# QUANTIFICATION AND COST IMPACTS OF RISK FACTORS CAUSING REWORKS IN ROAD INFRASTRUCTURE PROJECTS IN PAKISTAN

Thesis of

**Master's in Science**

**Construction Engineering & Management**

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This is to certify that the

thesis titled

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**THESIS ACCEPTANCE CERTIFICATE**

Certified that final copy of MS thesis written by Mr. Nauman Mustafa, Registration No. NUST2016MSCE&M0800000105861 of SCEE has been vetted by undersigned, found complete in all respects as per NUST Statutes / Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

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*This thesis is dedicated to my Mother and Father.*

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# ABSTRACT

The construction industry of Pakistan is facing many challenges leading up to several problems in the construction sector. These challenges include, but are not limited to, lack of skilled labor, political influence, environmental issues and inflation etc. The Project Management Body of Knowledge (PMBOK®) endorses that every project is governed by the triple constraint. The triple constraint includes the cost, time & quality of a certain project. All these factors affect each other in a positive or a negative way. One of the main factors affecting all these three constraints is the rework that is carried out.

Reworks result in cost overruns, time delays and in some cases, may also contribute to poor quality. However, many scenarios involve poor construction quality leading to reworks. The main purpose of this study is to identify, explore, quantify and hence rank the possible risks that may lead up to reworks in road infrastructure projects of Pakistan.

To this day, no research regarding the reworks in road infrastructure projects in Pakistan has been conducted. However, previous studies regarding reworks in construction industry have been conducted in other countries like Australia, China and Malaysia etc. From these studies it has been learned that the construction industry however being diverse have a high number of common potential risk factors that lead up to reworks regardless of the area of specific area of the industry.

Regardless of the generality of the potential risk factors, there is always some difference between the problems that might occur in a developed country and a developing country like Pakistan. Hence, these potential risk factors need to be vetted and analyzed to conform to the road infrastructure industry of Pakistan. With the help of this research the potential risk factors can be anticipated well within time and a proactive approach can be taken towards them instead of a reactive approach which will hugely affect the cost, time and quality of the project.

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| | |
|---|---|
| **BNA** | **Bin Nadeem Associates** |
| **BRT** | **Bus Rapid Transit** |
| **FWO** | **Frontier Works Organization** |
| **HCS** | **Habeeb Construction Services** |
| **JSK** | **Jaglot-Skardu Highway** |
| **LDA** | **Lahore Development Authority** |
| **MRA** | **Multiple Regression Analysis** |
| **NESPAK** | **National Engineering Services Pakistan** |
| **NLC** | **National Logistics Cell** |
| **PA** | **Percentage Agreement** |
| **PDA** | **Peshawar Development Authority** |
| **PMBOK** | **Project Management Body of Knowledge** |
| **PMI** | **Project Management Institute** |
| **RA** | **Rank Agreement Factor** |
| **RDA** | **Rawalpindi Development Authority** |
| **RII** | **Relative Importance Index** |
| **SPSS** | **Statistical Package for Social Sciences** |

# INTRODUCTION

## 1.1 Preamble

The construction industry and the overall construction process is susceptible to change. Drastic changes and unplanned events are likely to occur in the construction life cycle of a project. These changes may have positive or extremely adverse effects on the project. A risk event means that it consists of multiple outcomes which may be more or less desirable than the most likely outcome and that every possible outcome has a certain amount of probability (Smith, Merna et al. 2014).

Rework in any working environment, let alone the construction industry, is typically an undesirable event. Not only does it shatter the working spirit but can also be a leading cause of mistrust and fragile working relationship of the working team resulting in a series of blame-shaming. This negative working environment leads up to lack of productivity. During this “process by which an item is made to conform to the original requirement by completion or correction” (Ashford 2002), a deteriorating relationship can be seen amongst the stakeholders of a project which will further the negative effects on the project.

Over at the tangible effects counter, a huge effect on the cost and duration of a project can be seen. Not only the cost of the rework but also the cost of lost days is added into the budget at completion. The costs of various risks incurred during the project life results in the cost overruns, time overruns, and disputes causing problems for the stakeholders (Hillson 2003). A ripple effect can be seen because of these defects (Josephson and Hammarlund 1999) and quality failures (Barber, Graves et al. 2000). However, by focusing on the root problems and with a proactive approach these catastrophes can be avoided. The study identifies these core factors and rank them with respect to their importance in terms of cost impact and probability. The results of this study can be implemented on road infra projects in Pakistan to foresee these risks and act upon them in time.

### 1.2 Problem Statement

Cost escalations and time delays are common and amongst the main problems faced by the construction industry of Pakistan. Mega road projects in Pakistan have always faced these issues and are reported in the newspapers and official reports. Business Recorder, a renowned financial daily newspaper in Pakistan, in 2017 reported the cost escalation in some of the mega road projects in Pakistan as follows;

Lyari Expressway: Rs. 5.9 billion to Rs. 12.99 billion

Karachi Hyderabad Motorway(M-9): Rs. 24.93 billion to Rs. 36 billion

Lowari Tunnel: Rs. 7 billion to Rs. 27 billion

Hassanabdal-Havelian Expressway (E-35): Rs. 30.97 billion to Rs. 34.37 billion

Jhalkhad-Chilas Section of N-15: Rs. 2.3 billion to Rs. 7.8 billion

Takht-Bhai Overhead Bridge: Rs. 582.12 Million to Rs. 836.47 Million

The report highlighted that one of the main factors for the cost escalation is change of policies by the new government which results in rework of all the work that had already been done by their predecessor.

Similarly, Dawn News, another leading newspaper of Pakistan, published an article on April 03, 2019 which highlights the findings of a report compiled by PIT (Provincial Inspection Team) on BRT Peshawar. The official report claims that much portion of the project had to be redone because of faulty design and execution of works. It further states that an unrealistic schedule of six months was given which led to cost escalations. Flawed design and frequent changes led to reworks and cost escalations. It is noted that the cost of BRT Peshawar has escalated from Rs. 49 billion to Rs. 67.8 billion. According to (Mahmood and Kureshi 2014), the construction industry of Pakistan is facing an annual cost of Rs. 360 to Rs. 570 million as cost of poor quality. An estimated 16.91% to 26.90% of total revenue has been found as hidden cost of poor quality through 42 research studies. Poor quality is just one cause of reworks that are carried out in the construction industry.

This research study deals with the identification of these risk factors that lead up to reworks and their relative importance in terms of probability and cost impact.

## 1.3 Research Objectives:

The objectives of this study are:

- To identify risk factors causing reworks in road infrastructure projects in Pakistan
- To prioritize the identified risk factors in terms of cost escalation and probability
- Development and validation of regression model

## 1.4 Research Questions:

Following research questions are posed in the present study:

Which risk factors should a project manager, working on a road infrastructure project in Pakistan, look out for in order to avoid any rework?

What is the relative importance of these risk factors in terms of cost and probability?

## 1.5 Organization of Thesis

The thesis is organized in six chapters with the following main categories:

**Chapter 1:** Research background

**Chapter 2:** Literature review

**Chapter 3:** Research design and methodology

**Chapter 4:** Research analysis and discussions

**Chapter 5:** Subject study analysis and discussions

**Chapter 6:** Research conclusions and recommendations

The aforementioned chapters contain the following contents as stipulated below;

Chapter 1 describes the research outline, it’s need, the research objectives and questions.

Chapter 2 covers the detailed literature review part of research which will include different studies carried out throughout the globe and information about the rework factors and their impact on cost and duration of construction projects.

Chapter 3 covers the research methodology. The methodological approach includes the overall research strategy, the research design, and measures adopted for analysis of obtained data.

Chapter 4 contains the qualitative and quantitative data analysis and the discussion part. The RII ranking of the identified factors causing reworks in highway projects of Pakistan along with their cost impact via multiple regression analysis.

Chapter 5 contains the subject study analysis and discussion part. The application of the findings of the research on case studies and validation of regression model.

Chapter 6 highlights the conclusions of the research, followed by recommendations for taking corrective measures to cater for the factors causing reworks in road infrastructure industry of Pakistan.

