of correlations; positive correlations (as one variable increase so does the other) and negative correlation (as one variable increases, the other decreases).

Spiegel, Stephens and Kumar (2010) claimed that correlation analysis is a very powerful tool to explore relationships in data. Also, correlation analysis is a method of statistical evaluation used to study the strength of a relationship between two, numerically measured, continuous variables. This particular type of analysis is useful when a study needs to establish if there are possible connections between variables.

The degree of correlation between any two variables on a continuous scale is mathematically expressed as the correlation coefficient (also known as Pearson's correlation coefficient or "r"), a number whose values can vary between −1.0 and +1.0 (Schober, Boer & Schwarte, 2018).

2.7 Calibration

"Calibration is the degree of fit between a person's judgment of performance and his or her actual performance" (Bol & Hacker, 2012). Further, Peredaryenko & Krauss (2013) described calibration of the human instrument consisting of two elements, the researcher and the informant as given in Table 1.

Table 1 – Calibration of the human instrument

Dimension	Researcher Centered	Informant Centered
1. Where the knowledge phenomenon under study lies	I know the topic better while my informants are lacking some knowledge	As a researcher, I cannot know it better than my informants. It is the informant who knows his/her reality better. The reality is within the informant—in his or her experience
2. What kind of response the researcher is receiving from informants	Informants cannot handle questions, cannot give me full information, they seem to feel confused and perplexed	Informants are sharing a lot—beyond what I have asked. This makes them happy.
3. What kind of information the researcher is looking for	I know what to expect	Expect the unexpected, expect anything to come
4. What kind of information the researcher eventually received	I received what I expected	I received something that I did not expect

Note: From "Calibrating the human instrument: Understanding the interviewing experience of novice qualitative researchers" by M. S. Peredaryenko & S. E. Krauss, 2013, *The Qualitative Report*, 18(85) 1-17.

The continuum status of the human instrument status is given in Figure 2.

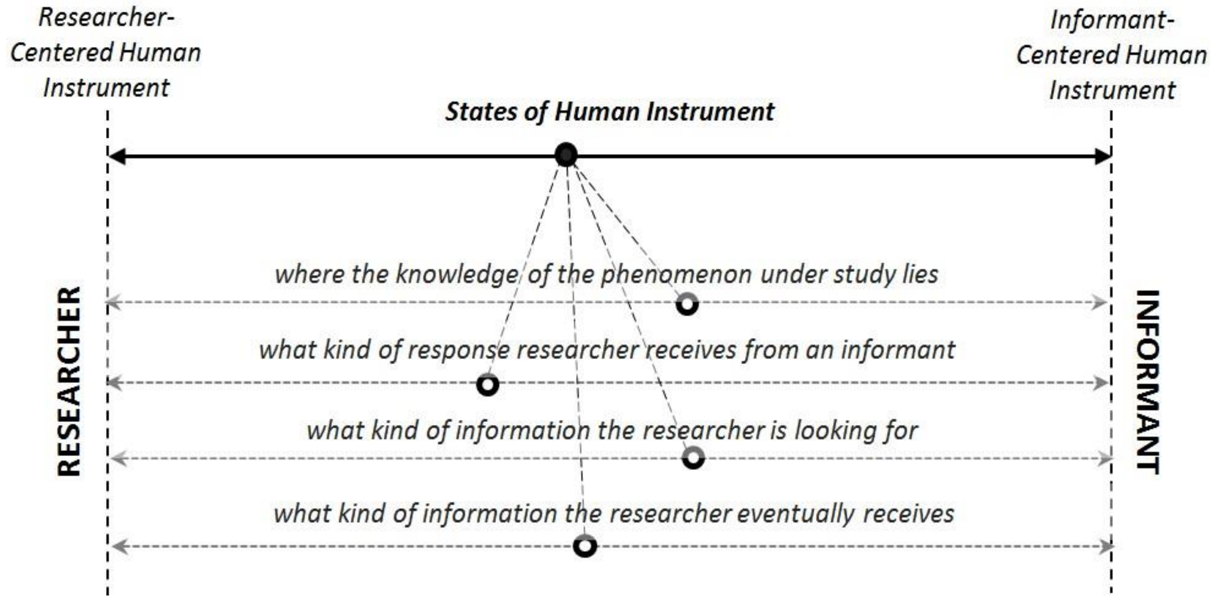

Figure 2 - Adapted from "Calibrating the human instrument: Understanding the interviewing experience of novice qualitative researchers" by M. S. Peredaryenko & S. E. Krauss, 2013, *The Qualitative Report,* 18(85) 1-17.

Peredaryenko & Krauss (2013) claimed that informant centred human instrument with openness to interact with the informants allows for greater complexity and richness in terms of findings. Using the researcher's own experiences can be used to get closer to the respondents of a given study to understand them better (Rennie, 1994; Schneider 1999).

Hacker, Bol, & Keener (2008) identified calibration has been measured in different ways but largely studied in more contrived contexts using college students. Further, Bol & Hacker (2012) observed varying levels of controls and varying research methods will improve the status of calibration.

2.8 Coherence

Chenail, Duffy, St. George & Wulff (2011) stated that the best way to improve the coherence of qualitative research is for researchers to focus on the aspects of coherence from the start of the conception and development of their research studies. Coombs (2017) stated that there is relatively limited advice in the engineering domain for undertaking qualitative studies and researchers have to rely on generic guidance that may result in the imprecise application of qualitative methods. Further, a set of questions were published to be considered when developing qualitative studies Coombs (2017) and are given in Table 2.

Table 2 - Questions to consider when developing qualitative studies.

Reflective questions for qualitative research	Sources for guidance
1. Have you stated your philosophical position?	Sarker, Xiao, Beaulieu & Lee (2018)
2. Have you explained the theoretical aims for your study?	Avison & Malaurent (2014); Gregor (2006)
3. Have you explained how you have chosen your data collection site and context and considered the limitations of these?	Davison & Martinsons (2016); Keutel, Michalik &Richter (2013); Sarker, Xiao & Beaulieu (2013)
4. Have you explained your sampling strategy? E.g. multiple, single, extreme, replication	Keutel, Michalik & Richter (2013); Sarker, Xiao & Beaulieu (2013)
5. Are you using more than interview data? E.g. observations, archival data, quantitative data, documents.	Keutel, Michalik & Richter (2013); Sarker, Xiao & Beaulieu (2013); Silverman (1998)
6. Have you described your sample? E.g. number of interviewees, job roles, number of follow up interviews, number of observations, data collection timespan.	Sarker, Xiao & Beaulieu (2013)
7. Have you included your interview schedule?	Sarker, Xiao & Beaulieu (2013)
8. Have you explained how you have analysed your qualitative data (including supporting data), providing a worked example of each analysis stage?	Sarker, Xiao & Beaulieu (2013)
9. Have you considered the generalisability of your study?	Konboy, Fitzgerald & Mathiassen (2013); Davison & Martinsons (2016).

Note: From "Coherence and transparency: some advice for qualitative researchers" by C. Coombs, 2017, *Production*, 27, e20170068. http://dx.doi.org/10.1590/0103-6513.006817

Seidenfeld (1985) stated subject to feedback, calibration, in the long run, is serving no practical purpose. It gives no ground for validating one coherent opinion over another as each coherent forecaster is almost sure about his long-run calibration.

2.9 Accuracy

O'relly (1978) stated informants could be motivated to provide biased and inaccurate data due to reasons such as achievements, security and social acceptance. Also, inaccuracy increases when the informants believe the information would harm their careers (Athanassisades, 1972).

Huber & Power (1985) identified that inaccuracies and misinterpretation of results due to problems and limitations of the situation (e.g. accuracy of reports, data they use) can be overcome by adopting strategies and tactics that focus on the accuracy of reports and data.

A serious obstacle in the use of replications for increasing accuracy is the tendency to get closely agreeing repetitions for irrelevant reasons (Wilson, 1952). Bernard, Killworth, Kronenfeld & Sailer (2016) observed that one's discipline teaches how to seek good informants (i.e. those who know a lot and report accurately).

Online Learning, (2008), indicated data refining as a process that refines disparate data within a common context to increase the awareness and understanding of data, to remove data variability and redundancy, and develop an integrated data resource. Disparate data are the raw material and an integrated data resource is the final product. To "IBM WATSON refining data consists of cleansing and shaping it. When data is cleansed, incorrect, incomplete, improperly formatted or duplicated data is fixed or removed and when data is shaped, data is customized by filtering, sorting, combining or removing columns, and performing operations" (https://www.google.com/search?client=firefox-b-d&q=Walter+de+Gruyter+GmbH%).

2.10 Bias

Data bias is defined as a particular tendency, trend, inclination, feeling or opinion, especially one that is preconceived or unreasonable. Survey results can be distorted by information bias, selection bias and confounding bias. (Dictionary.com).

Also, Simundic (2013) claimed authors, journal editors and reviewers need to be concerned about the quality of the work submitted for publication and ensure that only studies which have been designed, conducted and reported transparently, honestly and without any deviation from the truth get to be published. Any such trend or deviation from the truth in data collection, analysis, interpretation and publication is called bias.

Also, Smith & Noble (2014) stated bias exists in all research, across research designs and is difficult to eliminate; bias can occur at each stage of the research process and bias impacts the validity and reliability of study findings and misinterpretation of data can have important consequences for practice. Further types of research bias were given as; "Design bias, Selection

/ Participant bias, Data collection bias, Analysis bias and Publication bias". It was also stated, in quantitative studies selection bias is often reduced by the selection of random participants, and having a well-designed research protocol explicitly outlining data collection and analysis can assist in reducing bias. Further, statistical tests were used in quantitative research to assess the validity and reliability of the findings.

Pannucci & Wilkins (2010) concluded bias can occur in the planning, data collection, analysis, and publication phases of research. Understanding research bias allows readers to critically and independently review the scientific literature.

2.11 Accuracy and Bias

Huber & Power (1985) stated that there are four primary reasons that informants provide inaccurate or biased data. a) They are motivated to do so, b) Their perceptual and cognitive limitations result in inadvertent errors c) they lack crucial information about the event of interest and d) They have been questioned with an inappropriate data elicitation procedure.

Also, it was stated the first two of these sources of data distortion are linked because (1) motivation affects perception and cognition, and (2) perception and cognition 'produce' the information that results in motivations.

2.12 Research methodology

Review of literature on research methodologies identified eight types of methodologies Nallaperumal (2013), descriptions of research methods (Lawrence Berkeley National Laboratory) and description of mixed research methods (Borrego, Douglas & Amelink, 2009). It was noted that research in cost and time overruns in construction projects had used different types of research methodologies in their research; Jatarona, Yusof, Ismail & Saar, (2016) used quantitative analysis, Craigie (2015) used descriptive statistics, Vu, Wang, Min, Mai, & Nguyen (2016) used a questionnaire and 5 point Likert scale and Jackson (2000) used questionnaire survey.

2.13 Likert scale

Likert scale is one of the most frequently used measures in social sciences to gather data on attitudes, perceptions, values, intentions, habits and behaviour changes (Wu, 2007). Rensis Likert and Gardner Murphy suggested a method of constructing an attitude scale for the human response (Likert, 1932)**,** later known as the Likert Scale. Further, it was identified that several definable attitudes existed in a person with the possibility of grouping them into clusters of responses (Likert, 1932).

Joshi, Kale, Chandel & Pal (2015) stated the Likert scale was devised to measure attitude in a scientifically accepted and validated manner. Further, it was stated methods adopted for Likert Scale analysis largely depends on the item response variable assignment into ordinal or interval scale which in turn depends on the construct of the research instrument. This construct of the research instrument can be derived from the objectives of the study.

In a Likert scale survey, respondents are instructed to state their level of agreement with a series of statements. Each degree of agreement or disagreement is then given a numeric value on a predetermined scale. Likert statements are typically a five or seven-point scale (Wu, 2007; Sullivan & Artino, 2013 stated it has been established that population data are usually normally distributed and parametric tests can be used with data from Likert scales. Joshi, Kale, Chandel & Pal (2015) claimed when obtaining responses from statistically correct belief highlighted questionnaires, the Likert scale was most appropriate for quantifying respondent's belief as responses to the questionnaires.

2.14 Substantive Experts

Substantive expertise refers to working knowledge and skills as defined by different domains. Data provided by Substantive experts are accurate, coherent and calibrated.

Further, informant centred studies with the ability to associate with the informants allow for greater detail and plentifulness in terms of findings (Peredaryenko & Krauss, 2013). Also, Rennie (1994) and Schneider (1999) claimed the researcher's own experiences can be used to get closer to the respondents of a given study to understand them better. Also, see section 2.7) for "Calibration".

2.15 Summary

The related literature was reviewed under thirteen sections (and subsections as appropriate) and the review highlighted that design, planning and controlling, material issues were the key contributors to cost and time overruns of construction projects. Of these, design effects were identified as the most significant contributor to cost and time overruns of construction projects. The review also revealed that a possible relationship between the relevance and inadequacy of the analysis of pre-construction activities exist.

Hence, possible risks created by the inadequacies of outputs of pre-construction activities as inputs to the design phase of construction projects exist. Also, risks due to correlation (factors and their interrelations) between input data to the design phase, accuracy and coherence (empirical validity of the current elaboration, based on a large number of cases) of the input data are possible factors that affect the relevance of the pre-construction activity. The identification, quantification and management of the risks due to inadequacies, correlation, coherence and accuracy of input data would significantly improve the relevance of the input data to the design phase.

CHAPTER 3 – RESEARCH METHODOLOGY

3.1 General

This chapter describes the research methodology that was adopted for this study. It includes, how different methodologies were assessed, selected, and then used in the study. During this process, discussions and interviews were carried out with industry specialists (Directors, Chief Executive Officers, Project Managers, Senior Engineers from the construction industry in Sri Lanka, Design Manager from Singapore, Senior Engineers from Australia and the USA) and academics in civil engineering (Professors, PhDs, and PhD candidates from Sri Lanka, Singapore, Australia and the USA) regarding the research and the research methodologies.

The contents of this chapter are Research Methods, Selection of the Research Methods, Statistical Methods Used, Flowcharts of the Research Methodology, Selection of an Appropriate Research Method, Consideration of Questionnaire Options for Different Research Methods and Population and Sampling Methods for the Study (Creswell, 2009; Research design).

3.2 Research Methods

The literature review highlighted that a variety of methods have been employed in research. These include Quantitative analysis (Jatarona, Yusof, Ismail & Saar, 2016); Descriptive statistics (Craigie, 2015); Questionnaire along with a five-point Likert type scale (Vu, Wang, Min, Mai, & Nguyen 2016); and Questionnaire surveys (Jackson, 2000).

Study.com describes types of surveys as 1) Questionnaires - series of written questions which participant answer. This method gathers responses to questions that are easy or agree/neutral/disagree style; 2) Interviews - questions posed to an individual to obtain information about him or her. This type of survey is like a job interview, with one person asking another load of questions and 3) Surveys - brief interviews and discussions with individuals about a specific topic.

Nallaperumal (2013) identified eight research methods which are summarized in Table 3.

Table 3 - Eight Research Methods

Method	**Used in;**
Descriptive	Description of the state of affairs as it exists at present. This approach is suitable for social sciences and business and management studies for descriptive research studies. Also used in surveys and fact-finding.
Analytical	The researcher makes a critical evaluation of the material by analyzing facts and information already available.

Applied	The main target of Applied Research is to find a solution for an immediate problem facing a society or an industrial / business organization.
Fundamental	Fundamental or Pure Research is mainly concerned with generalizations and concentrates on the formulation of a theory.
Quantitative	Applicable to phenomena that can be expressed in terms of quantity.
Qualitative	Concerned with the qualitative phenomenon. Qualitative research is especially important in behavioural sciences where the aim is to discover the underlying motives of human behaviour.
Conceptual	Related to some abstract idea(s) or theory. It is generally used by philosophers and thinkers to develop new concepts or to reinterpret existing ones.
Experimental (Empirical)	Relies on experiment or observation alone, often without due regard for system and theory.

Note: From "Engineering Research Methodology, A Computer Science and Engineering and Information and Communication Technologies Perspective. First Edition" by K. Nallaperumal, 2013, http://www.engineeringresearchjournal.com

The Lawrence Berkeley National Laboratory grouped the research methods as Basic Research and Applied Research. This classification appears in Table 4.

Table 4 - Research Method Classification

Method	**Used in;**
Basic	Driven by a scientist's curiosity or interest in a scientific question. The main motivation is to expand man's knowledge, not to create or invent something.
Applied	Designed to solve practical problems of the modern world, rather than to acquire knowledge for knowledge's sake. One might say that the goal of the applied scientist is to improve the human condition.

Note: From "Basic vs. Applied Research" from Lawrence Berkeley National Laboratory, https://commons.lbl.gov/display/rst/Citation+Management

Findings of Creswell & Plano-Clark (2007) and Borrego, Douglas & Amelink (2009) regarding the mixed research method are given in Table 5.

Table 5 - Mixed Research Method.

Method	Used in;
Mixed method	Creswell & Plano-Clark (2007) stated four criteria for evaluating mixed methods studies; Whether the study is indeed mixed methods (collecting, analyzing and mixing quantitative and qualitative approaches). The most inclusive definitions allow for a representation of quantitative and qualitative perspectives in at least one of the following: data collection, data analysis, or theoretical perspective. Detail and consistency in describing the design, theoretical perspective, need for both quantitative and qualitative approaches, and how the two components are mixed. Detailed quantitative and qualitative procedures should be described, as well as sequential or concurrent data collection and analysis. Interpretations should be defended. Inclusion of advanced mixed methods features, including (a) specified type of design, (b) a visual diagram of the procedures, (c) mixed methods purpose statement, research question and data analysis, and (d) citation of mixed methods studies and methodological articles. The sensitivity to the challenges of using mixed research methods and how they are addressed should be highlighted. Specific challenges include threats to validity such as sampling, sample sizes, and integration phases. Also, Borrego, Douglas & Amelink (2009) claimed when quantitative, qualitative and mixed research methods in engineering education research are concerned, there is no particular method is privileged over any other and the choice must be driven by the research questions.

Note: From “Qualitative, quantitative and mixed research methods in engineering education” by M. Borrego, E. P. Douglas & C. T. Amelink, 2009, *Journal of Engineering Education.*

3.3 Selection of the Research Methods

While multiple research methods were used in this study, the nature of the study precluded the use of Fundamental, Conceptual, and Experimental research methods as they focus on basic research methodologies. Since the study is focused on a problem in the industry, the Applied research method was used. This is reinforced by Nallaperumal (2013) and Lawrence Berkeley National Laboratory. Further, a mixed type of research method (a mix between Quantitative and Qualitative research methods) together with a Descriptive research method was used in the study. The analytical research method was also used in the analysis of the study.

3.4 Analysis and Methods used in the study

3.4.1 Descriptive Analysis

For the descriptive analysis, Tables, Charts, Line Charts and Regression Analysis were used.

a) Tables

Some examples of using 'Tables' in this study are given below.

Table 1 - Two Different Ways of Seeing Oneself as a Human Instrument

Table - 3: Eight Research methods (Nallaperumal, 2013)

Table 5 - Description of mixed research methods (Borrego, Douglas and Amelink, 2009)

b) Charts

Pie Chart – Qualitative variables. The three highest contributory factors for the cost and time overruns of construction projects (see Figure-15) and the seven highest contributory factors for the cost and time overruns of construction projects (see Figure-16) were presented using pie charts.

c) Line Charts (Exponential Curve)

The relevance of a pre-construction activity for a project vs the Inadequacy of the output of the activity as the input to the design phase of the project was presented as a line chart (see Figure-17).

d) Regression Analysis

The relationship of Inadequacy and other independent variables was established using regression analysis (see Table 15)

3.5 Selection of an appropriate research method

A detailed description of Qualitative, Quantitative and Mixed research methods in the selection of the research methods for the study was carried out and are given in the following sections.

3.5.1 Qualitative research method

The probability sampling techniques used for quantitative studies are not appropriate when conducting qualitative research. Also, three types were identified in sampling for qualitative research as listed below (Marshall, 1996).

Three types of sampling methods for qualitative research;

a) Convenience sample

b) Judgement sample (purposeful sample)

c) Theoretical sample

Marshall (1996) stated Judgement sample method encourages to;

i) Actively select the most productive sample to answer the research question,

ii) Advocate to use the experience gained in the research area, liretaure and information from the study and

iii) It is more of a rational plan of action than collecting data of age, gender, social class, etc.

If the qualitative research method applies to this study, based on Marshall (1996), the Judgement sample method was considered as an option.

3.5.2 Quantitative research method

Quantitative Research is used to quantify the problem by way of generating numerical data or data that can be transformed into usable statistics. Also, it was stated four types of quantitative research methods were stated as given below (Klazema, 2014).

Four types of quantitative research methods:

a) Survey research,

b) Correlation research,

c) Causal – Comparative research and

d) Experimental research

Considering the four research methods in the quantitative research method and based on work done on similar research, the Survey research method would be considered as more appropriate to this study. Further, the Likert scale can be used to collect responses in the quantitative questionnaire (Joshi, Kale, Chandel & Pal 2015).

Some examples of similar research that used quantitative research method are; Wijekoon (2016), Dolage and Pathmarajah (2015) and Polat, Okay & Eray (2014).

3.5.3 Mixed research method

Creswell & Plano Clark, (2007), identified that there could be specific challenges when using the mixed research method and acknowledge the sensitivity to the challenges such as sampling, sample sizes, and integration phases (Creswell & Plano Clark, 2007).

Borrego, Douglas & Amelink (2009) stated mixed-method procedures as given in Figure 3.

Timing	*Weighting*	*Mixing*	*Theorizing*
No Sequence concurrent	Equal	Integrating	Explicit
Sequential-Qualitative first	Qualitative	Connecting	
Sequential-Quantitative first	Quantitative	Embedding	Implicit

Figure 3 – Adapted from “Qualitative, quantitative and mixed research methods in engineering education” by M. Borrego, E. P. Douglas & C. T. Amelink, 2009, *Journal of Engineering Education.*

Based on the literature review, work is done on similar research and the nature of the study, mixed research method was selected as appropriate research methods for this study.

3.6 Methodology for the development of a questionnaire for different research methods

This section describes the methodology for the development of questionnaire/s for different research methods that were considered (Bradley, Curry & Devers, 2007). For this purpose, inputs from the literature review, industry experts and academics in the field of civil engineering were considered.

The methodologies employed in the gathering of knowledge in the development of the questionnaires for different research methods used in the study are given below.

3.6.1 Methodology for the development of a questionnaire for the qualitative research method

The questionnaire for the qualitative research method was based on how to design a questionnaire for the qualitative research method (Bradley, Curry & Devers, 2007); Marshall, 1996; Borrego, Douglas and Amelink, 2009). Accordingly, a questionnaire for a qualitative research method was designed and a pilot survey was carried out based on open-ended questions and in-depth interviews with the selected industry experts and academics. Sample size would be finalized when the responses to the questions asked at the interviews are saturated (Bradley, Curry and Devers, 2007).

3.6.2 Methodology for development of a questionnaire for the quantitative research method

Babbie (2010) stated quantitative methods emphasize objective measurements and statistical, mathematical or numerical analysis of data collected through polls, questionnaires and surveys or by manipulating pre-existing statistical data using computational techniques. Further, it was stated quantitative research focuses on gathering numerical data and generalizing it across groups of people or to explain a particular phenomenon.

Also, it identified that quantitative surveys ask questions with specific, usually numerical answers. They are useful for gathering large amounts of data, but they are not designed to gather descriptive information (Harland, 2019).

3.6.3 Methodology for development of a questionnaire for the mixed research method

In mixed research method studies, at least one of the following; data collection, data analysis or theoretical perspective, would represent quantitative and qualitative perspectives. Further, the need for both quantitative and qualitative approaches, and how the two components, quantitative and qualitative are mixed, detail and consistency in describing the design, theoretical perspective, as well as sequential or concurrent data collection and analysis should be described (Creswell and Plano Clark, 2007); (see Annexure - 2).

3.7 Population and Sampling methods

This section explains the sampling size, sampling methods and calculation of sampling size based on the knowledge gathered from the literature review. These methodologies were used in considering the sampling methodology/technique of this study.

3.7.1 Sequence to determine sampling size;

There are different methods used to determine the sample size from a population. Taherdoost (2016) stated the following steps in determining the sample size.

- Define Target Population
- Select Sampling Frame
- Choose Sampling Technique
- Determine Sample Size
- Collect Data
- Assess Response Rate

3.7.2 Sampling techniques – Qualitative method

Taherdoost (2016) stated the following sampling techniques for the Qualitative method.

- Quota sampling

- Snowball sampling
- Convenience sampling
- Purposive or judgmental sampling

3.7.3 Sampling techniques – Quantitative method

Further, Taherdoost (2016) stated the following sampling techniques for the Quantitative method.

- Probability Sampling
- Simple random sampling
- Systematic sampling
- Stratified random sampling
- Cluster sampling
- Multi-stage sampling

3.7.4 Calculation of sample size – Formulae, Tables and Calculators

The literature review highlighted that there are many types of approaches in determining the sample size and some of them are listed below;

a) Taherdoost, (2016) indicated there are numerous approaches and highlighted the following formulae for calculating the sample size for categorical data.

Sample size, $n= p\ (100-p)\ z^2/E^2$ (1)

where p is the percentage occurrence of a state or condition, E is the percentage maximum error required and Z is the value corresponding to the level of confidence required

b) Yamane (1967) provided a simplified formula to calculate sample sizes as given below.

Sample size, $n = N / (1 + N\ (e)^2)$ (2)

Where '*N'* is the population size and 'e' is the level of precision.

c) Muhwezi, Acai, & Otim (2014) used the following formula to bring about the necessary sample:

Sample size, $s = (p/P)\ x\ S$ (3)

Where p is the number of key resource persons in each project, P is the study population and S is the population.

Smith (2017) claimed unless the sample encompasses a substantial portion of the population, the standard error of an estimator depends on the size of the sample, but not the size of the population.

3.8 Flowcharts of the Research Methodology

It was assumed that construction projects have the following phases; Pre-construction phase, Design phase and Construction phase. To initiate this study three possible options were considered and Option a) given in Table 6 was selected.

Table 6 - Options considered to start the process of the study

Options	Processes – Starting point and flow
a)	*(Starting Point)* Pre-construction → Design Phase ---> Construction ----> (check on overruns on Cost and Time)
b)	Pre-construction ← *(Starting Point)* Design Phase ----------> Construction ----> (check on overruns on Cost and Time)
c)	Pre-construction <---- Design Phase ← *(Starting Point)* Construction ----> (check on overruns on Cost and Time)

Options presented in flowcharts given in Figures 4, 5 and 6 were considered to understand and express the possible situations/relationships between the pre-construction activities and the design phase of construction projects.

The flowchart in Figure 4, indicates limitations and assumptions used for pre-construction activities which provide inputs to the design phase of a construction project.

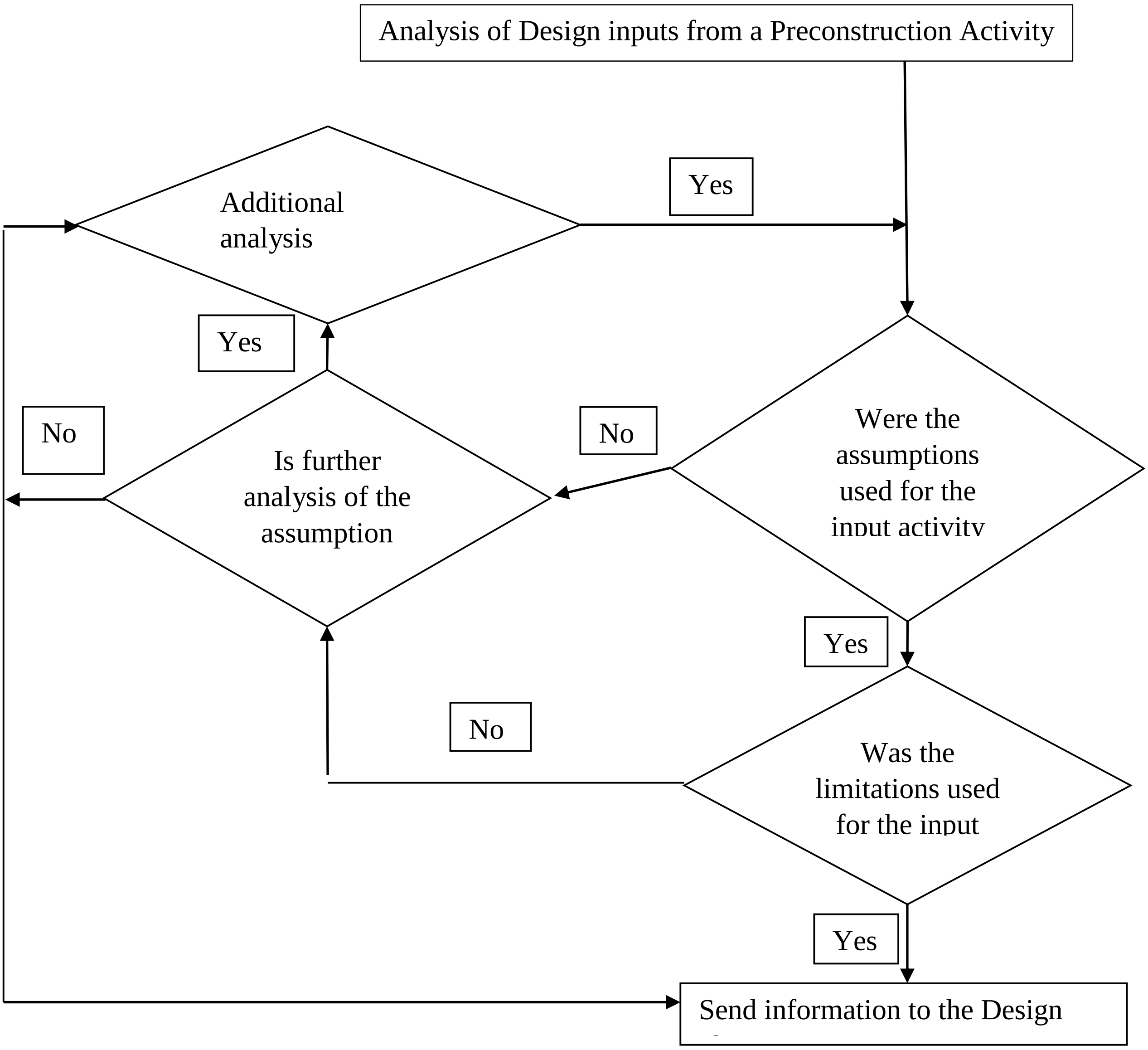

Figure 4 – Flow chart for analysis of design inputs from a preconstruction activity. Developed to indicate possible capture of limitations and assumptions of input by pre-construction activities to the design phase of construction projects.

The flowchart in Figure 5, indicates the identification of causes for cost and time overruns of construction projects due to possible inadequacies, inaccuracies, limitations and assumptions at the pre-construction phase of construction projects,

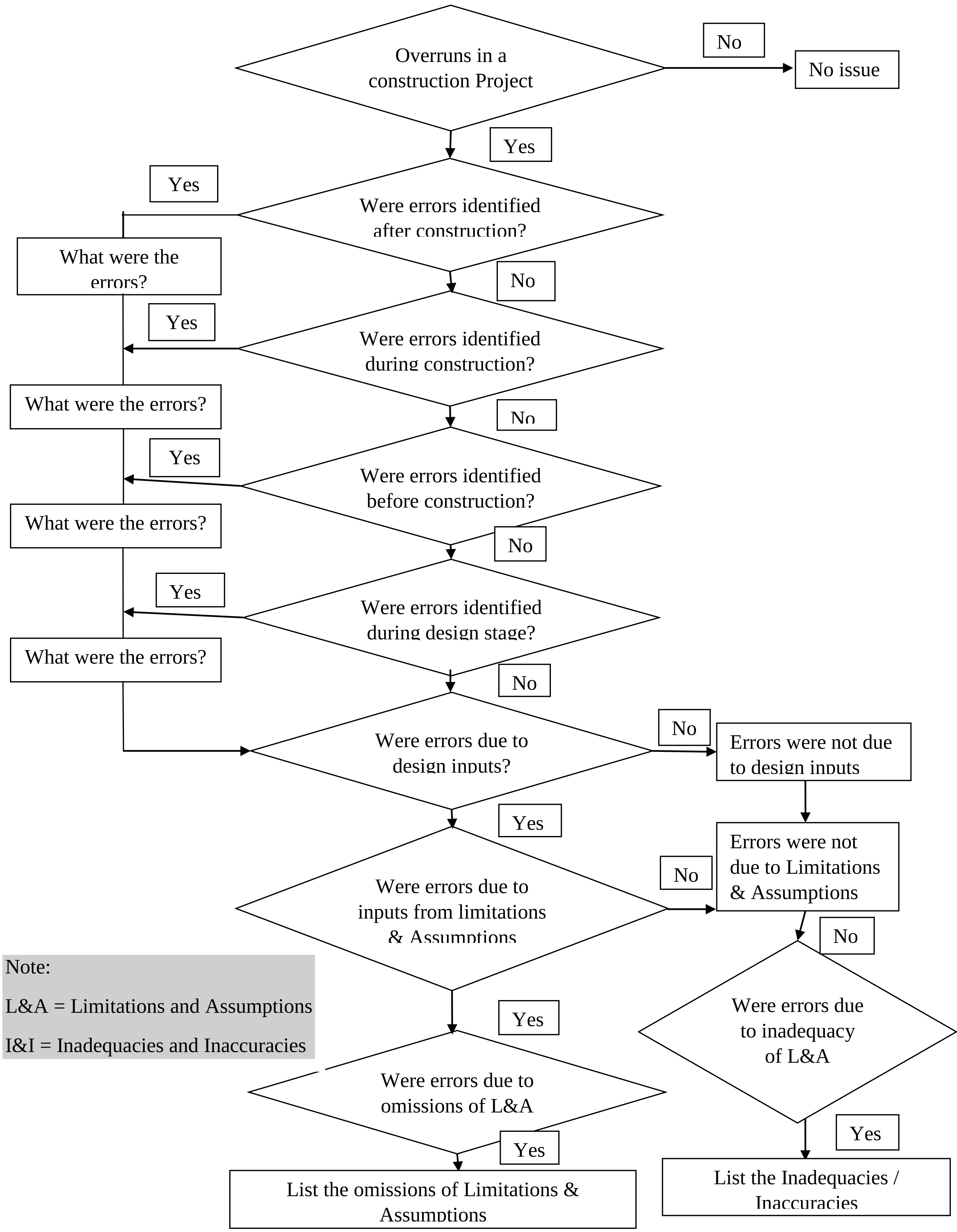

Figure 5 – Flowchart for Cost and Time overruns in construction projects. Developed to indicate possible Assumptions/Limitations and Inadequacies/Inaccuracies at the pre-construction stage.

The flowchart in Figure 6, indicates possible error generation due to assumptions and limitations during the pre-construction phase of construction projects.

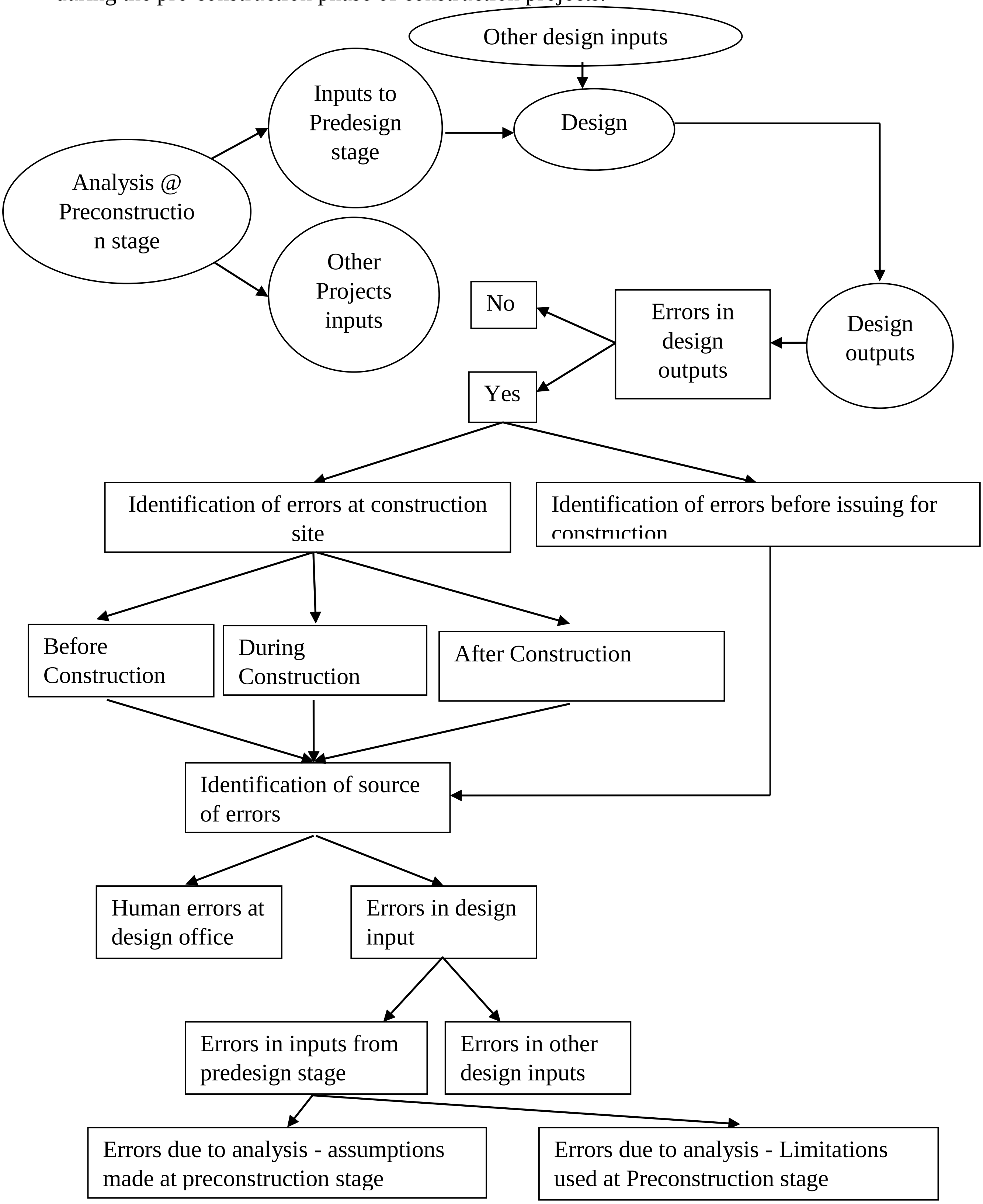

Figure 6 – Flow chart for possible generation of errors in construction projects. Developed to indicate possible error generation due to assumptions and limitations during the preconstruction stage of a construction project.

3.9 Validation of the guideline developed from the study

The guideline developed from the study was validated using two methods; (i) Testing Hypothesis and (ii) Using case studies from the construction industry.

3.9.1 Validation using testing Hypothesis

Null hypothesis testing is a formal approach to deciding whether a statistical relationship in a sample reflects a real relationship in the population or is just due to chance. If the sample result would be unlikely if the null hypothesis were true, then it is rejected in favour of the alternative hypothesis (https://opentextbc.ca/researchmethods/chapter/understanding-null-hypothesis-testing/).

3.9.2 Validation using case studies from the construction industry

Issues of Cost overruns and Time overruns of the completed projects from the construction industry was used as cases to validate the guideline developed.

3.10 Summary

The appropriateness of research methods to the study was discussed and the most appropriate research method/s out of the qualitative research method, quantitative research method and mixed research method were used for the study as given below. In the study,

i) Literature review was used to identify 'Forty-Two contributory factors' for cost and time overruns of construction projects. The analysis identified the 'Design Effects' as the worst contributor towards cost and time overruns of construction projects (Daluwatte and Ranasinghe, 2017).

ii) Literature review and questionnaire survey was used to establish 'Thirty-eight Pre-construction Activities' as input to the Design Phase. The analysis identified the relationship between the 'Relevance to a pre-construction activity' and 'Inadequacy of the input to the design phase' of a construction project. The relationship was indicated by the model "$y = 2.6916e^{0.024x}$" (Daluwatte and Ranasinghe, 2018) and,

iii) Further literature review and mixed research method were used to establish "Forty-nine Pre-construction Activities" as input to the design phase of construction projects which highlighted possible risks created by inadequate inputs from the pre-construction activities to the design phase of construction projects (Daluwatte and Ranasinghe, 2019).

iv) Validation of the developed case study was done by (i) testing Hypothesis and (ii) using case studies from the completed projects from the construction industry.