# LITERATURE REVIEW

## 2.1 Introduction

Successful completion of a project is one of the major priorities of a project manager. But what is the criteria to determine successful performance of a project? Several factors can be found in the literature to determine the success of a project. These factors include (but are not limited to) Cost, Time, Quality, Satisfaction, Management, Safety, Technology, Organization, Environment and Resources (Alzahrani and Emsley 2013). However, the most commonly used factors to define the success of a project are Cost, Time and Quality (Moura, Teixeira et al. 2007). Reworks in a project directly affect these factors leading to a significant impact towards the success of a project. Despite the unknown circumstances that might occur during the life of a project, certain factors are found in the literature review which can be seen as recurring on several projects. Individually or combined these factors have serious ramifications towards the successful completion of a project. However, if these factors are foreseen and dealt with in time then the cost escalations and time delays in a project can be controlled to some extent. The following sections highlights important definitions and most common factors, found after detailed literature review, that contribute towards reworks in a construction project.

## 2.2 Definitions

### 2.2.1 Risk

Numerous definitions of risk can be found in the literature review. However, among these (Chia 2006)has defined risks as an uncertain event in future that if occurs will have an impact on at least one of the project-performance factors like cost, time and quality etc. The possibility of risks in a construction project always remains by definition as probability of a risk event lies between 0 to 100%. Good management practices include anticipation of these risks and taking necessary measures accordingly. These risks cannot be ignored as "unmanaged or unmitigated risks are one of the primary causes of project failure" (Royer 2000).

### 2.2.2 Rework

There are many reasons due to which reworks may be carried out in a project. Therefore, several definitions can be found in literature review for reworks. (Love 2002)has defined reworks as the process or event to be carried out as a result of deviations, faults, unqualified quality problems, or quality accidents. However, in the same year (Josephson, Larsson et al. 2002) defines rework as unnecessary objective required due to mistakes undertaken during construction. No matter what the reason behind rework may be, it is an avoidable task which is carried out to conform to the specifications in line with the final deliverable.

### 2.2.3 Cost Overruns

Cost overruns can be simply defined as the cost incurred during the completion of the project which exceeds the planned or budgeted cost. (Shehu, Endut et al. 2014) explains cost overruns as a ratio between agreed contract sum and final project sum such that a value greater than 1 represent cost overruns. A higher value represents greater cost overruns and vice versa.

### 2.2.4 Probability

(Grimmett and Welsh 2014) describe probable space as any event which associates a certain amount of randomness to it. Similarly, (Ross 2014)argues that a certain event will not be predictable in advance and will display an inherent variation to it which is devised using a probability model.

## 2.3 Rework: A Global Phenomenon

The scope of this study may be limited to Pakistan; however, the impacts and probability of rework knows no borders. (Palaneeswaran, Love et al. 2008)criticizes rework as one of the critical problems of the construction industry. The high cost escalations due to reworks is a serious concern for the construction industry. And very rightly so, as a project could result in poor cost and schedule performance due to rework (Li and Taylor 2014). After detailed literature review it is found that many major construction industries face the challenges of rework. Some researchers have gone as far as to consider construction field rework as the primary source which usually significantly causes cost overruns in a project (Fayek, Dissanayake et al. 2003). Despite such a usual occurrence of the rework in construction, it as an unnecessary effort of redoing a process/activity (Love and Li 2000) and usually a complete waste which must be avoided (Sun and Meng 2009).

## 2.4 Impacts of rework

Direct cost of rework was found to be up to 5% by (Hwang, Thomas et al. 2009) upon analyzing 359 construction projects. Similarly, two cases studies by (Love and Li 2000) revealed cost of rework as 3.15% and 2.40% of their respective project values. For an average cost escalation of 12.6%, almost 52.1% was found to be due to reworks, in an analysis of 161 construction projects in Australia (Love 2002). In another study by (Ison 1995) it was found that the direct cost of rework is usually 10% in construction projects. Direct cost of rework was found to be between 5% and 20% of contract value by (Ye, Jin et al. 2015). (Oyewobi, Ibironke et al. 2011) revealed an average rework cost of 5.06% of contract value. (Barber, Graves et al. 2000) indicated that reworks could cost up to 23% of the contract value. A real-time study of 7 construction projects by (Josephson and Hammarlund 1999) revealed that the rework/defects costs range between 2.3 to 9.4% with a mean value of about 5% of total cost. (Hwang and Yang 2014) found that reworks cause schedule delays of around 24% to 32% in Singapore. In Australia, (Love 2002) calculated a 20.7% of schedule growth due to reworks.

## 2.5 Rework: Pakistan

As of now little research has been conducted specific to rework in the highway industry of Pakistan. However, the construction industry of Pakistan is hugely affected by cost overruns and time delays for which rework plays a major role. (Nawaz, Shareef et al. 2013)found rework as the 6$^{th}$ major contributor towards cost overruns due to contractor, in construction projects in Pakistan. An extensive research conducted by (Mahmood and Kureshi 2014)the construction industry of Pakistan is facing hidden an annual cost of poor quality of about Rs. 360 to 570 Million. Poor quality leads to rework which in turn leads to cost overruns and time delays. The detailed analysis of two highway construction projects by the author reveals the factors involved the cost of poor quality.

## 2.6 Causes of Rework:

Many researches and case studies throughout the globe can be found in the literature review which gives us a healthy set of data. The data of these studies and the iterations are summarized in the Table 2.1.

**Table 2.1. Factors of Reworks Collected Through Literature Review**

| Rework Factors | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poor quality of construction technology used and machinery breakdown | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | | | ✓ | | | | | | | | | ✓ | | | | | | |
| Lack of use of advanced mechanical equipment | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor quality of construction procedure | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Ineffective use of construction management standard | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Construction errors due to misunderstanding of design and unclear instructions to workers | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | | | | | | | ✓ | | | | | | | | | | | |
| Substandard material and quality management | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | | | | ✓ | | | | | | ✓ | | | |
| Poor management and supervision | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | | ✓ | ✓ | | | | | | | | | |
| Poor and adverse site conditions | | | | ✓ | | | | | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | | | | | | | | | | | | |
| Changes made by quite difficult construction methods | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| New request from end-users to improve standards during construction | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New request from end-users during final inspection and certification stage | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Changes in government regulations, laws, and policy | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Effect of social and cultural factors | | | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor communication of construction managers | | | | | ✓ | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor coordination of subcontractor between upstream and downstream | | | | | ✓ | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor communication of construction team members | | | | | ✓ | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Failure to provide protection to the completed works | | | | | ✓ | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Lack of constructability because of separation between design and construction conditions | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor coordination of design team | ✓ | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | | | | | | | | | | | | | ✓ | | |
| Insufficient time for design stage | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inappropriate /contradictory project instructions initiated by managers | | | ✓ | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor communication path of project instructions | | | ✓ | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Plan changes by client (Acceleration /Deceleration /Compression) | ✓ | ✓ | | ✓ | | | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | | | | | | | | | | | | | | | |
| Replacement of materials/equipment during construction | ✓ | ✓ | | ✓ | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Changes made by the designers to improve quality | | | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Changes made by the contractors to improve quality | | | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Poor coordination between client and end user | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | | | | | | | | | | | | | | | | |
| Delay in providing the site conditions, such as water and electricity, to the contractor | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Project scope was changed after work had been undertaken/completed | | | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |

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| Revisions and modifications of the project function initiated by the owner/end-user | | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | |
| Unclear and ambiguous project process management | | | ✓ | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Lack of strictly fulfilled for project process management | | | ✓ | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | |
| Improper handling machinery and equipment | | ✓ | | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | |
| Poor procurement method and untimely deliveries | | ✓ | ✓ | | | ✓ | | | | | | ✓ | | | | | ✓ | | ✓ | ✓ | | ✓ | ✓ | | | | | | | |
| Poor contract documentation | | | | | | ✓ | ✓ | | | | ✓ | ✓ | | | | | | | | | | | | | ✓ | ✓ | | | | |
| Poor sub-contractor management | | | | | | | | | | | ✓ | ✓ | | | | | | | | | | | | | | | | | | |
| Poor quality management by design team | | | | | | | | | | ✓ | | ✓ | | | | | | | | | | | | | | | | | | |
| Poor briefing and coordination with client | | | | | | | | ✓ | | | | ✓ | | | | | | ✓ | | | | ✓ | | | ✓ | ✓ | | | | |
| Unclear project management process | | | | | | | | | | | ✓ | ✓ | | | | | | | | | | | | | | | | | | |
| Conflicting information | | | | | | | | | | | | | | | | | ✓ | | | | | | | | | | | | | |
| Omissions | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Inadequate skills | | | | | | | | | | | | | | | | | ✓ | | | | | | | | | | | | | |
| Materials not in right place when needed | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design errors and unrealistic schedules | | | ✓ | ✓ | | | | | | | | | | | ✓ | | | | ✓ | | | ✓ | | | ✓ | | | ✓ | ✓ | |
| Late design changes | | | ✓ | | | | | | | | | | | | | | | | ✓ | | | | | | | | | | | |
| Ineffective use of technology | | | | | | | | | | | | | | | ✓ | | | | | | | | | | | | | | | |
| Lack of professionalism by design professionals | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ✓ |
| Poor communication/Misinformation | | | ✓ | ✓ | | | | | | | ✓ | | | | | | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | | | ✓ | |
| Lack of design knowledge & experience | | | | | | | | | | | | | | | | | | | | | ✓ | ✓ | | | | ✓ | | | | |
| Lack of funding | | | | | | | | | | | | | | | | | | | | | ✓ | | | | | ✓ | | | | |
| Changes in expectations | | | | | | | | | | | ✓ | | | | | | | | | | | | | | ✓ | | | | ✓ | |

1. (Josephson and Hammarlund 1999)
2. (Josephson, Larsson et al. 2002)
3. (Fayek, Dissanayake et al. 2003)
4. (Mastenbroek 2010)
5. (Palaneeswaran, Love et al. 2008)
6. (Love, Holt et al. 2002)
7. (Hwang, Thomas et al. 2009)
8. (Lopez, Love et al. 2010)
9. (Love, Irani et al. 2004)
10. (Love and Edwards 2004)
11. (Ye, Jin et al. 2015)
12. (Yap, Low et al. 2017)
13. (Hwang and Yang 2014)
14. (Love and Li 2000)
15. (Mahamid 2017)
16. (Alwi, Keith et al. 2001)
17. (Aiyetan 2013)
18. (Oyewobi and Ogunsemi 2010)
19. (McDonald 2015)
20. (Wasfy 2010)
21. (Al Zanati and Bajracharya 2017)
22. (Raghuram and Nagavinothini 2016)
23. (Meshksar 2012)
24. (Tsehayae and Fayek 2016)
25. (Adeoye 2014)
26. (Chandrusha and Basha 2017)
27. (Mills, Williams et al. 2010)
28. (Oyewobi, Ibironke et al. 2011)
29. (Zhao, Hwang et al. 2016)
30. (Love, Edwards et al. 2010)

## 2.7 Research Gap

Extensive research can be found regarding reworks in construction industry, in the literature review. However, no research has been done specifically for road infrastructure projects. Furthermore, the literature review indicates that researchers have focused on quality improvement in road infrastructure projects but did not study reworks in detail which was found to be a primary factor in most of the studies. This study would contribute towards the importance of reworks in road infrastructure projects in Pakistan and would highlight the cost impact of the identified rework factors. The results of this study would help fulfill the knowledge gaps and lead towards a better understanding of problems faced by the road infrastructure industry of Pakistan.

# METHODOLOGY

## 3.1 Introduction

This chapter explains the methodology of this research. The contents of this chapter are the research design, initial study and literature review, questionnaire design and content, data collection, data analysis and case studies.

## 3.2 Research Design

The research design of a case study describes the strategy or a framework following which the study is conducted. This research study was carried out in 4 phases, as shown in the diagram in Fig 3.1;

1. Initial Study

   In this first phase of the study; after brief analysis and overview of the area of study a research gap was identified. Through this research gap a problem statement was derived and relative research objectives were defined.

2. Detailed Literature Review

   In this second phase of the study; an extensive literature review was carried out to identify and obtain the risk factors contributing towards rework in the construction industry. These factors were shortlisted based on the iterations in the literature review and categorized in order to create a preliminary questionnaire. The data collected through preliminary questionnaire survey and personal interviews with highly experienced industry professionals was used to develop a main questionnaire.

3. Data Collection

   In this third phase of the study; the developed questionnaire was distributed among the industry professionals. At the same time field data and structured interviews have been

   conducted for two case studies.

4. Data Analysis and Results

   In this final phase of the study; the data collected through the questionnaire survey was analyzed through various tests. Through regression analysis a conceptual approach is developed and validated via six case studies.

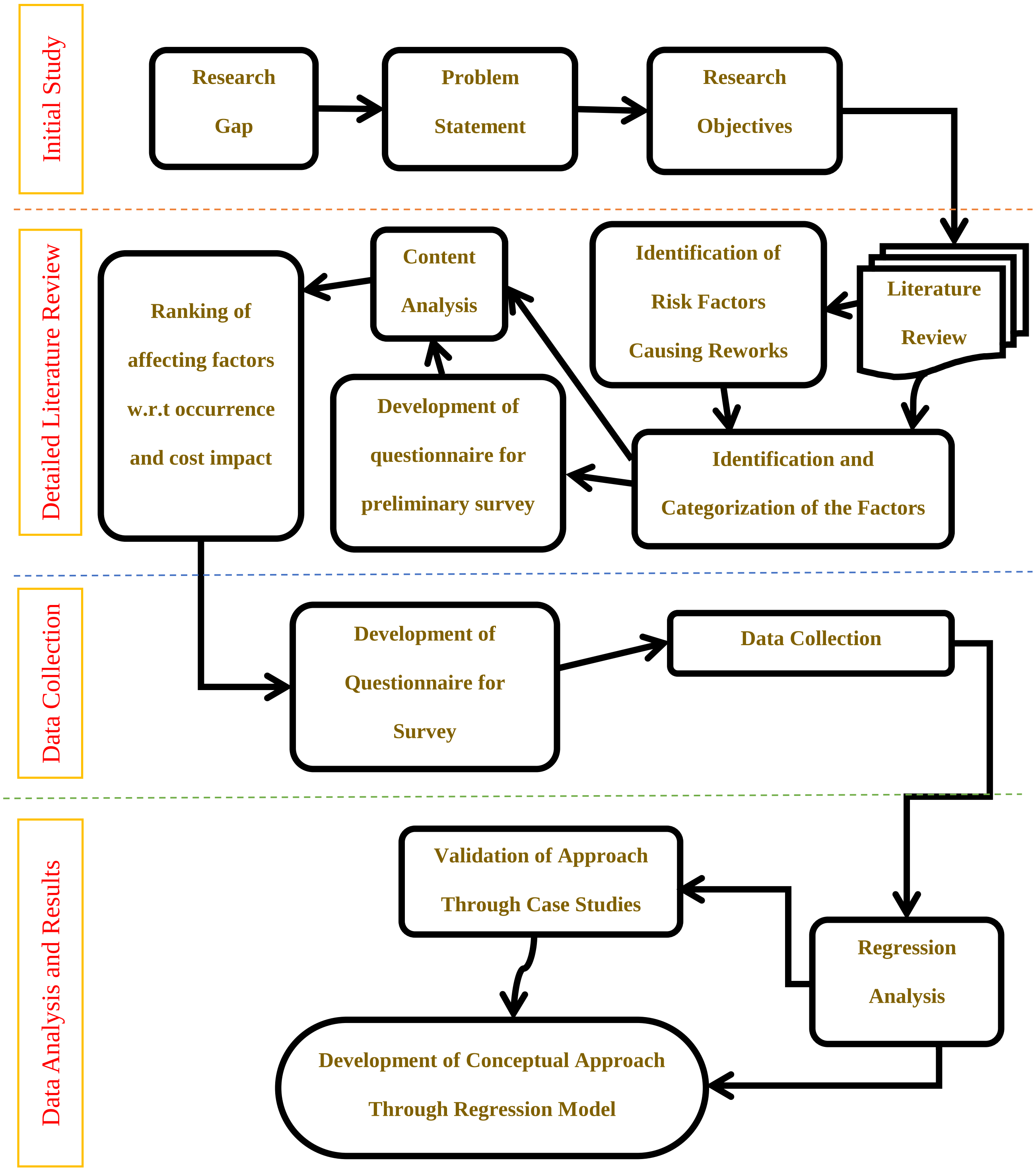


**Fig 3.1. Methodology for Research**

### 3.2.1 Initial Study & Literature Review

After consultation and detailed review of over 50 research papers, newspapers and books research gaps were discovered. These research gaps were filtered after discussion with field specialists and a problem statement was highlighted. The research objectives and targets were identified to develop a refined study. A total of 52 rework factors were acquired from the extensive literature of 30 research papers ranging from 1999 to 2017.