CHAPTER 4 - DEVELOPMENT OF THE ANALYSIS FRAMEWORK

4.1 General

This chapter describes the development of a framework to analyze possible risks created by the inadequacies of input of respective pre-construction activities to the design phase of a construction project. It would require data provided by the respondents, who are construction experts. The developed framework analyses the risks using Risk Matrix, Relative Importance Index (RII), Severity Index (SI), Descriptive Statistics, Reliability of data, Validity of data, Correlation of data, Sampling Adequacy, Accuracy of data, Bias of responses, Coherence of responses and Calibration of respondents.

4.2 Risks Created by the Inadequacies of Inputs

4.2.1 Risks

Risks and their impact on cost and time overruns are discussed extensively in the literature (Aven, 2016; Kiral and Comu, 2014; Dumbravă & Icob, 2013; Adam, Beck, Loon & Loon 2000). Kiral & Comu (2014) identified that construction projects are subjected to uncertainties and risks due to the complex nature of the projects. Also, ISO 9001(2015) standard of the International Standards Organization (ISO) had declared that there are risks in all systems, processes and functions. It is noted that the ISO 9001(2015) applies to a substantial segment of the construction industry (from CIDA grade C3 upward to the highest CIDA grade CS2) in Sri Lanka (CIDA guidelines).

The construction industry had been ranked as one of the most dangerous industries in the world with a higher prevalence of occupational accidents, injuries, and diseases (Nghitanwa & Zungu, 2017). The workers in the construction industry are listed as employed in one of the five most dangerous industries to work (workplacediversity.com). Implementation of construction projects through systems, processes, and functions would generate risks that negatively affect achieving objectives of construction projects (cost, time and scope of construction projects) and the efficient use of resources (human, machinery and equipment, material, fuel, etc.). Input to the design phase which precedes the construction phase provides opportunities to minimize or eliminate such risks in construction projects.

Risks created by the inadequacies of inputs of the relevant pre-construction activities to the design phase of construction projects should be captured, analyzed and responded through the risk management (identification, quantification, response, and management of the risks) by the developed framework.

4.2.2 Pre-construction Activities

Gidado, (2004) stated that the implementation of the proposed system for pre-construction planning contributed to capture knowledge and experience, produce consistency and reliability in practice, and innovation of construction projects. Also, Al-Reshaid, Kartam, Tewari & Albader (2005) claimed that a three-step sequential route was carried out during the planning or pre-design phase of construction projects; 1) Initial concept and scope of the work, 2) Professional evaluation of the project feasibility report and 3) Appropriate data collection and each step must be thoroughly analyzed and comparatively reviewed with similar data, preferably of similar origin of work. Also, Muller (1986) stated pre-construction activities were predominantly analytical and administrative but important since they set the framework of cost and schedule control of construction projects.

In this study activities providing inputs to the design phase of construction projects were considered as 'relevant pre-construction activities. Daluwatte & Ranasinghe, (2018) identified relevant thirty-eight pre-construction activities through an extensive literature review and a scientific survey. Further review of the literature (Perry '& Hayes, 1985; Gidado, 2004; Al-Reshaid, Kartam, Tewari & Albader, 2005) extended the number of relevant pre-construction activities to forty-nine as given in Table 7. These forty-nine relevant pre-construction activities were used to assess possible risks created by their inadequate input to the design phase of construction projects.

Table 7 – Derivation of Forty-nine relevant pre-construction activities.

#	Pre-construction Activities (Daluwatte & Ranasinghe, 2018)	Information types sought during pre-construction (Al-Reshaid, Kartam, Tewari & Albader, 2005)	Inputs sought during pre-construction (Gidado, 2004)	Designer/ Consultants Risks (Perry & Hayes, 1985)
	38 Activities	4 Categories	11 inputs	9 areas – 11 Activities
P1	Preliminary survey	Technical (P1,P2,P3,P4,P1, P20,P23,P24)	Subsoil constraints (P4)	Availability of Information (P1 to P20)
P2	Engineering survey	Environmental	Legal	Non-standard suppliers

P3	Land survey	Statutory	Energy	Temporary design, Quality, Responsibility, and Supervision
P4	Geotechnical survey	Financial, Technical	Suppliers	The capability of Professional staff
P5	Environmental issues		Money	Ground conditions – Inadequate site investigations
P6	Rules and regulations		Access	Relationship of professional staff to each other
P7	High flood levels		Material	Delay in information from Designers
P8	Low flood levels		Plant Information	Poor design and shop drawings
P9	Rainfall patterns		Availability of skills	Bid validity period extension
P10	Water table (variations)		People	
P11	Wind directions		Social attitudes	
P12	Variation patterns of wind		Social expectations	
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)		Customers	
P14	Identification of utility agencies			
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)			
P16	Type of project: design and build, tendered, proposed			

P17	Conditions of contracts of tendered projects			
P18	Special conditions of contracts of tendered projects			
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)			
P20	Assessment of capacities of culverts, bridges, etc. on the access roads			
P21	Availability of material			
P22	Proximity of material			
P23	Requirement of equipment/ machinery/vehicles etc.			
P24	Availability of equipment/ machinery / vehicles etc.			
P25	Subcontractors			
P26	Special subcontractors			
P27	Skilled manpower			
P28	Unskilled manpower			
P29	Type of leadership required (e.g., Project Managers) to drive the project			
P30	Availability of knowhow to do the			

	project - core and support areas			
P31	Adequacy of skills to do the project - core and support areas			
P32	Attitudes of individuals/team towards delivering the project			
P33	Identification of corrective measures, e.g., providing training to rectify gaps			
P34	Social issues			
P35	Neighbourhood issues			
P36	Religious issues			
P37	Political issues			
P38	Stakeholder issues			
P39				Innovative application
P40				New technology
P41				Level of details required and accuracy
P42				Appropriateness of specification
P43				Incomplete design scope
P44				Likelihood of change
P45				Interaction of design with the method of construction

P46				Non-standardisation of details
P47				Non-standardisation of suppliers
P48				Quality control - inspection and approvals
P49				Temporary design - quality, responsibility, and supervision

4.2.3 Inadequacy of Inputs

The inadequacy of the inputs to the design phase of construction projects from the relevant pre-construction activities was considered as the difference between the required input and the actual input of the activity, as described in the review of inadequacy (see section 2.4).

Kajtazi (2012) identified information inadequacy can be developed in three dimensions; a) further development of the content that represents information inadequacy, i.e. factors and their interrelations, b) empirical validity of the current elaboration, based on a very large number of cases and c) the research objectives. Further, inadequacy was also described as the state of lack of required quantity or quality.

4.3 Risk Matrix

Duijm (2015) claimed risk matrices are extensively used in risk management and they feature in regulation for risk management. Duijm further stated risk matrices display "severity" and "likelihood" of an event and the overall impression of risk (see 2.5.4).

Risk matrices are commonly used in the assessment and monitoring of risks in construction projects with a project value of LKR 150 million or above in Sri Lanka as stipulated by the Construction Industry Development Authority (CIDA). It is a mandatory requirement for construction companies implementing such projects (Grade 3 or above CIDA registration for construction projects in Sri Lanka) to get certified for ISO 9001:2015 Quality Management Standard, which stipulates Risk-based thinking in the implementation of the projects.

4.4 Likert Scale

The likert scale (see 2.13) is widely used to measure the attitudes of the respondents (Wu, 2007; Joshi, Kale, Chandel & Pal, 2015). Measurement of attitude using the Likert scale is scientifically accepted and validated. Likert scales are typically numeric and can be on a scale from 1 to 5 values and the respondents are instructed to state their levels of agreement on this numeric scale.

Accordingly, a Likert type scales with 1 to 5 numeric values was used in this study. Questions for respondents comprising pre-construction activities of construction projects were selected and Likert type scales from 1 to 5 numeric were used to obtain responses. The numeric used in the Likert type scales were, 1- Very low, 2- Low, 3- Neutral, 4- High and 5- Very high.

Two questionnaires with Likert type scales were used in the study. They are,

i) The Questionnaire with one Likert type scale and thirty-eight pre-construction activities to obtain information on Relevance and Adequacy of input of pre-construction activities to the design phase of construction projects and,

ii) The Questionnaire with five Likert type scales and forty-nine pre-construction activities to obtain information on a) Impact of Risk, b) Likelihood of Risk, c) Risk of exceeding Cost, d) Risk of exceeding Time and e) Possibility of reducing the risk of exceeding cost or time by verification of the design by a third party independent designer of construction projects.

Further, analysis of data collected using the two questionnaires with Likert type scales was analyzed, assuming normal distribution as per the central limit theorem (Sullivan & Artino, 2013).

4.5 Accuracy

It was stated that the possibility of data being inaccurate or biased due to personal reasons of the respondent such as achievements, security and social acceptance exist (O'relly, 1978). Athanassisades (1972) claimed that when respondents believe data would negatively impact their careers, then the responses would be inaccurate. Bernard, Killworth, Kronenfeld, & Sailer (2016) observed that when the respondent was interviewed in his area of expertise (discipline) the responses were accurate as he knew a lot in the area of questions and would report accurately (see 2.8).

The developed questionnaire requires respondents to provide data related to a project/s he/she was actively involved with responsibility. Confidentiality of the responses was assured and further the identity of the respondents was not requested and there was no impact whatsoever on the career of the respondents. Hence, personal reasons which could affect his/her career negatively, such as, achievements, security, and social acceptance were avoided. Therefore, issues with the accuracy of data would be minimized/eliminated.

The researcher is a professional engineer with more than thirty-six years of experience in the field of civil engineering having worked on different capacities in construction projects and possesses the capacity to select effective respondents who know a lot and report accurately on the study area as claimed by Bernard, Killworth, Kronenfeld, & Sailer, 2016.

4.6 Bias

Any trend or deviation from the truth in data collection, analysis, interpretation and publication is defined as bias (Simundic, 2013). The bias that can occur in this study area is design bias, selection/participant bias, data collection bias, analysis bias and publication bias (Smith & Noble, 2014; Pannucci & Wilkins, 2010).

Further, four reasons that respondents provide inaccurate or biased data were identified as; motivated to do so; perceptual and cognitive limitations result in inadvertent errors; lack of crucial information about the event of interest and were questioned with inappropriate data elicitation procedure (Huber & Power, 1985).

Also, Smith & Noble, 2014 claimed, in quantitative studies selection bias is often reduced by the selection of random participants, having a well-designed research protocol explicitly outlining data collection and analysis that can assist in reducing bias.

4.7 Coherence

4.7.1 Coherence in Respondent

The respondents of the study are assumed to be substantive experts in the construction industry as they are logically connected and consistent (Ranasinghe & Russell, 1992). Also, they would have time to respond calmly to the Likert scale-based questionnaires as there was no deadline to respond to the questionnaires. Further, considering the academic background, experience in the industry of the respondents and communications with them, it was evident Likert type scale questionnaires with specific instructions used in the study was clear for them to respond. Hence the respondents are assumed to be coherent.

4.7.2 Coherence in Data

Chenail, Duffy, St. George & Wulff (2011) stated, to improve qualitative research it is necessary to address coherence from the conception and development of the study (see 2.7). In addition, Coombs (2017) claimed that there is relatively limited advice in the engineering domain for undertaking qualitative studies. However, Table 8 provides a guideline to develop a questionnaire for qualitative studies.

Table 8 - Questions to consider in developing a qualitative questionnaire.

Reflective questions for qualitative research	Sources for guidance	(A)
1. Have you stated your philosophical position?	Conboy, K., Fitzgerald, G. & Mathiassen (2013), Sarker, Xiao & Beaulieu (2013)	Yes
2. Have you explained the theoretical aims for your study?	Avison & Malaurent (2014), Gregor (2006)	Yes
3. Have you explained how you have chosen your data collection site and context and considered the limitations of these?	Davison & Martinsons (2015), Keutel, Michalik & Richter (2013), Sarker et al. (2013)	Yes
4. Have you explained your sampling strategy? E.g. multiple, single, extreme, replication	Keutel, Michalik & Richter (2013), Sarker et al. (2013)	Yes
5. Are you using more than interview data? E.g. observations, archival data, quantitative data, documents.	Keutel, Michalik & Richter (2013), Sarker et al. (2013), Silverman (1998).	Yes
6. Have you described your sample? E.g. number of interviewees, job roles, number of follow up interviews, number of observations, data collection timespan.	Sarker et al. (2013).	Yes
7. Have you included your interview schedule?	Sarker et al. (2013).	
8. Have you explained how you have analyzed your qualitative data (including supporting data), providing a worked example of each analysis stage?	Sarker et al. (2013)	Yes
9. Have you considered the generalisability of your study?	Conboy, K., Fitzgerald, G. & Mathiassen, L. (2013), Davison & Martinsons (2015).	Yes

Note: From "Qualitative Methods Research in Information Systems: Motivations, Themes and Contributions", K. Conboy, G. Fitzgerald, & L. Mathiassen, 2013, *European Journal of Information Systems* 21(2) · January 2013 et al.

Also, Column (A) of Table 8 indicates the status of this study concerning the reflective questions for qualitative research as given in the first column.

4.8 Calibration

Peredaryenko & Kraus (2013) summarized the calibration of a human instrument as given in Table 1 and the continuum states of the human instrument status are given in Figure 2. (see 2.7).

Literature review on calibration is given in section see 2.7. Further, as this study is focused on inputs to the design phase of construction projects, a respondent who is assumed to be a substantive expert in the construction industry (Ranasinghe & Russell, 1992), has the best knowledge to respond to the questionnaire on the particular construction project he or she was involved. Further, despite the interaction between the researcher and the respondents was open, the researcher would not know the quality of responses as he was not involved in any of the projects where responses were received. Therefore, according to the states of human calibration found by Peredaryenko and Krauss (2013), the calibration of the human element of this study is respondent centred (see Figure 7). Also, the researcher has more than 36 years of experience in the construction industry and can get closer to the respondents and understand them (Rennie, 1994; Schneider, 1999). Accordingly, the findings of this study can be considered rich (Peredaryenko and Krauss, 2013).

4.9 Correlation

Correlation analysis is a powerful tool to explore relationships in data and is a method to study the strength of a relationship between two, numerically measured, continuous variables. This analysis is useful when a researcher wants to establish if there are possible connections between variables. The degree of correlation between any two variables on a continuous scale is mathematically expressed as the correlation coefficient (also known as Pearson's correlation coefficient or "r"), a number whose values can vary between −1.0 and +1.0. (Devore, 2008; Speiegel, Stephens & Kumar, N. 2010; Aggarwal and Ranganathan, 2016).

Further, correlation is a link present between things or between variables, be connected or happen jointly in a way not expected (Merriam-Webster dictionary).

Statistical package IBM SPSS 25, used in academia and industry for scientific correlation analysis to study the strength of the relationships between (two) variables was used in this study. It mathematically expresses the correlation coefficient "r", whose values vary between −1.0 and +1.0. The reliability of data was verified using IBM SPSS 25 too.

4.10 Substantive Experts

"Substantive expertise doesn't just experience. Substantive expertise refers to working knowledge and skills as defined by different domains varying from a chemical engineer to a product manager". (https://medium.com/@rushkirubi/why-substantive-expertise-in-data-science-isnt-just-experience-52276fe97132).

As the questionnaires were designed to be independent and mutually exclusive from the careers and reputation of the respondents it was assumed that respondents had no reason to be motivated or biased in providing data (Data received are Accurate).

Further, respondents are logically connected and consistent and had sufficient time to respond calmly to the Likert scale-based questionnaires. Also, there was no stipulated deadline to respond to the questionnaires. Questionnaires were clear to the respondents as they accompanied specific instructions on how to respond including an example. (Data received are Coherent)

Also, the study is informant centred and respondents of this study are calibrated (see 2.7 and 4.8).

Therefore, in this study, the data collected fulfils the requirements for accuracy, coherence and calibration and the respondents to the questionnaire survey are substantive experts (Ranasinghe & Russell, 1992) as described in this section.

4.11 Questionnaire design

Two different online questionnaires to obtain data for risk created by the inadequacy of inputs to the design phase of construction projects were designed and developed during the study. Both questionnaires were finalized considering the inputs of the responses received from respective pilot surveys.

The questionnaires were designed using the methodologies discussed in (see 3.1) of the study. The questionnaires were a mix of qualitative research method (Bradley, Curry & Devers, 2007; Marshall, 1996; Borrego, Douglas and Amelink, 2009) and quantitative research method (Babbie, 2010). It was based on open-ended questions for the initial gathering of responses from the substantive experts in the construction industry (Ranasinghe & Russell, 1992).

Further, these questionnaires used in the surveys to obtain data from the substantive experts in construction projects (Ranasinghe & Russell, 1992) at two different stages of the study as described below i) and ii).

i) To obtain data on relevance and adequacy of the inputs of thirty-eight relevant pre-construction activities to the design phase of construction projects (see Annexure 1), and

ii) To obtain data for the risks created by the inadequacy of inputs of forty-nine relevant pre-construction activities to the design phase of construction projects (see Annexure 4).

Also, 1 to 5 Likert type scales were used in both questionnaires to obtain data;

a) In the questionnaire i) above, a single Likert type scale was used to record the adequacy levels of inputs of thirty-eight relevant pre-construction activities to the design phase of construction projects and,

b) The questionnaire ii) above, comprised of five different Likert type scales (see section 4.4) were used to record responses on the questionnaire for; 1) Risk of Impact, 2) Risk of Likelihood, 3) Risk of exceeding cost and 4) Risk of exceeding time and 5) Verification of the Design by a Third-party Independent Designer would minimize the Risk (including due to inadequate inputs) of exceeding cost and time of construction projects.

Further, based on the outcome of the above questionnaire design, questionnaires were developed for the required data collection of the study (see 5.3).

4.12 Expected Outcome

4.12.1 Risk Rating

Risk rating of a relevant pre-construction activity due to inadequate input to the design phase of a construction project was calculated as a multiplication of the respondents' beliefs on the Likert scales on categories of *Impact* and *Likelihood*. i.e. the multiplication of the quantified value given on the Likert scale for the category of *Impact* on the design phase by an inadequate input and the quantified value given on the Likert scale for the category of *Likelihood* of such an impact occurring on the design phase. For example, for the pre-construction activity "P1- Preliminary survey", if the Likert value for *Impact* is 3 and the Likert value for *Likelihood* is 4 then the Risk Rating is 12 (see Figure-7).

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design Phase.					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design Phase.					(D) Risk Ratin g (A) x (B)
		1	2	3	4	5	1	2	3	4	5	
		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	
P1	Preliminary survey			3						4		12
P2	Engineering survey											
P3	Land survey											
P4	Geotechnical survey											
P5	Environmental issues											
P6	Applicable rules and regulations											
P7	Information about high flood levels											
P8	Recording of information about low flood levels											
P9	Rainfall patterns											
P10	Water table (variations)											
P11	Wind directions											
P12	Variation patterns of wind											

Figure 7 - Risk Rating of Pre-construction activity "P1- Preliminary survey".

4.12.2 Risk of Exceeding Cost/Time:

Individual quantification of Risk of Exceeding the estimated cost of a relevant pre-construction activity was calculated as a multiplication of the respondent's belief of exceeding the estimated cost due to an impact occurring on the design phase by an inadequate input quantified as a value on the Likert scale and the Risk Rating. Say for the pre-construction activity "P1- Preliminary survey", if the Likert value for the respondent's belief of exceeding the estimated cost is 4 and the Risk Rating is 12, then the individual quantification of Risk of Exceeding the estimated cost is 48 (see Figure 8).

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design Phase.					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design Phase.					(D) Risk Rating (A) x (B)	(E) Risk of exceeding Cost caused by the preconstruction activity considered.					(E) (C) x (D)
		1	2	3	4	5	1	2	3	4	5		1	2	3	4	5	
		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High		Very Low	Low	Neutral	High	Very High	
P1	Preliminary survey			3						4		12				4		48
P2	Engineering survey																	
P3	Land survey																	
P4	Geotechnical survey																	
P5	Environmental issues																	
P6	Applicable rules and regulations																	
P7	Information about high flood levels																	
P8	Recording of information about low flood levels																	
P9	Rainfall patterns																	
P10	Water table (variations)																	

Figure 8 - Quantification of Risk of Pre-construction Activity "P1- Preliminary survey".

Similarly, individual quantification of Risk of Exceeding the estimated time of a relevant pre-construction activity was calculated as a multiplication of the respondent's belief of exceeding the estimated time due to an impact occurring on the design phase by an inadequate input quantified as a value on the Likert scale and the Risk Rating. Say for the pre-construction activity "P1- Preliminary survey", if the Likert scale value for the respondent's belief of exceeding the estimated time is 3 and the Risk Rating is 12, then the individual quantification of Risk of Exceeding the estimated time is 36 (see Figure-9).

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design Phase.					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design Phase.					(D) Risk Rating (A) x (B)	(E) Risk of exceeding Cost caused by the preconstruction activity considered.					(E) (C)x (D)	(F) Risk of exceeding Time caused by the preconstruction activity considered.					(G) (C)x (E)
		1	2	3	4	5	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
#		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High		Very Low	Low	Neutral	High	Very High		Very Low	Low	Neutral	High	Very High	
P1	Preliminary survey			3						4		12				4		48			3			36
P2	Engineering survey																							
P3	Land survey																							
P4	Geotechnical survey																							
P5	Environmental issues																							
P6	Applicable rules and regulations																							
P7	Information about high flood levels																							
P8	Recording of information about low flood levels																							
P9	Rainfall patterns																							
P10	Water table (variations)																							

Figure 9 - Risk rating and quantification of Risk for Pre-construction activity "P1- Preliminary survey".

Risk estimates and quantification of Risk for forty-nine Pre-construction Activities for 'Cost' and 'Time' are given in (Annexure 4).

By averaging the individual quantifications of the Risk of Exceeding the estimated cost or time of a relevant pre-construction activity from the data set, the Risk of Exceeding the Cost or Time of the relevant pre-construction activity was quantified.

4.12.3 Critical Pre-construction Activities

By using the quantified lists as explained in 4.12.2, the critical pre-construction activities which contributed most to the Risk of exceeding cost and Risk of exceeding time due to their inadequate input to the design phase of construction projects were identified.

4.12.4 Risk Interpretations

Risk Interpretations for the risk of exceeding cost and risk of exceeding time was done by assuming 'normal distribution' as per the central limit theorem for the data set as explained in section 4.4.

4.13 Summary

The questionnaires developed were an outcome of the developed framework and was used in the questionnaire surveys to gather responses from the substantive experts (see 2.14 and 4.10) in the field of civil engineering. These questionnaires were used to find out;

i) Relevance and inadequacy of inputs of relevant pre-construction activities to the design phase of construction projects and,

ii) Possible risks created by the inadequacies of outputs of relevant pre-construction activities as inputs to the design phase of construction projects.

Analysis of the data collected from the study was done using the following techniques; Relative Importance Index (RII), Severity Index (SI), Descriptive Statistics, Reliability of data, Validity, Correlation, Sampling Adequacy, Accuracy, Bias of responses, Coherence of responses and Calibration of respondents. Processes of the analysis, the results of the analysis and relevant observations based on the analysis of data of the study are given in Chapter 6 – Analysis'.

CHAPTER 5 – DATA COLLECTION

5.1 General

This chapter describes the methods and the importance of data collection used for the study. Section 5.2 describes the contributory factors and pre-construction activities used for data collection while section 5.3 describes the development of questionnaires. Section 5.4 and 5.5 explain the finalized questionnaires and section 5.6 describes the collection of data for contributory factors and pre-construction activities.

Kabir (2016) stated Questionnaire method of data collection is among many methods of data collection (i.e. Interview method, Focus group discussion method, Observation method, Survey method, etc.) and often used for statistical analysis of the responses. Also, the importance of data collection was found to be a process where data was gathered and measured. It is also claimed through data collection that a business or management has the quality information they need to make informed decisions (University of Minnesota, USA, Types of data).

“Data collection in research is stated as the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer the stated research questions, test hypotheses, and evaluate outcomes” (US department of health and human services).

The ‘Questionnaire method’ was selected and used for data collection based on the nature of the analysis in this study. Data collection was done through responses of substantive experts in the construction industry. As stated by Taherdoost (2016), a probabilistic random sampling method was used to select the sample of respondents.

Data was collected on identified contributory factors for cost and time overruns of construction projects from an extensive literature review (Daluwatte & Ranasinghe, 2017); development of the questionnaires to capture data for the relevant pre-construction activities to be used in the study (Daluwatte & Ranasinghe, 2018; Daluwatte & Ranasinghe, 2019); data was collected using the developed questionnaires to identify relevance and adequacy of thirty-eight relevant pre-construction activities (Daluwatte & Ranasinghe, 2018) and how to minimize the risks of overruns of cost and time due to inadequate input from pre-construction activities to the design phase of construction projects (Daluwatte & Ranasinghe, 2019). Description of the identified contributory factors and pre-construction activities are given in section 5.2 below.

5.2 Contributory factors and pre-construction activities used for data collection

Through literature reviews and scientific surveys, three sets of parameters were evolved during this study; i) Forty-two contributory factors; ii) Thirty-eight pre-construction activities, and iii) Forty-nine pre-construction activities; These parameters were used in data collection and analysis as appropriate. The description of these parameters is given below.

5.2.1 Contributory factors

As described in section 2.1, forty-two contributory factors for cost and time overruns of construction projects were identified through an extensive literature review. Further, the literature review revealed these factors contributed to cost and time overruns in two hundred and thirty-seven occurrences (see Table 9). The contributory factors identified in Table 9 highlighted design effects as the most significant contributor to cost and time overruns of construction projects (Daluwatte & Ranasinghe, 2017). Hence, the study focused on identifying the inputs to the design phase of construction projects.

Table 9 - Contributory factors for cost and time overruns of construction projects

Rank	Factor	Occurrences
1	Design effects	29
2	Planning and Controlling	20
3	Material Issues	19
4	Scope Change	18
5	Finance	15
6	Client Influences – Changes	10
7	Management – Site	10
8	Contractor Inexperience	9
9	Poor Contract Management	8
10	Bid - Time given	7
11	Contractor – Defects	7
12	Construction Methods	7
13	Construction Technology	7
14	Approval – Delays	6
15	Communication-Project	6
16	Management - Strategies	6

Rank	Factor	Occurrences
22	Consultant's Issues	2
23	Contract Conditions	2
24	Construction- Pre-Construction Issues	2
25	Disputes within parties	2
26	Equipment and Plant - Cost	2
27	Government Policies	2
28	Information-Availability	2
29	Investigation – early	2
30	Perception of Issues	2
31	Quantities	2
32	Social Issues	2
33	Worker Productivity – Less	2
34	Construction - Issues (Implementation)	1
35	Equipment – Productivity	1
36	Estimation Issues	1
37	Internal Conflicts	1

17	Payment to Contractors	5	38	Optimism biased	1
18	Decision Delay	4	39	Procurement – Delays	1
19	Ground - Site Conditions-Unforeseen-	4	40	Records - Lack of	1
20	Worker Shortage	4	41	Uncertainties- Risks	1
21	Change Order Issues	3	42	Worker (Risky) Behavior	1
				Total occurrences	237

5.2.2 Pre-construction Activities to find the relationship between Relevance and Adequacy.

Through literature review and a scientific survey among substantive experts in the field of civil engineering, Daluwatte and Ranasinghe (2018) identified thirty-eight relevant pre-construction activities to find the relationship between relevance of activity and inadequacy of the output of the activity as an input to the design phase of construction projects. A survey-based on identified pre-construction activities was carried out among practitioners and scholars in the construction industry. Practitioners included Group CEO of CIDA CS2 Company, Chairman of a design/construction company, Directors, CEOs, General Managers. Scholars included Professors, PhDs and postgraduates. Most of them had a substantial number of experience (each more than 20 years) behind them. These pre-construction activities are given in Table 10.

Table 10 - Relevant Thirty-eight Pre-construction Activities.

#	Relevant Thirty-eight Pre-construction Activities identified for the study		
P1	Preliminary survey	P20	Assessment of capacities of culverts, bridges, etc. on the access roads
P2	Engineering survey	P21	Availability of material
P3	Land survey	P22	Proximity of material
P4	Geotechnical survey	P23	Requirement of equipment/ machinery/vehicles etc.
P5	Environmental issues	P24	Equipment/ machinery / vehicles etc.
P6	Rules and regulations	P25	Subcontractors
P7	High flood levels	P26	Special subcontractors
P8	Low flood levels	P27	Skilled manpower
P9	Rainfall patterns	P28	Unskilled manpower
P10	Water table (variations)	P29	Type of leadership required (e.g., Project Managers) to drive the project
P11	Wind directions	P30	Availability of knowhow to do the project - core and support areas
P12	Variation patterns of wind	P31	Adequacy of skills to do the project - core and support areas
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	P32	Attitudes of individuals/team towards delivering the project
P14	Identification of utility agencies	P33	Identification of corrective measures, e.g., providing training to rectify gaps
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	P34	Social issues
P16	Type of project: design and build, tendered, proposed	P35	Neighbourhood issues
P17	Conditions of contracts of tendered projects	P36	Religious issues
P18	Special conditions of contracts of tendered projects	P37	Political issues
P19	Investigation of access roads (capacity, width, surface, etc.)	P38	Stakeholder issues

5.2.3 Pre-construction Activities to find the Risk created by input to the design phase

Similar to section 5.2.2, Daluwatte and Ranasinghe (2019), identified forty-nine relevant pre-construction activities to identify Risks created by input to the design phase of construction projects. These pre-construction activities are given in Table 11.

Table 11 - Relevant Forty-nine Pre-construction Activities.

#	Forty-nine relevant Pre-construction Activities identified for the study		
P1	Preliminary survey	P26	Availability of special subcontractors
P2	Engineering survey	P27	Availability of skilled manpower
P3	Land survey	P28	Availability of unskilled manpower
P4	Geotechnical survey	P29	Type of leadership required (e.g., Project Managers)to drive the project
P5	Environmental issues	P30	Availability of knowhow to do the project - core and support areas
P6	Rules and regulations	P31	Adequacy of skills to do the project - core and support areas
P7	High flood levels	P32	Attitudes of individuals/team towards delivering the project
P8	Low flood levels	P33	Identification of corrective measures, e.g., providing training to rectify gaps
P9	Rainfall patterns	P34	Social issues
P10	Water table (variations)	P35	Neighbourhood issues
P11	Wind directions	P36	Religious issues
P12	Variation patterns of wind	P37	Political issues
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	P38	Stakeholder issues
P14	Identification of utility agencies	P39	Innovative application
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	P40	New technology
P16	Type of project: design and build, tendered, proposed	P41	Level of details required and accuracy
P17	Conditions of contracts of tendered projects	P42	Appropriateness of specification
P18	Special conditions of contracts of tendered projects	P43	Incomplete design scope

P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	P44	Likelihood of change
P20	Assessment of capacities of culverts, bridges, etc. on the access roads	P45	Interaction of design with the method of construction
P21	Availability of material	P46	Non-standardisation of details
P22	Proximity of material	P47	Non-standardisation of suppliers
P23	Requirement of equipment/ machinery/vehicles etc.	P48	Quality control - inspection and approvals
P24	Equipment/ machinery / vehicles etc.	P49	Temporary design - quality, responsibility and supervision
P25	Availability of subcontractors		

5.3 Development of Questionnaires for Data Collection

Two different questionnaires were developed using the outcome of the questionnaire design (see 4.11.1) for the collection of data for the study as explained below.

5.3.1 Development of Questionnaire for 38 pre-construction activities

The questionnaire prepared to capture data/information on the adequacy of the input to the thirty-eight relevant pre-construction activities to the design phase including its relevance to the design phase of a construction project is shown in Table 10. A pilot survey was prior to finalization of the questionnaire as described in section 5.3.2.

5.3.2 Pilot survey for the Questionnaire with 38 pre-construction activities

A pilot survey was carried out with the draft questionnaire among experts and academics in the field of civil engineering and the feedback received was used to finalize the questionnaire (see Figure-10).

The initial part of the questionnaire requested the following information regarding the project; type, planned cost, actual cost, planned duration, actual duration and space for comments. Further, the questionnaire requested responses on inputs from the thirty-five pre-construction activities to the design phase of a project on; i) Relevance of the activity to the project (yes/no and if the answer is no, specify the reason), ii) If the activity was relevant, was it Done (carried out) during the implementation of the project and iii) Adequacy of the input from the pre-construction activity to the design phase of the project in a scale of 20%, 40%, 60%, 80% and 100%. Based on the feedback received from the Pilot Survey, the following adjustments were made to the questionnaire.

i) Activities ‘Land Survey’, ‘Engineering Survey’ and ‘Study of stakeholder issues’ were added to the list of pre-construction activities and with these inclusions the pre-construction activity list expanded to thirty-eight.

ii) ‘Uncertain’ parameter was added to the response of the Relevance column, now the response read as ‘Yes/No/Uncertain’. The ‘Uncertain’ option in the ‘Relevance column’ provided the opportunity for a respondent to express ‘Uncertainty’ about the relevance of an activity to the project.

iii) Response area was introduced to capture the information, though activity was Relevant to the project, whether it was ‘Done’ (carried out) during the implementation of the project. The ‘Done’ column also had the options of response, ‘Yes/No/Uncertain’, to the respondent.

iv) Structure of the response to the Adequacy of the input was improved by including 0% response option to the initial response range of the draft, 20%, 40%, 60%, 80% and 100%.

If a response on an activity marked as 100% adequate, there would not be any contributions to overruns of cost or time from that activity to the project. Hence data received from the Likert scale on 1 to 5 points (0%, 20%, 40%, 60% and 80%) was used to carry out analysis on the data set.

v) Space was provided to record the possible impact of a pre-construction activity (If the inadequacy of the input to the design phase by the activity-induced overrun of cost or/and overrun of time of the activity/project).

vi) Wordings of some of the activities were rearranged to improve the clarity of the questionnaire to the respondents. For example, the wordings of the activities ‘Identification of requirements and study of the availability of equipment/machinery/ vehicles’ were grouped and wordings of the activities on ‘Availability of knowledge and adequacy of skills’ were simplified for clarity of the respondents.

vii) Notations for the Column Headers (A) to (E) were introduced to the questionnaire.

The questionnaire was finalized with the inputs received from the pilot survey. The finalized questionnaire addressed different activities in pre-construction; surveys, rules, and regulations, utilities, type of project, access, material, machinery and equipment, manpower including subcontractors, leadership, attitude, skills and knowledge of the team, social issues, stakeholder issues, religious issues, etc. The final questionnaire was developed in a few stages (see 5.4).

5.3.3 Development of Questionnaire for 49 pre-construction activities

Method to develop a Questionnaire to capture data for the Risks created by the inadequacy of inputs to the design phase of construction projects is described in detail in section 4.11. Based on that a questionnaire was developed to capture data from the substantive experts in the field of civil engineering on the possible risks created by the inadequacies of the inputs of relevant forty-nine pre-construction activities to the design phase of construction projects. A pilot survey on the questionnaire was carried out as described in section 5.3.4.

5.3.4. Pilot survey for the Questionnaire with 49 pre-construction activities

The pilot survey was carried out with the draft questionnaire among experts and academics in the field of civil engineering and the feedback received was used to finalize the questionnaire. The pilot survey requested information following response areas; i) Impact of Risk', 'ii) Likelihood of Risk', 'iii) Risk of exceeding Cost', 'iv) Risk of exceeding Time', and 'v) Verification of the design by a third party designer would minimise the Risks' for the final relevant forty-nine pre-construction activities. These data were obtained on five Likert type scales on the questionnaire, ranging from 1(very low) to 5(very high) (see Figure-12). Feedback received from the industry experts (similar to 5.3.2) on the pilot survey was incorporated into the questionnaire as appropriate.

5.4 Finalised Questionnaire of the 38 pre-construction activities

Contents of the questionnaire was finalized considering the feedback from the pilot survey (see section 5.3.2). Further, the final questionnaire contained; objectives regarding the research, purpose of the research, assurance of confidentiality, instructions to complete, space for comments by the respondent, position of the respondent, number of years of experience of the respondent, registered 'Grade' of the company in the Construction Industry Development Authority (CIDA) of Sri Lanka. Also, instruction for returning the completed questionnaire and contact information of the researcher for possible clarifications.

The questionnaire addressed different segments in pre-construction inputs to design phase in civil engineering construction projects such as surveys to be carried out, applicable rules and regulations, information regarding utilities, type of the project, access to the project site, material requirement and availability, requirement and availability of machinery and equipment, requirement and availability of manpower including subcontractors, leadership, attitude, skills and knowledge of the project team to implement the project, social issues, stakeholder issues and religious issues. The finalized questionnaire was used to obtain data from substantive experts in the construction industry.

5.5 Finalized Questionnaire with 49 pre-construction activities

The questionnaire was finalised using the draft questionnaire and the feedback received from the pilot survey (see section 5.3.5). Also, the final questionnaire contained, information regarding the research; the purpose of the research; confidentiality; instructions to fill; space for comments by the respondent, if any; the position of the respondent; the number of years of experience of the respondent; the role of the consultant (contractor. Designer/consultant, or client; registered 'Grade' of the company in the CIDA) of Sri Lanka. Also, instructions for returning the completed questionnaire and contact information of the researcher for possible clarification.

The finalized questionnaire obtained data from the substantive experts from the construction industry on the possible Risks induced by the inadequacies of the input of the relevant forty-nine pre-construction activities to the design phase of a construction project, Risk of exceeding Cost, Risk of exceeding Time and the possibility of minimizing the Risk of exceeding Cost or Time by verification of the design by a third party independent designer of a construction project. Also, it included five Likert like scales for responses ranging from 1(very low) to 5(very high) to obtain data (see Figure-12).

5.6 Collection of data for contributory factors and pre-construction activities

5.6.1 Collection of data for contributory factors

The collection of data for the study of forty-two contributory factors for cost and time overruns of construction projects was done through literature review (Daluwatte & Ranasinghe, 2017).

5.6.2 Collection of data for 38 pre-construction activities

The finalized questionnaire (see Figure-11) consists of thirty-eight pre-construction activities and was used to obtain data on construction projects from the substantive experts in the construction industry. The respondents were requested to report the Relevance of the activity to the project and if the activity was relevant, whether it was 'Done' (carried out) during the implementation of the project. Further, they were requested to report on the Adequacy of the input to the design phase by the relevant pre-construction activities of a project, similar to the Likert scale. Also, a part of the developed questionnaire to obtain responses on the pre-construction activities from experts in the construction industry is given in Figure-10. The description of Columns (A) to (E) are given below.

Relevance of Preconstruction Activities at Design stage of the project

Instructions: Please respond to the Activities in Questionnair as appropriate to the project concerned.
Please send your email responses to nath0224@gmail.com. Clarifications : Leelanath Daluwatte, 0718 331602
1. Mark the 'Activity was Done' column as ***Yes (Y) / No (N) / Uncertain (U).***
2. Mark the 'Activity was Relevant' column as ***Yes (Y) / No (N) / Uncertain (U)*** *.*
3. If Yes, (Relevant), mark the adequacy of the input activity to design as 20%...to...100%. If it is uncertain please give reason/s (in the last column)

Project Type: Building/ Roads/.........................		**Planned Cost :**								**Planned Duration:**
Year started:		**Actual Cost :**								**Actual Duration:**
(A) Preconstruction Activity		(B) Activity was Relevant to the Project	(C) Activity was Done	(D) **If Yes,** (Relevant and Done), adequacy of the input of activity (over the requirement) of the **Design phase of the project**						(E) If the Activity was less than 100% effective at the first attempt / stage, re: Answer of Column (D) **What were the Impacts / Issues to the Project ; Exceeding Cost, Exceeding Time,......**
		Yes/No/ Uncertain	Yes/No/ Uncertain	0%	20%	40%	60%	80%	100%	
P1	Preliminary survey									
P2	Engineering survey									
P3	Land survey									
P4	Geotechnical survey									
P5	Study of Environmental issues									
P6	Study of Rules and Regulations									
P7	Study of High flood level									

Figure 10- Part of the questionnaire of relevant thirty-eight pre-construction activities

(see Annexure 1 for the full questionnaire)

1. Column (A) – Identified pre-construction activity that may be relevant to the design phase (question)
2. Column (B) – Whether the pre-construction activity was relevant to the project concerned
3. Column (C) - Whether the pre-construction activity was done (carried out) at the project concerned
4. Column (D) – If the activity was 'relevant' and 'done', Adequacy of the input of the pre-construction activity to the design phase of the project concerned; response from 0% to 100% at 20% equal intervals.
5. Column (E) - Comment - If the Activity was less than 100% effective at the first attempt/stage, what were the Impacts / Issues to the project concerned; exceeding the cost or/and exceeding time.