### 3.2.2 Questionnaire Design & Content

To shortlist the 52 rework factors obtained from the literature review and validation of the shortlisted factors, content analysis and a pilot study was conducted respectively. These 52 factors were analyzed and a total of 20 factors were shortlisted and categorized into 6 major classifications. Namely; Field Management, Planning & Design Management, Client Management, External Environment, Contract Management and Project Communication. After discussion with field specialists a questionnaire was developed for a preliminary survey. The questionnaire is divided into three major parts. The first part comprises of the personal and demographic data to develop the profile of the candidate e.g. Name, Age, Work Experience etc. The second part of the questionnaire addresses the organizational aspects of the candidate's current workplace or the one for which the candidate was employed for the longest time, whichever deemed appropriate. The third part of the questionnaire requires the candidate to answer the importance of the 20 rework factors in terms of occurrence and cost, according to their field experience. A Likert scale ranging from 1 (Least Occurrence) to 5 (Highest Occurrence) was developed to answer the occurrence of a certain rework factor. Similarly, the candidates were required to answer the effect of a certain rework factor on the total cost of rework in a project with 5 options ranging from “<20%” to “>80%”. These options were later transformed into a Likert scale from 1 to 5 for calculation of RII values. By distribution of the developed questionnaire and interviews with experienced industry professionals 25 responses were collected for the validation of the pilot questionnaire itself and the shortlisted 20 rework factors. The candidates were also asked to give feedback regarding the questionnaire and add or remove any rework factor in retrospect to the road infrastructure industry of Pakistan.

## 3.3 Data Collection

Due to the area of study restricted to Pakistan, the pilot and main survey was carried out within the construction industry of Pakistan only. After positive response from the pilot survey the questionnaire was distributed at large and a total of 115 responses were collected including the responses from the pilot survey. According to (Dillman 2011)the maximum number of responses required with 95% confidence level, ±10% sampling error and 50/50 split is 96.

| | Sample size for the 95% confidence level | | | | | |
|---|---|---|---|---|---|---|
| | ±10% Sampling Error | | ±5% Sampling Error | | ±3% Sampling Error | |
| Population Size | 50/50 split | 80/20 split | 50/50 split | 80/20 split | 50/50 split | 80/20 split |
| 100 | 49 | 38 | 80 | 71 | 92 | 87 |
| 200 | 65 | 47 | 132 | 111 | 169 | 155 |
| 400 | 78 | 53 | 196 | 153 | 291 | 253 |
| 600 | 83 | 56 | 234 | 175 | 384 | 320 |
| 800 | 86 | 57 | 260 | 188 | 458 | 369 |
| 1,000 | 88 | 58 | 278 | 198 | 517 | 406 |
| 2,000 | 92 | 60 | 322 | 219 | 696 | 509 |
| 4,000 | 94 | 61 | 351 | 232 | 843 | 584 |
| 6,000 | 95 | 61 | 361 | 236 | 906 | 613 |
| 8,000 | 95 | 61 | 367 | 239 | 942 | 629 |
| 10,000 | 95 | 61 | 370 | 240 | 965 | 640 |
| 20,000 | 96 | 61 | 377 | 243 | 1,013 | 661 |
| 40,000 | 96 | 61 | 381 | 244 | 1,040 | 672 |
| 100,000 | 96 | 61 | 383 | 245 | 1,056 | 679 |
| 1,000,000 | 96 | 61 | 384 | 246 | 1,066 | 683 |
| 1,000,000,000 | 96 | 61 | 384 | 246 | 1,067 | 683 |

**Fig 3.2. Distribution of Sample Size (Dillman 2011)**

Concurrently, field data regarding six case studies; Lahore Ring Road Pakistan, BRT Lahore Pakistan, BRT Rawalpindi-Islamabad Pakistan, BRT Peshawar Pakistan, Jaglot-Skardu Highway Pakistan and Infra Development and Rehabilitation of Sector G-14/4 Islamabad, was collected from relevant departments. All case studies are mega road infrastructure projects, and each carry their distinctive features which gives a diverse set of conditions to validate the results of this research. The data is collected through structured interviews with the project participants actively involved in the construction of the project.

## 3.4 Data Analysis & Case Studies

### 3.4.1 Relative Importance Index

The first part of this research is, as the name suggests, the quantification of factors causing reworks in road infrastructure projects in Pakistan. For this purpose, weightages are calculated and the main factors and subfactors are ranked using relative importance index as done by (Kometa, Olomolaiye et al. 1994). The relative important index was calculated using the following equation:

$$\text{Relative importance index (RII)} = \Sigma w / (A \times N)$$

**Equation 3.1**

where w = weighting given to each factor by the respondents and ranges from 1 to 5 where '1' is 'irrelevant' and '5' is 'extremely significant', A = highest weight (i.e. 5 in this case), and N = total number of respondents (i.e. in this case 115).

In the case of sub factors, a risk score value was calculated first using the following equation as used by (Hallowell and Gambatese 2009):

Risk Score = Probability × Impact

**Equation 3.2**

where values of probability and Impact range from 1 to 5, where ‘1’ is ‘insignificant’ and ‘5’ is ‘extremely significant’.

Therefore, the Relative Importance Index equation for subfactors would be the following:

Relative importance index (RII) = Σ w / (A x N)

**Equation 3.3**

where w = risk score of each subfactor by the respondents and ranges from 1 to 25 where '1' is 'irrelevant' and '25' is 'extremely significant', A = highest weight (i.e. 25 in this case), and N = total number of respondents (i.e. in this case 115).

### 3.4.2 Rank Agreement Factor and Percentage Rank Agreement

To find out the amount of agreement between different stakeholders i.e. contractor, consultant and client, a rank agreement factor was used for any two groups as used by (Okpala and Aniekwu 1988). The factor is shown in the Equation 3.4 below.

$$RA = \frac{\sum_{i=1}^{N} |Ri1 - Ri2|}{N}$$

**Equation 3.4**

While a maximum Rank agreement (RA max) is defined as;

$$RA_{max} = \frac{\sum_{i=1}^{N} |Ri1 - Rj2|}{N}$$

**Equation 3.5**

The Percentage Disagreement (PD) and Percentage Agreement (PA) are defined as;

$$PD\ (\%) = (RA / RA_{max}) \times 100$$

**Equation 3.6**

$$PA\ (\%) = 100 - PD$$

**Equation 3.7**

### 3.4.3 Multiple Regression Analysis

A different approach was taken towards determining the cost impact of main factors on the project. A multiple regression model was established using the SPSS software. The responses on the five-point scale for the occurrence and cost impact of said factors was fed to the software to determine the importance and ranking of the 6 factors. Hence, an empirical equation was derived from the software to determine the relationship between estimated percentage rework cost and main factors contributing towards reworks.

### 3.4.4 Case Studies

The data collected from the relevant departments was analyzed critically. Structured interviews along the lines of the developed questionnaire, were conducted with the engineers and personnel involved in the project with total anonymity to rule out bias towards their respective organization. The results of these six case studies were compared and applied to the results of the multiple regression analysis to validate the findings of the research. With these results the research was concluded and recommendations for further study were drafted.

# RESULTS & ANALYSIS

## 4.1 Introduction

This chapter includes the results and analysis of the questionnaire survey carried out. The chapter displays the demographic data of the participants and describes the detailed statistical analysis of the responses used to derive the findings of this research. Statistical tests carried out for reliability of the data are also part of this chapter.

Demographic Characteristics

This part of the questionnaire survey was carried out to display the strength and diversity of the population in terms of age, work experience and designation etc. The more diverse the population is the more data is believed to be reliable as it eliminates the factor of biasedness and limited line of opinion.

## 4.2 Demographic Analysis

### 4.2.1 Age

The data of age distribution is shown in Fig 4.1.