A questionnaire containing relevant thirty-eight pre-construction activities was sent to the prospective respondents. Data were collected online. Clarifications of the questionnaire were done over the phone and in person. Construction projects done by both Government and Private sector organizations were involved in the survey. In this questionnaire survey, responses were collected from thirty-two construction projects for the identified relevant thirty-eight pre-construction activities regarding their Relevance and Adequacy of the inputs to the design phase. Collected data was verified for clarity from the respondents as appropriate.

5.6.3 Collection of data for 49 pre-construction activities

A part of the developed questionnaire to obtain responses on the possible inadequacies by the finalised forty-nine pre-construction activities for 'Impact', Likelihood', 'Cost',' Time' and 'Minimising the risk of from the experts in the construction industry is given in Figure-11. The description of Columns (A), (B), (C), (E), (F) and (H) are given below.

	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design					(E) Risk of exceeding Cost caused by the preconstruction activity considered.					(F) Risk of exceeding Time caused by the preconstruction activity considered.					(H) Verification of the Design (eg: by a Third party Independent Designer) would minimise the risk				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
#		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High
P1	Preliminary survey																									
P2	Engineering survey																									
P3	Land survey																									
P4	Geotechnical survey																									
P5	Environmental issues																									
P6	Applicable rules and regulations																									
P7	Information about high flood levels																									
P8	Recording of information about low flood levels																									
P9	Rainfall patterns																									
P10	Water table (variations)																									
P11	Wind directions																									
P12	Variation patterns of wind																									

Figure 11 - Part of the questionnaire of relevant forty-nine pre-construction activities

(see Annexure 2 for the full questionnaire)

a) Column (A) – Identified pre-construction activity that may contribute inadequate input to the design phase (question)
b) Column (B) - Impact of inadequate input of a pre-construction activity to the design phase,
c) Column (C) - Likelihood of such an impact occurring on the design phase by an inadequate input of a pre-construction activity
d) Column (E) - Risk of exceeding the estimated cost due to such an impact occurring on the design phase by an inadequate input of a pre-construction activity
e) Column (F) - Risk of exceeding the estimated time due to such an impact occurring on the design phase by an inadequate input of a pre-construction activity.
f) Column (H) – Verification of the Design by a Third-party Independent Designer would minimize the Risk (including due to inadequate inputs) of the Design Phase.

The questionnaire (see Figure-12) derived from the developed framework (see 4.11) was used for the collection of data from the respondents. Respondents to the survey were substantive experts (see 2.14 and 4.10) in the construction industry. Likert scale (see 2.13) of one (1) to five (5) was used for the collection of data where 1 represents "very low", 2 represents "low", 3 represents "neutral", 4 represents "high" and 5 represents "very high" to quantify respondent's belief as responses to the questionnaire.

5.7 Summary

Data collection for a study is recognized as very important in literature. Due attention was given to data collection of this study based on the knowledge gained through the literature reviews and academics who had plenty of experience in data collection for scientific research. The main instrument used in the data collection of this study was the 'Questionnaire' backed with five points 'Likert scale/s'. Respondents involved in the study were "substantive experts" (see 2.14 and 4.10) engaged in the field of civil engineering.

Two different questionnaires were used for data collection, namely,

a) Questionnaire established with *relevant 38 pre-construction activities* to obtain responses from substantive experts on 'Relevance' and then the 'Adequacy' of the input from the concerned pre-construction activities to the design phase of construction projects, and

b) Questionnaire established with *relevant 49 pre-construction activities* to obtain responses from substantive experts on possible Risks created by the Inadequacy of the input to the design phase and; 'Impact of Risk', 'Likelihood of Risk', 'Risk of Exceeding Cost of construction projects', 'Risk of Exceeding Time of construction projects' and 'Verification of the Design by a Third Party Independent Designer to minimize exceeding Cost or Time Overruns'. A questionnaire containing five-point Likert type scale response areas (from '0' to '5) was used.

Also, both questionnaires requested information of the projects on; the type, planned cost, planned time, actual cost, actual time, space for comments by the respondent, number of years of experience of the respondent, CIDA grade of the company and contact details of the researcher for clarifications of the project concerned. Further, the confidentially of the information provided by the respondents was assured.

The data collected for the study from substantive experts using the methods discussed in this chapter were analyzed using different scientific techniques in Chapter 6.

CHAPTER 6 – DATA ANALYSIS

6.1 General

This chapter describes the analysis of collected data for this study. It includes the analysis of:

i) Contributory factors for cost and time overruns of construction projects,

ii) Effects on the design phase by the inadequate inputs of pre-construction activities and the model derived from the analysis for the relationship between Relevance and Inadequacy of the inputs to pre-construction activities of construction projects, and

iii) Risks created by the Inadequacies, Correlations, Coherence, and Accuracy of the inputs to pre-construction activities in the design phase of construction projects.

6.2 Analysis of contributory factors for cost and time overruns

The top-ranking contributory factors towards Cost and Time overruns in construction projects based on the sums and the percentages obtained from the literature review are listed in Table 12 in section 6.2 (Daluwatte & Ranasinghe, 2017). It shows, Design effects, Planning and Controlling and Material Issues are the top three contributors towards the cost and time overruns in construction projects and these three factors are responsible for almost 30% of the total contributions. Factors like Worker shortage and Client influenced changes which are assumed as key contributors towards cost and time overruns in the Sri Lankan construction industry are ranked low in the analysis of contribution towards cost and time overruns in construction projects.

A detailed breakdown of the top three contributory factors derived from the analysis of the cost and time overruns in construction projects are listed as;

i) Design effects - design errors, poor design, delay in design, design changes, client-driven design changes, change orders due to design changes, erroneous design work and attitudes of the designer;

ii) Planning and Controlling - poor planning and controlling, deficiencies in planning and insufficient planning; and

iii) Material – availability of material, an increase of material cost during the project period and change of material specifications.

Also, the analysis highlighted that the top seven factors, Design, Planning, Material, Change in Scope, Finance, Changes by the Client and Site Management contributed 50% towards the cost and time overruns in construction projects. Forty-one contributory factors, except for the contributory factor ‘Changes by the client to the project’, accounted for 98% towards cost and time overruns of construction projects.

If the contributions by these factors are adequately addressed at the analysis of limitations and assumptions of the pre-construction stage of the projects, then a contribution towards cost and time overruns of the projects by the factors could have been eliminated/minimized. The above inadequacy of analysis in limitations and assumptions at the pre-construction stage highlights the gap in knowledge for successful completion of construction projects.

Sums and percentage contributions towards overruns of cost and time in construction projects by the top-ranking contributory factors are given in Table 12 below.

Table 12 - Sum and % Contribution of Top-Ranking Factors towards overruns.

Group	Factors	Sum of Contributions to Cost and Time Overruns	% from Total Contributions (237)
Group 1	Top 3 factors	68	~30%
Group 2	Top 7 factors	121	51%
Group 3	Top 17 Factors	189	80%

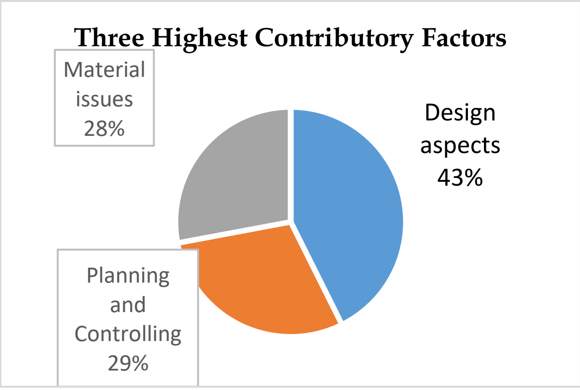

Figure 12 - Three highest contributory factors for Cost and Time overruns of construction projects.

Figure-12 indicates the composition of occurrences by the top three contributing factors which account for ~ 30% of the total of 237 occurrences. The top three factors have a total contribution of 68 occurrences, i.e. Design effects 29 occurrences, Planning and controlling 20 occurrences and Material issues 19 occurrences. Out of the top three contributory factors; i) Design effects is the most significant contributory factor with 43% of the occurrences, followed by ii) Planning and controlling 29% of the occurrences and iii) Material issues at 28% occurrences.

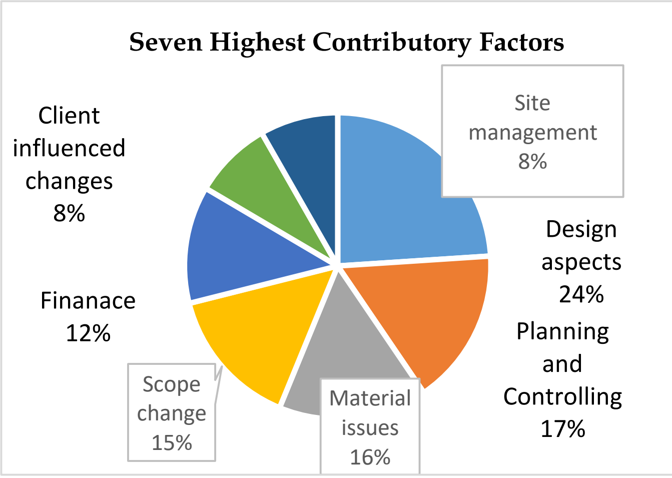

Figure 13 - Seven highest contributory factors for Cost and Time overruns of construction projects.

Figure-13 indicates the composition of occurrences of the top seven contributory factors for cost and time overruns of construction projects which account for ~51% of 237 total occurrences. The top seven factors have a total contribution of 121 occurrences (see Table 9). Contributory factor 'Design effects' alone lead as the highest contributor among the top seven factors with 24% ((29/121)*100%) with the second contributory factor being 'Planning and controlling' with 17%. Contributory factor 'Design effects' is the highest single contributor with 12% (29/237), to the total contribution of 237 contributions of cost and time overruns of construction projects.

6.3 Effects of the inputs to pre-construction activities in the design phase of construction projects

6.3.1 Preliminary Analysis

Daluwatte & Ranasinghe (2018) identified 38 pre-construction activities that provide inputs to the design phase of construction projects (see Table 10). Data was collected for the 38 pre-construction activities regarding their Relevance to the project and Adequacy of the input by them to the design phase of the project from 32 construction projects.

A preliminary analysis was carried out on a data set received from 18 construction projects for 12 pre-construction activities (see Table 13). The responses indicated that the relevance of inputs and inadequacies of inputs from pre-construction activities to the design phase exists at different percentages for different pre-construction activities of construction projects.

Table 13 – Relevance and Adequacy of 12 preconstruction activities of 18 Projects

	Pre-construction Activity	Number of Projects (X)	Percentage of Relevant number of Projects (x) %	Number of 100% Adequate inputs of a project (Y)	Percentage of 100% Adequate inputs (y) %
P1	Preliminary survey	12	100%	4	33%
P2	Engineering survey	10	83%	5	42%
P3	Land survey	11	92%	5	42%
P4	Geotechnical survey	10	83%	4	33%
P5	Environmental issues	9	75%	2	17%
P6	Rules and Regulations	12	100%	3	25%
P7	High flood level	7	58%	2	17%
P8	Low flood level	5	42%	1	8%
P9	Rainfall pattern	9	75%	2	17%
P10	Water table (variations)	8	75%	1	8%
P11	Wind directions	6	50%	1	8%
P12	Variation patterns of wind	4	33%	1	8%

Note in Table 13: Sample is based on responses for 12 pre-construction activities from 18 construction projects

Analysis of 38 pre-construction activities of 32 projects is given in Table 14 with relevance and adequacy of analysis based on the responses from the industry. The analysis indicates that inadequacies of the input from the pre-construction activities to the design phase of construction projects *exist*.

6.3.2 Relationship between Relevance and Adequacy of pre-construction activities

The data highlighted a possible relationship between the responses on the Relevance of the pre-construction activities and the Adequacy of use of the outputs of pre-construction activities as inputs to the design phase of construction projects. A model to predict the relationship between relevance and adequacy (or inadequacy) of pre-construction activities would be useful during the design phase to gauge the contribution of the pre-construction activities.

Table 14 – Relevance and Adequacy of 38 preconstruction activities of 32 projects

	Pre-construction Activity	Relevant number of Projects (X)	Percentage of Relevant number of Projects (x) %	Number of 100% Adequate inputs of a project (Y)	Percentage of 100% Adequate inputs (y) %
P1	Preliminary survey	31	97%	12	38%
P2	Engineering survey	31	97%	14	44%
P3	Land survey	30	94%	13	41%
P4	Geotechnical survey	25	78%	7	22%
P5	Environmental issues	29	91%	9	9%
P6	Rules and regulations	32	100%	10	31%
P7	High flood levels	20	63%	6	19%
P8	Low flood levels	14	44%	2	6%
P9	Rainfall patterns	20	63%	3	9%
P10	Water table (variations)	19	59%	7	22%
P11	Wind directions	13	41%	7	22%
P12	Variation patterns of wind	8	25%	3	9%
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	32	100%	13	41%
P14	Identification of utility agencies	29	91%	14	44%
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	32	100%	14	44%
P16	Type of project: design and build, tendered, proposed	29	91%	11	34%
P17	Conditions of contracts of tendered projects	29	91%	11	34%
P18	Special conditions of contracts of tendered projects	25	78%	11	34%

P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	28	88%	11	34%
P20	Assessment of capacities of culverts, bridges, etc. on the access roads	22	69%	10	31%
P21	Availability of material	31	97%	8	25%
P22	Proximity of material	28	88%	10	31%
P23	Requirement of equipment/ machinery/vehicles etc.	32	100%	8	25%
P24	Equipment/ machinery / vehicles etc.	31	97%	7	22%
P25	Subcontractors	27	84%	8	25%
P26	Specialized subcontractors	24	75%	7	22%
P27	Skilled manpower	31	97%	3	9%
P28	Unskilled manpower	28	88%	2	6%
P29	Type of leadership required (e.g., Project Managers) to drive the project	29	91%	12	38%
P30	Availability of knowhow to do the project - core and support areas	32	100%	10	31%
P31	Adequacy of skills to do the project - core and support areas	31	97%	8	25%
P32	Attitudes of individuals / team towards delivering the project	28	88%	10	31%
P33	Identification of corrective measures, e.g., providing training to rectify gaps	24	75%	3	9%
P34	Social issues	24	75%	8	6%
P35	Neighborhood issues	28	88%	8	6%
P36	Religious issues	9	28%	1	3%

P37	Political issues	10	31%	1	3%
P38	Stakeholder issues	20	63%	1	3%

Note in Table 14: Result is based on responses for 38 pre-construction activities from the total response of 32 construction projects.

For example, consider pre-construction activity “Availability of subcontractors”, P25 (highlighted), from Table 14. Accordingly, activity P25 is relevant to 27 projects out of 32 projects considered and input to the design phase from activity P25 is 100% Adequate for 8 out of 32 projects. Percentage of Relevant number of Projects out of all Projects, x = (27/32)*100 = 84%, and, Percentage of 100% Adequate inputs to the projects, y = (8/32)*100 = 25%

Analysis indicates, out of the 32 projects considered, none of the inputs from preconstruction activities to the design phase of construction projects had even reached an adequacy level of 50%; the highest percentage of projects which had 100% adequacy level of the inputs to the design by a preconstruction activity was 44%, the average was 23% and the lowest 3% (see Table 14, Daluwatte and Ranasinghe 2018).

6.3.3 Relationship between Relevance and input of pre-construction activities 100% adequate to the design phase of construction projects.

When a pre-construction activity is relevant for the design phase of a construction project, it appears the output of the activity (as the input) to the design phase has to be adequate to satisfy the purpose of an effective design. Hence the finding of a relationship between the two, Relevance and Adequacy is explained below.

Line fitting was utilized to test the relationship between the relevance of the pre-construction activities and the adequacy of the outputs of pre-construction activities as inputs to the design phase of construction projects. Regression analysis was used and the most appropriate relationship was determined as the exponential relationship between the variables Relevance and Adequacy, as it had the highest coefficient of determination, R^2 (=0.4) and it was closest to the perfect fit (=1.0) among the relationships considered (see Table 15).

Table 15 - Results of the Regression analysis

Relationship Relevance (x) and Adequacy (y)		
Type of Relationship	r^2	Equation Relevance % (x), Adequacy % (y)
Exponential	0.4	$y = 2.6916e^{0.024x}$
Power	0.38	$y = 0.0448x^{1.3884}$
Polynomial	0.37	$y = 0.0034x^2 - 0.0785x + 6.7274$
Linear	0.36	$y = 0.3706x - 6.1054$
Logarithmic	0.33	$y = 20.88\ln(x) - 66.898$

Hence, the exponential relationship between 'Relevance' and 'Adequacy' was found to be the most appropriate relationship as given in equation 6.1 below.

$$y = 2.6916e^{0.024x} \tag{6.1}$$

When a designer estimates the adequacy of the outcome of a pre-construction activity as input to the design, he/she can use the model given by equation (6.1).

For example, consider the pre-construction activity, 'Geotechnical Survey', which is 100% relevant to a project. Using equation (6.1) the adequacy of the pre-construction activity 'Geotechnical Survey', $y = 2.6916e^{0.024x100} = 30\%$.

Also, % Inadequacy (z) = 100% - %Adequacy(y).

Therefore, % of Inadequacy (z) = $100\% – 2.6916e^{0.024x} = 70\%$

Further, Figure-14 was derived using equation (6.1), the most appropriate relationship for Relevance and Inadequacy, $z = 100\% - 2.6916e^{0.024x}$ as explained above.

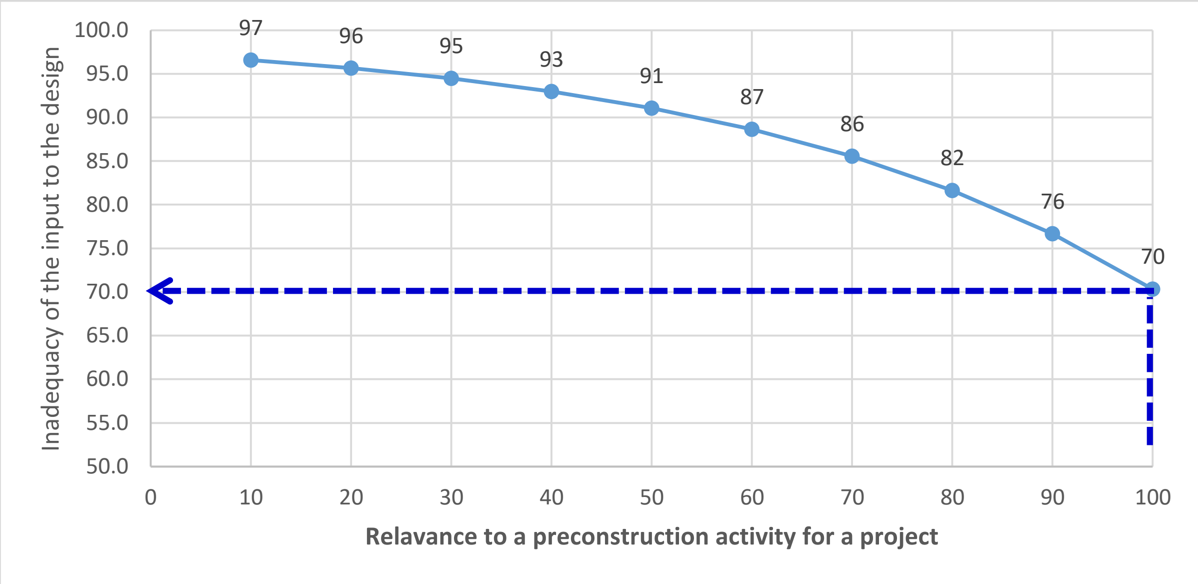

Figure 14 – Relationship of Relevance (%) and Inadequacy (%) of a preconstruction activity

The model in Figure-14 can be used to find the appropriate Inadequacy level of the input from a pre-construction activity to the design phase for a known Relevance of the activity of a construction project.

6.4 Methods used for Data analysis.

6.4.1 Data analysis for the qualitative research method

Thorne (2000) stated, creating a database is not sufficient to conduct a qualitative study. To generate findings that transform raw data into new knowledge, a qualitative researcher must engage in active and demanding analytic processes throughout all phases of the research. Understanding these processes is therefore an important aspect not only of doing qualitative research, but also of reading, understanding, and interpreting data (Thorne, 2000).

6.4.2 Data analysis for the quantitative research method

6.4.2.1 Reliability analysis

Cronbach's alpha, α, which was developed by Lee Cronbach in 1951, measures reliability, or internal consistency and tests to see if multiple question Likert scale surveys are reliable. The formula for Cronbach's alpha (α) is:

$$RII = \Sigma W / (A*N) \qquad (6.2)$$

Where N is the number of items, $\bar{c}$ is the average covariance between item pairs and $\bar{v}$ is the average variance.

Six numbers of Likert type scales were used in two questionnaires to obtain responses from the industry in this study. Field (2005) stated Cronbach's alpha is the most common measure for testing the reliability of a questionnaire. Also, Pallant (2015) claimed a minimum value of 0.6 for Cronbach's alpha indicated internal consistency or reliability of the questionnaire.

Testing of Cronbach's alpha for reliability can be done using IBM SPSS statistical package or Microsoft Excel software. IBM SPSS 25 statistical package was used to test the reliability of data in this study.

6.4.2.2 Relative Importance Index (RII)

Relative Importance Index (RII) is used to find the relative importance of each factor and the higher the value of RII, the more important is the factor (Rajgor, Paresh, Dhruv, Chirag & Dhrmesh 2016).

The formula for Relative Importance Index, *RII*, is;

$$RII = \Sigma W / (A * N) \qquad (6.3)$$

Where W is the weightage given to each factor by the respondents, A is the highest weight, and N is the total number of respondents.

6.4.2.3 Severity Index (SI)

Severity Index (*SI*) analysis was used to rank the activities according to their relative importance level using the following formula (Polat, Okay & Eray, 2014); for a Likert type scale with a range from 1 to 5,

$$SI = \sum_{i=1}^{i=5} w_i \times (fi / n) / a \qquad (6.4)$$

Where i is the point given to each factor by the respondent,

w_i is the weight for each point,

fi is the frequency of the point i by all respondents,

n is the total number of responses and a is the highest weight (5 in this example).

6.4.2.4 Sampling adequacy

KMO correlation matrix to find out the sampling adequacy is used to measure sampling adequacy (Muhwezi, Acai & Otim, 2014). Further, Shread (2018) stated, using statistical tests of quantitative data need more insight like what, how, appropriateness etc. of data to be used.

6.5 Risks created by Inadequacies, Correlations, Coherence, Accuracy, etc.

6.5.1 Background

This section describes the analysis and observations of Risks created by the Inadequacies, Correlations, Coherence, Accuracy, Risk rating, Risk of exceeding the Cost/Time; minimising the Risk of exceeding Cost and Time by a third-party independent designer; Critical Pre-construction activities, Interpretations of Risks, Relative Importance Index (RII); Severity Index (SI); Descriptive Statistics; Reliability of data; Validity of data; Correlation; and Sampling Adequacy; of inadequate input from the pre-construction activities to the design phase of construction projects.

The analysis was done for the data set obtained from responses of 100 construction projects for inadequate inputs for 49 relevant pre-construction activities to the design phase of projects.

Results of the above analysis are discussed and displayed below in the text, tables, and figures as appropriate. The body of the report displays parts from the analysis, say 10 out of 49 activities, in some instances. This was done to maintain clarity of the report and results of the entire analysis are given in the Annexures as indicated where appropriate. Observations based on the entire analysis is given 6.8 and the summary of the analysis is given in 6.8.

6.5.2 Development of the Questionnaire

The questionnaire was developed to collect data regarding a construction project from the following;

1. Impact of inadequate input of a relevant pre-construction activity to the design,
2. Likelihood of such an impact occurring on the design phase by an inadequate input of a pre-construction activity,
3. Risk of exceeding the cost due to the impact and likelihood of the design phase by an inadequate input of a pre-construction activity,
4. Risk of exceeding the time due to the impact and likelihood of the design phase by an inadequate input of a pre-construction activity.

5. Verification of the design (including the inputs from pre-construction activities to the design phase) by introducing a third-party independent designer to minimise the risk of exceeding cost or time.

1 to 5 Likert type scale (Likert, (1932); Joshi, Kale, Chandel & Pal 2015) was used to quantify the respondent's belief as responses to the questionnaire. Notations to respond for the Likert scale was 1- representing Very low, 2- representing Low, 3- representing Neutral, 4- representing High and 5- representing Very high.

A pilot survey was completed on the developed questionnaire and the responses were used to improve the questionnaire. Respondents to the survey were substantive experts (see 2.14 and 4.10) in the construction industry whose work experience ranged from 05 years to more than 25 years.

As given in Figure-15 below the respondents were requested to respond on the Likert type scales for i) Impact of Risk, ii) Likelihood of Risk, iii) Risk of exceeding Cost and iv) Risk of exceeding Time for the inadequacies of input from the relevant forty-nine pre-construction activities (see Table - 8) to the design phase of construction projects.

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design					(E) Risk of exceeding Cost caused by the preconstruction activity considered					(F) Risk of exceeding Time caused by the preconstruction activity considered				
		1 Very Low	2 Low	3 Neutral	4 High	5 Very High	1 Very Low	2 Low	3 Neutral	4 High	5 Very High	1 Very low	2 Low	3 Neutral	4 High	5 Very high	1 Very Low	2 Low	3 Neutral	4 High	5 Very High
P1	Preliminary survey					5				4			2							4	
P2	Engineering survey					5				4					4						5
P3	Land survey				4					4					4					4	
P4	Geotechnical survey					5					5		2								5
P5	Environmental issues				4					4			2					2			
P6	Applicable rules and regulations					5		2							4					4	
P7	Information about high flood levels					5				4			2					2			
P8	Recording of information about low flood levels		2					2					2					2			
P9	Rainfall patterns		2					2					2					2			
P10	Water table (variations)				4					4			2							4	
P11	Wind directions				4			2				1								4	
P12	Variation patterns of wind				4			2				1						2			
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)				4					4			2								5
P14	Identification of utility agencies				4					4			2							4	
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)					5				4					4						5
P16	Type of project : design and build, tendered, prepared				4					4			2								5
P17	Conditions of contracts of tendered projects					5					5				4					4	
P18	Special conditions of contracts of tendered projects					5				4					4					4	
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)		2					2					2					2			
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads		2							4			2					2			
P21	Availability of material		2								5		2							4	
P22	Proximity of material		2							4			2							4	
P23	Requirement of equipment/ machinery/vehicles etc.		2								5				4					4	
P24	Availability of equipment/ machinery / vehicles etc.					5				4					4					4	
P25	Availability of subcontractors				4					4					4					4	
P26	Availability of special subcontractors		2							4					4					4	

Figure 15 - Part of Responses to the Questionnaire for the forty-nine pre-construction activities and four categories concerned 'Impact', 'Likelihood', 'Cost' and 'Time'.

Note: Full questionnaire is available in Annexure – 2.

A description of the questionnaire is given below.

a) Column (A) – Identified pre-construction activity that may contribute inadequate input to the design phase of a construction project (question)

b) Column (B) - Impact of inadequate input of a pre-construction activity to the design phase of a construction project,
c) Column (C) - Likelihood of such an impact occurring on the design phase of a construction project by an inadequate input of a pre-construction activity
d) Column (E) - Risk of exceeding the estimated cost due to such an impact occurring on the design phase of a construction project by an inadequate input of a pre-construction activity
e) Column (F) - Risk of exceeding the estimated time due to such an impact occurring on the design phase of a construction project by an inadequate input of a pre-construction activity.
f) Column (H) - Verification of the design (including the inputs from pre-construction activities to the design phase) by introducing a third-party independent designer to minimise the risk of exceeding Cost and Time.

In addition, though most of the established preconstruction activities are from contextual settings outside Sri Lanka they also include pre-construction activities established by substantive experts in Sri Lankan settings too.

Despite the discussions held with industry professionals/academics in the US, Australia, New Zealand, Singapore, etc. regarding the possible input to the study, the study was carried out using the established preconstruction activities based on the input of 157 construction projects in Sri Lanka.

6.5.3 Risk Rating

Risk rating of a pre-construction activity due to inadequate input to the design phase of a construction project is calculated as a multiplication of the respondent's belief on the ***Impact*** on the design phase of construction projects by an inadequate input and the respondent's belief on the ***Likelihood*** of such an impact occurring on the design phase of construction projects by an inadequate input (Duijm, 2015) (see 4.3).

Risk Rating = Respondent's belief on the ***Impact*** x ***Likelihood*** (6.5)

Risk of exceeding the cost by a pre-construction activity from quantification of belief by a respondent is the multiplication of the *Risk Rating* calculated from equation (6.5) and the respondent's belief in the risk of exceeding the cost due to an inadequate input of that pre-construction activity while the risk of exceeding the time of by a pre-construction activity from quantification of belief by a respondent is the multiplication of the *Risk Rating* calculated from equation (6.5) and the respondent's belief in the risk of exceeding the time due to an inadequate input of that pre-construction activity.

Figure-16 highlights the estimation of the risk of exceeding cost due to a pre-construction activity as *Risk Rating* (Column D) x Risk of exceeding cost (Column E), the estimation of the risk of exceeding time due to a pre-construction activity as *Risk Rating* (Column D) x Risk of exceeding time (Column F) and minimising the risk of exceeding Cost and Time due to a pre-construction activity by verification of the design (including the inputs from pre-construction activities to the design phase) by introducing a third-party independent designer as *Risk Rating* (Column D) x minimising the Risk of exceeding cost or time (Column H).

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design					(D) Risk Rating	(E) Risk of exceeding Cost caused by the preconstruction activity considered					(D)x(E)	(F) Risk of exceeding Time caused by the preconstruction activity considered					(D)x(F)
		1	2	3	4	5	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
#		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High		Very low	Low	Neutral	High	Very high		Very Low	Low	Neutral	High	Very High	
P1	Preliminary survey					5				4		20		2				40				4		80
P2	Engineering survey					5				4		20				4		80					5	100
P3	Land survey				4					4		16				4		64				4		64
P4	Geotechnical survey					5					5	25		2				50					5	125
P5	Environmental issues				4					4		16		2				32		2				32
P6	Applicable rules and regulations					5		2				10				4		40				4		40
P7	Information about high flood levels					5				4		20		2				40		2				40
P8	Recording of information about low flood levels		2					2				4		2				8		2				8
P9	Rainfall patterns		2					2				4		2				8		2				8
P10	Water table (variations)				4					4		16		2				32				4		64
P11	Wind directions				4			2				8	1					8				4		32
P12	Variation patterns of wind				4			2				8	1					8		2				16
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)				4					4		16		2				32					5	80
P14	Identification of utility agencies				4					4		16		2				32				4		64
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)					5				4		20				4		80					5	100
P16	Type of project : design and build, tendered, prepared				4					4		16		2				32					5	80
P17	Conditions of contracts of tendered projects					5					5	25				4		100				4		100
P18	Special conditions of contracts of tendered projects					5				4		20				4		80				4		80
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)		2					2				4		2				8		2				8
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads		2							4		8		2				16		2				16
P21	Availability of material		2								5	10		2				20				4		40
P22	Proximity of material		2							4		8		2				16				4		32
P23	Requirement of equipment/ machinery/vehicles etc.		2								5	10				4		40				4		40
P24	Availability of equipment/ machinery / vehicles etc.					5				4		20				4		80				4		80
P25	Availability of subcontractors				4					4		16				4		64				4		64

Figure 16 - Risk rating, Risk of exceeding Cost and Time due to an inadequate input of a pre-construction activity

(see Annexure – 3 for a sample of results of an entire response)

6.5.4 Risk of Exceeding Cost/Time and minimising the Risk of exceeding Cost and Time by a third-party independent designer

Third-party verification by an independent designer confirms the adequacy of the input of the preconstruction activity to the design phase against the required input of the same activity.

When the input from a preconstruction activity fails to reach the required input, the inadequacy of the input occurs (and was captured on a 1 to 5 Likert scale). Respondents were able to understand the role of a third party independent designer and implications arise as described above.

By averaging individual risk quantifications of exceeding cost or time due to a pre-construction activity from the beliefs of the respondents in the sample, the Risk of Exceeding Cost or Time of the pre-construction activity can be estimated. Table 16, gives the Risk of Exceeding Cost or

Time of the pre-construction activity given by the Mean of Risk Estimates. The pre-construction activities with higher means of risk estimates would be more critical to the design phase of construction projects by an inadequate input of that pre-construction activity based on the sample of the respondents surveyed.

For example, the calculation of Sum of Individual Risk Estimates and Mean of Risk Estimates for Risk of Exceeding Cost for the project given in Figure-19 is as follows. Consider the Pre-construction Activity 'Preliminary survey' (P1). The *Risk Rating* is the Impact of Risk x Likelihood of Risk, which is 5 x 4 = 20, (Equation 6.5). The Sum of Individual Risk Estimate for P1 = Risk Rating x Response for Risk of Exceeding Cost = 20x2 = 40. The Sum of 'Individual Risk Estimate for P1 for the total number of projects (100) considered= 4,256. Then the Average Mean of Risk Estimate for P1= 4,256 / 100 = 42.56

Similarly, the Sum of Individual Risk Estimates and Mean of Risk Estimates for Risk of Exceeding Cost and Risk of Exceeding Time was calculated for the pre-construction activities considered for the responses received (see Table 16).

Table 16 - Risk Estimates of preconstruction activities; Cost, Time and Designer

Act. No.	(A) Pre-construction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Sum and Mean of Individual Risk Estimate of exceeding Cost		(C) Sum and Mean of Individual Risk Estimate of exceeding Time		(D) Minimising Risk of exceeding Cost and Time by a third-party independent designer	
		Sum	Mean	Sum	Mean	Sum	Mean
P1	Preliminary survey	4256	42	4332	43	3822	38
P2	Engineering survey	4216	52	5320	53	4660	47
P3	Land survey	4516	45	4546	45	3734	37
P4	Geotechnical survey	5515	55	5589	56	5437	54
P5	Environmental issues	3419	34	3711	37	3209	32
P6	Rules and regulations	4458	45	4631	46	4300	43
P7	High flood levels	3613	36	3623	36	3225	32
P8	Low flood levels	2119	21	2022	20	1939	19
P9	Rainfall patterns	2537	25	3015	30	2547	25

P10	Water table (variations)	3166	32	3054	31	2923	29
P11	Wind directions	2167	22	2081	21	2209	22
P12	Variation patterns of wind	1927	19	1862	19	1928	19
P13	Location of existing utilities (water, power, telecom, Wi-Fi)	3954	40	3891	39	3482	35
P14	Identification of utility agencies	3130	31	3198	32	2858	29
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	4331	43	4367	44	3699	37
P16	Type of project: design and build, tendered, proposed	4270	43	3818	38	3911	39
P17	Conditions of contracts of tendered projects	4081	41	3923	39	3723	37
P18	Special conditions of contracts of tendered projects	4555	46	4258	43	4124	41
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	3413	34	3535	35	3153	32
P20	Assessment of capacities of culverts, bridges, etc. on the access roads	3198	32	3174	32	3137	31
P21	Availability of material	4634	46	4718	47	3780	38
P22	Proximity of material	3488	35	3584	36	3085	31
P23	Requirement of equipment/ machinery/vehicles etc.	4294	43	4301	43	3431	34
P24	Equipment/ machinery / vehicles	4476	45	4552	46	3606	36
P25	Subcontractors	4388	44	4412	44	3601	36
P26	Special subcontractors	4648	46	4709	47	3693	37
P27	Skilled manpower	5310	53	5531	55	4009	40
P28	Unskilled manpower	4192	42	4316	43	3336	33
P29	Type of leadership required (e.g. Project Managers) to drive the project	6364	64	6914	69	5325	53

P30	Availability of knowhow to do the project - core and support areas	5252	53	5319	53	4281	43
P31	Adequacy of skills to do the project - core and support areas	4779	48	4839	48	4193	42
P32	Attitudes of individuals / team towards delivering the project	5040	50	5377	54	4224	42
P33	Identification of corrective measures, e.g., providing training to rectify gaps	3756	38	3688	37	3179	32
P34	Social issues	2939	29	2969	30	2674	27
P35	Neighborhood issues	3243	32	3387	34	2881	29
P36	Religious issues	1806	18	1846	18	1972	20
P37	Political issues	3065	31	3106	31	2509	25
P38	Stakeholder issues	4223	42	4364	44	4090	41
P39	Innovative application	3476	35	3677	37	3929	39
P40	New technology	4039	40	4246	42	4631	46
P41	Level of details required and accuracy	5109	51	5408	54	5525	55
P42	Appropriateness of specification	4831	48	4970	50	4967	50
P43	Incomplete design scope	5960	60	5933	59	6012	60
P44	Likelihood of change	4983	50	4977	50	4886	49
P45	Interaction of design with method of construction	4979	50	5102	51	4992	50
P46	Non-standardisation of details	4273	43	4357	44	4009	40
P47	Non-standardisation of suppliers	3384	34	3586	36	2871	29
P48	Quality control - inspection and approvals	5482	55	5551	56	5102	51
P49	Temporary design - quality, responsibility and supervision	3429	34	3566	36	3475	35

6.5.5 Critical Pre-Construction Activities

The critical pre-construction activities which contribute most to the Risk of exceeding cost, Risk of exceeding time and minimise the Risk of exceeding cost and time by a third-party independent designer due to their inadequate input to the design phase of a construction project based on the sample of the respondents surveyed can be identified from the ranks of the mean of risk estimates. Further, the pre-construction activities which have a higher mean of risk estimates are more critical. The pre-construction activities which have a higher mean of risk estimates are more critical. Table-19 and Table-20 identify the ten most critical pre-construction activities for the risk of exceeding Cost and Time respectively. Similarly, Table-21 identifies the ten most critical pre-construction activities to minimise the Risk of exceeding cost and time by a third-party independent designer.

Table 17- Top Ten Critical pre-construction activities to Risk of exceeding Cost.

Rank	**Activity No.**	**(A) Pre-construction Activities contributed Inadequate Input to the Design phase**	**Risk of Exceeding the Cost**	
			Sum of Individual Risk Estimates	**Mean of Risk Estimates**
1	P29	Type of leadership required (e.g., Project Managers) to drive the project	6392	64
2	P43	Incomplete design scope	5972	60
3	P4	Geotechnical survey	5501	55
4	P48	Quality control - inspection and approvals	5490	55
5	P27	Skilled manpower	5310	53
6	P2	Engineering survey	5237	52
7	P30	Availability of knowhow to do the project - core and support areas	5208	52
8	P41	Level of details required and accuracy	5125	51
9	P32	Attitudes of individuals/team towards delivering the project	5124	51
10	P45	Interaction of design with the method of construction	4995	50

Results of the analysis for all 49 pre-construction activities for categories ‘Cost’ and ‘Time’ are in Annexure 5 and Annexure 6 respectively.

Table 18 - Top Ten Critical pre-construction activities to Risk of exceeding Time.

Rank	Activity No.	(A) Pre-construction Activities contributed Inadequate Input to the Design phase	Risk of Exceeding the Time	
			Sum of Individual Risk Estimates	Mean of Risk Estimates
1	P29	Type of leadership required (e.g., Project Managers) to drive the project	6957	70
2	P43	Incomplete design scope	5925	59
3	P4	Geotechnical survey	5650	57
4	P48	Quality control - inspection and approvals	5589	56
5	P27	Skilled manpower	5531	55
6	P32	Attitudes of individuals/team towards delivering the project	5470	55
7	P41	Level of details required and accuracy	5456	55
8	P2	Engineering survey	5340	53
9	P30	Availability of knowhow to do the project - core and support areas	5276	53
10	P45	Interaction of design with the method of construction	5142	51

Table 19 - Minimising Risk of exceeding Cost and Time by an Independent Designer

Rank	Activity No.	Pre-construction Activities contributed Inadequate Input to the Design phase	Minimising Risk of exceeding Cost and Time by verification by an Independent Designer	
			Sum of Individual Risk Estimates	Mean of Risk Estimates
1	P43	Incomplete design scope	6012	60
2	P41	Level of details required and accuracy	5523	55
3	P4	Geotechnical survey	5437	54
4	P29	Type of leadership required (e.g., Project Managers) to drive the project	5321	53
5	P48	Quality control - inspection and approvals	5100	51
6	P45	Interaction of design with the method of construction	4990	50
7	P42	Appropriateness of specification	4967	50
8	P44	Likelihood of change	4886	49
9	P2	Engineering survey	4656	47
10	P40	New technology	4629	46

Table 20 highlights the Top Five Critical pre-construction activities for Risk of exceeding Cost and Risk of exceeding Time.

Table 20 - Top five ‘Identical’ preconstruction activities for ‘Cost’ and ‘Time’

Cost Rank	**Time Rank**	**Activity**	**Top five pre-construction activities for Cost or Time**
1	1	P29	Type of leadership required (e.g., Project Managers) to drive the project
2	2	P43	Incomplete design scope
3	3	P4	Geotechnical survey
4	4	P48	Quality control - inspection and approvals
5	5	P27	Availability of skilled manpower

It is observed, these Top Five Critical pre-construction activities are not only common to Risk of exceeding Cost and Risk of exceeding Time but also are identical in the order of the ranks (see Table 20). Further, the Top Ten pre-construction activities critical to the Risk of exceeding cost and Risk of exceeding time due to their inadequate input to the design phase of construction projects were identified and found to be common.

Also, six out of the top ten critical pre-construction activities hold identical ranks (ranks from 1 to 5 and rank 10). They are, from the top rank in descending order; ‘P29-Type of leadership required (e.g., Project Managers) to drive the project’; ‘P43-Incomplete design scope’; ‘P4-Geotechnical survey’; ‘P48-Quality control - inspection and approvals’; ‘P27-Availability of skilled manpower; and ‘P45-Interaction of design with the method of construction’ (see Table 21).

Table 21- Top Ten pre-construction activities for Risk of exceeding ‘Cost’ and ‘Time’

Cost Rank	Time Rank	Activity	Top Ten common activities
1	1	P29	Type of leadership required (e.g., Project Managers) to drive the project
2	2	P43	Incomplete design scope
3	3	P4	Geotechnical survey
4	4	P48	Quality control - inspection and approvals
5	5	P27	Availability of skilled manpower
6	8	P2	Engineering survey
7	9	P30	Availability of knowhow to do the project - core and support areas
8	7	P41	Level of details required and accuracy
9	6	P32	Attitudes of individuals/team towards delivering the project
10	10	P45	Interaction of design with the method of construction

6.5.6 Risk Interpretations

The normal distribution was assumed for the considered sample from the central limit theorem (Sullivan & Artino, 2013). Then the mean value of the standard normal distribution (mean value of zero and standard deviation of one) was shifted to a normal distribution of 62.5 and a standard deviation of 31.25 to represent the Risk of exceeding cost and Risk of exceeding time. Like the Likert scale, limits to give equal probabilities, i.e. five of 20% each on the shifted normal distribution (see Figure 18) with a range of 1 to 125 was developed to quantify the Risk of exceeding cost and Risk of exceeding time. Then the values of these limits were 36.203, 54.584, 70.415 and 88.796.

Table 22 - Ranges for Risk Interpretation

#	**Equally distributed probability (20%)**		
	Limit (Score, "S")	**Risk Interpretation**	**Abbreviation**
1	S < 36.203	Low	L_o
2	36.203 < S < 54.584	Moderate	M
3	54.584 < S < 70.415	Likely	L_i
4	70.415 < S < 88.796	High	H
5	88.796 < S	Very High	VH

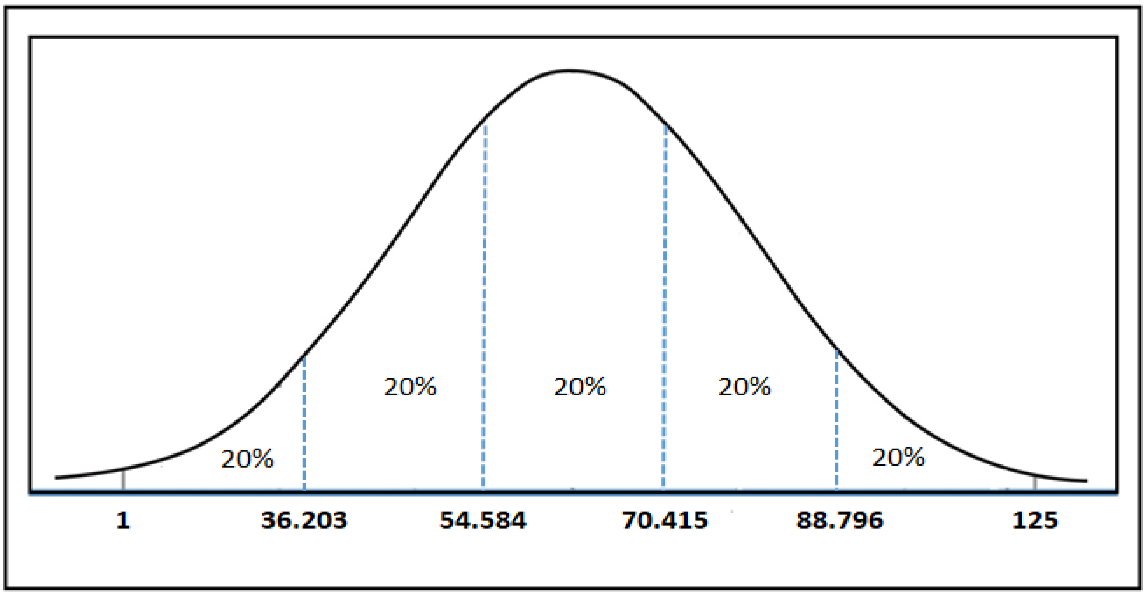

Figure 17 - Limits of the shifted normal distribution for equal probabilities

Risk interpretation for ten critical pre-construction activities that contribute most to the Risk of exceeding Cost and Risk of exceeding Time due to their inadequate input to the design phase of construction projects based on the sample of the respondents surveyed is given below in Table 23 and Table 24 respectively.

Risk interpretation indicates 04 critical pre-construction activities, ‘P29- Type of leadership required (e.g., Project Managers) to drive the project’; ‘P-43 Incomplete design scope’; ‘P-4 Geotechnical survey’; and ‘P-48 Quality control - inspection and approvals’; are *‘Likely’* to induce Risk of exceeding *Cost* due to inadequate input to the design phase of construction projects (see Table 23).

Table 23 – Interpretation of Risk of exceeding the ‘Cost’

	#	**Interpretation for Risk of exceeding the Cost**		
		Pre-construction activity	**Mean of Risk Estimate**	**Risk Interpret**
1	P29	Type of leadership required (e.g. Project Managers) to drive the project	64	Likely
2	P43	Incomplete design scope	60	Likely
3	P4	Geotechnical survey	55	Likely
4	P48	Quality control - inspection and approvals	55	Likely
5	P27	Availability of skilled manpower	53	Moderate
6	P2	Engineering survey	52	Moderate
7	P30	Availability of knowhow to do the project - core and support areas	52	Moderate
8	P41	Level of details required and accuracy	51	Moderate
9	P32	Attitudes of individuals/team towards delivering the project	51	Moderate
10	P45	Interaction of design with the method of construction	50	Moderate

Note: Risk interpretation of 49 pre-construction activities for exceeding Cost is given in Annexure 7.

Also, Risk interpretation indicates 07 pre-construction activities; ‘P29-Type of leadership required (e.g., Project Managers) to drive the project’, ‘P-43 Incomplete design scope’, ‘P-4 Geotechnical survey’, ‘P48-Quality control - inspection and approvals’, ‘P27- Availability of skilled manpower, ‘P32-Attitudes of individuals/team towards delivering the project’, and ‘P41- Level of details required and accuracy’ are *‘Likely’* to induce Risk of exceeding *Time* due to inadequate input to the design phase of construction projects (see Table 24).

Table 24 - Interpretation of Risk of exceeding the ‘Time’

	#	Interpretation for Risk of exceeding the Time		
		Pre-construction activity	**Mean of Risk Estimate**	**Risk Interpret**
1	P29	Type of leadership required (e.g., Project Managers) to drive the project	70	Likely
2	P43	Incomplete design scope	59	Likely
3	P4	Geotechnical survey	57	Likely
4	P48	Quality control - inspection and approvals	56	Likely
5	P27	Availability of skilled manpower	55	Likely
6	P32	Attitudes of individuals/team towards delivering the project	55	Likely
7	P41	Level of details required and accuracy	55	Likely
8	P2	Engineering survey	53	Moderate
9	P30	Availability of knowhow to do the project - core and support areas	53	Moderate
10	P45	Interaction of design with the method of construction	51	Moderate

Note: Risk interpretation of 49 pre-construction activities for exceeding Time is given in Annexure 8.

Further, Risk interpretation of pre-construction activities minimising the Risk of exceeding Cost and Time indicates 02 critical pre-construction activities, ‘P43-Incomplete design scope’ and ‘P41-Level of details required and accuracy’ are *‘Likely’* to minimise the Risk of exceeding Cost and Time due to inadequate input to the design phase of construction projects (see Table 25).

Table 25 – Interpretation of Risk of ‘Minimising the Risk of exceeding Cost and Time’

	#	Interpretation for minimising the Risk of exceeding Cost and Time		
		Pre-construction activity	**Mean of Risk Estimate**	**Risk Interpret**
1	P43	Incomplete design scope	60	Likely
2	P41	Level of details required and accuracy	55	Likely
3	P4	Geotechnical survey	54	Moderate

4	P29	Type of leadership required (e.g. Project Managers) to drive the project	53	Moderate
5	P48	Quality control - inspection and approvals	51	Moderate
6	P45	Interaction of design with the method of construction	50	Moderate
7	P42	Appropriateness of specification	50	Moderate
8	P44	Likelihood of change	49	Moderate
9	P2	Engineering survey	47	Moderate
10	P40	New technology	46	Moderate

Note: Risk interpretation of 49 pre-construction activities for exceeding Cost is given in Annexure – 8.

Moreover, it is observed that all 49 relevant pre-construction activities contributed to the Risk of exceeding Cost and Risk of exceeding Time due to their inadequate input to the design phase of construction projects. Risk interpretation of all 49 pre-construction activities indicates all of them fall to three risk ranges out of possible five risk ranges. i.e. 'Likely', 'Moderate', and 'Low' ranges of inducing Risks. (see Table 26).

Table 26- Number of pre-construction activities in Ranges of Risk interpretation

	Number of pre-construction activities (PCA) in Ranges of Risk interpretation			**Total number of PCAs**
The range for Risk Interpretation	**Likely**	**Moderate**	**Low**	
Risk of Exceeding Cost	04 (from P1 to P4)	27 (from P5 to P31)	18 (from P32 to P49)	49
Risk of Exceeding Time	07 (from P1 to P7)	25 (from P8 to P32)	17 (from P33 to P49)	49

6.5.7 Analysis of the data set using the Relative Importance Index (*RII*)

The literature review highlighted that many types of research (Assaf, AI-Khalil & AI-Hazmp 1995; Faridi & El-Sayaegh, 2006; Iyer & Jha, 2005; Kumaraswamy & Chan, 1998) have used

Relative Importance Index (*RII)* as a better-suited method to rank factors. Also, it was noted that the mean and standard deviation of each factor derived from descriptive statistics was not a suitable measure to assess overall rankings as they do not reflect any relationship between the factors.

Hence, the *RII* method was used to rank the pre-construction activities of this study. The equation (6.3) (Rajgor, Paresh, Dhruv, Chirag, & Dhrmesh, 2016) was used to calculate *RII* of the activities for Risk of exceeding Cost and Risk of exceeding Time.

Based on equation (6.3) and using IBM SPSS 25 statistical package *RII* values of the pre-construction activities which provided inadequate input to the design phase of construction projects were calculated (see Table 27).

It was noted that *RII* values given in Table 27 indicate eight out of ten of the top-ranking pre-construction activities are common for Risk of Exceeding Cost and Risk of Exceeding Time, Namely; 'P43- Incomplete design scope', 'P27-Availability of skilled manpower, 'P29- Type of leadership required (e.g., Project Managers) to drive the project', 'P4- Geotechnical survey', 'P2- Engineering survey', 'P26- Availability of special subcontractors', 'P30-Availability of knowhow to do the project - core and support areas' and 'P21- Availability of material'.

Furthermore, pre-construction activities, 'P27- Availability of skilled manpower (Rank 2)' and 'P21- Availability of material (Rank 8)' placed in identical ranks for both Risk of exceeding cost and Risk of exceeding time due to inadequate input of pre-construction activities to the design phase of construction projects (see Table 27).

Table 27 - RII values of Top Ten preconstruction activities inducing Risks

Rank	**Pre-construction Activity**	**Risk exceeding Cost**	**Rank**	**Pre-construction Activity**	**Risk exceeding Time**
		***RII* Value**			***RII* Value**
1	P43	0.76	1	P29	0.822
2	P27	0.748	2	P27	0.786
3	P29	0.748	3	P4	0.762
4	P4	0.74	4	P43	0.746
5	P2	0.714	5	P30	0.734
6	P26	0.708	6	P2	0.73
7	P30	0.708	7	P26	0.728

8	P21	0.698	8	P21	0.726
9	P31	0.696	9	P32	0.724
10	P24	0.694	10	P28	0.718

In addition, RII values were found for the categories of 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time' for the responses received (see Table 28).

Table 28 - RII values of 'Impact', 'Likelihood', 'Cost' and 'Time' categories

Rank	PCA	RII value for category 'Impact'	PCA	RII value for category 'Likelihood'	PCA	RII value for category 'Cost'	PCA	RII value for category 'Time'
1	P2	0.834	P29	0.766	P43	0.76	P29	0.822
2	P29	0.828	P43	0.73	P27	0.748	P27	0.786
3	P4	0.82	P27	0.714	P29	0.748	P4	0.762
4	P6	0.788	P41	0.706	P4	0.74	P43	0.746
5	P42	0.782	P48	0.7	P2	0.714	P30	0.734
6	P41	0.77	P45	0.694	P26	0.708	P2	0.73
7	P43	0.77	P32	0.692	P30	0.708	P26	0.728
8	P1	0.76	P30	0.688	P21	0.698	P21	0.726
9	P30	0.758	P44	0.686	P31	0.696	P32	0.724
10	P45	0.754	P31	0.684	P24	0.694	P28	0.718

Annexure – 9 contains the values of RII analysis for relevant forty-nine preconstruction activities.

Following observations are made on the outcome of the Relative Importance Index analysis of the data set (see Table 28);

Three pre-construction activities, i.e. 'P29-Type of leadership required (e.g., Project Managers) to drive the project', 'P30-Availability of knowhow to do the project - core and support areas' and 'P43-Incomplete design scope' are common in top ten ranks for all four categories, 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time'.

Moreover, pre-construction activity 'P29-Type of leadership required (e.g., Project Managers) to drive the project' has ranked number one in both categories of Likelihood of Risk' and ''Risk of exceeding Time', ranked number two in the 'Impact of Risk' category and ranked number three in the 'Risk of exceeding Cost' category. Thus, the pre-construction activity 'P29-Type of leadership required (e.g., Project Managers) to drive the project' is placed in the top three ranks for all four categories, 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time'.

Further, pre-construction activity 'P43-Incomplete design scope' has ranked number one in the 'Risk of exceeding Cost' category, ranked number two in the 'Likelihood of Risk' category and ranked number four in the 'Risk of exceeding Time' category in the top four ranks.

In addition to the above, pre-construction activities 'P4-Geotechnical survey' and 'P27-Availability of skilled manpower' are common to three of the top four ranks. i.e. The pre-construction activity 'P27-Availability of skilled manpower', has ranked number two in 'Risk of exceeding Cost' and 'Risk of exceeding Time' categories and ranked number three in the 'Likelihood of Risk' category while pre-construction activity 'P4-Geotechnical survey' has ranked number three in the 'Impact of Risk' and 'Risk of exceeding Time' categories and number four in the 'Risk of exceeding Cost' category.

Table 29 - RII values for 'Minimising the Risk of exceeding Cost and Time'

Rank	Pre-construction activity	*RII* value of the preconstruction activities minimising the Risk of exceeding Cost and Time
1	P43	0.78
2	P4	0.76
3	P42	0.724
4	P44	0.704
5	P41	0.698
6	P45	0.686
7	P40	0.676
8	P2	0.67
9	P6	0.666
10	P18	0.644

Note in Table 29: Results of the Top Ten preconstruction activities

In addition to the above, the following observations are made on *RII* values of the preconstruction activities for minimising the Risk of exceeding Cost and Time (see Table 29).

According to the *RII* values preconstruction activities 'P43- Incomplete design scope', 'P4-Geotechnical survey' and 'P42- Appropriateness of specification' are the top three ranks in minimising the Risk of exceeding Cost and Time. It is also observed the preconstruction activity 'P43- Incomplete design scope' which is ranked number one in minimising the Risk of exceeding Cost and Time has ranked number one in the 'Risk of exceeding Cost' category and ranked number four in the 'Risk of exceeding Time' category (see Table 28). Also, preconstruction activity 'P4-Geotechnical survey' which is ranked number two in minimising the Risk of exceeding Cost and Time has ranked number three in 'Risk of exceeding Time' and number four in 'Risk of exceeding Cost' respectively (see Table 29 and Table 28 respectively).

6.5.8 Analysis of the Data set using Severity Index (*SI*)

Caspi, Turner, Panas & Gastfriend (2001) stated that Severity Index can be used in capturing, calculating, interpreting and applying the patterns of data use. Similarly, the equation (6.4) (Polat, Okay & Eray, 2014) was used to calculate *SI* of the activities for Risk of exceeding Cost and Risk of exceeding Time.

Part of the results of *SI* analysis for the category 'Time' is given as an example in Table-32. Further results of the analysis are given in Annexure 10.

Table 30 – SI values of pre-construction activities for 'Time'

Rank	PCA Number	Pre-construction Activity	Value of *SI*
1	P29	Type of leadership required (e.g., Project Managers) to drive the project	0.822
2	P27	Availability of skilled manpower	0.786
3	P4	Geotechnical survey	0.762
4	P43	Incomplete design scope	0.746
5	P30	Availability of knowhow to do the project - core and support areas	0.734
6	P2	Engineering survey	0.73
7	P26	Availability of special subcontractors	0.728
8	P21	Availability of material	0.726
9	P32	Attitudes of individuals/team towards delivering the project	0.724
10	P28	Availability of unskilled manpower	0.718

Note on Table 30: Results of the Top Ten preconstruction activities

Annexure – 10 gives the results of Severity analysis for the relevant forty-nine preconstruction activities for categories 'Cost' and 'Time'.

Also, *SI* analysis was carried out for the categories of 'Impact of Risk', 'Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time' for the responses received and results are given in Table-33.

Table 31 - SI values of 'Impact', 'Likelihood', 'Cost' and 'Time' categories

Rank	PCA No.	*SI* for Impact	PCA No.	*SI* for Likelihood	PCA No.	*SI* for Cost	PCA No.	*SI* for Time
1	P2	0.834	P29	0.734	P43	0.76	P29	0.822
2	P29	0.828	P43	0.696	P27	0.748	P27	0.786
3	P4	0.82	P41	0.682	P29	0.748	P4	0.762
4	P6	0.788	P27	0.682	P4	0.74	P43	0.746
5	P42	0.782	P48	0.676	P2	0.714	P30	0.734
6	P43	0.77	P45	0.67	P26	0.708	P2	0.73
7	P41	0.77	P32	0.666	P30	0.708	P26	0.728
8	P1	0.76	P44	0.662	P21	0.698	P21	0.726
9	P30	0.758	P30	0.662	P31	0.696	P32	0.724
10	P45	0.754	P31	0.658	P24	0.694	P28	0.718

Table 31 indicates the results of the Top Ten preconstruction activities and also the 'Risk' in the header means values of 'Impact' and 'Likelihood' given in the Table.

Following observations are made on the outcome of the Severity Index analysis of the data set (see Table-33). Three pre-construction activities; 'P29-Type of leadership required (e.g., Project Managers) to drive the project', 'P43- Incomplete design scope' and 'P30- Availability of knowhow to do the project - core and support areas' are in the top ten ranks of all four categories 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time'.

Also, the pre-construction activity 'P29-Type of leadership required (e.g., Project Managers) to drive the project' is within the top three ranks of all four categories; 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time'. It has ranked number one in two of the categories, 'Likelihood of Risk' and 'Risk of exceeding Time', number two in the 'Impact of Risk' category and ranked number three in the 'Risk of exceeding Cost'.

Further, the pre-construction activity 'P43- Incomplete design scope' is within the top six ranks of all four categories, 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time'. It has ranked number one in the 'Risk of exceeding Cost' category and number two in the 'Likelihood of Risk' category.

Also, the pre-construction activity ‘P30- Availability of knowhow to do the project - core and support areas’ is within the top ten ranks of all four categories, ‘Impact of Risk’, Likelihood of Risk’, ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’. The highest and lowest ranks ‘P30’ has reached are number five in the ‘Risk of exceeding Cost’ category and number nine in the categories of ‘Impact of Risk’ and ‘Likelihood of exceeding Time’ respectively.

Furthermore, two of the pre-construction activities, ‘P27-Availability of skilled manpower’ and ‘P4-Geotechnical survey’ are within the top three ranks of all four categories, ‘Impact of Risk’, Likelihood of Risk’, ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’.

Moreover, the pre-construction activity ‘P27-Availability of skilled manpower’ appears in the top ten ranks of three of the four categories; ‘Likelihood of Risk’, ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’, but it has not reached the top ten in the ranks of the ‘Impact of Risk’ category. Further, ‘P27’ has ranked number two in the categories of ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’ and number four in the category of ‘Likelihood of Risk’.

Similarly, the pre-construction activity ‘P4-Geotechnical survey’, appears in the top ten ranks for three of the four categories but it has not reached the top ten in the ranks of the ‘Likelihood of Risk’ category. It ranks number three in the categories of ‘Impact of Risk’ and ‘Risk of exceeding Time’ categories and ranks number four in the ‘Risk of exceeding Cost’ category.

Table 32 – SI values for ‘Minimising the Risk of exceeding Cost and Time’

Rank	Preconstruction activity	*SI* value of the preconstruction activities minimising the Risk of exceeding Cost and Time
1	P43	0.78
2	P4	0.76
3	P42	0.724
4	P44	0.704
5	P41	0.698
6	P45	0.686
7	P40	0.676
8	P2	0.67
9	P6	0.666
10	P18	0.644

Note in Table 32: Results of the Top Ten preconstruction activities

In addition to the above, the following observations are made on SI values of the preconstruction activities for minimising the Risk of exceeding Cost and Time (see Table 32);

According to the results of *SI* values preconstruction activities ‘P43- Incomplete design scope’, ‘P4-Geotechnical survey’ and ‘P42- Appropriateness of specification’ are the top three ranks in minimising the Risk of exceeding Cost and Time. Also, top two ranks of pre-construction activities minimising the Risk of exceeding Cost and Time; i) ‘P-43 Incomplete design scope’ is ranked number one in ‘Risk of exceeding Cost’ and ranked number four in ‘Risk of exceeding Time’ (see Table 31) and ii) ‘P-4 Geotechnical survey’ is ranked number three in ‘Risk of exceeding Time’ and ranked number four in ‘Risk of exceeding Cost’ (see Table 31).

6.5.9 Analysis of the data set using Descriptive Statistics

Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures like mean and standard deviation. Descriptive statistics used in this research is to simply describe what the data indicate in a more general sense and a more manageable form. Mean is used to describe the central tendency of the collected data in this study. As the questionnaire with Likert type scales ranging from 1 (very low) to 5 (very high), a higher mean score reflects responses that indicate higher attributions of the characteristics of pre-construction activities and vice versa.

Also, it is observed that calculating descriptive statistics represents a vital first step when conducting research and should always occur before making inferential statistical comparisons (Kaur, Stolzfus, & Yellapu, 2018).

Descriptive statistics analysis was done using IBM SPSS 25 statistical package for the data set of the study. Sample of the results for ten (out of forty-nine) pre-construction activities and the category ‘Impact of Risk’ for the inadequate input from the pre-construction activities to the design phase of construction projects are given in Table 33. Similarly, Descriptive statistics analysis was done for pre-construction activities for minimising the Risk of exceeding Cost and Time and a sample of the results is given in Table 34.

Table 33 - Mean score and Standard Deviation of ‘Impact of Risk’.

#	Activity No.	Number of responses	Minimum value from the scale	Maximum value from the scale	Mean score	Standard Deviation
1	P2	100	1	5	4.17	1.111
2	P4	99	1	5	4.14	1.134
3	P29	100	1	5	4.14	1.015
4	P6	100	1	5	3.94	1.081
5	P42	100	1	5	3.91	0.975
6	P43	99	1	5	3.89	1.151
7	P41	100	1	5	3.85	0.999
8	P1	100	1	5	3.80	1.318
9	P30	100	1	5	3.79	1.085
10	P45	100	1	5	3.77	1.062

Note in Table 33: Results of the Top Ten preconstruction activities

Further, results of Descriptive Statistics analysis of categories ‘Cost’ and ‘Time’ are given in Annexure 11 and Annexure 12.

Table 34 – Mean score and Standard Deviation of ‘Minimising the Risk of exceeding Cost and Time’.

#	Activity Number	Number of responses	Minimum value from the scale	Maximum value from the scale	Mean score	Standard Deviation
1	P43	99	1	5	3.94	1.038
2	P4	100	1	5	3.80	1.247
3	P42	100	1	5	3.62	1.080
4	P44	100	1	5	3.52	1.283
5	P41	100	1	5	3.49	1.235
6	P45	100	1	5	3.43	1.191
7	P40	100	1	5	3.38	1.369
8	P2	100	1	5	3.35	1.306

9	P6	100	1	5	3.33	1.173
10	P18	100	1	5	3.22	1.425

Note in Table 34: Results of the Top Ten preconstruction activities

6.5.10 Analysis of the data set for Reliability

One of the main requirements of any research process is the reliability of data. Cronbach's alpha as given in equation (6.2), is the most commonly used to assess the reliability (internal consistency) of a survey/questionnaire that is made up of multiple Likert type scales. According to the thumb rules given by George & Mallery (2003) in interpreting the values of Cronbach's alpha, when the value of alpha is ≥ 0.9 reliability is interpreted as excellent (see 6.4.2.1).

George & Mallery (2003) provided the following thumb rules for Cronbach's alpha value and rating for the reliability of data:

i) ≥ 0.9 – Excellent,

ii) ≥ 0.8; Good,

iii) ≥ 0.7; Acceptable,

iv) ≥ 0.6; Questionable and

v) ≥ 0.5; Poor and

vi) < 0.5 – Unacceptable

Cronbach's alpha values of the data set of the study were analyzed using the IBM SPSS 25 statistical package. A summaryry of the reliability analysis of the data set for this study is given in Table-37. Cronbach's alpha value for each of the four categories 'Impact of Risk', 'Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time' is greater than 0.9. as per categorisation the Reliability or the Internal Consistency of the data as Excellent when the Cronbach's alpha value is ≥ 0.9 (George & Mallery, 2003).

Therefore, the Reliability or the Internal Consistency of the data is interpreted as Excellent.

Table 35 – Results of Reliability (Cronbach's alpha) analysis

#	Category	Value of Cronbach's Alpha from the Analysis	Status	Value of Cronbach's Alpha from the 'Rule'	Interpretation of Reliability (Internal Consistency)
1	Impact	0.929	>	0.9	Excellent
2	Likelihood	0.980	>	0.9	Excellent
3	Exceeding cost	0.947	>	0.9	Excellent
4	Exceeding time	0.949	>	0.9	Excellent
5	Minimising the Risk of exceeding Cost and Time	0.939	>	0.9	Excellent

6.5.11 Analysis of Validity of data

Salkind (2007) claimed that the Validity Coefficient is a statistical index used to report evidence of validity for intended interpretations of test scores and defined as the magnitude of the correlation between test scores and a criterion variable (i.e., a measure representing a theoretical component of the intended meaning of the test). Validity is an essential criterion for evaluating the quality and acceptability of research. Fraenkel & Wallen (2003) stated the quality of the research instruments used is critical as the researchers use the information obtained through these research instruments for analysis.

Moreover, the data and instruments must be validated. Validity is calculated using the Pearson coefficient (Kirch, 2008). When the calculated value for the Pearson coefficient from the collected data is greater than the standard Pearson coefficient value from the table (see 6.4), Critical values for Pearson's Correlation Coefficient) data is considered valid. Degree of Freedom (DF) is taken as n-2, where n = number of responses of the sample.

In this study, n = number of responses of the sample =100 and the Degree of Freedom = n -2 = 100 – 2 = 98. Hence corresponding standard Pearson coefficient value for the data set of this research for DF = 98 is 0.1966 (Re: Standard Table of Critical Values for Pearson's Correlation Coefficient.)

The Pearson coefficient (also known as 'r') value for the data set for this study was calculated using IBM SPSS 25 statistical package. The results indicated 'r' values for the data set of the study were greater than the standard Pearson coefficient value from the standard table of 0.1966. Part of the results of the validity analysis is given in Table-38 and Table-39.

Therefore, it is observed the data set for this research is Valid.

Comparison of data sample of the ourcome of the analysis of Pearson coefficient (from the data set of the research) and Pearson coefficient value from the standard table of 0.1966 for the top ten pre-construction activities for the category of the 'Cost' and the lowest ten pre-construction activities for category 'Impact' is given below in Table-38 and Table-39 respectively.

Table 36 - Validity analysis for 'Risk of exceeding Cost'

#	Pre-construction Activity	Pearson coefficient (From the analysis of the data set)	Status	Pearson coefficient (From the standard table)	Result
1	P49	0.707	>	0.1966	Valid
2	P42	0.693	>	0.1966	Valid
3	P41	0.692	>	0.1966	Valid
4	P46	0.690	>	0.1966	Valid
5	P47	0.673	>	0.1966	Valid
6	P30	0.672	>	0.1966	Valid
7	P48	0.668	>	0.1966	Valid
8	P33	0.667	>	0.1966	Valid
9	P37	0.649	>	0.1966	Valid
10	P45	0.636	>	0.1966	Valid

Note in Table 36: Results of the Top Ten preconstruction activities

Also, results of Validity analysis of categories 'Cost' and 'Time' are given in Annexure 13 and Annexure 14.

Table 37 – Validity analysis: ‘Lowest’ values of category ‘Impact’

#	Pre-construction Activity	Pearson coefficient (From the analysis of the data set)	Status	Pearson coefficient (From the standard table)	Result
	P12	0.197	>	0.1966	Valid
2	P11	0.244	>	0.1966	Valid
3	P5	0.250	>	0.1966	Valid
4	P6	0.336	>	0.1966	Valid
5	P2	0.337	>	0.1966	Valid
6	P4	0.350	>	0.1966	Valid
7	P36	0.360	>	0.1966	Valid
8	P1	0.363	>	0.1966	Valid
9	P16	0.363	>	0.1966	Valid
10	P25	0.372	>	0.1966	Valid

Note in Table 37: Results of the Top Ten preconstruction activities

Also, Validity analysis for the data set for minimising the Risk of exceeding Cost and Time was done and the ‘Lowest value’ of the results of the Validity analysis was found as 0.321 for the preconstruction activity ‘P2- Engineering survey’ (see Table 38) which in turn found to be greater than the Pearson coefficient value from the standard table of 0.1966. Since the remaining values for the data set considered are greater than the ‘Lowest value’ of the results, 0.321, it is observed the data set for minimising the Risk of exceeding Cost and Time is valid.

Table 38 – Validity analysis: 10 'Lowest' values of the category 'Minimising the Risk of exceeding Cost and Time'

Preconstruction Activity	Lowest Pearson coefficient values (From data set)	Pearson coefficient values (From table)	Validity
P2	.321**	0.1966	Valid
P1	.323**	0.1966	Valid
P11	.337**	0.1966	Valid
P4	.339**	0.1966	Valid
P22	.341**	0.1966	Valid
P3	.356**	0.1966	Valid
P12	.362**	0.1966	Valid
P44	.391**	0.1966	Valid
P6	.402**	0.1966	Valid
P5	.407**	0.1966	Valid

6.5.12 Correlation analysis

Correlation analysis is a method of statistical evaluation used to study the strength of a relationship between two, numerically measured, continuous variables. This analysis is used to establish if there are possible connections between variables (see 2.6).

The degree of correlation between any two variables on a continuous scale is mathematically expressed as the correlation coefficient (also known as Pearson's correlation coefficient or "r"), a number whose values can vary between −1.0 and +1.0.

Relationship between two variables X and Y are found using the following formula:

$$r = \frac{\Sigma(X-\overline{X})(Y-\overline{Y})}{\sqrt{\Sigma(X-\overline{X})^2}\sqrt{(Y-\overline{Y})^2}} \qquad (6.6)$$

Where, $\overline{X}$ = mean of X variable
$\overline{Y}$ = mean of Y variable

where $\mathbf{r_{xy}}$ is the correlation coefficient of the linear relationship between the variables x and y, $\mathbf{x_i}$ – the values of the x-variable in a sample, $\mathbf{\bar{x}}$ – the mean of the values of the x-variable, $\mathbf{y_i}$ – the values of the y-variable in a sample and $\mathbf{\bar{y}}$ – the mean of the values of the y-variable.

Correlation analysis was carried out for the responses received from the substantive experts for the categories of 'Impact of Risk', 'Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time' using the IBM SPSS 25 statistical package. Pearson correlation values varied according to the data combinations. For example, the Pearson correlation value for the pair of pre-construction activities, 'P1- Preliminary survey' and 'P3-Land survey' for the category of 'Impact of Risk' is 0.739 (see Table-39).

Part of the results, Pearson correlation values, derived from the Correlation analysis of the data set of the study is given in Table-39. Further results for the categories 'Risk of exceeding Cost' and ''Risk of exceeding Time' are in Annexure 15 and Annexure 16 respectively.

Table 39 - Pearson correlation values for the category of 'Impact of Risk'

Pearson Correlation	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	1	.631	.739	.341	.387	.275	.265	.160	.206	.217
P2	.631	1	.652	.650	.345	.345	.347	.130	.177	.176
P3	.739	.652	1	.482	.381	.285	.516	.354	.270	.300
P4	.341	.650	.482	1	.269	.355	.30	.099	.200	.267
P5	.387	.345	.381	.269	1	.280	.394	.310	.148	.196
P6	.275	.345	.285	.355	.280	1	0.184	.097	.072	.139
P7	.265	.347	.516	.350	.394	0.184	1	.520	.277	.497
P8	.160	.130	.354	0.099	.310	0.097	.520	1	.378	.200
P9	.206	.177	.270	.200	.148	0.072	.277	.378	1	.334
P10	.217	.176	.300	.267	.196	0.139	.497	.200	.334	1

Note in Table 39: Results of correlation of Ten preconstruction activities

Example (see Table 39); Pearson correlation value for the pair of pre-construction activities, 'P1- Preliminary survey' and 'P3-Land survey' for the category of 'Impact of Risk' = 0.739

Table 40 - Pearson correlation values for 'Minimising the Risk of exceeding Cost and Time'.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	1	.603	.529	.238	.317	.247	.217	.259	.244	.275
P2	.603	1	.562	.397	.422	.122	.22	.244	.25	.236
P3	.529	.562	1	.332	.35	.047	.331	.315	.235	.4
P4	.238	.397	.332	1	.154	.128	.233	.273	.145	.140
P5	.317	.422	.35	.154	1	.453	.363	.38	.197	.319
P6	.247	.122	.047	.128	.453	1	.068	.116	.251	.106
P7	.217	.22	.331	.233	.363	.068	1	.652	.35	.539
P8	.259	.244	.315	.273	.38	.116	.652	1	.45	.492
P9	.244	.25	.235	.145	.197	.251	.35	.45	1	.515
P10	.275	.236	0.4	.140	.319	.106	.539	.492	.515	1

Note in Table 40: Results of correlation of Ten preconstruction activities

Pearson correlation values for preconstruction activities have strong and not so strong values in the part of the results shown in Table 40. For example, a strong correlation value of 0.603 between activities P1 and P2 and a correlation value of 0.068 between activities P6 and P7 (see Table 40).

6.5.13 Sampling Adequacy

Factor Analysis is a statistical tool that measures the impact of a few unobserved variables called factors on a large number of observed variables. It is used as a data reduction method. It may be used to uncover and establish the cause and effect relationship between variables (see 6.4.2.4).

Further, Factor analysis is different from many of the other techniques performed above. It is not designed to test the hypothesis or tell one group is significantly different from another. It is named as 'Data reduction' technique in the IBM SPSS. It takes a larger set of variables and looks for a way the data may be reduced or summarized using a smaller set of factors or components.

The Kaiser-Meyer-Olkin (KMO) represents the ratio of the squared correlation between variables to squared partial correlation between variables. The KMO value varies between '0' and '1'. When the values are closer to '1' it indicates that factor analysis should return definite and certain factors (Doloi, 2013). Field, (2005) recommended a minimum value of KMO for a satisfactory factor analysis as 0.5. The IBM SPSS algorithms document lists the formula for KMO as follows;

The Kaiser-Mayer-Olkin measure of sample adequacy is

$$KMO_j = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} a_{ij}^{2*}} \quad KMO = \frac{\sum_{i \neq j} \Sigma r_{ij}^2}{\sum_{i \neq j} \Sigma r_{ij}^2 + \sum_{i \neq j} \Sigma a_{ij}^{2*}} \tag{6.7}$$

where a_{ij}^* is the anti-image correlation coefficient.

r_{ij} is the original correlations between *i* and *j*. (https://stats.stackexchange. com/questions/333149/what-is-the-intuition-behind-the-kmo-formula).

Factor analysis for the data set of this study was carried out using the IBM SPSS 25 statistical package and the results are listed in Table-43. Also, KMO results indicate the maximum and minimum KMO values as 0.751 and 0.694 respectively (see Table-43).

Further, Field (2005) found the minimum recommended KMO value as 0.5 for satisfactory factor analysis. Accordingly, the data set of the study is considered satisfactory and the results of the analysis justify the use of the entire data set for the analysis.

Table 41 - Kaiser-Meyer-Olkin (KMO) sampling Adequacy of the data set.

Factors in category	Impact	Likelihood	Cost	Time
KMO Measure of Sampling Adequacy.	.694	.694	.721	.751

6.6 Observations made from the results of the analysis

49 relevant pre-construction activities were established which provide input to the design phase of construction projects. In addition, a questionnaire was finalized to obtain responses for the inadequate inputs from the 49 relevant pre-construction activities to the design phase of the construction projects for the categories of ‘Impact of Risk’, ‘Likelihood of Risk’, ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’. Further, the above questionnaire was used to obtain responses from the substantive experts (see 2.14 and 4.10) working in the field of civil engineering. Finally, 100 responses were collected which constitutes the data set for the analysis of this study and the analysis of the data set was done as explained in section 6.5.1.

Following observations were made from the results of the analysis for “Risk of exceeding Cost and Risk of exceeding Time”.

1. Inadequate input from the 49 relevant pre-construction activities to the design phase of construction projects contribute to the Risk of exceeding Cost and Risk of exceeding Time of construction projects.

2. The pre-construction activity ‘Type of leadership required (e.g., Project Managers) to drive the project’, is the most critical activity contributing to the Risk of exceeding Cost or Risk of exceeding Time of construction projects.
3. Pre-construction activities ranked in the top ten of the categories of ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’ of construction projects are common. These pre-construction activities are; ‘Type of leadership required (e.g., Project Managers) to drive the project’, ‘Incomplete design scope’, ‘Geotechnical survey’, ‘Quality control - inspection and approvals’, ‘Availability of skilled manpower’, ‘Engineering survey’, ‘Availability of knowhow to do the project - core and support areas’, ‘Level of details required and accuracy’, ‘Attitudes of individuals/team towards delivering the project’ and ‘Interaction of design with the method of construction.
4. In addition to the above 3), pre-construction activities ranked in the top five of the categories of ‘Risk of exceeding Cost’ and ‘Risk of exceeding Time’ of construction projects are common and hold similar ranks. i.e., These five pre-construction activities according to the ranks are; i) ‘Type of leadership required (e.g., Project Managers) to drive the project’, ii) ‘Incomplete design scope’, iii) ‘Geotechnical survey’, iv) ‘Quality control - inspection and approvals’ and v) ‘Availability of skilled manpower’.
5. According to the Risk Interpretation of the study, the following four pre-construction activities are ‘Likely’ to induce ‘Risk of exceeding Cost’ due to inadequate input by them to the design phase in construction projects. These four pre-construction activities are; ‘Type of leadership required (e.g., Project Managers) to drive the project’, ‘Incomplete design scope’, ‘Geotechnical survey’ and ‘Quality control - inspection and approvals’ for ‘Cost’ category.
6. Similarly, there are seven pre-construction activities ‘Likely’ to induce ‘Risk of exceeding Time’ due to inadequate input by them to the design phase of construction projects and they are; ‘Type of leadership required (e.g., Project Managers) to drive the project’, ‘Incomplete design scope’, ‘Geotechnical survey’, ‘Quality control - inspection and approvals’, ‘Availability of skilled manpower’, ‘Attitudes of individuals/team towards delivering the project’ and ‘Level of details required and accuracy’ for Time category.
7. Further, Risk Interpretation for the category of ‘Risk of exceeding Cost’ indicates 45 out of 49 pre-construction activities (other than the four pre-construction activities listed in above 5) induce a ‘Moderate’ risk due to inadequate input by them to the design phase of construction projects.