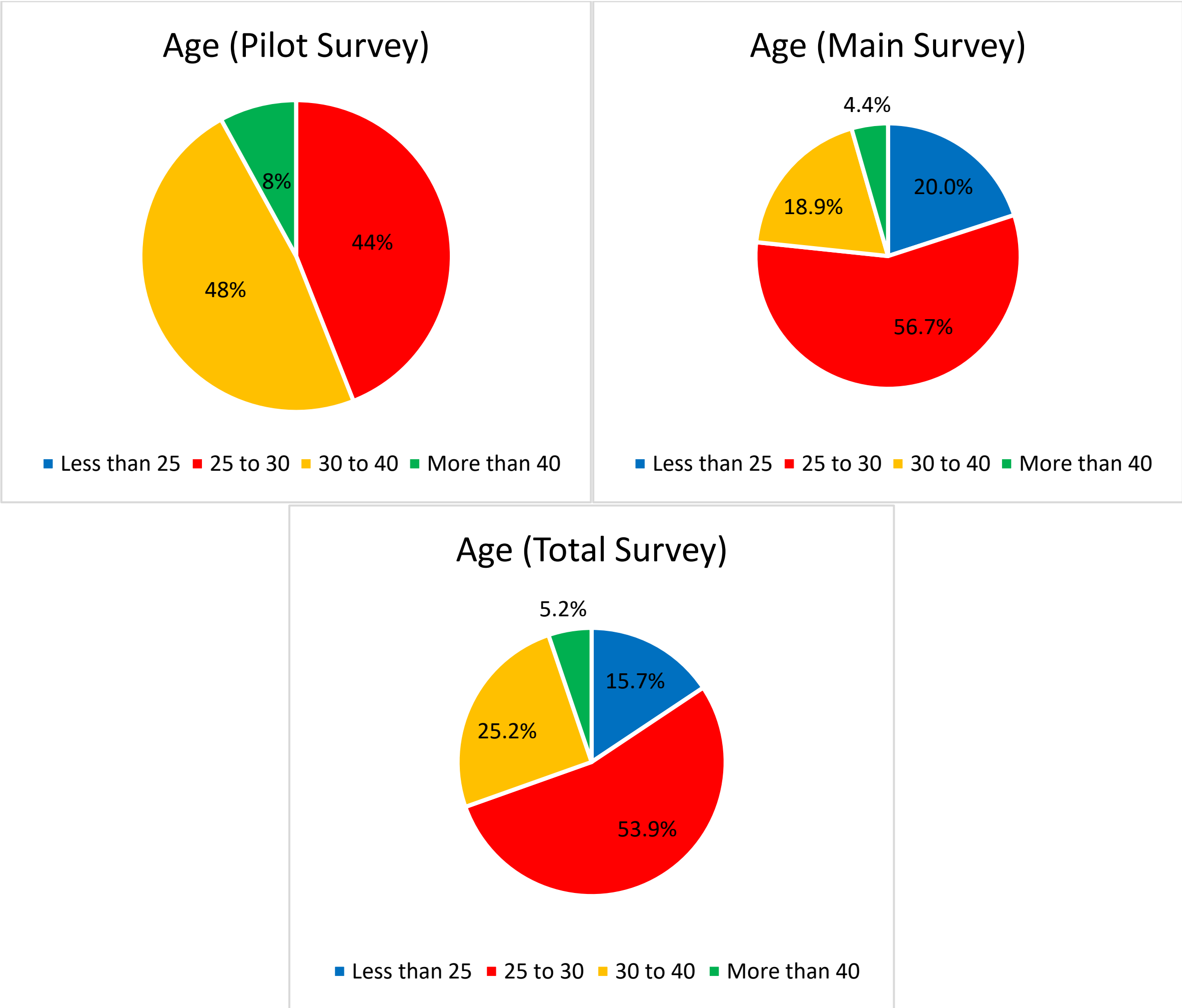


**Fig 4.1. Data for Age Distribution**

The breakdown of age responses of 25 pilot survey responses is as follows:

- Less than 25: 0 responses
- 25 to 30: 11 responses
- 30 to 40: 12 responses
- More than 40: 2 responses

The breakdown of age responses of 90 main survey responses is as follows:

- Less than 25: 18 responses
- 25 to 30: 51 responses
- 30 to 40: 17 responses
- More than 40: 4 responses

The breakdown of age responses of a total of 115 survey responses is as follows:

- Less than 25: 18 responses
- 25 to 30: 62 responses
- 30 to 40: 29 responses
- More than 40: 6 responses

### 4.2.2 Qualification

The data for qualification of respondents of pilot survey (Fig 4.2), main survey (Fig 4.3) and total survey (Fig 4.4) is shown below.

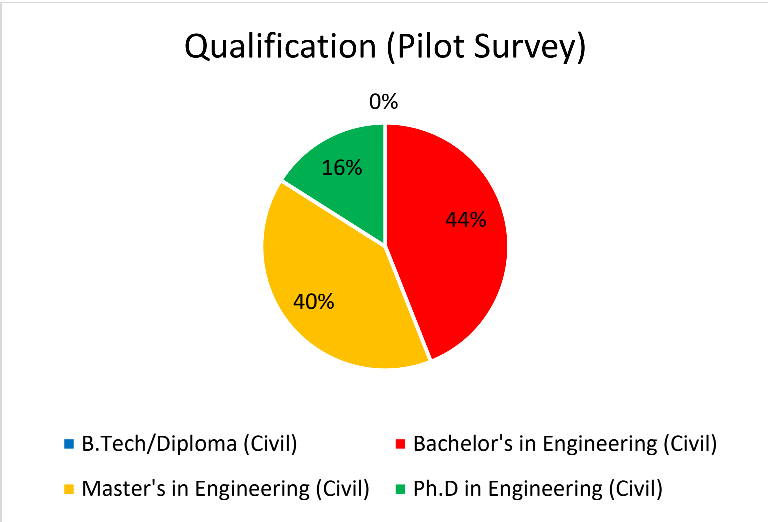


**Fig. 4.2. Data for Qualification (Pilot Survey)**

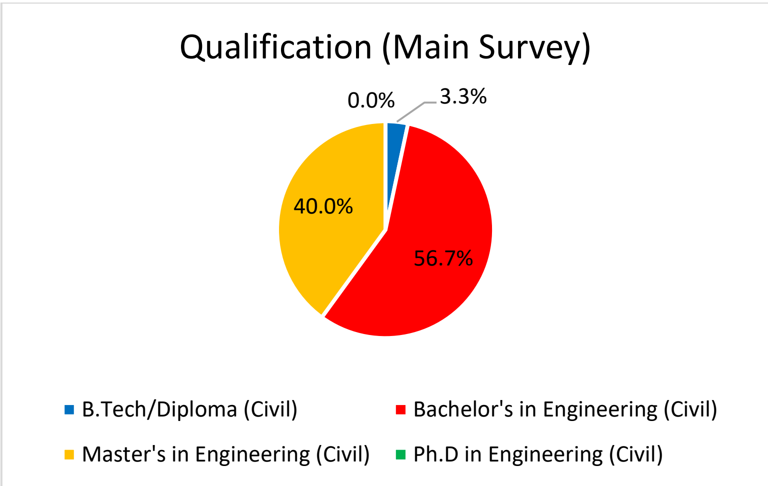


**Fig 4.3. Data for Qualification (Main Survey)**

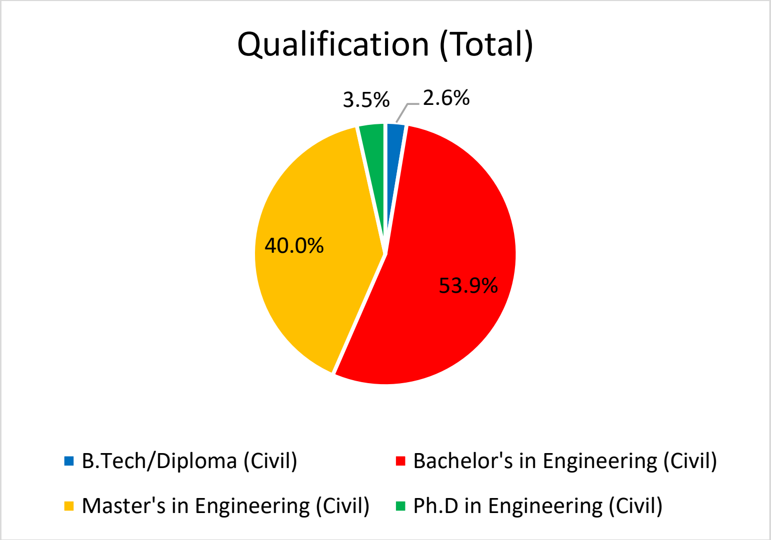


**Fig 4.4. Data for Qualification (Total)**

The breakdown of highest qualification responses of 25 pilot survey responses is as follows:

- B.Tech/Diploma (Civil): 0 responses
- Bachelor's in Engineering (Civil): 11 responses
- Master's in Engineering (Civil): 10 responses
- Ph.D. in Engineering (Civil): 4 response

The breakdown of highest qualification responses of 90 main survey responses is as follows:

- B.Tech/Diploma (Civil): 3 responses
- Bachelor's in Engineering (Civil): 51 responses
- Master's in Engineering (Civil): 36 responses
- Ph.D. in Engineering (Civil): 0 responses

The breakdown of highest qualification responses of a total of 115 survey responses is as follows:

- B.Tech/Diploma (Civil): 3 responses
- Bachelor's in Engineering (Civil): 62 responses

- Master's in Engineering (Civil): 46 responses
- Ph.D. in Engineering (Civil): 4 responses

### 4.2.3 Work Experience (Overall)

The data for work experience (Overall) of respondents for pilot survey (Fig 4.5), main survey (Fig 4.6) and total survey (Fig 4.7) is shown below.

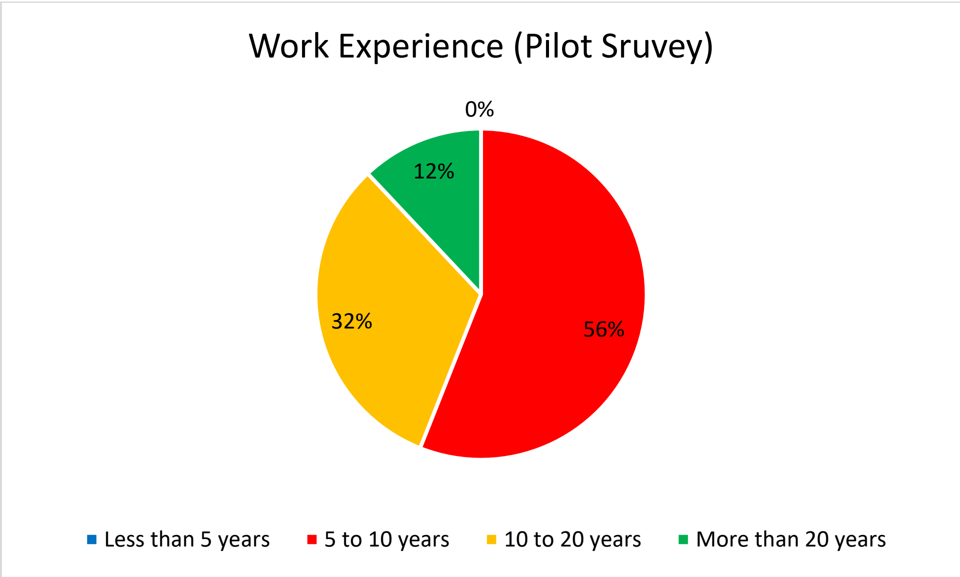


**Fig 4.5. Data for Work Experience – Overall (Pilot Survey)**

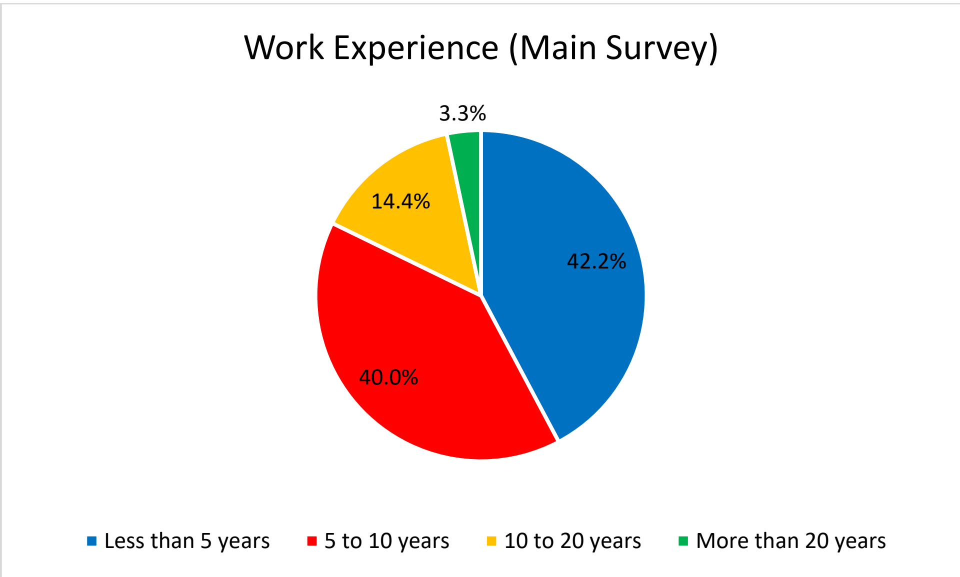


**Fig 4.6. Data for Work Experience – Overall (Main Survey)**

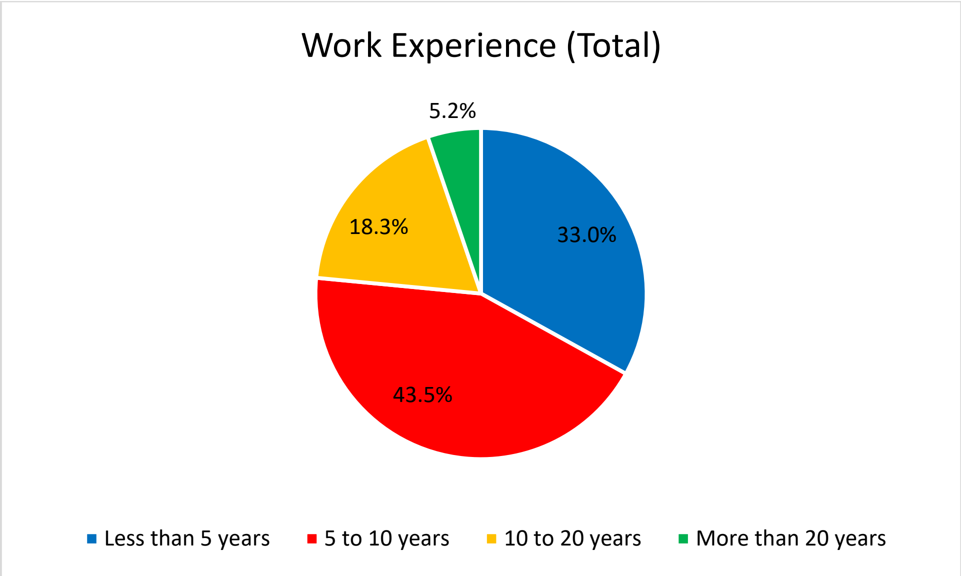


**Fig 4.7. Data for Work Experience – Overall (Total)**

The breakdown of overall work experience responses of 25 pilot survey responses is as follows:

- Less than 5 years: 0 responses
- 5 to 10 years: 14 responses
- 10 to 20 years: 8 responses
- More than 20 years: 3 responses

The breakdown of overall work experience responses of 90 main survey responses is as follows:

- Less than 5 years: 38 responses
- 5 to 10 years: 36 responses
- 10 to 20 years: 13 responses

- More than 20 years: 3 responses

The breakdown of overall work experience responses of a total of115 survey responses is as follows:

- Less than 5 years: 38 responses
- 5 to 10 years: 50 responses
- 10 to 20 years: 21 responses
- More than 20 years: 6 responses

### 4.2.4 Work Experience (Road Infrastructure)

The data for work experience (Road Infrastructure) of respondents for pilot survey (Fig 4.8), main survey (Fig 4.9) and total survey (Fig 4.10) is shown below.

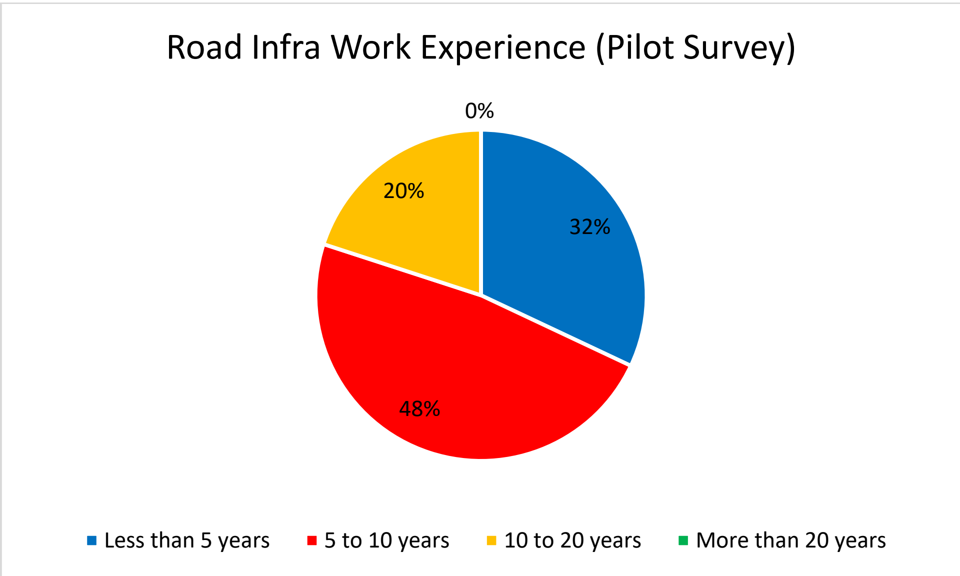


**Fig 4.8. Data for Work Experience – Road Infrastructure(Pilot Survey)**

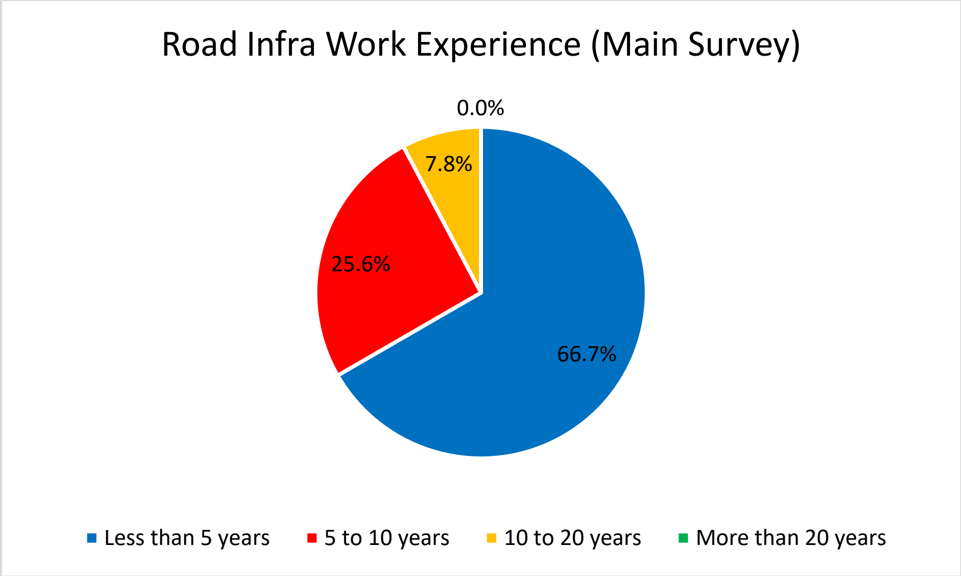


**Fig 4.9. Data for Work Experience – Road Infrastructure (Main Survey)**

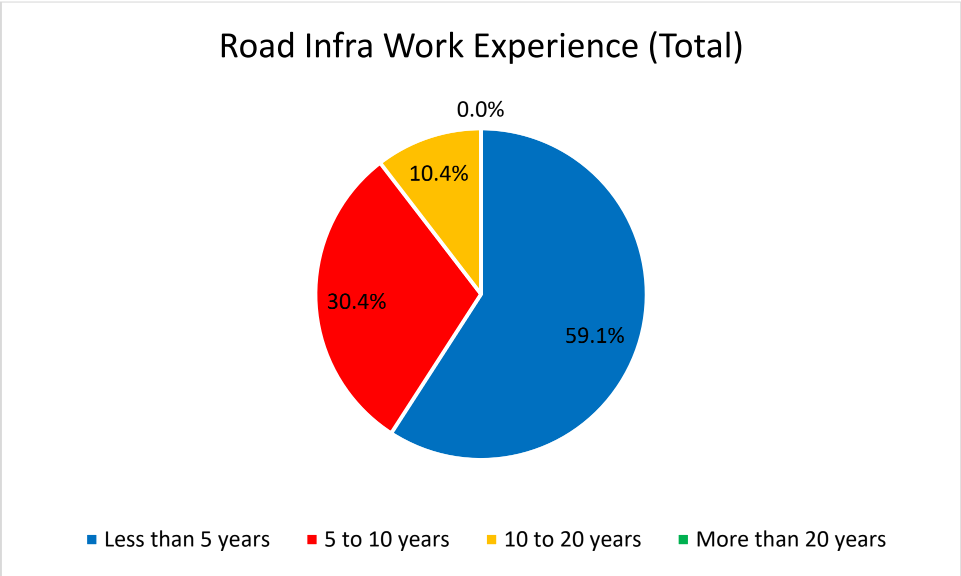


**Fig 4.10. Data for Work Experience – Road Infrastructure (Total)**

The breakdown of road infrastructure work experience responses of 25 pilot survey responses is as follows:

- Less than 5 years: 8 responses
- 5 to 10 years: 12 responses
- 10 to 20 years: 5 responses
- More than 20 years: 0 responses

The breakdown of road infrastructure work experience responses of 90 main survey responses is as follows:

- Less than 5 years: 60 responses
- 5 to 10 years: 23 responses
- 10 to 20 years: 7 responses
- More than 20 years: 0 responses

The breakdown of road infrastructure work experience responses of a total of 115 survey responses is as follows:

- Less than 5 years: 68 responses
- 5 to 10 years: 35 responses
- 10 to 20 years: 12 responses
- More than 20 years: 0 responses

### 4.2.5 Sector

The data for professional sector distribution of respondents of pilot survey (Fig 4.11), main survey (Fig 4.12) and total survey (Fig 4.13) is shown below.