8. Also, Risk Interpretation for the category of 'Risk of exceeding Time' indicates 43 out of 49 pre-construction activities (other than the seven pre-construction activities listed in above 6) induce a 'Moderate' risk due to inadequate input by them to the design phase of construction projects.

RII Analysis – *(Risk of exceeding Cost and Risk of exceeding Time)*

9. The results of the Relative Importance Index, RII, analysis indicate that three pre-construction activities are within the Top Ten ranks for all four categories; 'Impact of Risk', Likelihood of Risk', 'Risk of exceeding Cost' and 'Risk of exceeding Time'. These three activities are; 'P29-Type of leadership required (e.g., Project Managers) to drive the project', 'P30-Availability of knowhow to do the project-core and support areas' and 'P43-Incomplete design scope'.
10. Also, the *highest* and *lowest* values of the RII analysis for the four categories are observed as:
    i) Category 'Impact of Risk', 0.822 and 0.384 for the activities 'P29-Type of leadership required (e.g., Project Managers) to drive the project' and 'P12- Variation patterns of wind respectively;
    ii) Category 'Likelihood of Risk', 0.834 and 0.44 for the activities 'P2- Engineering survey' and 'P12-Variation patterns of wind' respectively;
    iii) Category 'Risk of exceeding Cost', 0.766 and 0.408 for the activities 'P- 29-Type of leadership required (e.g., Project Managers) to drive the project' and 'P12-Variation patterns of wind' respectively; and
    iv) Category 'Risk of exceeding Time are 0.76 and 0.384 for the activities 'P43- Incomplete design scope' and 'P36 - Possible religious issues' respectively.
11. Further RII analysis reveals that pre-construction activities;
    i) 'P29-Type of leadership required (e.g., Project Managers) to drive the project' is at the top of the ranks for *two* categories 'Impact of Risk' and 'Risk of exceeding Cost'; *and*
    ii) 'P12- Variation patterns of wind' is at the bottom of the ranks three categories, 'Impact of Risk', 'Likelihood of Risk' and 'Risk of exceeding Time'.

Severity Index – *(Risk of exceeding Cost and Risk of exceeding Time)*

12. The results of Top Ten ranks of Severity Index analysis indicate there are three common pre-construction activities, 'P29-Type of leadership required (e.g., Project Managers) to drive the project', 'P43-Incomplete design scope' and 'P30-Availability of knowhow to

do the project - core and support areas' for all four categories concerned, 'Impact', 'Likelihood', 'Cost' and 'Time'.

13. Also, the results of Severity Index analysis indicate pre-construction activity 'P29-Type of leadership required (e.g., Project Managers) to drive the project' was the number one rank in the categories 'Likelihood' and 'Time' *and* the top three ranks in all four categories concerned, 'Impact', 'Likelihood', 'Cost' and 'Time' and it.
14. Further, Severity Index analysis indicates pre-construction activity 'P43- Incomplete design scope' has ranked number one in the 'Cost' category and number two in the 'Likelihood' category. It ranks within the top six for all four categories concerned, 'Impact', 'Likelihood', 'Cost' and 'Time'.
15. The pre-construction activity 'P12-Variation patterns of wind' was ranked the lowest in the Severity Index analysis for three out of four categories concerned, 'Impact', 'Likelihood' and 'Time' *and* pre-construction activity 'P36- Possible religious issues' was ranked the lowest in the category of 'Cost'.

Cronbach's Alpha – *(Risk of exceeding Cost and Risk of exceeding Time)*

16. It is interpreted when Cronbach's alpha value is greater or equal to 0.9 reliability (internal consistency) of the questionnaire as excellent (George and Mallery, 2003). Reliability analysis of the data set indicates Cronbach's alpha values for all four categories concerned 'Impact', 'Likelihood', 'Cost' and 'Time' are greater than 0.9 (lowest Cronbach's alpha value was 0.929 for the category 'Impact'). Hence the internal consistency is interpreted as excellent for all four categories concerned, 'Impact', 'Likelihood', 'Cost' and 'Time' for the inadequate inputs from the pre-construction activities concerned to the design phase.

Validity – *(Risk of exceeding Cost and Risk of exceeding Time)*

17. The results of Validity analysis indicate that responses received for the pre-construction activities for the categories concerned, 'Impact', 'Likelihood', 'Cost' and 'Time' are Valid as the Pearson coefficient for the responses received is greater than the Pearson coefficient value from the standard table value of 0.1966.

Correlation Analysis – *(Risk of exceeding Cost and Risk of exceeding Time)*

18. The results of Correlation analysis indicate that there are strongly correlated pre-construction activities like 'P1-Preliminary survey' and 'P3- Land survey' with 'r' value 0.739 and also there are not so strongly correlated pre-construction activities like 'P6-Applicable rules and regulations and 'P8- Recording of information about low flood levels' with 'r' value 0.072.

19. The Kaiser-Meyer-Olkin (KMO) value of 0.5 is recommended as the minimum value for satisfactory factor analysis (Field, 2005) for a set of data. The results of the KMO value analysis for the concerned data set indicated a minimum KMO value as 0.694 which is greater than 0.5 as stated above. Therefore, the factor analysis of the data set of this research can be considered satisfactory.

Further to the above, based on the analysis, the following observations were made on "Minimising Risk of exceeding Cost and Time" due to inadequate input from 49 relevant preconstruction activities to the design phase of construction projects.

20. Minimising the Risk of exceeding Cost and Time of construction projects by a third-party independent designer applied to relevant 49 preconstruction activities which provided inadequate input to the design phase of construction projects (see Table 19).
21. In addition, Risk interpretation of pre-construction activities minimising the Risk of exceeding Cost and Time indicates two critical pre-construction activities, 'Incomplete design scope' and 'Level of details required and accuracy' are 'Likely' to minimise the Risk of exceeding Cost and Time due to inadequate input to the design phase of construction projects.
22. Further, the preconstruction activity 'Incomplete design scope' which has the second-highest Risk of exceeding Cost and Risk of exceeding Time due to inadequate input to the design phase of construction projects would 'Likely' minimise the Risk of exceeding Cost and Time by a third-party independent designer.
23. It is also observed that the preconstruction activity 'Type of leadership required (e.g., Project Managers) to drive the project' which is the worst contributing activity for both Risks of exceeding Cost and Risk of exceeding Time would 'Moderately' minimise the Risk of exceeding Cost and Time due to inadequate input to the design phase of construction projects.

RII Analysis – *(Minimising Risk of exceeding Cost and Time)*

24. The results of the Relative Importance Index, *RII*, analysis indicates preconstruction activity 'Incomplete design scope' is the highest in inducing Risk of exceeding Cost and fourth highest in inducing Risk of exceeding Time and the activity has the highest minimising effect on Risk of exceeding Cost and Time.
25. Similarly, preconstruction activity 'Geotechnical survey' is the third highest in inducing Risk of exceeding Time and fourth highest in inducing Risk of exceeding Cost and the

activity has the second-highest minimising the effect on Risk of exceeding Cost and Time induced.

26. Further, the remaining two of the top three preconstruction activities ('Skilled manpower' and 'Type of leadership required (e.g., Project Managers) to drive the project') for Risk of exceeding Cost and Risk of exceeding Time are considered, they have ranked 16^{th} and 27^{th} in the results of *RII* analysis for minimising Risk of exceeding Cost and Time respectively.
27. Also, the *highest* and *lowest* values of the *RII* analysis for minimising Risk of exceeding Cost and Time are observed as 'Incomplete design scope-0.780' and 'Possible religious issues-0.394'respectively.

Severity Index – *(Minimising Risk of exceeding Cost and Time)*

28. The results of the top ten ranks of Severity Index analysis indicate preconstruction activities 'P43- Incomplete design scope', 'P4-Geotechnical survey' and 'P42- Appropriateness of specification' are the top three ranks in minimising the Risk of exceeding Cost and Time.
29. Further, the results of Severity Index analysis indicate top-ranked pre-construction activity for minimising the Risk of exceeding Cost and Time, 'P-43 Incomplete design scope', is also ranked number one in 'Risk of exceeding Cost' and ranked number four in 'Risk of exceeding Time'.
30. Similarly, the second-highest ranked pre-construction activity for minimising the Risk of exceeding Cost and Time, 'P-4 Geotechnical survey', is also ranked number three in 'Risk of exceeding Time' and ranked number four in 'Risk of exceeding Cost'
31. In addition, the pre-construction activity 'P12-Variation patterns of wind' is ranked the lowest in the Severity Index analysis for three out of four categories concerned, 'Impact', 'Likelihood' and 'Time' is also ranked 48^{th} (out of 49 activities) for minimising the Risk of exceeding Cost and Time.
32. Similarly, the pre-construction activity 'P36- Possible religious issues' which is ranked the lowest in the category of 'Cost' is also ranked the lowest for minimising the Risk of exceeding Cost and Time.

Cronbach's Alpha – *(Minimising Risk of exceeding Cost and Time)*

33. The value of Cronbach's alpha for minimising the Risk of exceeding Cost and Time of construction projects is 0.939 which is greater than 0.9. As George and Mallery (2003)

claimed when Cronbach's alpha value is greater or equal to 0.9 reliability (internal consistency) of the questionnaire is excellent.

Validity – *(Minimising Risk of exceeding Cost and Time)*

34. The lowest value of the Pearson coefficient for the responses received from the Validity analysis is 0.321 is greater than the Pearson coefficient value from the standard table value of 0.1966. Hence all the results are valid.

Correlation Analysis – *(Minimising Risk of exceeding Cost and Time)*

35. The results of Correlation analysis for minimising the Risk of exceeding Cost and Time of construction projects due to inadequate input of 49 preconstruction activities to design phase indicate there is a strongly correlated activity with 'r' value = 0.603 (e.g. 'P1- Preliminary survey' and 'P2- Engineering survey') and not so strong activity with 'r' value = 0.068 (e.g. 'P6- Applicable rules and regulations 'and 'P7- Information about high flood levels) exist.

6.7 Best practice Guideline developed based on the outcome of the analysis

The results of the analysis highlight that minimising Risk of exceeding Cost and Risk of exceeding Time by employing a third-party independent designer applied to all 49 preconstruction activities which could provide inadequate input to the design phase of construction projects. Accordingly, the best practice Guideline defines that by retaining the services of a third-party independent designer to verify the input from preconstruction activities to the design phase, Risk of exceeding **Cost** and/or **Time** due to inadequate input from preconstruction activities to the design phase of construction projects is minimised.

6.8 Summary

Analysis of data gathered from responses from 100 construction projects was in sections 6.2 to 6.4, namely, i) Analysis of contributory factors for cost and time overruns ii) Effects of the inputs to pre-construction activities in the design phase of construction projects iii) Methods used for data analysis and iv) Risks created by Inadequacies, Correlations, Coherence, Accuracy, etc. using techniques appropriate for the study. Further, Exhaustive analysis was done for the data set on Risk related categories (6.5). Results of the analysis indicated that all the parameters considered satisfied the specified requirements for each category analysed. Observations made from the results of the analysis were in section 6.6. Based on the outcome of the analysis, a best practice Guideline was developed to minimise the Risk of exceeding Cost and Risk of exceeding

Time overruns of construction projects (6.7). The Guideline was validated using accepted Statistical methods and Case studies from the industry as given in Chapter 7.

CHAPTER 7 - VALIDATION OF THE DEVELOPED GUIDELINE

7.1 General

This chapter describes the validation of the Guideline developed from the study to minimise the Risk of exceeding Cost and Risk of exceeding Time due to inadequate input to the design phase from preconstruction activities of construction projects. Section 7.2 summarizes the developed Guideline, section 7.3 describes the statistical validation of the developed Guideline from testing Hypotheses, and section 7.4 describes the validation of the developed Guideline by applying it to Case Studies from the construction industry.

7.2 The Guideline

The second objective of this study was to develop an industry best practice framework/model/guideline to minimize/eliminate cost and time overruns of construction projects due to risks of inadequacies, correlations, coherence and accuracy of the inputs of pre-construction activities to the design phase of the projects. A Guideline to minimize/eliminate cost and time overruns of construction projects due to risks of inadequacies, correlations, coherence and accuracy of the inputs of pre-construction activities to the design phase of the projects was developed (6.7).

Further, it was highlighted that inadequate input to the design phase by all forty-nine preconstruction activities which provide input to the design phase of construction projects induced Risk of exceeding Cost and Risk of exceeding Time in construction projects. Hence, the 49 preconstruction activities are used in the validation process.

It was also highlighted that verification by a third party independent designer would minimise Risk of exceeding Cost and Time of all 49 preconstruction activities of construction projects. For statistical validation, 20% of the forty-nine preconstruction activities; i. e. 49*20/100 = 10 preconstruction activities were used. Selected activities were the 10 most critical preconstruction activities for Risk of exceeding Cost and Risk of exceeding Time of construction projects from the outcome of the study.

The selection of data for validation of the Guideline using Case Studies from the construction industry is described in section 7.4.

7.3 Validation using testing Hypothesis

Hypothesis testing is defined as, “The theory, methods, and practice of testing a hypothesis by comparing it with the null hypothesis. The null hypothesis is only rejected if its probability falls below a predetermined significance level, in which case the hypothesis being tested is said to have that level of significance" (https://www.lexico.com/definition/hypothesis_testing, Powered by OXFORD).

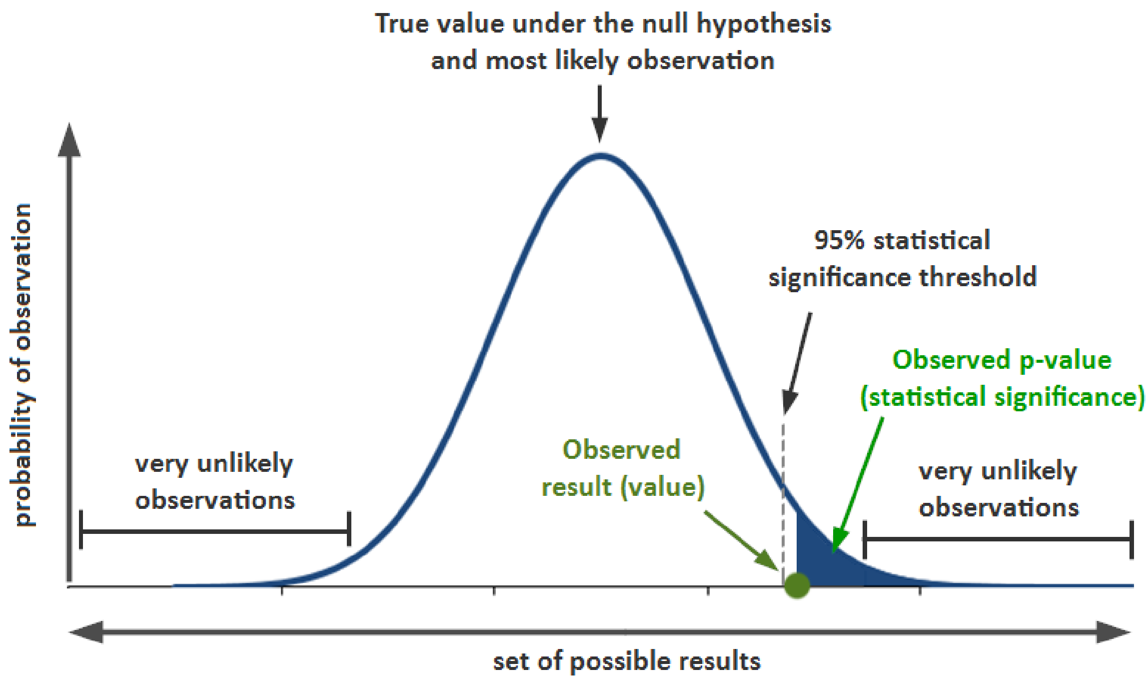

Figure 18 - 'p' value and statistical significance (simplypsychology.org)

The published statistical theory states, when the observed result value is less than the statistical significance value (say, 0.05 for a significant level of 95%) the Null hypothesis is rejected. Also, in standard notations in statistics, Null hypothesis is identified as 'H_0' and the alternative hypothesis is identified as 'H_1'. Following are the Null Hypothesis (7.3.1) and Alternative Hypothesis (7.3.2) for testing the results of the study.

7.3.1 Null Hypothesis, H_0:

Null Hypothesis 1: Risk of exceeding Cost due to inadequate input from preconstruction activity to the design phase and Risk of exceeding Cost and Time of the construction project is not minimised by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

Null Hypothesis 2: Risk of exceeding Time due to inadequate input from preconstruction activity to the design phase and Risk of exceeding Cost and Time of the construction project is not minimised by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

7.3.2 Alternative Hypothesis, H_1:

Alternative Hypothesis 1: Risk of exceeding Cost due to inadequate input from preconstruction activity to the design phase and Risk of exceeding Cost and Time of the construction project is minimised by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

Alternative Hypothesis 2: Risk of exceeding Time due to inadequate input from preconstruction activity to the design phase and Risk of exceeding Cost and Time of the construction project is minimised by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

7.3.3 Testing of hypothesis

Two Null hypotheses described in section 7.3.1 were tested for the ten top most critical pre-construction activities identified as inducing Risk of exceeding Cost and Risk of exceeding Time of construction projects given in Table 21 from section 6.5.5. The study revealed the ten top most critical pre-construction activities inducing Risk of exceeding Cost and inducing Risk of exceeding Time of construction projects were similar and hence the Null hypotheses stated above are appropriate.

Even though the ten top most critical pre-construction activities inducing Risk of exceeding Cost and Time of construction projects are similar to those activities inducing Risk of exceeding Cost and inducing Risk of exceeding Time, as the sum of individual Risk estimates (and Mean of Risk estimates) differ from each pre-construction activity to other, hypothesis tests were performed for each of the pre-construction activity separately for Cost and Time.

As described above, IBM SPSS 25 (and verified by Microsoft Excel 2019) was used to find the relevant 'p' values for each of the top ten activities and 95% significance level ('α' value of 0.05) and Standard normal distribution was considered for the tests of hypothesis. Accordingly, the results of 'p' test values from tests of IBM SPSS 25 and Microsoft Excel 2019 for each preconstruction activity for Cost (Table 42) and Time (Table 43) were found.

7.3.3.1 Results of the hypothesis testing of 'Risk of exceeding Cost' and 'Minimising Risk of exceeding Cost and Time' by verification by a third party independent Designer.

Table 42 - 'p' test values of 'Minimising Risk of exceeding Cost'

Activity No.	Ten top most critical pre-construction activities induce Risk of exceeding Cost (worst contributor at the top)	'p' test value		'α' value for 95% significance level
		IBM SPSS 25	Microsoft Excel 2019	
P29	Type of leadership required (e.g., Project Managers) to drive the project	0.000	$5.47x10^{-27}$	0.05
P43	Incomplete design scope	0.000	$1.87x10^{-36}$	0.05
P4	Geotechnical survey	0.000	$4.44x10^{-47}$	0.05
P48	Quality control - inspection and approvals	0.000	$3.1x10^{-36}$	0.05
P27	Skilled manpower	0.000	$5.38x10^{-29}$	0.05
P2	Engineering survey	0.000	$3.14x10^{-39}$	0.05
P30	Availability of knowhow to do the project - core and support areas	0.000	$8.79x10^{-25}$	0.05
P41	Level of details required and accuracy	0.000	$1.8x10^{-33}$	0.05
P32	Attitudes of individuals/team towards delivering the project	0.000	$8.96x10^{-32}$	0.05
P45	Interaction of design with the method of construction	0.000	$1.24x10^{-23}$	0.05

Note: Result sheets of 'p' value for both IBM SPSS 25 and Microsoft Excel 2019 tests for all 10 preconstruction activities given in Table 42 are available in Annexure 17.

Above results in Table 42 highlight the following.

a) Verification of 'p' test values derived for the critical preconstruction activities on the results using the IBM SPSS 25 by Microsoft Excel 2019 on minimising the Risk of exceeding Cost indicated similar values. Thus the 'p' values given in Table 42 are confirmed.

b) 'p' test value for each of ten top most critical pre-construction activities inducing Risk of exceeding Cost is less than the α value of 0.05 (for 95% of significance level). Hence the Null hypothesis is rejected and the Alternative hypothesis is accepted.

In other words, the risk of exceeding Cost due to inadequate input from preconstruction activity to the design phase of construction projects is minimised by retaining the services of a third-party independent designer to verify the input information.

The statistical validation of the Guideline by Hypothesis testing confirm that minimising the Risk of exceeding Cost due to inadequate input from preconstruction activity to the design phase and minimising the Risk of exceeding Cost and Time of the construction project can be achieved by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

7.3.3.2 Results of the hypothesis testing of 'Risk of exceeding Time' and 'Minimising Risk of exceeding Cost and Time' verification by a third party independent Designer.

Table 43 - 'p' test values of 'Minimising Risk of exceeding Time'.

Activity No.	**Ten top most critical pre-construction activities induce Risk of exceeding Time (worst contributor at the top)**	**'p' test value**		**'α' value for 95% significance level**
		IBM SPSS 25	**Microsoft Excel 2019**	
P29	Type of leadership required (e.g., Project Managers) to drive the project	0.000	1.99×10^{-29}	0.05
P43	Incomplete design scope	0.000	3.29×10^{-41}	0.05
P4	Geotechnical survey	0.000	3.37×10^{-56}	0.05
P48	Quality control - inspection and approvals	0.000	1.32×10^{-38}	0.05
P27	Skilled manpower	0.000	1.65×10^{-30}	0.05
P2	Engineering survey	0.000	2.67×10^{-34}	0.05
P30	Availability of knowhow to do the project - core and support areas	0.000	3.58×10^{-30}	0.05
P41	Level of details required and accuracy	0.000	5.6×10^{-44}	0.05
P32	Attitudes of individuals/team towards delivering the project	0.000	2.79×10^{-38}	0.05
P45	Interaction of design with the method of construction	0.000	1.24×10^{-24}	0.05

Note: Result sheets of 'p' value for both IBM SPSS 25 and Microsoft Excel 2019 tests for all 10 preconstruction activities given in Table 43 are available in Annexure 18.

Above results in Table 43 highlight the following.

a) Similar to the results of minimising Risk of exceeding Cost (see Table 42), verification of 'p' test values derived for the critical preconstruction activities on the results using the IBM SPSS 25 by Microsoft Excel 2019 on minimising the Risk of exceeding Time indicated similar values. Thus the 'p' values given in Table 43 are confirmed.

b) 'p' test value for each of ten top most critical pre-construction activities inducing Risk of exceeding Time is less than the α value of 0.05 (for 95% of significance level). Hence the Null hypothesis is rejected and the Alternative hypothesis is accepted.

In other words, the risk of exceeding Time due to inadequate input from preconstruction activity to the design phase of construction projects is minimised by retaining the services of a third-party independent designer to verify the input information.

The statistical validation of the Guideline by Hypothesis testing confirm that minimising the Risk of exceeding Time due to inadequate input from preconstruction activity to the design phase and minimising the Risk of exceeding the Cost and Time of the construction project can be achieved by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

7.4 Validation using Case Studies from the construction industry

7.4.1 General

Cases of completed construction projects were studied to examine the possible causes of Cost overruns and Time overruns of the projects to validate the Guideline developed through the study. Initially, 'Issues' that contributed towards exceeding Cost and exceeding Time were identified after construction projects. Factors identified as contributing towards Cost and Time overruns were named as 'Issues'. Then, the 'Issues' that contributed towards exceeding Cost and exceeding Time, after construction projects were categorised as follows for the case studies.

a) 'Issues' Uncontrollable by the project. For example, when the government decides to limit the transportation of sand during the construction phase of the project. Such activities are considered uncontrollable by the project.

b) 'Issues' Controllable by the project. For example, when the productivity of machinery used at the project is low. Control of such activity is within the project.

'Issues' controllable by the project, as defined in b), were further divided into two segments,

c) 'Issues' which arose during the construction phase of the project. For example, issues due to; layout of the project, movement of machinery, maintenance of machinery, equipment, vehicles etc. Control of such activities is possible during the construction phase.

d) ‘Issues’ which arose during the design phase of the project. For example, details of the foundation issued for construction. As the details of the foundation are done during the design phase using the required input, control of such activity is within the design phase of the project.

Also, the ‘Issues’ given in d) were compared with the 49 preconstruction activities which were established during the study as those providing input to the design phase too;

i) Examine possible relationships between them;

ii) if a relationship is found, to determine the root cause for Cost overrun and Time overrun to the ‘Issues’; and

iii) Examine if the outcome is an acceptable reason for Cost overrun and Time overrun due to those ‘Issues’.

7.4.2 Projects considered as Case Studies

The following projects were considered Case Studies.

a) Project A: Multi-storeyed Luxury Apartment Towers - Cost overrun 7% and Time overrun 14% (Initial Project value LKR 5.8 billion). Project A incurred a Cost overrun of LKR 400 million and a Time overrun of 5 months (over the 36-month contractual period).

b) Project B: 21 Km of expansion of ‘A’ class road - Cost overrun 30% and Time overrun 50% (Initial Project value LKR 2.1 billion). Project B incurred a Cost overrun of LKR 630 million and a Time overrun of 12 months (over the 24-month contractual period).

c) Project C: Multi-storeyed Multi-purpose building - Cost overrun 62% and Time overrun 50% (Initial Project value LKR 800 million). Project C incurred a Cost overrun of LKR 500 million and a Time overrun of 12 months (over the 24-month contractual period).

7.4.3 Categorization of ‘Issues’ identified as contributing towards exceeding Cost and exceeding Time after projects.

‘Issues’ that contributed towards exceeding Cost and exceeding Time after the above three projects were identified. Details of the ‘Issues’ of each project are given in Table 45, Table 46 and Table 47. It is noted these issues are project-specific. The contribution of ‘Issues’ towards exceeding Cost and exceeding Time was categorised as follows.

a) High (H); when the ‘Issue’ exceeded its estimated value by 10% to 35%; and

b) Very High (VH); when the ‘Issue’ exceeded its estimated value by 35%.

Values exceeding up to 10% were not considered as overruns as the construction industry normally assumes a 10% contingency value in practice. This inference was formed on information from substantive experts from the construction industry.

'Issues' contributed towards exceeding Cost by 7% and exceeding Time by 14% after project A: Multistoried Luxury Apartment (Initial Project value LKR 5.8 billion and project duration 36 months) is given in Table 44.

Table 44 - 'Issues' contributed to exceeding 'Cost' and 'Time' - Project A.

	'Issues' that contributed towards exceeding Cost and exceeding Time after Project A.	**Cost**	**Time**
1	*Changes in laws on transportation of sand/debris*	VH	VH
2	*Substantial changes made by the client on internal layouts of the apartments during the construction phase.*	VH	VH
3	*Inaccuracies of the layout of piling*	VH	VH
4	Environmental issues – work stoppages – Noise, Dust, Night and Sunday work	VH	VH
5	Erroneous garbage disposal methods against regulations	H	H
6	Restrictions to access by neighbours	H	H
7	Inappropriate material (Aluminum) was specified to use for the handrails – later changed to steel.	H	H
8	Shortage of Masons, Carpenters, Bar benders	H	H
9	Shortage of casual labour	H	H
10	Flaws in the Project manager's leadership	VH	VH
11	Inadequacy of skills of painters, tilers (lots of rectification work)	VH	VH
12	The weakness of attitude of the project team toward delivering the project	H	H
13	Identification of a lack of knowledge and skill/training	H	H
14	Restrictions of access to the project devotees to nearby Kovil and Mosque.	VH	VH
15	Unhappy neighbours, heavy vehicles, road damages, dust,	H	H
16	Morning Kovil Poojas, Friday Mosque prayers blocking roads/ stopping of transport of concrete	VH	VH
17	Disputes with a client overpayment of approved additional work	H	H
18	Insufficient and inaccurate details given for construction.	H	H

19	Inaccurate/inadequate specifications – restrictions in buildability requirements	VH	VH
20	Exclusion of sprinklers	VH	VH
21	Inclusion of garbage shoots against regulations	VH	VH
22	Many changes due to customizing apartments from the prototype	VH	VH
23	Construction and design clashes – congested reinforcement in structural elements, eg: when a column meets a junction crossing beam, floating columns, element changes from carpark floor to residential floors	VH	VH
24	Use of non-standard items, geezer (space), ducts	H	H
25	Delays in the quality control process	H	H

Accordingly, Project A had 3 Uncontrollable 'Issues' identified as exceeding Cost and exceeding Time after the project (see 7.4.1 a, Table 44 Items 1, 2 and 3 in italics). Other 22 'Issues' are identified as Controllable and within the scope of the project. The last two columns indicate the severity of exceeding Cost and exceeding Time.

'Issues' contributed towards exceeding Cost by 30% and exceeding Time by 50% after project B: 21 Km of expansion of A-class road are given in Table 45 (Initial Project value LKR 2.1 billion and project duration 24 months).

Table 45 - 'Issues' contributed towards exceeding 'Cost' and 'Time'- Project B.

	'Issues' that contributed towards exceeding Cost and exceeding Time at the completion of Project B.	**Cost**	**Time**
1	*Acquisition of land for the project.*	VH	VH
2	*Laying of water line along the road trace by the Water Board disrupting the progress of the project.*	VH	VH
3	*Change of centerline of the road once construction started.*	VH	VH
4	The centerline of the road was shifted to the hillside during the project period increasing the cut and reducing the fill, forced to change the methodology of the construction phase.	VH	VH
5	Many changes from the preliminary survey	VH	VH
6	Volumes of excavations/fill on roadsides changed considerably, locations of retaining walls changed/added.	H	H
7	The land survey was continued during the construction phase as it was incomplete.	VH	VH

8	Many landslides caused the stoppage of vehicular movements on the road.	VH	VH
9	Work was pushed to the rainy season due to delays in the early stages of the project.	VH	VH
10	Progress of work was interrupted due to pipe laying by the Water Board.	VH	VH
11	An additional number of retaining walls had been constructed.	H	H
12	The production capacity of the contractors' quarry was insufficient and hence material had to be purchased from other sources.	H	H
13	As the filing material was in excess (due to change in centerline) capacity of dumping yards exceeded.	H	H
14	Lack of a systematic approach to implementing the project by the Project Manager.	VH	VH
15	Ineffective use of machinery and equipment.	VH	VH
16	Relevant training (workshops etc.) was provided to improve effectiveness during the construction phase.	H	H
17	Public protests during the construction phase due to road blockages/road closure.	H	VH
18	Resistance from neighbours in three specific areas (road junctions).	H	H
19	Lack of details in structures to build, inaccurate slopes on cuts and additional locations for structures.	H	H
20	Design errors in slope stabilization, steep cuts inducing many landslides.	VH	VH
21	Considerable design changes were done during the construction phase.	VH	VH

Similar to Project A (see Table 44), Project B had 3 Uncontrollable ‘Issues’ identified as exceeding Cost and exceeding Time at the completion of the project (see 7.4.1 a, Table 45 Items 1, 2 and 3 in italics). Other 18 ‘Issues’ are identified as Controllable and within the scope of the project. Last two columns indicate the severity of exceeding Cost and exceeding Time.

‘Issues’ contributed towards exceeding Cost by 62% and exceeding Time by 100% at the completion of project C: Multi storeyed Multipurpose building (Initial Project value LKR 800 million and project duration 24 months) are given in Table 46.

Table 46 - ‘Issues’ contributed towards exceeding ‘Cost’ and ‘Time’- Project C.

	'Issues' that contributed towards exceeding Cost and exceeding Time after Project C.	**Cost**	**Time**
1	*Transportation of sand was prohibited causing an additional burden on the project to use ABC.*	VH	VH
2	*Extensive delays in approval of claims from the client.*	VH	VH
3	*The type of contract of the project was changed to design and build from the status of the tendered project during the construction phase.*	VH	VH
4	Error in the boundaries given, hence delay in implementing the project	H	H
5	A geotechnical survey had to be done during the construction phase as the design team had used an erroneous geotechnical report to design	VH	VH
6	Flooding of project area due to rainwater causing a work stoppage	VH	VH
7	The project team did not possess the knowledge/data regarding the rainfall	H	H
8	The screed of pile caps was underwater for a longer period	H	H
9	Identification of shifting of Power cables/overhead Telephone lines was done during the construction phase	H	H
10	Power supply to the project was to be provided by the client through an existing supply. However, the capacity was insufficient and the project had to depend on generators for power for an extensive period of time	VH	VH
11	The type of contract of the project was converted to Design and Build from Tendered status.	VH	VH
12	Transportation of sand was prohibited causing an additional burden on the project to use ABC.	VH	VH
13	Delay in getting the Tower crane to the project	H	H
14	Unavailability of skilled manpower; Masons, Carpenters, Bar benders etc. to the project causing delays of more than three months	VH	VH
15	Unproductive work methods and disorderly approach in project implementation by the Project Manager.	VH	VH
16	Lack of knowledge of the project team - on the job training was provided during the construction phase.	VH	VH
17	The skill of the project team p to the requirement of the project - on the job training was provided during the construction phase.	VH	VH
18	Undue delay in payments by the client causing cash flow issues to the project	VH	VH

19	Inadequate accuracies and errors in drawings issued for construction by the design office.	H	H
20	There were significant errors in the original design and the errors had to be rectified during the construction phase of the project.	VH	VH
21	Many changes during the construction phase; errors in original boundary, layout, type of foundation, utility supply, unexpected training needs for the staff, lack of manpower etc.	VH	VH

Similar to Project A (see Table 44) and Project B (see Table 45), Project C has 3 Uncontrollable 'Issues' identified as exceeding Cost and exceeding Time after the project (see 7.4.1 (a), Table 46 Items 1, 2 and 3 in italics). Other 18 'Issues' are identified as Controllable and within the scope of the project. The last two columns indicate the severity of exceeding Cost and exceeding Time.

7.4.4 Project-specific Uncontrollable 'Issues' for Project A, Project B and Project C.

Uncontrollable 'Issues' by projects affect the progress and incur Cost overruns and Time overruns of the projects, yet the projects have no control over them (see 7.4.1 a). That being the case, uncontrollable 'Issues' concerning Projects A, B and C are given in Table 47.

Table 47 - Uncontrollable 'Issues' created 'Cost' and 'Time' overruns in Projects

Uncontrollable 'Issues'		**Cost**	**Time**
Project A: Multi-storied Luxury Apartment			
1	Changes in laws on transportation of sand	VH	VH
2	Substantial changes made by the client on internal layouts of the apartments during the construction phase.	VH	VH
3	Inaccuracies of the layout of piling	VH	VH
Project B: 21 Km of expansion of A-class road			
1	Acquisition of land for the project.	VH	VH
2	Laying of water line along the road trace by the Water Board disrupting the progress of the project.	VH	VH
3	Change of centerline of the road once construction started.	VH	VH
Project C: Multi-storeyed Multipurpose building			
1	Transportation of sand was prohibited causing an additional burden on the project to use ABC as filler material.	VH	VH
2	Extensive delays in approval of claims from the client.	VH	VH

3	The type of contract of the project was changed to design and build from the status of the tendered project during the construction phase.	VH	VH

It was noted that all of the ‘Issues’ listed in Table 47 were beyond the control of the projects concerned. Though these items had caused ‘Very High’ contributions towards exceeding Cost and exceeding Time at the completion of projects A, B and C, further study regarding their contributions were excluded as it was beyond the scope of this study.

7.4.5 Project-specific Controllable ‘Issues’ for Project A, Project B and Project C.

Controllable ‘Issues’ by the projects are within the control of the projects but had contributed towards exceeding Cost and exceeding Time at the completion of Projects A, B & C due to ineffective and inefficient implementation of the projects from their inception (see 7.4.1 d). Such ‘Issues’ for each Projects A, B and C are given in Tables 46, 47 and 48. There were fifty-eight (58) controllable ‘Issues’ (22, 18 and 18 ‘Issues’ from Projects A, B and C respectively) were recorded as contributing towards exceeding Cost and exceeding Time at the completion of Projects A, B and C. Out of the 58 controllable ‘Issues’, 32 issues had caused Very High Cost and 33 ‘Issues’ had caused Very High Time overruns at the completion of Projects A, B and C. Further, 26 ‘Issues’ had caused High Cost and 25 ‘Issues’ had caused High Time overruns at the completion of Projects A, B and C. Table 48 gives the number and the category of overrun caused by Controllable ‘Issues’ at the completion of Projects A, B and C.

Table 48 – Summary of Overruns due to Controllable Issues in Projects.

Project	Controllable Issues	Number and Type of Overruns caused by Controllable Issues			
	Total	'Very High' Cost	'Very High' Time	'High' Cost	'High' Time
A	22	10	10	12	12
B	18	10	11	8	7
C	18	12	12	6	6

Note on Table 48: Summarised from Tables 47, 48 and 49.

7.4.6 Categorization of Controllable issues of projects.

The 'Issues' that were controllable by projects which yet contributed towards Cost overruns and Time overruns at the completion of the projects were examined to identify if the 'Issues' were generated at the;

a) Design phase of the projects; or

b) Construction Phase of the projects.

The possible outcome of this examination would be as follows.

i) 'Issues' were generated at the Design phase

ii) 'Issues' were generated at the Construction Phase of the projects.

iii) 'Issues' were generated at the Design phase and Construction Phase of the projects.

iv) 'Issues' were generated by other means.

Also, the possible answers to the above i) to iv) categories could be 'Yes', 'No' or 'May be'.

7.4.6.1 Examination if the Controllable Issues were generated at the Design phase of projects.

The initial examination of the Controllable issues of projects was done to check if they were generated from the design phase of the project. Hence, possible relationships between Controllable 'Issues' that caused Cost overruns and Time overruns in the case study projects (see Table 45, Table 46 and Table 47) *and* the preconstruction activities that provide input to the design phase of projects identified previously (Daluwatte and Ranasinghe, 2020) (see Table 11) were examined and results of those examinations for case study projects A, B and C are listed in Tables 51, 52 and 53 respectively.

Table 49 - Links of Controllable 'Issues' *and* Pre-construction activities-Project A

Controllable 'Issues' that caused Cost overruns and Time overruns in Project A		#	Preconstruction activities that provide inputs to the design phase
4	Environmental issues – work stoppages – Noise, Dust, Night and Sunday work	P5	Environmental issues
5	Erroneous garbage disposal methods against regulations	P6	Rules and regulations
6	Restrictions to access by neighbours	P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)
7	Inappropriate material (Aluminum) was specified to use for the handrails – later changed to steel.	P21	Availability of material
8	Shortage of Masons, Carpenters, Bar benders	P27	Availability of skilled manpower
9	Shortage of casual labour	P28	Availability of unskilled manpower
10	Flaws in Project manager's leadership	P29	Type of leadership required (e.g., Project Managers)to drive the project
11	Inadequacy of skills of Painters, Tilers (lots of rectification work)	P31	Adequacy of skills to do the project - core and support areas
12	Weakness of attitude of the project team toward delivering the project	P32	Attitudes of individuals/team towards delivering the project
13	Identification of a lack of knowledge and skill/training	P33	Identification of corrective measures, e.g., providing training to rectify gaps
14	Restrictions of access to the project devotees to nearby Kovil and Mosque.	P34	Social issues
15	Unhappy neighbours, heavy vehicles, road damages, dust,	P35	Neighbourhood issues
16	Morning Kovil Poojas, Friday Mosque prayers blocking roads/ stopping of transport of concrete	P36	Religious issues

17	Disputes with client overpayment of approved additional work	P38	Stakeholder issues
18	Insufficient and inaccurate details given for construction.	P41	Level of details required and accuracy
19	Inaccurate/inadequate specifications – restrictions in buildability requirements	P42	Appropriateness of specification
20	Exclusion of sprinklers	P43	Incomplete design scope
21	Inclusion of garbage shoots against regulations	P43	Incomplete design scope
22	Many changes due to customizing apartments from the prototype	P44	Likelihood of change
23	Construction and design clashes – congested reinforcement in structural elements, eg: when a column meets a junction crossing beam, floating columns, element changes from carpark floor to residential floors	P45	Interaction of design with the method of construction
24	Use of non-standard items, geezer (space), ducts	P46	Non-standardisation of details
25	Delays in the quality control process	P48	Quality control - inspection and approvals

Note: Items 1, 2 and 3 of Project A were not considered as they are Uncontrollable (see Table 44)

Table 50 - Links of Controllable 'Issues' *and* Pre-construction activities-Project B.

Controllable 'Issues' that caused Cost overruns and Time overruns in Project B		#	Preconstruction activities that provide inputs to the design phase
4	The centerline of the road was shifted to hillside during the project period increasing the cut and reducing the fill, forced to change the methodology of the construction phase.	P1	Preliminary survey
5	Many changes from the preliminary survey.	P1	Preliminary survey
6	Volumes of excavations / fill on roadsides changed considerably, locations of retaining walls changed/added.	P2	Engineering survey

7	The land survey was continued during the construction phase as it was incomplete.	P3	Land survey
8	Many landslides caused the stoppage of vehicular movements on the road.	P5	Environmental issues
9	Work was pushed to the rainy season due to delays in the early stages of the project.	P9	Rainfall patterns
10	Progress of work was interrupted due to pipe laying by the Water Board.	P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)
11	Additional number of retaining walls had to be constructed.	P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)
12	The production capacity of the contractor's quarry was insufficient and hence material had to be purchased from other sources.	P21	Availability of material
13	As the filing material was in excess (due to change in centerline) capacity of dumping yards exceeded.	P21	Availability of material
14	Lack of a systematic approach to implementing the project by the Project Manager.	P29	Type of leadership required (e.g., Project Managers)to drive the project
15	Ineffective use of machinery and equipment.	P32	Attitudes of individuals/team towards delivering the project
16	Relevant training (workshops etc.) was provided to improve effectiveness during the construction phase.	P33	Identification of corrective measures, e.g., providing training to rectify gaps
17	Public protests during the construction phase due to road blockages/road closure.	P34	Social issues
18	Resistance from neighbours in three specific areas (road junctions).	P35	Neighbourhood issues
19	Lack of details in structures to build, inaccurate slopes on cuts and additional locations for structures.	P41	Level of details required and accuracy
20	Design errors in slope stabilization, steep cuts inducing many landslides.	P43	Incomplete design scope

21	Considerable design changes were done during the construction phase.	P43	Incomplete design scope

Note: Items 1, 2 and 3 of Project B were not considered as they are Uncontrollable (see Table 45)

Table 51 - Links of Controllable 'Issues' *and* Pre-construction activities-Project C

	Controllable 'Issues' that caused Cost overruns and Time overruns in Project C	#	Preconstruction activities that provide inputs to the design phase
4	Error in the boundaries given, hence delay in implementing the project	P3	Land survey
5	Geotechnical survey had to be done during the construction phase as the design team had used an erroneous geotechnical report to design	P4	Geotechnical survey
6	Flooding of project area due to rainwater causing work stoppage	P7	High flood levels
7	The project team did not possess the knowledge/data regarding the rainfall	P9	Rainfall patterns
8	Screed of pile caps was underwater for a longer period	P10	Water table (variations)
9	Identification of shifting of Power cables/overhead Telephone lines was done during the construction phase	P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)
10	Power supply to the project was to be provided by the client through an existing supply. However, the capacity was insufficient and the project had to depend on generators for power for an extensive period of time	P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)
11	The type of contract of the project was converted to Design and Build from Tendered status.	P16	Type of project: design and build, tendered, proposed
12	Transportation of sand was prohibited causing an additional burden on the project to use ABC.	P21	Availability of material

13	Delay in getting the Tower crane to the project	P24	Equipment/ machinery / vehicles etc.
14	Unavailability of skilled manpower; Masons, Carpenters, Bar benders etc. to the project causing delays of more than three months	P27	Availability of skilled manpower
15	Unproductive work methods and disorderly approach in project implementation by the Project Manager.	P29	Type of leadership required (e.g., Project Managers)to drive the project
16	Lack of knowledge of the project team - on the job training was provided during the construction phase.	P30	Availability of knowhow to do the project - core and support areas
17	Skill of the project team p to the requirement of the project - on the job training was provided during the construction phase.	P31	Adequacy of skills to do the project - core and support areas
18	Undue delay in payments by the client causing cash flow issues to the project	P38	Stakeholder issues
19	Inadequate accuracies and errors in drawings issued for construction by the design office.	P41	Level of details required and accuracy
20	There were significant errors in the original design and the errors had to be rectified during the construction phase of the project.	P43	Incomplete design scope
21	Many changes during the construction phase; errors in original boundary, layout, type of foundation, utility supply, unexpected training needs for the staff, lack of manpower etc.	P44	Likelihood of change

Note: Items 1, 2 and 3 of Project C were not considered as they are Uncontrollable (see Table 46)

7.4.6.2 Comparison of Controllable 'Issues' that cause Cost and Time overruns *and* Preconstruction activities that provide inputs to the design phase of projects.

Relationships between the Controllable 'Issues' that cause Cost overruns and Time overruns and Preconstruction activities that provide inputs to the design phase were established in Table 49, Table 50 and Table 51 for the respective case study Projects A, B and C. Following is a description of how they were compared.

Out of the total of 58 Controllable issues for the three case study projects considered, three preconstruction activities that provide inputs to the design phase of projects were identified as common to all three projects. The three preconstruction activities were i) Type of leadership required (e.g., Project Managers) to drive the project (P29) ii) Incomplete design scope (P43) and iii) Level of details required and accuracy (P41). Also, these three preconstruction activities highlighted are within the Top Ten ranks (P29 – Rank 1), (P43 – Rank 2) and (P41 - 7) for causing Cost overruns and Time overruns (see Tables 19 and 20) in construction projects.

The three Controllable Issues that fall into i) Incomplete design scope (P43) ii) Type of leadership required (e.g., Project Managers) to drive the project (P29) and iii) Level of details required and accuracy (P41) (see Table 42) are discussed in detail as follows.

Table 52 – Comparison of Controllable 'Issues' of Projects and 'Preconstruction activities'.

Refer: Table 49 - Project A – Item 21		
21	Exclusion of an effective garbage disposal method for the apartments.	P43 - Incomplete design scope
	Explanation: It was stated that the inclusion of an effective garbage disposal method should have been done during the design phase of the project. Hence, the 'Issue' falls within the scope of the preconstruction activity, "Incomplete design scope". Further, a correction to the 'Issue' had been done during the construction phase incurring additional Cost and Time.	
Refer: Table 50 - Project B – Item 20		
20	Design errors in slope stabilization, steep cuts inducing many landslides.	P43 - Incomplete design scope
	Explanation: It was reported the angles used to stabilize slopes in steep cuts on road banks were incorrect and as a result, many landslides were resulting in road blockages in this busy 'A' grade road. Inclusion of the correct angles should have done during the design phase of the project. Above inadequacy of the input to the design phase falls within the scope of the preconstruction activity, "Incomplete design scope". Eventually, the corrections incurred Cost and Time Overruns to the project.	
Refer: Table 51 - Project C – Item 20		

20	There were significant errors in the original design and the errors had to be rectified during the construction phase of the project.	P43 - Incomplete design scope
	Explanation: Feedback indicated that the original design was based on the geotechnical report of the adjoining building in the foundation design. Failing to use the correct design report had caused inadequacy of the input to the design phase which falls within the scope of the preconstruction activity, "Incomplete design scope". In the end, it caused Cost and Time overruns to the project.	
Refer: Table 49 - Project A – Item 10		
10	Flaws in the Project manager's leadership	P29 - Type of leadership required (e.g., Project Managers) to drive the project
	Explanation: It was reported, though the Project Manager had certain strengths, lack of effective communication and enthusiasm induced complexities among the project team. If a Project Manager with the required skills was selected at the initial stages, i. e. the design phase, such ineffectiveness would have been avoided. Failing to do so had caused an inadequacy of the input to the design phase of the 'Issue' and it falls within the scope of preconstruction activity Type of leadership required (e.g., Project Managers) to drive the project. Eventually, it had caused Cost and Time overruns to the project.	
Refer: Table 50 - Project B – Item 14		
14	Lack of a systematic approach to implementing the project by the Project Manager.	P29 - Type of leadership required (e.g., Project Managers) to drive the project
	Explanation: Feedback received indicated that work implementation by the Project manager was chaotic at times. For example, the haphazard movement of machinery along with the 21 Km road project. The explanation for the issue is similar to Table 49 - Project A – Item 10.	
Refer: Table 51 - Project C – Item 15		
15	Unproductive work methods and disorderly approach in project implementation by the Project Manager.	P29 - Type of leadership required (e.g., Project Managers) to drive the project

	Explanation: It was stated, the project was the first job of the project manager in that capacity. The methods adopted by the project manager for the implementation of the project was unproductive. For example, opting for manual work while the machinery was idling, site layout was inefficient with stockpiles, office, stores and machinery positions. The explanation for the issue is similar to Table 49 - Project A – Item 10	
Refer: Table 49 - Project A – Item 18		
18	Insufficient and inaccurate details given for construction.	P 41 - Level of details required and accuracy.
	Explanation: The project being a luxury apartment complex, many inaccurate and insufficient details were reported during the construction phase. For eg: – the level of washroom floors (changed three times), unsuitable marbles on window sills (had to replace twice), insufficient working spaces in ducting etc. The project had failed to address the required input to the design phase about this 'Issue' and it falls within the scope of preconstruction activity, "Level of details required and accuracy". Further, the correction to the 'Issue' had been done during the construction phase incurring additional Cost and Time to the project.	
Refer: Table 50 - Project B – Item 19		
19	Lack of details in structures to build, inaccurate slopes on cuts and additional locations for structures.	P 41 - Level of details required and accuracy.
	Explanation: In the road project considered, it was reported details of some of the retaining walls, culverts, slops on the cuts, locations of new retaining walls were inaccurate / not given. The explanation for the issue is similar to Table 49 - Project A – Item 18.	
Refer: Table 51 - Project C – Item 19		
19	Inadequate accuracies and errors in drawings issued for construction by the design office.	P 41 - Level of details required and accuracy.
	Explanation : Feedback indicated there were many inaccuracies in the drawings issued for corrections. These were included, 1.5m floor level difference between the new and	

	existing building, erroneous foundation drawings based on an incorrect geotechnical report, incorrect setting out details etc. The explanation for the issue is similar to Table 49 - Project A – Item 18.

As explained above, three different ‘Issues’ in each of the (three) projects equate to nine different scenarios and had gaps in the input of the preconstruction activities from the inception of those projects. Further, ‘Required Input’ for an “Issue” was identified at the design phase of the project and if the ‘Actual Input’ for the ‘Issue’ did not meet the ‘Required Input’, an inadequacy of input to the design phase occurs.

When input with inadequacy was used in the design phase, it would result in erroneous output from the design phase, which would be the input to the construction phase of the construction project. As explained above, corrections of these errors were done during the construction phase of the projects and resulted in overruns in Cost and Time of the projects. To overcome such situations, arresting of inadequacies should happen at the design phase of a construction project.

It is seen that if the inadequacy of the input of the ‘Issue’ to the design phase was done effectively, the Risk of exceeding Cost and Risk of exceeding Time of the ‘Issue’ would be minimised/eliminated. If the above process was applied to all inputs at the design phase of the project the Risk of exceeding Cost and Risk of exceeding Time of the ‘Issue’ due to such inputs (Issues) would be minimised/eliminated.

Comparison of how all Controllable ‘Issues’ (see Table 49, Table 50 and Table 51) that caused Cost overruns and Time overruns in all three projects *and* Preconstruction activities that provide inputs to the design phase of the projects were closely examined and results found to be similar to Table 52.

As seen from Table 52, if a credible checker can verify that the ‘Actual Input’ of the ‘Issue’ meets the ‘Required Input’ of the ‘Issue’ before the input is used at the design phase, Risk of exceeding Cost and Risk of exceeding Time of the project could be minimised/eliminated.

This study identified the ‘credible checker’ as the ‘third party independent designer’ in section 6.5.4 and the ‘Issue’ in the study were related to ‘Preconstruction activity’. Hence, the results of this chapter show that verification by a third party independent designer would minimise the Risk of exceeding Cost and Risk of exceeding Time of construction projects validating the developed guideline.

The substantive experts who were involved in the case studies expressed similar views on Cost and Time overruns of construction projects; third party verifications by an expert (individual or a company) of the input at the preconstruction stage would minimise/eliminate the cost overruns and time overruns of construction projects. Hence the results of the case studies validate the development of the study.

Further, it can be claimed that validation of the developments of the study is successful as both, a) Statistical methods and b) Case study methods demonstrate validity.

It must be noted as the causes of all the ‘Controllable Issues’ considered were found to be within the design phases of the case studies, further analysis was not done for the same in the construction phase. The analysis of ‘Uncontrollable Issues’ from the design phase and ‘Uncontrollable Issues’ from the projects were not analysed as they were outside the scope of the study.

7.5 Summary

The aim of this chapter was to validate the Guideline of the study to minimise the Risks of exceeding Cost and Risks of exceeding Time due to inadequate input to the design phase by preconstruction activities of construction projects *by* retaining the services of an independent designer. Validation of the results was done; i) Statistically by using IBM SPSS 25 (and further verified by Microsoft Excel 2019) and ii) Case studies; using results of completed construction projects. In both methods, validation of the best practice guideline developed from the study for the construction industry was successful (see 7.3 and 7.4).

Therefore, the best practice guideline developed from the study as described in Chapter 6 is validated.

CHAPTER 8 – CONCLUSIONS and RECOMMENDATIONS

8.1 General

The objectives of this research study were as follows.

1. Review, identify and analyze the risks created by the inadequacies, correlations, coherence and accuracy of the input data of pre-construction activities to the design phase of construction projects.
2. Develop industry best practice framework/model/guideline to minimize/eliminate cost and time overruns of construction projects due to risks of inadequacies, correlations, coherence and accuracy of the inputs of pre-construction activities to the design phase of the projects.
3. Validate the developed best practice framework/model/guideline as per Objective 2.

The literature review highlighted that inadequacies of input of preconstruction activities to the design phase of construction projects contributed towards Cost overruns and Time overruns in construction projects. The above finding was further confirmed by the extensive responses received from substantive experts in the industry to the structured questionnaire developed using accepted research methodologies. The data collected from a number of questionnaire surveys were analysed for correlations, coherence, accuracy, (ranking, internal consistency, validity and factor analysis) in the development of the best practice Guideline. The analysed results from the developed best practice Guideline were validated through both statistical validations and case studies. Accordingly Objectives of the study were achieved.

8.2 Conclusions

The main conclusions of this research study are as follows.

1. Inadequacies of input from preconstruction activities to the design phase contributed towards Cost overruns and Time overruns in construction projects.

2. Risks created by the inadequacies, correlations, coherence and accuracy of the input data of pre-construction activities to the design phase of construction projects contributed towards Cost overruns and Time overruns in construction projects.

3. Verification of the input from preconstruction activities to the design phase of construction projects by a third party independent designer would minimise the Risk of exceeding Cost, the Risk of exceeding Time of construction projects.

The followng conclusions are derived from this research study too.

4. Design aspects (12%), Planning and Controlling (8%) and Material (8%) were the top three key contributory factors for overruns of Cost and overruns of Time in construction projects. These three factors accounted for 30% of the occurrences inducing cost and time overruns of construction projects.

5. The top 7 factors, design aspects, planning and controlling, material issues, scope change, finance, client influenced changes and contractor inexperience accounted for 51% of the occurrences and the top 17 factors contributed to 80% of the occurrences inducing cost and time overruns of construction projects.

6. 38 relevant pre-construction activities which provide input to the design phase of construction projects were established through literature review and scientific survey. These pre-construction activities were used to derive a model between 'Relevance of the activity to the design phase of a project' and 'Inadequacy of the input by the activity'.

7. A model to predict the relationship between relevance (x) and adequacy (y)/ inadequacy (z) of inputs of preconstruction activities to the design phase was derived using the equation $y = 2.6916e^{0.024x}$ for adequacy and $z = 100 – 2.6916e^{0.024x}$ for inadequacy. A designer could use this model to predict the inadequacy of input of a preconstruction activity to the design phase for a known relevance of the preconstruction activity of construction projects.

8. None of the inputs from preconstruction activities to the design phase of construction projects had even reached an adequacy level of 50%; the highest percentage of projects which had 100% adequacy level of the inputs to the design by a preconstruction activity was 44%, the average was 23% and the lowest 3%.

9. Questionnaires designed based on literature reviews, expert opinions and pilot survey were effective in obtaining responses for the study. Likert scale (single and multiple in the two questionnaires) was used as the main tool and a test for Cronbach's alpha rated the internal consistency of the questionnaires as excellent.

10. Online data collection was done in two stages from substantive experts using two different questionnaires. The total number of construction projects involved in obtaining responses

was 132. Responses received were complete and data collection was effective. The sample size used for the study was tested using KMO test and proven adequate.

11. 49 relevant pre-construction activities that contribute towards the Risk of exceeding Cost and Risk of exceeding Time due to their inadequate input to the design phase of construction projects were established. All 49 relevant pre-construction activities were considered as above to minimise the Risk of exceeding Cost and Time.

12. Risk interpretation concluded that pre-construction activities P29, P43, P4 and P48 are ‘Likely’ to exceed the Cost and pre-construction activities P29, P43, P4, P48, P27, P32 and P41 are ‘Likely’ to exceed Time due to inadequate input from pre-construction activities to the design phase of construction projects.

13. The top five preconstruction activities (P29, P43, P4, P48 and P27) that contributed to the Risk of exceeding Cost and the Risk of exceeding Time due to inadequate input to the design phase of construction projects, were not only identical but also ranked in the same order.

14. The top ten preconstruction activities that contributed to the Risk of exceeding Cost and the Risk of exceeding Time due to inadequate input to the design phase of construction projects were identical and six of them were of the same rank.

15. Risk interpretation concluded that pre-construction activities P43 and P41 were the top two activities that minimized the Risk of exceeding Cost and Time of construction projects. Both P43 and P41, were in the Top ten of the critical pre-construction activities for exceeding Cost and exceeding Time.

16. “Type of leadership required (e.g., Project Managers) to drive the project – P29” was the preconstruction activity that induced the highest Risk of exceeding Cost and the highest Risk of exceeding Time due to inadequate input to the design phase of construction projects.

17. “Religious issues – P36” was the preconstruction activity that induced the lowest Risk of exceeding Cost and the lowest Risk of exceeding Time due to inadequate input to the design phase of construction projects.

18. The preconstruction activity "Incomplete design scope –P43" had the highest effect on minimising Risk of exceeding Cost and Time due to its inadequate input to the design phase of construction projects.

19. The top four ranked preconstruction activities inducing Risk of exceeding Cost and Risk of exceeding Time of Construction projects (P29, P43, P4 and P48) were within the top 5 ranked preconstruction activities minimising Risk of exceeding Cost and Time due to its inadequate input to the design phase of construction projects.

20. Statistical validation of the developed best practice Guideline through Hypothesis testing confirmed that minimising the Risk of exceeding Time due to inadequate input from preconstruction activity to the design phase and minimising the Risk of exceeding Cost and Time of the construction project were achieved by retaining the services of a third-party independent designer to verify the input from preconstruction activity to the design phase.

21. Three pre-construction activities i) Type of leadership required (e.g., Project Managers) to drive the project (P29) ii) Incomplete design scope (P43) and iii) Level of details required and accuracy (P41) were identified to be common to the three case studies of construction projects used for validation of the developed best practice Guideline. (Total planned cost of projects was Rs. 8.7 billion). These three pre-construction activities were within the top ten ranks of the relevant pre-construction activities identified as contributing to cost and time overruns of construction projects.

22. Worst and second-worst pre-construction activities that induced overruns of both Cost and Time were identified as; 'Type of leadership required (e.g., Project Managers) to drive the project (P29)' and 'Incomplete design scope (P43)'. Both these activities were common to all the projects used for the case studies and had incurred very high overruns (more than 35%) in both Cost and Time.

8.3 Recommendations for future work

1. Contribution towards Sustainability of the Planet by minimising Cost and Time Overruns of construction projects;

   When Cost and Time overruns occur in construction projects, overuse of the limited resources occurs. Most of such resources take an extremely long time to regenerate and hence Cost and Time overruns in construction projects possibly deplete the limited resources available on the planet and thereby dent the effort of Sustainability.

   This happens in the backdrop of where the United Nations (UNDP) had set Sustainable Development Goals (SDG) to meet the urgent environmental, political and economic challenges for the entire world, including Sri Lanka, to be achieved in 2030.

   To contribute effectively to save scarce resources of the planet and there by contribute to the Universal effort of achieving the SDG, it is recommended to carry out further research on the possible effort to “Minimise or eliminate Cost and Time Overruns in the Construction Industry”.

2. Possibility of application of the developed approach of the study to Any Project or Any Process in Any Sector:

   Background, direction and the outcome of the study indicates, any “Project” or “Process” use an Input can benefit from the approach of the study. To achieve the desired result, it would be critical not to have gaps between the “Required input” and “Actual input” of the relevant activities. Establishing the “Required input” and measurement of the “Actual input” would be crucial to the effectiveness (and efficiency) of the implementation to achieve the desired outcome.

   Furthermore, it is not only Projects and Processes relevant to Construction Industry, but other sectors including Consultancy, Information Technology, Banking, Finance, Legal, the Academy etc. which use various forms of inputs to their projects or processes that can benefit from the developed approach.

3. This thesis, based on the study, finally looked at the input of one hundred construction projects to the design phase by forty-nine relevant preconstruction activities of the projects, accepted methodologies, analytical tools and validation. Further, though the core of the preconstruction activities may be common to some of the projects, activities may vary in number and nature. However, the approach in the study would be useful in

effectively analysing and applying input of preconstruction activities to construction projects irrespective of the depth and breadth of the preconstruction activities concerned.

REFERENCE LIST

Adam, A., Josephson, P. & Lindahl, G. (2014). Implications of cost overruns and time delays on major public construction projects. *Proceedings of the 19th International Symposium on the Advancement of Construction Management and Real Estate, 7-9 Nov 2014,* Chongqing.

Adam, A., Josephson, P. & Lindahl, G. (2017). Aggregation of factors causing cost overruns and time delays in large public construction projects: Trends and implications. *Journal of Engineering Construction & Architectural Management, vol 24 (3).* doi.10.1108/ECAM-09-2015-0135

Adam, B., Beck, U., Loon, J.V. & Loon, B.V. (2000). *The Risk Society and Beyond: Critical Issues for Social Theory*. London. SAGE Publications.

Aggarwal, R. & Ranganathan, P. (2016). Common pitfalls in statistical analysis: *The use of correlation techniques.*187–190. doi: 10.4103/2229-3485.192046

Akinsiku, O. E. & Akinsulire A. (2012). Stakeholders' perception of the causes and effects of construction delays on project delivery. *KICEM Journal of Construction Engineering and Project Management* Online ISSN 2233-9582 25 www.jcepm.org http://dx.doi.org/10.6106/ JCEPM.2012.2.4.025

Alexander, C. & Marshall, M.I. (2006). The risk matrix: Illustrating the importance of risk management strategies. https://www.researchgate.net/publication/294151921

Allahaim & Liu (2013). An empirical classification of cost overrun in infrastructure projects by using analysis, *University of New South Wales, Built Environment,* www.be.unsw.edu.au

AlNasseri, H. A. (2015). Understanding applications of project planning and scheduling in construction projects department of construction sciences. *PhD Thesis, Lund University*

AlNasseri, H. A., & Aulin, R. (2016). Enablers and barriers to project planning and scheduling based on construction projects in Oman. *Journal of Construction in Developing Countries, vol. 21 1*

Al-Reshaid, K., Kartam, N., Tewari, N. & Albader, H. (2005). A project control process in pre-construction phases: Focus on effective methodology, *Article in Engineering Construction & Architectural Management vol.12(4):351-372* doi: 10.1108/09699980510608811

Ameh, O. J. Soyingbe, A. A. and Odusami, K. T. (2010). Significant factors causing cost overruns in telecommunication projects in Nigeria. *Journal of Construction in Developing Countries, vol. 15 (2). pp. 49-67*.

Anderson, C. & Rosenberg, L. (2012). The pre-construction planning process from a site manager perspective. *Chalmers University of Technology, Göteborg, Sweden, Master's Thesis 2012:18*

Asiedu, R. O. & Hans, H. W. (2015) Understanding the underlying reasons behind time overruns of government building projects in Ghana, *KSCE J Civ Eng (2016) 20: 2103.* doi: 10.1007/s12205-015-0544-4

Assaf, S.A., AI-Khalil, M. & AI-Hazmp, M. (1995). Causes of delay in large building construction projects. *Journal of Management in Engineering. vol.11 (2), pp. 45-50*.

Athanassisades, A. C. (1972). The distortion on upward communication in hierarchical Organisation. *Academy of management journal, 16(2), pp. 207-226*.

Aven, T. (2015). Risk assessment and risk management: Review of recent advances on their foundation. *European Journal of Operational Research · December 2015*. doi: 10.1016/j.ejor.2015.12.023

Avison, D., & Malaurent, J. (2014). Is Theory King? A Rejoinder. *Journal of Information Technology*. https://doi.org/10.1057/jit.2014.24

Azhar, A., Farooqui, R. U. & Ahmed, S.M. (2008). Cost overrun factors in construction industry of Pakistan, First International Conference on Construction In Developing Countries (ICCIDC–I). *Advancing and Integrating Construction Education. Research & Practice*. August 4-5, 2008, Karachi, Pakistan

Babbie, E. R. (2010). *The Practice of Social Research.* 12th ed. Belmont, CA. http://libguides.usc.edu/writingguide/quantitative

Batson, R. (2009). Project Risk Identification Methods for Construction Planning and Execution. https://www.researchgate.net/publication/269124294.

Bekr, G. A. (2015). Identifying factors leading to cost overrun in construction projects in Jordan. *Journal of Construction engineering, Technology & Management. vol 5*, No 3 (2015)

Bernard, H. R., Killworth, P., Kronenfeld, P. & Sailer, L. (2016). The Problem of Informant Accuracy: *The Validity of Retrospective Data. Annual Review of Anthropology, vol. 13 (1984)*, pp. 495-517. http://www.jstor.org/stable/2155679

Bhatia, D. & Apte, M. R. (2015). Schedule overrun and cost overrun in the construction of private residential construction project: Case study of Pune, India.

International Journal of Technical Research and Applications. vol. 4, Issue 2 (March-April, 2016), PP. 174-177. e-ISSN: 2320-8163, www.ijtra.com

Bol, L. & Hacker, D. J. (2012). Calibration Research: Where Do We Go from Here? *Published online 2012 Jul 9*. doi: 10.3389/fpsyg.2012.00229

Borrego, M., Douglas, E. P. & Amelink C. T. (2009), Qualitative, quantitative and mixed research methods in engineering education, *Journal of Engineering Education*, https://doi.org/10.1002/j.2168-980.2009.tb01005.x

Bradley, E., Curry, L. & Devers, K., (2007) Implementing qualitative analysis: moving from codes to theory. *Health Services Research 2007, vol* 42, 758-1772.

Buys, F (2015) Five causes of project delay and cost overrun, and their mitigation measures. Paper, *LinkedIn.com*

Caspi, Y., Turner, W.M., Panas, L., & Gastfriend, D.R. (2001). The Severity Index. *Alcoholism Treatment Quarterly vol. 19(4):49-64.* https://www.researchgate.net/publication/254358134_The_Severity_Index. doi: 10.1300/J020v19n04_03

Chenail, R. J., Duffy, M., St. George, S., & Wulff, D. (2011). Facilitating Coherence across Qualitative Research Papers. *The Qualitative Report, 16(1),* 263-275. http://nsuworks.nova.edu/tqr/vol16/iss1/17

Conboy, K., Fitzgerald, G. & Mathiassen, L. (2013) Qualitative Methods Research in Information Systems: Motivations, *Themes and Contributions European Journal of Information Systems 21(2) · January 2013*. doi: 10.1057/ejis.2011.57

Choi, S. Y., Oliveira, D. P., Stephen, P., Mulva, P. & Kang, Y. (2016). Measuring project management inputs throughout capital project delivery. *International Journal of Project Management, vol.34 (7):1167–1182.* doi: 10.1016/j.ijproman.2016.06.004

Coombs, C. (2017). Coherence and transparency: some advice for qualitative researchers. *Production, 27,* e20170068. http://dx.doi.org/10.1590/0103-6513.006817

Correlation Analysis - Market Research, https://www.djsresearch.co.uk/glossary/item/correlation-analysis-market-research

Craigie, E. K., (2015). A framework for estimating pre-construction service costs at the functional level for highway construction projects. *Graduate essays and Dissertations. Paper 14752*.

Creswell, J. W. (2009). *Research Design: Qualitative, quantitative and mixed methods approaches*, 3rd edition, SAGE Publications.

Creswell, J.W. & Plano-Clark, V.L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications.

Construction Development Authority (CIDA), Sri Lanka http://www.cida.gov.lk/index_en.html).

Curry, L. (2013), Fundamentals of qualitative research methods, Yale school of medicine, Yale global health leadership institute

Daluwatte, L. and Ranasinghe, M. (2017). Contributory factors for cost and time overruns of construction Projects. *Transactions 2017 Part B, Technical Papers,* The Institution of Engineers, Sri Lanka, pp. 89-96.

Daluwatte, L. and Ranasinghe, M. (2018). Analysis of inputs of pre-construction activities: Effects on the Design phase, *ENGINEER – vol.* No. 02, pp. [31 – 40], 2018

Daluwatte, L. and Ranasinghe, M. (2019). Effects on construction project completion due to inadequate inputs at the design phase. *Transactions 2019 Part B, Technical Papers,* The Institution of Engineers, Sri Lanka, pp. 159-168

Davison, R. M. & Martinsons, M. (2015). Context is king! Considering particularism in research design and reporting. *Journal of Information Technology 31(3) · June 2015* doi: 10.1057/jit.2015.19.

Desai, N. J., S., Pitroda, J. & Bhavsar, J.J. (2015). A review on change order and assessing causes affecting change order in construction, *Journal for International Academic Research for Multidisciplinary*. ISSN: 2320-5083, *vol. 2, Issue 12, January 2015.*

Devore, J.L. (2008). *Probability and statistics for engineers* (1st ed.). Boston, MA.

Dolage, D.A.R. & Pathmarajah, T. (2015). Mitigation of delays attributable to the contractors in the construction industry of Sri Lanka - consultants' perspective. *Engineer - Journal of the Institution of Engineers, Sri Lanka, vol.48 (1):21*, doi: 10.4038/engineer.v48i1.6845.

Doloi, H. (2013). Cost overruns and failure in project management: Understanding the roles of key stakeholders in construction projects, *Journal of Construction Engineering and Management*, *vol*. 139, No. 3: pp. 267-279 doi: 10.1061/(ASCE)CO.1943-7862.0000621)

Duijm, N. J. (2015). Recommendations on the use and design of risk matrices. doi: 10.1016/j.ssci.2015.02.014

Dumbravă & Icob, (2013). Using probability impact matrix in analysis and risk management projects. *Journal of Knowledge Management, Economics and Information Technology*. pp: 77-88.

Edwards, P., Bowen, P., Hardcastle, C., and Stewart, P. (2009). Identifying and communicating project stakeholder risks. *Building a sustainable future: pp. 776-785*. doi: 10.1061/41020(339)79 ASCE

Eldash, K., Abd-Raboh, E. & El-Dars, Z. (2006), Risk management in the design phase of large-scale construction projects, doi: 10.13140/2.1.1137.2328

El-Kholy, A. M. (2015). Predicting cost overrun in construction projects. *International Journal of Construction Engineering and Management* p-ISSN: 2326-1080 e-ISSN: 2326-1102 2015; *vol 4(4)*: 95-105

Emam, H., Farrell, P. and Abdelaal, M. (2015). Causes of delay on large Infrastructure projects in Qatar. *31st Annual ARCOM Conference, At Lincoln, UK*. doi: 10.13140/RG.2.1.1732.0400

Endut, I. R., Akintoye, A. & Kelly, J. (2013). Cost and time overruns of projects in Malaysia [online] 14 (5). p. 440-456. http://tvn.sagepub.com.ezproxy.staffs.ac.uk/

European Union Technical report 2014-2478, Luxembourg.

Faridi, A. & El-Sayegh, S. (2006). Significant Factors Causing Delay in the UAE Construction Industry. *Construction Management and Economics*, *24*, *1167-1176*.

Fiedler, J. & Schust, S. (2015). Large infrastructure projects in Germany - between ambition and realities. www.hertie-school.org/infrastructure

Field, A. (2005). *Discovering statics using SPSS*, Saga, Thousand Oaks, CA.

Fraenkel, J. R. & Wallen, N. E. (2003). *How to design and evaluate research in education.* Fifth Edition. New York: McGraw-Hill Higher Education.

George, D. & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference* 11.0 update (4th ed.). Boston: Allyn & Bacon

Gidado, K. (2004). Enhancing the prime contractor's pre-construction planning. *Journal of Construction Research, Vol. 5, No. 1 (2004) 87–106*

Goral, J. (2007). Risk management in the conceptual design phase of building projects. *Master's Thesis, Chalmers University of Technology, Goteborg, Sweden.*

Gregor, S. (2006). The Nature of Theory in Information Systems. *Management Information Systems Quarterly*. aisel.aisnet.org › *vol30* › iss3

Guidebook on risk analysis tools and management practices to control transportation project costs, (2010). *The National Academy of Sciences, Engineering and Medicine,* Chapter 7, The National Academy Press

Hacker, D. J., Bol, L., & Keener, M. C. (2008). *Metacognition in education: A focus on calibration.* In J. Dunlosky & R. A. Bjork (Eds.), *Handbook of metamemory and memory* (p. 429–455). Psychology Press.

Hameed, A. & Woo, S. (2007). Risk importance and allocation in Pakistan construction industry: A contractors' perspective. *KSCE Journal of Civil Engineering, Vol. 11, No 2 / March 2007, pp. 73-80.*

Haponawa, T. & Al-Jibouri, S. (2009). Identifying key performance indicators for use in control of pre-project process in construction. *International Journal of Productivity and Performance Management. ISSN: 1741-0401*.

Harland, B. (2019). How to Do a Quantitative Research Questionnaire. *sciencing.com*. https://sciencing.com/how-to-do-a-quantitative-research-questionnaire-12748929.html

Huber, G.P. & Power, D. J. (1985). Research notes and Communications - Retrospective reports of strategic-level managers: Guideline for increasing their accuracy. *Strategic Management Journal, Volume 6., pp 171-180*

https://www.lexico.com/definition/hypothesis_testing, Powered by OXFORD

Iqbal, S., Choudhry, R.M., Holschemacher, K. & Ali, A. (2015). Risk management in construction projects. *Technological and Economic Development 21(1):65-78 · January 2015* doi: 10.3846/20294913.2014.994582.

Ismail, I., Rahman, I. A. & Memon, A. H. (2013). Study of factors causing time and cost overrun throughout life cycle of construction projects. *Proceedings of Malaysian technical universities Conference on Engineering & Technology* (MUCET)-4 December 2013 , Kuantan, Pahang

Iyer, K.C. & Jha, K.N. (2005). Factors Affecting Cost Performance: Evidence from the Indian Construction Projects. *International Journal of Project Management, 23, 283-295.*

Jackson, S., (2000). Project cost overruns and risk management. https://www.reading.ac.uk>web>files

Jatarona, N. A., Yusof, A. M., Ismail, S. and Saar, C. C. (2016). Public construction projects performance In Malaysia. *Journal of Southeast Asian Research*. *Article ID 940838*, 7 pages doi: 10.5171/2016.940838.

Joshi, A., Kale, S., Chandel, S. & Pal, D.K. (2015). Likert scale: Explored and Explained. *British Journal of Applied Science and Technology.* doi: 10.9734/BJAST/2015/14975

Kabir, S.M.S. (2016). *Basic Guidelines for Research: An Introductory Approach for All Disciplines.* Edition: First. Chapter: 9. Publisher: Book Zone Publication, Chittagong-4203, Bangladesh.

Kajtazi M. (2012). Information Inadequacy: The lack of needed information in human, social and industrial affairs. *Critical Infrastructures and Society. HCC 2012. IFIP Advances in Information and Communication Technology, vol 386.* Springer, Berlin, Heidelberg.

Kaur, P., Stoltzfus, J. & Yellapu, V. (2018). Descriptive statistics. *Int J Acad Med [serial online] 2018* [cited 2020 Jan 21]; 4:60-3. http://www.ijam-web.org/text.asp?2018/4/1/60/230853

Kaveen, S., Aleem, M. I. A. and Thaarrini, J. (2015) Application of value engineering in construction project to predict time and cost overrun – An overview. *International Journal of Scientific Engineering and Applied Science*. *vol. 1, Issue-9*. 2015ISSN: 2395-3470 www.ijseas.com

Keutel, M., Michalik, J. & Richter, J. (2013). Towards mindful case study research in IS: A critical analysis of the past ten years. *European Journal of Information Systems 23(3).* doi: 10.1057/ejis.2013.26

Kiral, I. A. & Comu, Z. K. (2014). Risk Identification in Construction Projects. https://www.researchgate.net/publication/301697522.

Kirch, W. (2008). *Encyclopedia of Public Health*, 2008 Edition.

Klazema, A, (2014). Types of Quantitative Research for Students and Researchers, https://blog.udemy.com

Konboy, K., Fitzgerald, G. & Mathiassen, L. (2013). Qualitative methods research in information systems: Motivations, themes and contributions. *European Journal of Information Systems vol. 21(2)* doi: 10.1057/ejis.2011.57

KPMG – PMI study in India (2012). Study on project schedule and cost overruns in infrastructure projects in India.

Kreitler, C. (2011). Effect of precondition planning on costs and sustainability. *Thesis for Master of Science in Building Construction*, University of Florida, USA.

Kumaraswamy, M.M. & Chan, D.W.M. (1998). Contributors to construction delays. *Construction Management and Economics.* 16(1):17-29, doi: 10.1080/014461998372556

Larsen, J. K., Shen, G. Q., Lindhard, S. M. & Brunoe, T. D. (2015). Cost overrun, Denmark, quality level, schedule delay. http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000391.

Laufer, A., Tucker, R.L., Shapiria, A. & Shenhar, A., (1994). The multiplicity concept in construction project planning. *Journal of Construction Management and Economics. vol. 12(1):53-65* · January 1994. doi: 10.1080/01446199400000007

Lawrence Berkeley National Laboratory, Basic vs. Applied Research. https://commons.lbl.gov/display/rst/Citation+Management

Lee, J. (2008). Cost overrun and cause in Korean social overhead capital Projects: Roads, Rails, Airports, and Ports. *Journal of Urban Planning Development. 10.1061/ (ASCE) 0733-9488(2008)134:2(59), 59-62.*

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 22 140,* 55.

Long, N.D., Ogunlana, S., Quang, T. & Lam, K. C. (2004). Large construction projects in developing countries: a case study from Vietnam. *International Journal of Project Management, vol.22: 553-561*

Mahadik, U. A. (2015). Cost reduction in construction projects. *International Journal of Engineering Technology, Management and Applied Sciences*. September 2015, *volume 3,* Special Issue, ISSN 2349-4476

Marshall, M. N., (1996), Sampling for qualitative research, *Family Practice, volume 13,* Issue 6, pp 522-525 https://doi.org/10.1093/fampra/13.6.522

Memon A.H., Abdullah, M. A. H. I. A. M. R. & Azis, A. A. (2010). Factors affecting construction cost in mara large construction project: Perspective of project management consultant. *International Journal of Construction Engineering & Technology Vol 1, No 2, December 2010*.

Memon, A. H., Rahman, I. A. & Azis, A. A. A. (2011). Preliminary study on causative factors leading to construction cost overrun. *International Journal of Sustainable Construction Engineering & Technology vol 2, Issue 1, June 2011*

Memon, A. H. (2014). Contractor perspective on time overrun factors in Malaysian construction projects. *International Journal of Science, Environment* ISSN 2278-3687 (O) and Technology, *vol. 3, No 3, 2014, 1184 – 1192*

Memon, A. H., Rahman, I. A., Zainun, N. Y. & Karim, A. T. A. (2014) Web-based Risk Assessment Technique for Time and Cost Overrun http://dx.doi.org/10.1016/j.sbspro.2014.03.664

Meyer, W.G. (2015). Quantifying risk: measuring the invisible. *PMI Global Congress 2015* – EMEA, London, England. Newtown square, PA: Project management Institute

Morris, S. (1990). Cost and time overruns in public sector projects. *Economic and Political Weekly, vol. 25*, No. 47, pp.M154-M168, November 24, 1990

Muhwezi. U. L., Acai, J. & Otim, G. (2014). An assessment of the factors causing delays on building construction projects in Uganda. *International Journal of Construction Engineering and Management 2014, 3(1): vol. 13-23* doi: 10.5923/j.ijcem.20140301.02

Mukuka, M., Aigbavboa, C., & Thwala, W. (2015). Understanding construction projects' schedule overruns in South Africa. *ICCREM 2015: pp. 591-602*. doi: 10.1061/9780784479377.068 ASCE

Mulla S.S. & Waghmare A.P. (2015) A study of factors caused for time and cost overruns in construction project and their remedial measures. *International Journal of Engineering Research and Application.* www.ijera.com ISSN: 2015 Jan; 5(1):48-53.

Naji, H. I. & Ali, R. H. (2018). Risk Response Selection in Construction Projects. *Civil Engineering Journal vol. 3(12):1208,* doi: 10.28991/cej-030950

Nallaperumal, K. (2013). *Engineering Research Methodology, A Computer Science and Engineering and Information and Communication Technologies Perspective*. First Edition, http://www.engineeringresearchjournal.com

Nghitanwa, E. M. & Zungu, L.I. (2017). Occupational Health and Safety Status in the Windhoek Construction Industry: A Namibian Perspective. DOI:10.4236/ojsst.2017.73011

Ojo, G. K. & Odediran, S. J. (2015). Significance of construction cost estimating risks in Nigeria. *International Journal of Civil Engineering and Construction Science. vol. 2, No. 1*, 2015, pp. 1-8. 2015; 2(1): 1-8 published online April 20, 2015. http://www.aascit.org/journal/ijcecs.

Okpala, D. & Aniekwu, A. (1988). Causes of high costs of construction in Nigeria. *Journal of Construction Engineering and Management, June 1988, Vol. 114,* No. 2: pp. 233-244

Olander, S. (2007) Stakeholder impact analysis in construction project management, *Journal of Construction Management and Economics*, *vol. 25*, Issue 3, 277-287.

Olawale, Y. A. & Sun, M. (2010). Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice. *Construction Management and Economics, 28(5), 509-526*

O'relly, C. (1978). The international distortion of organisational communications: a laboratory and field approach. *Human relations, vol. 31(2), pp. 173-193*.

Pallant, J. (2015). *SPSS Survival Manual*. Open University Press, Berkshire.

Pannucci, C.J. & Wilkins, E.G. (2010). Identifying and Avoiding Bias in Research. Plastic Reconstruction Surgery 126(2): 619–625. doi: 10.1097/PRS.0b013e3181de24bc

Patel, A (2014). Effects and causes of cost overrun on building construction projects, Academia.edu

Patel, C. H., Chaturvedi, H., Rao, M. R., Katta, P. & Prasad, K. N. N. (2015). An analysis of cost and time overruns in construction projects. *NICMAR Journal of Construction Management, Vol. XXX April - June 2015 No. II*

Patil, Y. K. & Bhangale, P.P. (2013). Investigation of factors influencing cost overrun in high-rise building constructions. *International Journal in Latest Trends in Engineering Technology (IJLTET), Volume 6, Issue 3, January 2016*, ISSN: 2278-621X

Peredaryenko, M. S. & Krauss, S. E. (2013). Calibrating the human instrument: *Understanding the interviewing experience of novice qualitative researchers. The Qualitative Report*, *18*(85), 1-17; http://www.nova.edu/ssss/QR/QR18/peredaryenko85.pdf

Perry, J. G. & Hayes, R.W. (1985). Construction projects – knows the risk, *Chartered Mechanical Engineer.* February, pp. 42-45

Priyadharshini, N. S. & Kumar S. S. (2015). Project communication: Is key to productive construction and its research needs in the future of construction engineering and management. *International Journal of Science*, *Technology & Management* www.ijstm.com *Vol. 04, Special Issue No. 01*, March 2015 ISSN (online): 2394-1537

Polat, G., Okay, F. & Eray, E. (2014). Factors effecting cost overruns in micro-scaled construction companies. doi: 10.1016/j.proeng.2014.10.569

Rahman, I.A., Memon, A. H., Karim, A. T. A. & Tarmizi, A. (2013). Significant factors causing cost overruns in large construction Projects in Malaysia. *Journal of Applied Sciences vol. 13 (2): 286-293*, 2013 ISSN 1812-5654 / doi: 10.3923ljas.2013.286.293 O 2013 Asian Network for Scientific Information

Rahman, I.S., Memon, A. H., Nagapan, S. & Latif, Q. B. A.I. (2012). Time and cost performance of construction projects in southern and central regions of peninsular Malaysia. *IEEE Colloquium on Humanities, Science and Engineering* (CHUSER)

Rajgor, M., Paresh, C., Dhruv, P., Chirag, P. & Dhrmesh, B. (2016). RII & IMPI: Effective Techniques for finding delay in construction project. *International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 - 0056Volume: 03 Issue: 01 | Jan-2016*

Rajguru, A. & Mahatme, P. (2015). *International Journal of Research in Engineering and Technology* ISSN: 2319-1163 | pISSN: 2321-7308

Ranasinghe, M. & Russell, A.D. (1992), Treatment of correlation for risk analysis of engineering projects, *Journal of Civil Engineering Systems*, Gordon & Breach Science Publishers, U.K, *Vol.9*, pp.17-39.

Rennie, D. L (1994). Human science and counseling psychology: Closing the gap between research and practice. *Counseling Psychology Quarterly, 7, 235-250*

Rwakarehe, E.E. & Mfinanga. (2014). Effect of inadequate design on cost and time overrun of road construction projects in Tanzania. *Journal of Construction Engineering and Project Management. 4(1).* DOI: 10.6106/JCEPM.2014.4.1.015

Sage, A. P. (1981) Behavioural and organisational in the design of information systems and processes for planning and decision support *IEEE Transactions for systems, man and cybernetics, SMC 11*(9), pp.640-678.

Salkind, N., (2007). Encyclopedia of Measurement and Statistics. http://dx.doi.org/10. 4135/9781412952644n470

Sarker, S., Xiao, X., & Beaulieu, T. (2013). Guest editorial: Qualitative studies in information systems: A critical review and some guiding principles. *MIS Quarterly, 37(4), iii-xviii.*

Sarker, S., Xiao, X., Beaulieu, T. & Lee, A.S. (2018). Learning from First-Generation Qualitative Approaches in the IS Discipline: An Evolutionary View and Some Implications for Authors and Evaluators (PART 1/2). *Journal of the Association for Information Systems, vol. 19 issue 8*

Schneider, K. J. (1999). Multiple-case depth research. *Journal of Clinical Psychology, 55(12), 1531-1540.*

Schober,P., Boer, C. & Schwarte, L.A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia & Analgesia 126(5):1*. doi: 10.1213/ANE.0000000000002864

Seidenfeld, T (1985). Calibration, coherence, and scoring rules. *Philosophy of Science, vol. 52, no. 2 (Jun., 1985), pp. 274-294*, https://www.jstor.org/stable/187511

Sepasgozar, S. M. E., Razkenari, M. A. & Barati, K. (2015). The importance of new technology for delay mitigation in construction projects in Iran. *American Journal of Civil Engineering and Architecture,* 2015 *vol.3 (1), pp 15-20*. doi: 10.12691/ajcea-3-1-3

Shibani, A. (2015). Time and cost overrun in construction projects in Egypt, https://www.researchgate.net/publication/282219318

Shibani, A. & Arumugam, K. (2015). Avoiding cost overruns in construction projects in India. *Management Studies, August 2015, Vol. 3, No*. 7-8, 192-202 D doi: 10.17265/2328-2185/2015.0708.003

Sihombing, L. (2016). Identification of factors effecting cost overruns in the construction of industrial buildings. https://www.researchgate.net/publication/318813764

Simundic, A. M. (2013). Bias in research. *Biochemical Medical vol 23*(1), pp: 12-15 Researchgate. doi: 10.11613/BM.2013.003

Shrestha, P. P., Burns, L. A. and Shield, D. R. (2013) Magnitude of construction cost and schedule overruns in public work projects. *Journal of Construction Engineering Volume 2013* (2013), Article ID 935978, 9 pages http://dx.do

Smith, J. & Noble, H. (2014). Bias in research. *Evidence Based Nursing, volume 17*, number 4, RCN publishing company 10.1136/eb-2014-101946. https://ebn.bmj.com › content › ebnurs › 100.full.pdf

Smith, M. H. (2017). A Sample/Population Size Activity: Is it the sample size of the sample as a fraction of the population that matters? https://doi.org/10.1080/10691898.2004.11910735

Solís-Carcaño, R. G., Corona-Suárez, G. A. & García-Ibarra, A.J. (2015). The use of project time management processes and the schedule performance of construction projects in Mexico. *Journal of Construction Engineering, Volume 2015 (2015)*, Article ID 868479, 9 pages http://dx.doi.org/10.1155/2015/868479

Spiegel, M.R., Stephens, L.J. & Kumar, N. (2010). *Statistics* (4th ed.). New York. McGrew Hill.

Sullivan, G. M. & Artino, A.R. (2013). Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education. 2013 Dec; vol. 5(4)*: pp: 541-2. doi: 10.4300/JGME-5-4-18.

Taherdoost, H. (2016). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research, *International Journal of Academic Research in Management*, *vol*. 5, No. 2, 2016, Page:18 - 27, ISSN: 2296-1747

Thomas, P., Bratvold, R.B., & Bickel, J.E. (2014). The risk of using risk matrices. *SPE Economics & Management. Volume 6, Issue 02, Publication Date, April 2014.* doi. https://doi.org/10.2118/166269-PA

Thorne, S., (2000) Data analysis in qualitative research http://dx.doi.org/10.1136/ebn.3.3.68

Silverman, D. (1998). Qualitative research: meanings or practices? *Information Systems Journal*. https://doi.org/10.1046/j.1365-2575.1998.00002.x

University of Minnesota, USA, Types of data, https://cyfar.org

US department of health and human services. Data Collection - The Office of Research Integrity. https://ori.hhs.gov/content/Chapter-6-Data-Management-Practices-Data-collection

Vu H.A., Wang, J., Min, L., Mai, S.H. & Nguyen, H. P. (2016). Research on cost overrun risk of construction phase of Vietnam highway international contracting project. http://www.scirp.org/journal/eng http://dx.doi.org/10.4236/eng.2016.83011

Washington State Department Project Risk Management Guide, (2018) Engineering and Regional Operations

Wijekoon, S.B. (2016). Identification of significant factors influencing performance of road construction industry using factor analysis. http://dl.lib.mrt.ac.lk/handle/123/11592

Wilks, S. (2015). The century's most troublesome construction projects. *Globule Construction Review, 5 October 2015*. Website of the Chartered Institute of Building. Article.

Wilson, E. B. (1952). *An introduction to scientific research.* (1991) New York, Dover Publications.

Wilson, V., (2014), Research Methods: Sampling, http://creativecommons.org/licenses/by-nc-sa/2.5/ca/

Wu, C. (2007). An Empirical Study on the Transformation of Likert-scale Data to Numerical Scores. *Applied Mathematical Sciences, vol. 1, 2007, no 58, 2851-2862*.

Yamane, T., (1967) Determining sample size, Tarleton State University. https://www.tarleton.edu

APPENDICIES

Annexure - 1: Questionnaire used for the survey of *thirty-eight* preconstruction activities.

	(A) Preconstruction Activity	(B) Activity was Relevant to the Project	(C) Activity was Done	(D) If Yes, (Relevant and Done), adequacy of the input of activity (over the requirement) of the Design phase of the project						(E) If the Activity was less than 100% effective at the first attempt / stage, re: Answer of Column (D) **What were the Impacts / Issues to the Project ; Exceeding Cost, Exceeding Time,……**
		Yes/No/ Uncertain	Yes/No/ Uncertain	0%	20%	40%	60%	80%	100%	
P1	Preliminary survey									
P2	Engineering survey									
P3	Land survey									
P4	Geotechnical survey									
P5	Study of Environmental issues									
P6	Study of Rules and Regulations									
P7	Study of High flood level									
P8	Study of Low flood level									
P9	Study of Rainfall pattern									
P10	Study of Water table (variations)									
P11	Study of Wind directions									
P12	Study of Variation patterns of wind									
P13	Locating of existing Utilities (water, power, telecom, Wi-Fi etc.)									
P14	Identification of Utility agencies									
P15	Availability of Utilities (water, power, telecom, Wi-Fi etc.)									
P16	Study of Type of project : Design and Build, Tender,Proposed									
P17	For Tendererd projects - Study of Conditions of contracts									
P18	For Tendered projects - Study of Special conditions of contracts									
P19	Investigation of Access roads (capacity, width, surface, bottlenecks, etc.)									
P20	Assesment of Capacities of culverts, bridges, etc. on access roads									
P21	Investigation on availability of Material									
P22	Investigation on proximity of Material									
P23	Identification of requirements of equipment/ machinery/ vehicles etc. for the project									
P24	Study of availability of equipment/ machinery/ vehicles etc. for the project									
P25	Study of availability of Sub Contractors									
P26	Study of requirement and availability of Special Sub Contractors									
P27	Study of requirement and availability of Skilled Manpower									
P28	Study of requirement and availability of Un-skilled Manpower									
P29	Study of assessment of the leadership required - Project Manager etc.- to drive the project									
P30	Study of availability of knowledge to do the project - core and support areas									
P31	Study of adequacy of the skills to do the project - core and support areas									
P32	Study of attitude of the Individuals / Team towards delivering the project									

P33	Study of identification of corrective measures, eg. Training to rectify the gaps found									
P34	Study of possible Social issues									
P35	Study of possible Neighbourhood issues									
P36	Study of possible Religious issues									
P37	Study of possible Political issues									
P38	Study of Stakeholder issues									

Annexure 2 - Questionnaire used for the survey of *forty-nine* preconstruction activities.

This survey is done by the Department of Civil Engineering of the University of Moratuwa, Sri Lanka, as part of a doctoral research to determine a methodology of how to minimise the Cost and Time overruns of construction projects

Note: **Research candidate: Eng. Leelanath Daluwatte**, Doctoral candidate, University of Moratuwa, Sri Lanka. http://www.iesl.lk/Sys/PublicProfile/3956860/1517689, https://www.linkedin.com/in/leelanath-daluwatte-18ba5381/

Research supervisor: Eng. (Prof) Malik Ranasinghe, Senior Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka. https://www.mrt.ac.lk/staff/Ranasinghe.KAMK.php

Data provided will be treated with strict confidentiality and will be used for the research purpose only.

Important:

1. An example of responses are in the sheet "Example".

2. Curser on Header Cell of columns (A),(B) and (C) explains; (A) on Preconstruction activity (B) Impact of Risk and (C) Likelihood of Risk respectively.

3. Please use appropriate figure 1,2,3,4,5 to respond_not "✓", "X" etc.

4. Please 'Rate' the columns (B), (C), (E), (F) and (G) on the given scale of 1 to 5 according to the 'effect' caused by each of the preconstruction activity

5. If a Preconstruction activity is not applicable to the project concerned, please the leave relevant raw blank.

Thank you very much for your kind Contribution. Really appreciate! Once completed, I will provide you with the final outcome of the research - Leelanath Daluwatte

Project type: Building, Roads, Bridges, Water supply, Harbour, Flood protection, Other(Please specify)		Planned Cost:	---	Planned Duration:	---
**** if available*	Year Started: ---	Actual Cost:	---	Actual Duration:	---

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design Phase.					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design Phase.					(E) Risk of exceeding Cost caused by the preconstruction activity considered.					(F) Risk of exceeding Time caused by the preconstruction activity considered.					(H) Verification of the Design (eg: by a Third party Independent Designer) would minimise the risk (including due to inadequate inputs) of Design Phase				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High
P1	Preliminary survey																									
P2	Engineering survey																									
P3	Land survey																									
P4	Geotechnical survey																									
P5	Environmental issues																									
P6	Applicable rules and regulations																									
P7	Information about high flood levels																									
P8	Recording of information about low flood levels																									
P9	Rainfall patterns																									
P10	Water table (variations)																									
P11	Wind directions																									
P12	Variation patterns of wind																									
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)																									
P14	Identification of utility agencies																									
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)																									
P16	Type of project : design and build, tendered, prepared																									
P17	Conditions of contracts of tendered projects																									
P18	Special conditions of contracts of tendered projects																									
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)																									
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads																									
P21	Availability of material																									
P22	Proximity of material																									
P23	Requirement of equipment/ machinery/vehicles etc.																									
P24	Availability of equipment/ machinery / vehicles etc.																									
P25	Availability of sub contractors																									
P26	Availability of special sub contractors																									
P27	Availability of skilled manpower																									
P28	Availability of unskilled manpower																									
P29	Type of leadership required (e.g., Project Managers)to drive the project																									
P30	Availability of knowhow to do the project - core and support areas																									
P31	Adequacy of skills to do the project - core and support areas																									
P32	Attitudes of individuals / team towards delivering the project																									
P33	Identification of corrective measures, e.g., providing training to rectify gaps																									
P34	Possible social issues																									
P35	Possible neighborhood issues																									
P36	Possible religious issues																									
P37	Possible political issues																									
P38	Stakeholder issues																									
P39	Innovative application																									
P40	New technology																									
P41	Level of details required and accuracy																									
P42	Appropriateness of specification																									
P43	Incomplete design scope																									
P44	Likelihood of change																									
P45	Interaction of design with method of construction																									
P46	Non-standardization of details																									
P47	Non-standardization of suppliers																									
P48	Quality control - inspection and approvals																									
P49	Temporary design - quality, responsibility and supervision																									

Information of the Respondent: *(Please 'tick' / state as applicable)*

In this project - responded worked for the;	Contractor:		Designer/Consul		Client:	
	Position		Years of Experie		CIDA Grade of the Company (as applicable):	

Please send your **email responses to nath0224@gm** **Clarifications: Leelanath Daluwatte, Tel: 0718 331602, email: n**

hank you very much Again! All the best!!

Annexure - 3: Sample of the response of survey of 100 projects.

#	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	(B) Impact of Risk caused by the inadequacy of input of the preconstruction activity to the Design					(C) Likelihood of Risk caused by the inadequacy input of the preconstruction activity to the Design					(D) Risk Rating	(E) Risk of exceeding Cost caused by the preconstruction activity considered.					(D)x (E)	(F) Risk of exceeding Time caused by the preconstruction activity considered.					(D)x (F)
		1	2	3	4	5	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
		Very Low	Low	Neutral	High	Very High	Very Low	Low	Neutral	High	Very High		Very low	Low	Neutral	High	Very high		Very Low	Low	Neutral	High	Very High	
P1	Preliminary survey					5				4		20		2				40				4		80
P2	Engineering survey					5				4		20				4		80					5	100
P3	Land survey				4					4		16				4		64				4		64
P4	Geotechnical survey					5					5	25		2				50					5	125
P5	Environmental issues				4					4		16		2				32		2				32
P6	Applicable rules and regulations					5		2				10				4		40				4		40
P7	Information about high flood levels					5				4		20		2				40		2				40
P8	Recording of information about low flood levels		2					2				4		2				8		2				8
P9	Rainfall patterns		2					2				4		2				8		2				8
P10	Water table (variations)				4					4		16		2				32				4		64
P11	Wind directions				4			2				8	1					8				4		32
P12	Variation patterns of wind				4			2				8	1					8		2				16
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)				4					4		16		2				32					5	80
P14	Identification of utility agencies				4					4		16		2				32				4		64
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)					5				4		20				4		80					5	100
P16	Type of project : design and build, tendered, prepared				4					4		16		2				32					5	80
P17	Conditions of contracts of tendered projects					5					5	25				4		100				4		100
P18	Special conditions of contracts of tendered projects					5				4		20				4		80				4		80
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)		2					2				4		2				8		2				8
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads		2							4		8		2				16		2				16
P21	Availability of material		2								5	10		2				20				4		40
P22	Proximity of material		2							4		8		2				16				4		32
P23	Requirement of equipment/ machinery/ vehicles etc.		2								5	10				4		40				4		40
P24	Availability of equipment/ machinery / vehicles etc.					5				4		20				4		80				4		80
P25	Availability of subcontractors				4					4		16				4		64				4		64
P26	Availability of special subcontractors		2							4		8				4		32				4		32
P27	Availability of skilled manpower		2							4		8				4		32				4		32
P28	Availability of unskilled manpower		2							4		8				4		32				4		32
P29	Type of leadership required (e.g., Project Managers) to drive the project			3							5	15				4		60					5	75
P30	Availability of knowhow to do the project - core and support areas		2							4		8		2				16				4		32
P31	Adequacy of skills to do the project - core and support areas		2							4		8		2				16				4		32
P32	Attitudes of individuals / team towards delivering the project					5					5	25				4		100					5	125
P33	Identification of corrective measures, e.g., providing training to rectify gaps				4					4		16		2				32		2				32
P34	Possible social issues		2							4		8				4		32		2				16
P35	Possible neighborhood issues		2					2				4		2				8		2				8
P36	Possible religious issues		2					2				4	1					4	1					4
P37	Possible political issues		2							4		8		2				16	1					8
P38	Stakeholder issues		2							4		8		2				16				4		32
P39	Innovative application				2			4				8				2		16				2		16
P40	New technology				2			4				8				2		16				2		16
P41	Level of details required and accuracy		4					4				16				2		32		4				64
P42	Appropriateness of specification	5								2		10				2		20		4				40
P43	Incomplete design scope				2			4				8		4				32		4				32
P44	Likelihood of change				2					2		4				2		8				2		8
P45	Interaction of design with method of construction			3				4				12				2		24		4				48
P46	Non-standardisation of details			3						2		6				2		12				2		12
P47	Non-standardisation of suppliers				2				3			6				2		12				2		12
P48	Quality control - inspection and approvals				2		5					10				2		20	5					50
P49	Temporary design - quality, responsibility and supervision				2			4				8				2		16				2		16

Annexure - 4: Risk estimates of *forty-nine* pre-construction activities.

Activity No.	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	Sum of Individual Risk Estimates		Mean of Risk Estimates	
		Exceeding Cost	Exceeding Time	Exceeding Cost	Exceeding Time
P1	Preliminary survey	4216	4332	42.2	43.3
P2	Engineering survey	5157	5240	51.6	52.4
P3	Land survey	4436	4451	44.4	44.5
P4	Geotechnical survey	5451	5525	54.5	55.3
P5	Environmental issues	3369	3591	33.7	35.9
P6	Applicable rules and regulations	4426	4599	44.3	46.0
P7	Information about high flood levels	3573	3583	35.7	35.8
P8	Recording of information about low flood levels	2079	1982	20.8	19.8
P9	Rainfall patterns	2529	3007	25.3	30.1
P10	Water table (variations)	3158	3046	31.6	30.5
P11	Wind directions	2135	2017	21.4	20.2
P12	Variation patterns of wind	1919	1830	19.2	18.3
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	3946	3875	39.5	38.8
P14	Identification of utility agencies	3098	3123	31.0	31.2
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	4299	4303	43.0	43.0
P16	Type of project: design and build, tendered, proposed	4190	3723	41.9	37.2
P17	Conditions of contracts of tendered projects	4049	3848	40.5	38.5
P18	Special conditions of contracts of tendered projects	4455	4158	44.6	41.6
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	3333	3455	33.3	34.6
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	3190	3166	31.9	31.7

P21	Availability of material	4618	4702	46.2	47.0
P22	Proximity of material	3468	3544	34.7	35.4
P23	Requirement of equipment/ machinery/vehicles etc.	4278	4269	42.8	42.7
P24	Availability of equipment/ machinery / vehicles etc.	4436	4512	44.4	45.1
P25	Availability of subcontractors	4308	4332	43.1	43.3
P26	Availability of special subcontractors	4584	4645	45.8	46.5
P27	Availability of skilled manpower	5278	5499	52.8	55.0
P28	Availability of unskilled manpower	4160	4284	41.6	42.8
P29	Type of leadership required (e.g., Project Managers)to drive the project	6332	6882	63.3	68.8
P30	Availability of knowhow to do the project - core and support areas	5192	5249	51.9	52.5
P31	Adequacy of skills to do the project - core and support areas	4763	4807	47.6	48.1
P32	Attitudes of individuals / team towards delivering the project	5024	5345	50.2	53.5
P33	Identification of corrective measures, e.g., providing training to rectify gaps	3656	3568	36.6	35.7
P34	Possible social issues	2907	2937	29.1	29.4
P35	Possible neighborhood issues	3211	3371	32.1	33.7
P36	Possible religious issues	1798	1838	18.0	18.4
P37	Possible political issues	3061	3102	30.6	31.0
P38	Stakeholder issues	4207	4356	42.1	43.6
P39	Innovative application	3460	3645	34.6	36.5
P40	New technology	4023	4230	40.2	42.3
P41	Level of details required and accuracy	5093	5392	50.9	53.9
P42	Appropriateness of specification	4799	4906	48.0	49.1
P43	Incomplete design scope	5940	5893	59.4	58.9
P44	Likelihood of change	4951	4945	49.5	49.5
P45	Interaction of design with method of construction	4971	5094	49.7	50.9
P46	Non-standardisation of details	4249	4309	42.5	43.1

P47	Non-standardisation of suppliers	3372	3574	33.7	35.7
P48	Quality control - inspection and approvals	5470	5539	54.7	55.4
P49	Temporary design - quality, responsibility and supervision	3409	3516	34.1	35.2

Annexure - 5: Risk of Exceeding Cost due to Inadequate Inputs

Rank	Activity No.	Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	Risk of Exceeding Cost	
			Sum	Mean
1	P29	Type of leadership required (e.g., Project Managers) to drive the project	6392	64
2	P43	Incomplete design scope	6006	60
3	P4	Geotechnical survey	5565	56
4	P48	Quality control - inspection and approvals	5488	55
5	P27	Availability of skilled manpower	5310	53
6	P2	Engineering survey	5237	52
7	P30	Availability of knowhow to do the project - core and support areas	5208	52
8	P41	Level of details required and accuracy	5113	51
9	P32	Attitudes of individuals / team towards delivering the project	5124	51
10	P45	Interaction of design with method of construction	5007	50
11	P44	Likelihood of change	5051	51
12	P42	Appropriateness of specification	4831	48
13	P31	Adequacy of skills to do the project - core and support areas	4779	48
14	P21	Availability of material	4638	46
15	P26	Availability of special subcontractors	4616	46
16	P18	Special conditions of contracts of tendered projects	4535	45
17	P24	Availability of equipment/ machinery / vehicles etc.	4516	45
18	P3	Land survey	4500	45
19	P6	Applicable rules and regulations	4466	45
20	P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	4379	44
21	P25	Availability of subcontractors	4372	44
22	P23	Requirement of equipment/ machinery/vehicles etc.	4318	43
23	P46	Non-standardisation of details	4309	43
24	P1	Preliminary survey	4256	43
25	P38	Stakeholder issues	4223	42
26	P16	Type of project: design and build, tendered, proposed	4222	42
27	P28	Availability of unskilled manpower	4192	42
28	P17	Conditions of contracts of tendered projects	4149	41
29	P40	New technology	4071	41
30	P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	3978	40

31	P33	Identification of corrective measures, e.g., providing training to rectify gaps	3688	37
32	P7	Information about high flood levels	3613	36
33	P22	Proximity of material	3484	35
34	P39	Innovative application	3492	35
35	P49	Temporary design - quality, responsibility and supervision	3443	34
36	P5	Environmental issues	3401	34
37	P47	Non-standardisation of suppliers	3428	34
38	P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	3341	33
39	P35	Possible neighborhood issues	3219	32
40	P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	3206	32
41	P10	Water table (variations)	3190	32
42	P14	Identification of utility agencies	3130	31
43	P37	Possible political issues	3077	31
44	P34	Possible social issues	2939	29
45	P9	Rainfall patterns	2537	25
46	P11	Wind directions	2143	21
47	P8	Recording of information about low flood levels	2087	21
48	P12	Variation patterns of wind	1927	19
49	P36	Possible religious issues	1802	18

Annexure - 6: Risk of Exceeding Time due to Inadequate Inputs

Rank	Activity No.	Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	Risk of Exceeding Time	
			Sum	Mean
1	P29	Type of leadership required (e.g., Project Managers) to drive the project	6957	70
2	P43	Incomplete design scope	5949	59
3	P4	Geotechnical survey	5714	57
4	P48	Quality control - inspection and approvals	5549	55
5	P27	Availability of skilled manpower	5531	55
6	P32	Attitudes of individuals / team towards delivering the project	5470	55
7	P41	Level of details required and accuracy	5408	54
8	P2	Engineering survey	5340	53
9	P30	Availability of knowhow to do the project - core and support areas	5276	53
10	P45	Interaction of design with method of construction	5130	51
11	P44	Likelihood of change	5057	51
12	P42	Appropriateness of specification	4930	49
13	P31	Adequacy of skills to do the project - core and support areas	4839	48
14	P21	Availability of material	4742	47
15	P26	Availability of special subcontractors	4677	47
16	P6	Applicable rules and regulations	4639	46
17	P24	Availability of equipment/ machinery / vehicles etc.	4592	46
18	P3	Land survey	4510	45
19	P1	Preliminary survey	4412	44
20	P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	4403	44
21	P25	Availability of subcontractors	4396	44
22	P38	Stakeholder issues	4388	44
23	P46	Non-standardisation of details	4365	44
24	P28	Availability of unskilled manpower	4316	43
25	P23	Requirement of equipment/ machinery/vehicles etc.	4309	43
26	P40	New technology	4254	43
27	P18	Special conditions of contracts of tendered projects	4238	42
28	P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	3955	40
29	P17	Conditions of contracts of tendered projects	3943	39
30	P16	Type of project: design and build, tendered, proposed	3798	38

31	P39	Innovative application	3661	37
32	P7	Information about high flood levels	3623	36
33	P5	Environmental issues	3618	36
34	P33	Identification of corrective measures, e.g., providing training to rectify gaps	3595	36
35	P47	Non-standardisation of suppliers	3626	36
36	P22	Proximity of material	3576	36
37	P49	Temporary design - quality, responsibility and supervision	3552	36
38	P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	3463	35
39	P35	Possible neighborhood issues	3379	34
40	P14	Identification of utility agencies	3182	32
41	P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	3182	32
42	P10	Water table (variations)	3110	31
43	P37	Possible political issues	3110	31
44	P9	Rainfall patterns	3015	30
45	P34	Possible social issues	2953	30
46	P11	Wind directions	2049	20
47	P8	Recording of information about low flood levels	1990	20
48	P12	Variation patterns of wind	1846	18
49	P36	Possible religious issues	1842	18

Annexure - 7: Interpretation of Risk of exceeding Cost due to Inadequate Inputs

Activity No.	Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	Risk Interpretation for Exceeding 'Cost'	
		Mean of Risk Estimates	Risk Interpretation
P29	Type of leadership required (e.g., Project Managers) to drive the project	64	Likely
P43	Incomplete design scope	60	Likely
P4	Geotechnical survey	55	Likely
P48	Quality control - inspection and approvals	55	Likely
P27	Availability of skilled manpower	53	Moderate
P2	Engineering survey	52	Moderate
P30	Availability of knowhow to do the project - core and support areas	52	Moderate
P41	Level of details required and accuracy	51	Moderate
P32	Attitudes of individuals / team towards delivering the project	51	Moderate
P45	Interaction of design with method of construction	50	Moderate
P44	Likelihood of change	50	Moderate
P42	Appropriateness of specification	48	Moderate
P31	Adequacy of skills to do the project - core and support areas	48	Moderate
P21	Availability of material	46	Moderate
P26	Availability of special subcontractors	46	Moderate
P18	Special conditions of contracts of tendered projects	45	Moderate
P24	Availability of equipment/ machinery / vehicles etc.	45	Moderate
P3	Land survey	45	Moderate
P6	Applicable rules and regulations	45	Moderate
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	44	Moderate
P25	Availability of subcontractors	44	Moderate
P23	Requirement of equipment/ machinery/vehicles etc.	43	Moderate

P46	Non-standardisation of details	43	Moderate
P1	Preliminary survey	43	Moderate
P38	Stakeholder issues	42	Moderate
P16	Type of project: design and build, tendered, proposed	42	Moderate
P28	Availability of unskilled manpower	42	Moderate
P17	Conditions of contracts of tendered projects	41	Moderate
P40	New technology	40	Moderate
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	40	Moderate
P33	Identification of corrective measures, e.g., providing training to rectify gaps	37	Moderate
P7	Information about high flood levels	36	Low
P22	Proximity of material	35	Low
P39	Innovative application	35	Low
P49	Temporary design - quality, responsibility and supervision	34	Low
P5	Environmental issues	34	Low
P47	Non-standardisation of suppliers	34	Low
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	33	Low
P35	Possible neighborhood issues	32	Low
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	32	Low
P10	Water table (variations)	32	Low
P14	Identification of utility agencies	31	Low
P37	Possible political issues	31	Low
P34	Possible social issues	29	Low
P9	Rainfall patterns	25	Low
P11	Wind directions	21	Low
P8	Recording of information about low flood levels	21	Low
P12	Variation patterns of wind	19	Low
P36	Possible religious issues	18	Low

Annexure - 8: Interpretation of Risk of exceeding Time due to Inadequate Inputs

Activity No.	(A) Preconstruction Activity contributed Inadequate Input to the Design phase (PCA)	Risk Interpretation for Exceeding 'Time'	
		Mean of Risk Estimates	Risk Interpretation Time
P29	Type of leadership required (e.g., Project Managers)to drive the project	69.57	Likely
P43	Incomplete design scope	59.25	Likely
P4	Geotechnical survey	56.5	Likely
P48	Quality control - inspection and approvals	55.89	Likely
P27	Availability of skilled manpower	55.31	Likely
P32	Attitudes of individuals / team towards delivering the project	54.7	Likely
P41	Level of details required and accuracy	54.56	Likely
P2	Engineering survey	53.4	Moderate
P30	Availability of knowhow to do the project - core and support areas	52.76	Moderate
P45	Interaction of design with method of construction	51.42	Moderate
P44	Likelihood of change	49.53	Moderate
P42	Appropriateness of specification	49.46	Moderate
P31	Adequacy of skills to do the project - core and support areas	48.39	Moderate
P21	Availability of material	47.42	Moderate
P26	Availability of special subcontractors	46.77	Moderate
P6	Applicable rules and regulations	46.39	Moderate
P24	Availability of equipment/ machinery / vehicles etc.	45.92	Moderate
P3	Land survey	45.1	Moderate
P1	Preliminary survey	44.12	Moderate
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	44.03	Moderate
P25	Availability of subcontractors	43.96	Moderate
P38	Stakeholder issues	43.88	Moderate
P46	Non-standardisation of details	43.21	Moderate

P28	Availability of unskilled manpower	43.16	Moderate
P23	Requirement of equipment/ machinery/vehicles etc.	43.09	Moderate
P40	New technology	42.46	Moderate
P18	Special conditions of contracts of tendered projects	42.38	Moderate
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	39.55	Moderate
P17	Conditions of contracts of tendered projects	39.43	Moderate
P16	Type of project: design and build, tendered, proposed	37.98	Moderate
P39	Innovative application	36.61	Moderate
P7	Information about high flood levels	36.23	Moderate
P5	Environmental issues	36.18	Low
P33	Identification of corrective measures, e.g., providing training to rectify gaps	35.95	Low
P47	Non-standardisation of suppliers	35.86	Low
P22	Proximity of material	35.76	Low
P49	Temporary design - quality, responsibility and supervision	35.32	Low
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	34.63	Low
P35	Possible neighborhood issues	33.79	Low
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	31.82	Low
P14	Identification of utility agencies	31.82	Low
P10	Water table (variations)	31.1	Low
P37	Possible political issues	31.1	Low
P9	Rainfall patterns	30.15	Low
P34	Possible social issues	29.53	Low
P11	Wind directions	20.49	Low
P8	Recording of information about low flood levels	19.9	Low
P12	Variation patterns of wind	18.46	Low
P36	Possible religious issues	18.42	Low

Annexure - 9: Results of RII analysis of forty-nine preconstruction activities.

#	Preconstruction Activity	RII Value for 'Impact'	RII Value for 'Likelihood'	RII Value for 'Cost'	RII Value for 'Time'
P1	Preliminary survey	0.76	0.594	0.63	0.648
P2	Engineering survey	0.834	0.628	0.714	0.73
P3	Land survey	0.738	0.612	0.636	0.644
P4	Geotechnical survey	0.82	0.628	0.74	0.762
P5	Environmental issues	0.674	0.614	0.578	0.644
P6	Applicable rules and regulations	0.788	0.644	0.658	0.71
P7	Information about high flood levels	0.678	0.554	0.55	0.558
P8	Recording of information about low flood levels	0.526	0.464	0.428	0.414
P9	Rainfall patterns	0.624	0.524	0.49	0.616
P10	Water table (variations)	0.66	0.582	0.574	0.57
P11	Wind directions	0.498	0.418	0.414	0.4
P12	Variation patterns of wind	0.44	0.408	0.414	0.384
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	0.706	0.612	0.63	0.622
P14	Identification of utility agencies	0.648	0.572	0.536	0.55
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	0.746	0.648	0.646	0.642
P16	Type of project: design and build, tendered, proposed	0.724	0.58	0.676	0.622
P17	Conditions of contracts of tendered projects	0.68	0.626	0.636	0.624
P18	Special conditions of contracts of tendered projects	0.712	0.636	0.666	0.64
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	0.674	0.572	0.578	0.596

P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	0.624	0.548	0.546	0.548
P21	Availability of material	0.718	0.658	0.698	0.726
P22	Proximity of material	0.628	0.596	0.622	0.638
P23	Requirement of equipment/ machinery/vehicles etc.	0.698	0.61	0.682	0.69
P24	Availability of equipment/ machinery / vehicles etc.	0.732	0.624	0.694	0.708
P25	Availability of subcontractors	0.7	0.616	0.686	0.698
P26	Availability of special subcontractors	0.712	0.634	0.708	0.728
P27	Availability of skilled manpower	0.752	0.714	0.748	0.786
P28	Availability of unskilled manpower	0.652	0.678	0.672	0.718
P29	Type of leadership required (e.g. Project Managers) to drive the project	0.828	0.766	0.748	0.822
P30	Availability of knowhow to do the project - core and support areas	0.758	0.688	0.708	0.734
P31	Adequacy of skills to do the project - core and support areas	0.722	0.684	0.696	0.708
P32	Attitudes of individuals / team towards delivering the project	0.73	0.692	0.686	0.724
P33	Identification of corrective measures, e.g., providing training to rectify gaps	0.656	0.618	0.578	0.574
P34	Possible social issues	0.608	0.554	0.522	0.542
P35	Possible neighborhood issues	0.602	0.564	0.546	0.586
P36	Possible religious issues	0.454	0.426	0.398	0.424
P37	Possible political issues	0.574	0.544	0.526	0.526
P38	Stakeholder issues	0.698	0.66	0.614	0.652
P39	Innovative application	0.662	0.582	0.55	0.578
P40	New technology	0.718	0.644	0.594	0.614

P41	Level of details required and accuracy	0.77	0.706	0.658	0.688
P42	Appropriateness of specification	0.782	0.67	0.674	0.686
P43	Incomplete design scope	0.77	0.73	0.76	0.746
P44	Likelihood of change	0.706	0.686	0.69	0.666
P45	Interaction of design with method of construction	0.754	0.694	0.676	0.7
P46	Non-standardisation of details	0.698	0.628	0.646	0.64
P47	Non-standardisation of suppliers	0.64	0.594	0.592	0.622
P48	Quality control - inspection and approvals	0.754	0.7	0.686	0.718
P49	Temporary design - quality, responsibility and supervision	0.628	0.594	0.584	0.61

Annexure - 10: Results of SI analysis of forty-nine preconstruction activities.

#	Preconstruction Activity	SI value for 'Impact'	SI value for 'Likely-hood'	SI value for 'Cost	SI value for 'Time'
P1	Preliminary survey	0.676	0.58	0.63	0.648
P2	Engineering survey	0.718	0.614	0.714	0.73
P3	Land survey	0.696	0.59	0.636	0.644
P4	Geotechnical survey	0.718	0.612	0.74	0.762
P5	Environmental issues	0.674	0.578	0.578	0.644
P6	Applicable rules and regulations	0.722	0.616	0.658	0.71
P7	Information about high flood levels	0.608	0.538	0.55	0.558
P8	Recording of information about low flood levels	0.524	0.45	0.428	0.414
P9	Rainfall patterns	0.57	0.506	0.49	0.616
P10	Water table (variations)	0.652	0.568	0.574	0.57
P11	Wind directions	0.452	0.402	0.414	0.4
P12	Variation patterns of wind	0.438	0.39	0.414	0.384
P13	Location of existing utilities (water, power, telecom, Wi-Fi etc.)	0.678	0.586	0.63	0.622
P14	Identification of utility agencies	0.628	0.55	0.536	0.55
P15	Availability of utilities (water, power, telecom, Wi-Fi etc.)	0.73	0.62	0.646	0.642
P16	Type of project: design and build, tendered, proposed	0.646	0.564	0.676	0.622
P17	Conditions of contracts of tendered projects	0.706	0.606	0.636	0.624
P18	Special conditions of contracts of tendered projects	0.712	0.608	0.666	0.64
P19	Investigation of access roads (capacity, width, surface, bottlenecks etc.)	0.628	0.548	0.578	0.596
P20	Assessment of the capacities of culverts, bridges, etc. on the access roads	0.602	0.516	0.546	0.548
P21	Availability of material	0.738	0.634	0.698	0.726

P22	Proximity of material	0.66	0.572	0.608	0.638
P23	Requirement of equipment/ machinery/vehicles etc.	0.698	0.592	0.682	0.69
P24	Availability of equipment/ machinery / vehicles etc.	0.704	0.604	0.694	0.708
P25	Availability of subcontractors	0.7	0.6	0.686	0.686
P26	Availability of special subcontractors	0.722	0.618	0.708	0.728
P27	Availability of skilled manpower	0.788	0.682	0.748	0.786
P28	Availability of unskilled manpower	0.754	0.644	0.672	0.718
P29	Type of leadership required (e.g., Project Managers) to drive the project	0.834	0.734	0.748	0.822
P30	Availability of knowhow to do the project - core and support areas	0.758	0.662	0.708	0.734
P31	Adequacy of skills to do the project - core and support areas	0.754	0.658	0.696	0.708
P32	Attitudes of individuals / team towards delivering the project	0.77	0.666	0.686	0.724
P33	Identification of corrective measures, e.g. providing training to rectify gaps	0.698	0.596	0.578	0.574
P34	Possible social issues	0.638	0.554	0.522	0.528
P35	Possible neighborhood issues	0.624	0.546	0.546	0.586
P36	Possible religious issues	0.496	0.426	0.398	0.424
P37	Possible political issues	0.624	0.544	0.526	0.526
P38	Stakeholder issues	0.744	0.636	0.614	0.652
P39	Innovative application	0.656	0.57	0.55	0.578
P40	New technology	0.732	0.622	0.594	0.614
P41	Level of details required and accuracy	0.82	0.682	0.658	0.688
P42	Appropriateness of specification	0.752	0.644	0.674	0.686
P43	Incomplete design scope	0.828	0.696	0.76	0.746
P44	Likelihood of change	0.76	0.662	0.69	0.666
P45	Interaction of design with method of construction	0.77	0.67	0.676	0.7
P46	Non-standardisation of details	0.712	0.608	0.646	0.64
P47	Non-standardisation of suppliers	0.674	0.572	0.592	0.622

P48	Quality control - inspection and approvals	0.782	0.676	0.686	0.718
P49	Temporary design - quality, responsibility and supervision	0.662	0.572	0.584	0.61

Annexure - 11: Results of Descriptive Statistics analysis for category 'Cost'.

#	Preconstruction Activity	N	Minimum	Maximum	Mean	Standard Deviation
1	P43	99	1	5	3.84	1.193
2	P29	100	1	5	3.74	1.079
3	P27	100	1	5	3.74	0.97
4	P4	99	1	5	3.74	1.234
5	P2	100	1	5	3.57	1.233
6	P30	100	1	5	3.54	1.15
7	P26	100	1	5	3.54	1.141
8	P31	99	1	5	3.52	1.101
9	P21	100	1	5	3.49	1.243
10	P24	100	1	5	3.47	1.141
11	P44	100	1	5	3.45	1.095
12	P48	100	1	5	3.43	1.305
13	P32	100	1	5	3.43	1.208
14	P25	100	1	5	3.43	1.121
15	P23	100	0	5	3.41	1.181
16	P16	100	1	5	3.38	1.339
17	P45	100	1	5	3.38	1.17
18	P42	100	1	5	3.37	1.125
19	P28	100	1	5	3.36	1.01
20	P18	100	1	5	3.33	1.231
21	P41	100	1	5	3.29	1.258
22	P6	100	1	5	3.29	1.057
23	P46	100	1	5	3.23	1.254
24	P15	100	1	5	3.23	1.205
25	P17	100	1	5	3.18	1.29
26	P3	100	1	5	3.18	1.274
27	P13	100	1	5	3.15	1.234
28	P1	100	1	5	3.15	1.313
29	P22	99	1	7	3.14	1.204
30	P38	100	1	5	3.07	1.208
31	P40	100	1	5	2.97	1.185
32	P47	100	1	5	2.96	1.127
33	P49	100	1	5	2.92	1.186
34	P19	99	1	5	2.92	1.167
35	P5	100	1	5	2.89	1.127
36	P33	100	0	5	2.89	1.222
37	P10	100	1	5	2.87	1.22
38	P39	99	1	5	2.78	1.242
39	P7	99	1	5	2.78	1.266
40	P35	100	0	5	2.73	1.347
41	P20	100	1	5	2.73	1.246

42	P14	100	1	5	2.68	1.197
43	P37	100	1	5	2.63	1.261
44	P34	100	1	5	2.61	1.188
45	P9	100	0	5	2.45	1.282
46	P8	99	1	5	2.16	1.076
47	P12	99	0	5	2.09	1.179
48	P11	99	0	5	2.09	1.246
49	P36	100	1	4	1.99	0.99

Annexure - 12: Results of Descriptive Statistics analysis for category 'Time'

#	Preconstruction Activity	N	Minimum	Maximum	Mean	Standard Deviation
1	P29	100	1	5	4.11	1.043
2	P27	100	1	5	3.93	0.946
3	P4	100	1	5	3.81	1.261
4	P43	99	1	5	3.77	1.219
5	P2	99	1	5	3.69	1.251
6	P30	100	1	5	3.67	1.129
7	P26	100	1	5	3.64	1.202
8	P21	100	1	5	3.63	1.16
9	P32	100	1	5	3.62	1.293
10	P28	100	1	5	3.59	1.006
11	P48	100	1	5	3.59	1.296
12	P6	100	1	5	3.55	1.123
13	P31	100	1	5	3.54	1.167
14	P24	100	1	5	3.54	1.201
15	P45	100	0	5	3.5	1.243
16	P25	100	1	6	3.49	1.259
17	P23	100	1	5	3.45	1.158
18	P41	100	1	5	3.44	1.225
19	P42	100	1	5	3.43	1.085
20	P44	100	1	5	3.33	1.272
21	P38	100	1	5	3.26	1.244
22	P1	100	1	5	3.24	1.327
23	P22	99	1	5	3.22	1.139
24	P5	100	1	5	3.22	1.244
25	P3	100	1	5	3.22	1.323
26	P15	100	0	5	3.21	1.274
27	P18	100	1	5	3.2	1.214
28	P46	100	1	5	3.2	1.231
29	P17	100	1	5	3.12	1.208
30	P47	100	1	5	3.11	1.163
31	P13	100	1	5	3.11	1.205
32	P16	100	1	5	3.11	1.163
33	P9	100	1	5	3.08	1.39
34	P40	100	1	5	3.07	1.225
35	P49	100	1	5	3.05	1.201
36	P19	99	1	5	3.01	1.191
37	P35	99	1	5	2.96	1.269
38	P39	99	1	5	2.92	1.267
39	P33	100	1	5	2.87	1.143
40	P10	100	1	5	2.85	1.282
41	P7	99	1	5	2.82	1.257

42	P14	100	1	5	2.75	1.242
43	P20	100	1	5	2.74	1.22
44	P34	100	1	7	2.71	1.233
45	P37	100	1	5	2.63	1.397
46	P36	100	1	4	2.12	1.076
47	P8	99	1	5	2.09	1.117
48	P11	99	1	5	2.02	1.204
49	P12	99	1	5	1.94	1.159

Annexure - 13: Results of Validity analysis for the category 'Cost'.

#	Preconstruction Activity	Pearson coefficient (from Data Set)	Pearson coefficient (from Standard Table)	Validity (of Preconstruction Activity)
1	P1	.439**	0.1966	Valid
2	P2	.352**	0.1966	Valid
3	P3	.433**	0.1966	Valid
4	P4	.391**	0.1966	Valid
5	P5	.520**	0.1966	Valid
6	P6	.496**	0.1966	Valid
7	P7	.479**	0.1966	Valid
8	P8	.546**	0.1966	Valid
9	P9	.444**	0.1966	Valid
10	P10	.392**	0.1966	Valid
11	P11	.291**	0.1966	Valid
12	P12	.277**	0.1966	Valid
13	P13	.634**	0.1966	Valid
14	P14	.537**	0.1966	Valid
15	P15	.498**	0.1966	Valid
16	P16	.436**	0.1966	Valid
17	P17	.549**	0.1966	Valid
18	P18	.592**	0.1966	Valid
19	P19	.620**	0.1966	Valid
20	P20	.525**	0.1966	Valid
21	P21	.415**	0.1966	Valid
22	P22	.616**	0.1966	Valid
23	P23	.360**	0.1966	Valid
24	P24	.412**	0.1966	Valid
25	P25	.354**	0.1966	Valid
26	P26	.476**	0.1966	Valid
27	P27	.442**	0.1966	Valid
28	P28	.437**	0.1966	Valid
29	P29	.480**	0.1966	Valid
30	P30	.672**	0.1966	Valid
31	P31	.554**	0.1966	Valid
32	P32	.540**	0.1966	Valid
33	P33	.667**	0.1966	Valid

34	P34	$.445^{**}$	0.1966	Valid
35	P35	$.543^{**}$	0.1966	Valid
36	P36	$.578^{**}$	0.1966	Valid
37	P37	$.649^{**}$	0.1966	Valid
38	P38	$.544^{**}$	0.1966	Valid
39	P39	$.605^{**}$	0.1966	Valid
40	P40	$.600^{**}$	0.1966	Valid
41	P41	$.692^{**}$	0.1966	Valid
42	P42	$.693^{**}$	0.1966	Valid
43	P43	$.635^{**}$	0.1966	Valid
44	P44	$.591^{**}$	0.1966	Valid
45	P45	$.636^{**}$	0.1966	Valid
46	P46	$.690^{**}$	0.1966	Valid
47	P47	$.673^{**}$	0.1966	Valid
48	P48	$.668^{**}$	0.1966	Valid
49	P49	$.707^{**}$	0.1966	Valid

Annexure - 14: Results of Validity analysis for the category 'Time'.

#	Preconstruction Activity	Pearson coefficient (from Data Set)	Pearson coefficient (from Standard Table)	Validity of Preconstruction Activity
1	P41	$.783^{**}$	0.1966	Valid
2	P19	$.744^{**}$	0.1966	Valid
3	P42	$.740^{**}$	0.1966	Valid
4	P33	$.703^{**}$	0.1966	Valid
5	P49	$.693^{**}$	0.1966	Valid
6	P43	$.689^{**}$	0.1966	Valid
7	P22	$.672^{**}$	0.1966	Valid
8	P44	$.670^{**}$	0.1966	Valid
9	P17	$.654^{**}$	0.1966	Valid
10	P46	$.636^{**}$	0.1966	Valid
11	P45	$.634^{**}$	0.1966	Valid
12	P18	$.633^{**}$	0.1966	Valid
13	P30	$.627^{**}$	0.1966	Valid
14	P48	$.611^{**}$	0.1966	Valid
15	P20	$.607^{**}$	0.1966	Valid
16	P47	$.603^{**}$	0.1966	Valid
17	P21	$.597^{**}$	0.1966	Valid
18	P14	$.595^{**}$	0.1966	Valid
19	P23	$.586^{**}$	0.1966	Valid
20	P8	$.584^{**}$	0.1966	Valid
21	P13	$.580^{**}$	0.1966	Valid
22	P24	$.576^{**}$	0.1966	Valid
23	P32	$.575^{**}$	0.1966	Valid
24	P31	$.562^{**}$	0.1966	Valid
25	P29	$.550^{**}$	0.1966	Valid
26	P40	$.542^{**}$	0.1966	Valid
27	P26	$.536^{**}$	0.1966	Valid
28	P25	$.530^{**}$	0.1966	Valid
29	P39	$.525^{**}$	0.1966	Valid
30	P7	$.504^{**}$	0.1966	Valid
31	P5	$.499^{**}$	0.1966	Valid
32	P9	$.499^{**}$	0.1966	Valid
33	P37	$.488^{**}$	0.1966	Valid
34	P34	$.485^{**}$	0.1966	Valid

35	P3	.475**	0.1966	Valid
36	P27	.474**	0.1966	Valid
37	P4	.467**	0.1966	Valid
38	P36	.454**	0.1966	Valid
39	P28	.440**	0.1966	Valid
40	P16	.438**	0.1966	Valid
41	P12	.402**	0.1966	Valid
42	P6	.400**	0.1966	Valid
43	P15	.383**	0.1966	Valid
44	P11	.350**	0.1966	Valid
45	P38	.338**	0.1966	Valid
46	P10	.321**	0.1966	Valid
47	P1	.302**	0.1966	Valid
48	P2	.274**	0.1966	Valid
49	P35	.272**	0.1966	Valid

Annexure - 15: Results of Pearson coefficient for the category of 'Cost'.

Part of Correlations between Pre-construction Activities for the possible Overruns of Cost and results runs to thirty-six pages – hence part is presented. However, Results of the analysis of the entire Data Set is available).

Pre-construction Activity		P1	P2	P3	P4	P5	P6
P1	Pearson Correlation	1	.602**	.636**	.218*	.414**	.318**
	Sig. (2-tailed)		0.000	0.000	0.030	0.000	0.001
	N	100	100	100	99	100	100
P2	Pearson Correlation	.602**	1	.538**	.452**	.358**	0.058
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.567
	N	100	100	100	99	100	100
P3	Pearson Correlation	.636**	.538**	1	.242*	.351**	.328**
	Sig. (2-tailed)	0.000	0.000		0.016	0.000	0.001
	N	100	100	100	99	100	100
P4	Pearson Correlation	.218*	.452**	.242*	1	.344**	0.106
	Sig. (2-tailed)	0.030	0.000	0.016		0.000	0.296
	N	99	99	99	99	99	99
P5	Pearson Correlation	.414**	.358**	.351**	.344**	1	.375**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000
	N	100	100	100	99	100	100
P6	Pearson Correlation	.318**	0.058	.328**	0.106	.375**	1
	Sig. (2-tailed)	0.001	0.567	0.001	0.296	0.000	
	N	100	100	100	99	100	100
P7	Pearson Correlation	.265**	.231*	.283**	.245*	0.167	.284**
	Sig. (2-tailed)	0.008	0.022	0.005	0.015	0.099	0.004
	N	99	99	99	98	99	99
P8	Pearson Correlation	.246*	.217*	.230*	0.117	.378**	.298**
	Sig. (2-tailed)	0.014	0.031	0.022	0.250	0.000	0.003
	N	99	99	99	98	99	99
P9	Pearson Correlation	.283**	0.136	.247*	0.130	.258**	0.044
	Sig. (2-tailed)	0.004	0.176	0.013	0.201	0.009	0.661

	N	100	100	100	99	100	100
P10	Pearson Correlation	.416**	.271**	.321**	0.026	0.166	.257**
	Sig. (2-tailed)	0.000	0.006	0.001	0.798	0.099	0.010
	N	100	100	100	99	100	100
P11	Pearson Correlation	.231*	0.007	.264**	-0.008	0.124	0.180
	Sig. (2-tailed)	0.022	0.948	0.008	0.935	0.221	0.074
	N	99	99	99	98	99	99
P12	Pearson Correlation	0.085	-0.098	0.131	0.090	.208*	.231*
	Sig. (2-tailed)	0.403	0.332	0.197	0.376	0.039	0.021
	N	99	99	99	98	99	99
P13	Pearson Correlation	.354**	0.182	0.195	0.071	.237*	.377**
	Sig. (2-tailed)	0.000	0.070	0.052	0.483	0.018	0.000
	N	100	100	100	99	100	100
P14	Pearson Correlation	0.076	-0.074	-0.015	0.087	.296**	.314**
	Sig. (2-tailed)	0.453	0.466	0.884	0.394	0.003	0.001
	N	100	100	100	99	100	100
P15	Pearson Correlation	.323**	0.183	0.144	0.176	.264**	.463**
	Sig. (2-tailed)	0.001	0.069	0.153	0.081	0.008	0.000
	N	100	100	100	99	100	100
P16	Pearson Correlation	.277**	0.094	0.096	.281**	0.189	0.171
	Sig. (2-tailed)	0.005	0.353	0.344	0.005	0.060	0.089
	N	100	100	100	99	100	100
P17	Pearson Correlation	.222*	0.075	.336**	0.035	.222*	.324**
	Sig. (2-tailed)	0.026	0.461	0.001	0.731	0.026	0.001
	N	100	100	100	99	100	100
P18	Pearson Correlation	.313**	0.141	.400**	0.021	.281**	.430**
	Sig. (2-tailed)	0.002	0.162	0.000	0.835	0.005	0.000
	N	100	100	100	99	100	100
P19	Pearson Correlation	0.154	.238*	.256*	.369**	.365**	.201*
	Sig. (2-tailed)	0.127	0.018	0.011	0.000	0.000	0.047
	N	99	99	99	98	99	99

P20	Pearson Correlation	.303**	0.154	.387**	.310**	.482**	.298**
	Sig. (2-tailed)	0.002	0.127	0.000	0.002	0.000	0.003
	N	100	100	100	99	100	100
P21	Pearson Correlation	0.128	.218*	-0.043	.390**	.334**	.214*
	Sig. (2-tailed)	0.205	0.029	0.667	0.000	0.001	0.033
	N	100	100	100	99	100	100
P22	Pearson Correlation	0.170	0.105	0.096	0.179	.231*	.263**
	Sig. (2-tailed)	0.093	0.302	0.346	0.078	0.022	0.009
	N	99	99	99	98	99	99
P23	Pearson Correlation	-0.086	0.088	-0.063	.213*	0.186	0.082
	Sig. (2-tailed)	0.397	0.386	0.534	0.035	0.064	0.419
	N	100	100	100	99	100	100
P24	Pearson Correlation	-0.068	0.102	-0.073	.289**	.245*	0.145
	Sig. (2-tailed)	0.503	0.313	0.472	0.004	0.014	0.149
	N	100	100	100	99	100	100
P25	Pearson Correlation	-0.058	0.025	-0.062	.347**	0.110	0.158
	Sig. (2-tailed)	0.567	0.801	0.541	0.000	0.277	0.117
	N	100	100	100	99	100	100
P26	Pearson Correlation	-0.055	0.073	-0.012	.302**	0.180	.204*
	Sig. (2-tailed)	0.589	0.468	0.906	0.002	0.073	0.042
	N	100	100	100	99	100	100
P27	Pearson Correlation	-0.072	-0.069	0.022	0.187	0.149	.212*
	Sig. (2-tailed)	0.476	0.495	0.829	0.064	0.139	0.034
	N	100	100	100	99	100	100
P28	Pearson Correlation	0.104	.207*	.334**	0.059	0.124	0.157
	Sig. (2-tailed)	0.305	0.039	0.001	0.564	0.220	0.120
	N	100	100	100	99	100	100
P29	Pearson Correlation	-0.029	0.166	0.093	.317**	.292**	0.155
	Sig. (2-tailed)	0.773	0.099	0.357	0.001	0.003	0.123
	N	100	100	100	99	100	100
P30	Pearson Correlation	0.126	0.073	0.098	.336**	.366**	.327**

	Sig. (2-tailed)	0.210	0.471	0.330	0.001	0.000	0.001
	N	100	100	100	99	100	100
P31	Pearson Correlation	0.104	0.046	-0.060	.295**	.298**	.215*
	Sig. (2-tailed)	0.305	0.651	0.556	0.003	0.003	0.033
	N	99	99	99	98	99	99
P32	Pearson Correlation	-0.003	0.078	0.107	0.118	.213*	.281**
	Sig. (2-tailed)	0.977	0.441	0.291	0.245	0.033	0.005
	N	100	100	100	99	100	100
P33	Pearson Correlation	0.168	0.089	0.130	0.158	0.152	.338**
	Sig. (2-tailed)	0.095	0.379	0.199	0.119	0.130	0.001
	N	100	100	100	99	100	100
P34	Pearson Correlation	0.154	.229*	.220*	0.192	.382**	0.179
	Sig. (2-tailed)	0.125	0.022	0.028	0.056	0.000	0.074
	N	100	100	100	99	100	100
P35	Pearson Correlation	.400**	.282**	.429**	0.054	.439**	.417**
	Sig. (2-tailed)	0.000	0.004	0.000	0.593	0.000	0.000
	N	100	100	100	99	100	100
P36	Pearson Correlation	.265**	.236*	0.154	0.031	.334**	.312**
	Sig. (2-tailed)	0.008	0.018	0.127	0.760	0.001	0.002
	N	100	100	100	99	100	100
P37	Pearson Correlation	.302**	.332**	.237*	.270**	.419**	.218*
	Sig. (2-tailed)	0.002	0.001	0.018	0.007	0.000	0.029
	N	100	100	100	99	100	100
P38	Pearson Correlation	.324**	.285**	.353**	0.175	.273**	.300**
	Sig. (2-tailed)	0.001	0.004	0.000	0.084	0.006	0.002
	N	100	100	100	99	100	100
P39	Pearson Correlation	.263**	0.168	.269**	0.134	0.119	.352**
	Sig. (2-tailed)	0.008	0.096	0.007	0.190	0.240	0.000
	N	99	99	99	98	99	99
P40	Pearson Correlation	.302**	0.164	.278**	0.140	0.141	.265**
	Sig. (2-tailed)	0.002	0.103	0.005	0.166	0.161	0.008

	N	100	100	100	99	100	100
P41	Pearson Correlation	.212*	0.114	0.181	0.101	0.137	.308**
	Sig. (2-tailed)	0.034	0.260	0.071	0.322	0.175	0.002
	N	100	100	100	99	100	100
P42	Pearson Correlation	.413**	.349**	.404**	.305**	.295**	.198*
	Sig. (2-tailed)	0.000	0.000	0.000	0.002	0.003	0.049
	N	100	100	100	99	100	100
P43	Pearson Correlation	.269**	.256*	.380**	.391**	.266**	.207*
	Sig. (2-tailed)	0.007	0.010	0.000	0.000	0.008	0.040
	N	99	99	99	98	99	99
P44	Pearson Correlation	0.142	-0.012	.202*	.320**	.253*	.200*
	Sig. (2-tailed)	0.158	0.903	0.044	0.001	0.011	0.046
	N	100	100	100	99	100	100
P45	Pearson Correlation	.258**	0.086	.218*	0.108	.239*	.253*
	Sig. (2-tailed)	0.009	0.393	0.029	0.287	0.017	0.011
	N	100	100	100	99	100	100
P46	Pearson Correlation	.298**	.261**	.334**	0.154	.275**	.201*
	Sig. (2-tailed)	0.003	0.009	0.001	0.129	0.006	0.045
	N	100	100	100	99	100	100
P47	Pearson Correlation	0.161	0.140	0.153	0.124	.227*	0.188
	Sig. (2-tailed)	0.110	0.164	0.129	0.222	0.023	0.061
	N	100	100	100	99	100	100
P48	Pearson Correlation	0.168	0.141	0.068	0.152	.211*	.202*
	Sig. (2-tailed)	0.094	0.161	0.499	0.134	0.035	0.044
	N	100	100	100	99	100	100
P49	Pearson Correlation	.215*	0.170	0.157	0.166	.295**	0.188
	Sig. (2-tailed)	0.032	0.092	0.120	0.101	0.003	0.061
	N	100	100	100	99	100	100
Total score	Pearson Correlation	.439**	.352**	.433**	.391**	.520**	.496**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	100	100	100	99	100	100

Annexure - 16: Results of Pearson coefficient for the category of 'Time'.

Part of Correlations between Pre-construction Activities for the possible Overruns of TIME and results runs to thirty-six pages – hence part is presented. However, Results of the analysis of the entire Data Set is available).

Pre-construction Activity		P1	P2	P3	P4	P5	P6
P1	Pearson Correlation	1	.591**	.614**	.221*	.378**	.284**
	Sig. (2-tailed)		0.000	0.000	0.027	0.000	0.004
	N	100	99	100	100	100	100
P2	Pearson Correlation	.591**	1	.546**	.554**	.357**	0.161
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.112
	N	99	99	99	99	99	99
P3	Pearson Correlation	.614**	.546**	1	.358**	.455**	.387**
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000
	N	100	99	100	100	100	100
P4	Pearson Correlation	.221*	.554**	.358**	1	.265**	0.189
	Sig. (2-tailed)	0.027	0.000	0.000		0.008	0.060
	N	100	99	100	100	100	100
P5	Pearson Correlation	.378**	.357**	.455**	.265**	1	.339**
	Sig. (2-tailed)	0.000	0.000	0.000	0.008		0.001
	N	100	99	100	100	100	100
P6	Pearson Correlation	.284**	0.161	.387**	0.189	.339**	1
	Sig. (2-tailed)	0.004	0.112	0.000	0.060	0.001	
	N	100	99	100	100	100	100
P7	Pearson Correlation	.202*	0.184	.391**	.221*	.392**	0.115
	Sig. (2-tailed)	0.044	0.070	0.000	0.028	0.000	0.256
	N	99	98	99	99	99	99
P8	Pearson Correlation	-0.001	0.021	0.138	.216*	0.164	.211*
	Sig. (2-tailed)	0.995	0.839	0.175	0.032	0.105	0.036
	N	99	98	99	99	99	99
P9	Pearson Correlation	0.077	0.022	0.040	.216*	.299**	-0.003
	Sig. (2-tailed)	0.446	0.826	0.694	0.031	0.002	0.980

	N	100	99	100	100	100	100
P10	Pearson Correlation	-0.008	-0.131	0.014	0.101	-0.023	-0.082
	Sig. (2-tailed)	0.935	0.198	0.892	0.318	0.817	0.415
	N	100	99	100	100	100	100
P11	Pearson Correlation	0.080	-0.041	0.131	0.104	0.045	0.014
	Sig. (2-tailed)	0.432	0.687	0.196	0.308	0.657	0.889
	N	99	98	99	99	99	99
P12	Pearson Correlation	-0.083	-0.032	0.015	0.138	0.044	-0.005
	Sig. (2-tailed)	0.412	0.752	0.879	0.173	0.664	0.959
	N	99	98	99	99	99	99
P13	Pearson Correlation	0.192	0.035	.295**	0.120	.341**	.298**
	Sig. (2-tailed)	0.056	0.733	0.003	0.233	0.001	0.003
	N	100	99	100	100	100	100
P14	Pearson Correlation	0.135	-0.005	0.175	0.131	.337**	.223*
	Sig. (2-tailed)	0.181	0.958	0.081	0.195	0.001	0.026
	N	100	99	100	100	100	100
P15	Pearson Correlation	.299**	.225*	.320**	0.101	.302**	.335**
	Sig. (2-tailed)	0.003	0.025	0.001	0.319	0.002	0.001
	N	100	99	100	100	100	100
P16	Pearson Correlation	0.186	.239*	.247*	.235*	.270**	.309**
	Sig. (2-tailed)	0.064	0.017	0.013	0.019	0.007	0.002
	N	100	99	100	100	100	100
P17	Pearson Correlation	.228*	0.173	.413**	0.134	.372**	.368**
	Sig. (2-tailed)	0.023	0.087	0.000	0.182	0.000	0.000
	N	100	99	100	100	100	100
P18	Pearson Correlation	.308**	0.135	.425**	0.065	.312**	.393**
	Sig. (2-tailed)	0.002	0.181	0.000	0.523	0.002	0.000
	N	100	99	100	100	100	100
P19	Pearson Correlation	0.185	.241*	.282**	.300**	.296**	.308**
	Sig. (2-tailed)	0.067	0.017	0.005	0.003	0.003	0.002
	N	99	98	99	99	99	99

P20	Pearson Correlation	0.164	0.091	.255*	.243*	.324**	0.069
	Sig. (2-tailed)	0.103	0.372	0.010	0.015	0.001	0.498
	N	100	99	100	100	100	100
P21	Pearson Correlation	0.098	.313**	0.159	.455**	.197*	.321**
	Sig. (2-tailed)	0.334	0.002	0.114	0.000	0.050	0.001
	N	100	99	100	100	100	100
P22	Pearson Correlation	0.181	0.193	.405**	.230*	.243*	.229*
	Sig. (2-tailed)	0.073	0.057	0.000	0.022	0.015	0.023
	N	99	98	99	99	99	99
P23	Pearson Correlation	0.047	.246*	.258**	.336**	0.183	.289**
	Sig. (2-tailed)	0.640	0.014	0.010	0.001	0.068	0.003
	N	100	99	100	100	100	100
P24	Pearson Correlation	0.026	.256*	0.134	.342**	0.170	0.167
	Sig. (2-tailed)	0.800	0.010	0.183	0.000	0.091	0.097
	N	100	99	100	100	100	100
P25	Pearson Correlation	-0.071	0.020	0.007	.352**	0.027	0.172
	Sig. (2-tailed)	0.482	0.848	0.942	0.000	0.788	0.087
	N	100	99	100	100	100	100
P26	Pearson Correlation	-0.059	0.079	0.095	.354**	0.101	0.148
	Sig. (2-tailed)	0.558	0.436	0.348	0.000	0.318	0.141
	N	100	99	100	100	100	100
P27	Pearson Correlation	0.086	0.033	0.053	.268**	0.108	0.056
	Sig. (2-tailed)	0.395	0.748	0.602	0.007	0.286	0.582
	N	100	99	100	100	100	100
P28	Pearson Correlation	0.037	0.114	.213*	0.153	0.073	0.041
	Sig. (2-tailed)	0.717	0.260	0.034	0.129	0.472	0.688
	N	100	99	100	100	100	100
P29	Pearson Correlation	0.068	0.147	0.143	.446**	.261**	0.163
	Sig. (2-tailed)	0.500	0.147	0.155	0.000	0.009	0.104
	N	100	99	100	100	100	100
P30	Pearson Correlation	0.134	0.130	.225*	.346**	.354**	.272**

	Sig. (2-tailed)	0.183	0.201	0.024	0.000	0.000	0.006
	N	100	99	100	100	100	100
P31	Pearson Correlation	-0.137	0.083	0.060	.448**	0.119	0.064
	Sig. (2-tailed)	0.175	0.414	0.555	0.000	0.238	0.527
	N	100	99	100	100	100	100
P32	Pearson Correlation	-0.070	0.003	0.091	.290**	0.034	0.132
	Sig. (2-tailed)	0.489	0.980	0.369	0.003	0.740	0.192
	N	100	99	100	100	100	100
P33	Pearson Correlation	0.067	0.076	0.099	.312**	.205*	0.104
	Sig. (2-tailed)	0.505	0.456	0.326	0.002	0.041	0.305
	N	100	99	100	100	100	100
P34	Pearson Correlation	0.105	0.030	0.108	0.179	.450**	.372**
	Sig. (2-tailed)	0.300	0.765	0.286	0.075	0.000	0.000
	N	100	99	100	100	100	100
P35	Pearson Correlation	0.151	-0.028	0.182	-0.075	.424**	.279**
	Sig. (2-tailed)	0.135	0.786	0.071	0.463	0.000	0.005
	N	99	98	99	99	99	99
P36	Pearson Correlation	0.015	-0.042	0.095	-0.013	.282**	0.196
	Sig. (2-tailed)	0.882	0.679	0.348	0.899	0.004	0.051
	N	100	99	100	100	100	100
P37	Pearson Correlation	0.152	0.101	0.176	0.178	.408**	0.060
	Sig. (2-tailed)	0.131	0.319	0.080	0.077	0.000	0.552
	N	100	99	100	100	100	100
P38	Pearson Correlation	0.139	0.034	.204*	0.064	.269**	0.142
	Sig. (2-tailed)	0.167	0.742	0.041	0.527	0.007	0.157
	N	100	99	100	100	100	100
P39	Pearson Correlation	.283**	0.151	.399**	0.137	.310**	.246*
	Sig. (2-tailed)	0.004	0.137	0.000	0.178	0.002	0.014
	N	99	98	99	99	99	99
P40	Pearson Correlation	0.195	0.068	.252*	0.081	.321**	0.192
	Sig. (2-tailed)	0.052	0.506	0.011	0.425	0.001	0.056

	N	100	99	100	100	100	100
P41	Pearson Correlation	0.115	0.124	.351**	.310**	.320**	0.182
	Sig. (2-tailed)	0.256	0.220	0.000	0.002	0.001	0.070
	N	100	99	100	100	100	100
P42	Pearson Correlation	.243*	.198*	.278**	.370**	.289**	.210*
	Sig. (2-tailed)	0.015	0.049	0.005	0.000	0.004	0.036
	N	100	99	100	100	100	100
P43	Pearson Correlation	.210*	0.178	.309**	.381**	.322**	.295**
	Sig. (2-tailed)	0.037	0.079	0.002	0.000	0.001	0.003
	N	99	98	99	99	99	99
P44	Pearson Correlation	0.132	0.034	.221*	.361**	.273**	0.056
	Sig. (2-tailed)	0.190	0.738	0.027	0.000	0.006	0.583
	N	100	99	100	100	100	100
P45	Pearson Correlation	.300**	0.159	.344**	.338**	0.183	0.170
	Sig. (2-tailed)	0.002	0.116	0.000	0.001	0.069	0.091
	N	100	99	100	100	100	100
P46	Pearson Correlation	0.113	-0.031	.277**	0.181	.288**	.256*
	Sig. (2-tailed)	0.265	0.759	0.005	0.072	0.004	0.010
	N	100	99	100	100	100	100
P47	Pearson Correlation	0.120	0.031	.319**	0.173	.325**	.356**
	Sig. (2-tailed)	0.233	0.760	0.001	0.085	0.001	0.000
	N	100	99	100	100	100	100
P48	Pearson Correlation	-0.001	0.045	0.071	.298**	0.169	0.184
	Sig. (2-tailed)	0.993	0.659	0.484	0.003	0.092	0.066
	N	100	99	100	100	100	100
P49	Pearson Correlation	0.132	0.056	.286**	.206*	.290**	0.174
	Sig. (2-tailed)	0.191	0.582	0.004	0.039	0.003	0.083
	N	100	99	100	100	100	100

Annexure - 17: 'p' values for 'Minimization of Risk of exceeding Cost using IBM SPSS Analysis

Results of IBM SPSS Analysis for the most critical preconstruction activity with highest risks of exceeding Cost of construction projects as identified from the study.

P29 - Project Manager Leadership SPSS Cost-Designer

```
CORRELATIONS
  /VARIABLES=VAR00001 VAR00002
  /PRINT=TWOTAIL NOSIG
/MISSING=PAIRWISE.
```

Correlations

Notes

Output Created		10-APR-2020 13:02:43
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=VAR00001 VAR00002 /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.01

```
[DataSet0]
```

Correlations

		VAR00001	VAR00002
VAR00001	Pearson Correlation	1	.833**
	Sig. (2-tailed)		.000

	N	100	100
VAR00002	Pearson Correlation	.833**	1
	Sig. (2-tailed)	.000	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
/DEPENDENT VAR00002
  /METHOD=ENTER VAR00001.
```

Regression

Notes

Output Created		10-APR-2020 13:03:23
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT VAR00002 /METHOD=ENTER VAR00001.

Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.01
	Memory Required	2400 bytes
	Additional Memory Required for Residual Plots	0 bytes

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	VAR00001[b]	.	Enter

a. Dependent Variable: VAR00002

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.833[a]	.695	.692	23.23477

a. Predictors: (Constant), VAR00001

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	120352.236	1	120352.236	222.934	.000[b]
	Residual	52905.764	98	539.855		
	Total	173258.000	99			

a. Dependent Variable: VAR00002

b. Predictors: (Constant), VAR00001

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.322	4.408		-.527	.600
	VAR00001	.875	.059	.833	14.931	.000

a. Dependent Variable: VAR00002

```
 DESCRIPTIVES VARIABLES=VAR00001 VAR00002
/STATISTICS=MEAN STDDEV MIN MAX.
```

Descriptives

Notes

Output Created		10-APR-2020 13:04:54
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=VAR00001 VAR00002 /STATISTICS=MEAN STDDEV MIN MAX.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.00

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
VAR00001	100	3.00	200.00	63.9200	39.85344
VAR00002	100	1.00	200.00	53.6000	41.83397
Valid N (listwise)	100				

Annexure - 18: 'p' values for 'Minimization of Risk of exceeding Cost using Microsoft Excel 2019.

For the most critical preconstruction activity with highest risks of exceeding Cost of construction projects as identified from the study.

P29 - Project Manager Leadership - Results of Excel Analysis; Cost-Designer
(Minimising Risk of exceeding Time by Verification by an Independent Designer)

SUMMARY OUTPUT

Regression Statistics			
Multiple R	0.833452		
R Square	0.694642	r=	0.833452
Adjusted R Square	0.691526		
Standard Error	22.13478		
Observations	100		

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	109226.4	109226.4	222.9345	5.47E-27
Residual	98	48014.95	489.9485		
Total	99	157241.4			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	21.36193	3.60885	5.919316	4.77E-08	14.20028	28.52357	14.20028	28.52357
y Minimising Risk by Independent Designer	0.793994	0.053178	14.93099	5.47E-27	0.688465	0.899523	0.688465	0.899523

Annexure - 19: 'p' values for 'Minimization of Risk of exceeding Time using IBM SPSS Analysis

For the most critical preconstruction activity with highest risks of exceeding Cost of construction projects as identified from the study.

P29 - Project Manager Leadership - Results of SPSS Analysis; Time-Designer
(Minimising Risk of exceeding Time by Verification by an Independent Designer)

```
CORRELATIONS   /VARIABLES=VAR00001 VAR00002
  /PRINT=TWOTAIL NOSIG   /MISSING=PAIRWISE.
```

Correlations

Notes

Output Created		10-APR-2020 13:19:50
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=VAR00001 VAR00002 /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

[DataSet0]

Correlations

		VAR00001	VAR00002
VAR00001	Pearson Correlation	1	.853**
	Sig. (2-tailed)		.000

	N	100	100
VAR00002	Pearson Correlation	.853**	1
	Sig. (2-tailed)	.000	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT VAR00002

```
/METHOD=ENTER VAR00001   /METHOD=ENTER VAR00001.
```

Regression

Notes

Output Created		10-APR-2020 13:21:44
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT VAR00002 /METHOD=ENTER VAR00001 /METHOD=ENTER VAR00001.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.02

	Memory Required	2640 bytes
	Additional Memory Required for Residual Plots	0 bytes

a Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	VAR00001[b]	.	Enter

Dependent Variable: VAR00002

All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.853[a]	.728	.725	21.94596

a. Predictors: (Constant), VAR00001

a

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	126058.731	1	126058.731	261.736	.000[b]
	Residual	47199.269	98	481.625		
	Total	173258.000	99			

Dependent Variable: VAR00002

Predictors: (Constant), VAR00001

a

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-6.718	4.326		-1.553	.124
	VAR00001	.867	.054	.853	16.178	.000

a. Dependent Variable: VAR00002

```
DESCRIPTIVES VARIABLES=VAR00001 VAR00002   /STATISTICS=MEAN
STDDEV MIN MAX.
```

Descriptives

Notes

Output Created		10-APR-2020 13:23:05
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	100
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=VAR00001 VAR00002 /STATISTICS=MEAN STDDEV MIN MAX.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
VAR00001	100	1.00	200.00	69.5700	41.15682
VAR00002	100	1.00	200.00	53.6000	41.83397
Valid N (listwise)	100				

Annexure - 20: 'p' values for 'Minimization of Risk of exceeding Time using Microsoft Excel 2019

For the most critical preconstruction activity with highest risks of exceeding Time of construction projects as identified from the study.

P29 - Project Manager Leadership - Results of Excel Analysis; Time-Designer
(Minimising Risk of exceeding Time by Verification by an Independent Designer)

Regression Statistics			
Multiple R	0.852982		
R Square	0.727578	r =	0.852982
Adjusted R Square	0.724798		
Standard Error	21.59073		
Observations	100		

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	122010.9	122010.9	261.7362	1.99E-29
Residual	98	45683.65	466.1597		
Total	99	167694.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	24.59021	3.520149	6.985561	3.44E-10	17.60459	31.57583	17.60459	31.57583
y Minimising Risk by Independent Designer	0.839175	0.051871	16.17826	1.99E-29	0.73624	0.94211	0.73624	0.94211