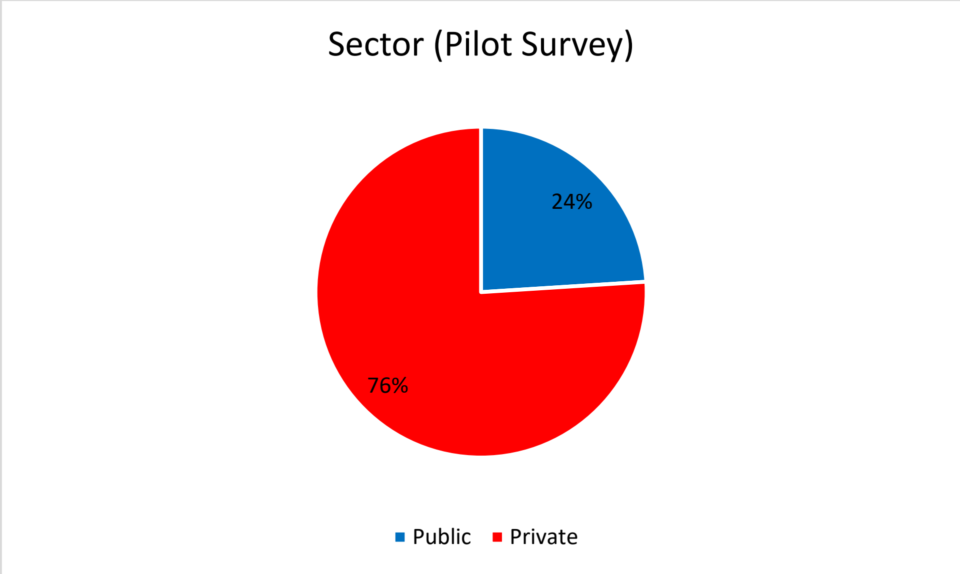


**Fig 4.11. Data for Sector Distribution (Pilot Survey)**

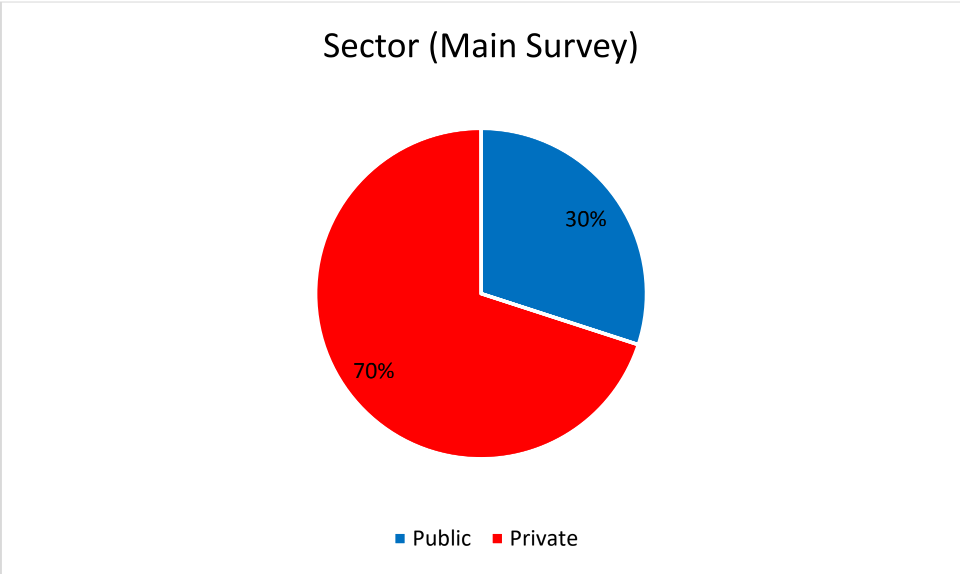


**Fig 4.12. Data for Sector Distribution (Main Survey)**

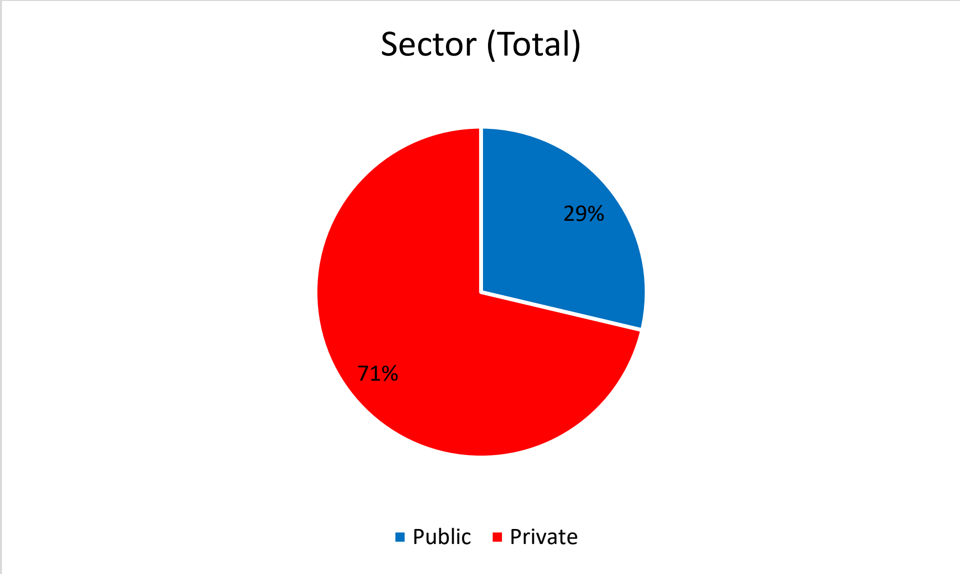


**Fig 4.13. Data for Sector Distribution (Total)**

The breakdown of work sector responses of 25 pilot survey responses is as follows:

- Public: 6 responses
- Private: 19 responses

The breakdown of work sector responses of 90 main survey responses is as follows:

- Public: 27 responses
- Private: 63 responses

The breakdown of work sector responses of a total of 115 survey responses is as follows:

- Public: 33 responses
- Private: 82 responses

### 4.2.6 Organization

The data for organizational distribution of respondents of pilot survey (Fig 4.14), main survey (Fig 4.15) and total survey (Fig 4.16) is shown below.

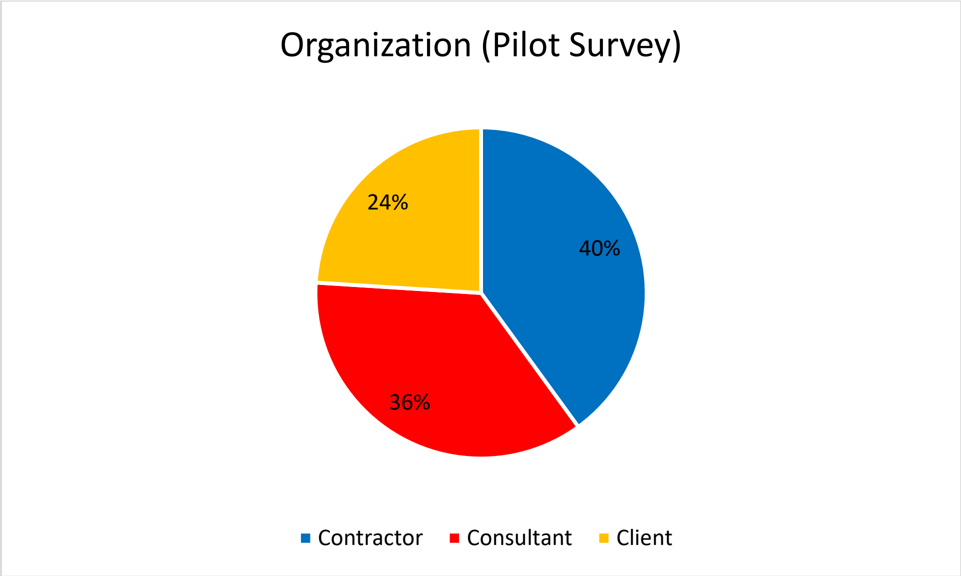


**Fig 4.14. Data for Organizational Distribution (Pilot Survey)**

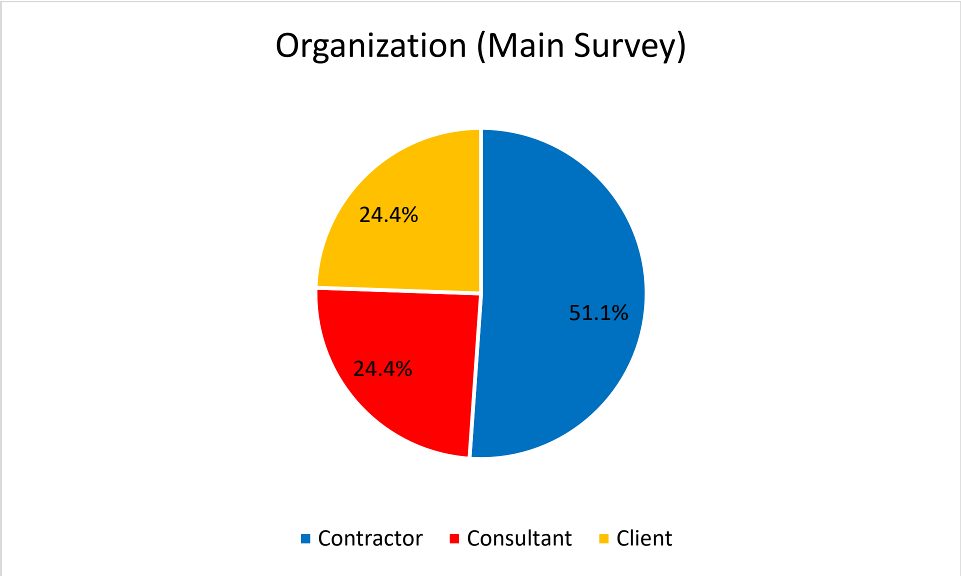


**Fig 4.15. Data for Organizational Distribution (Main Survey)**

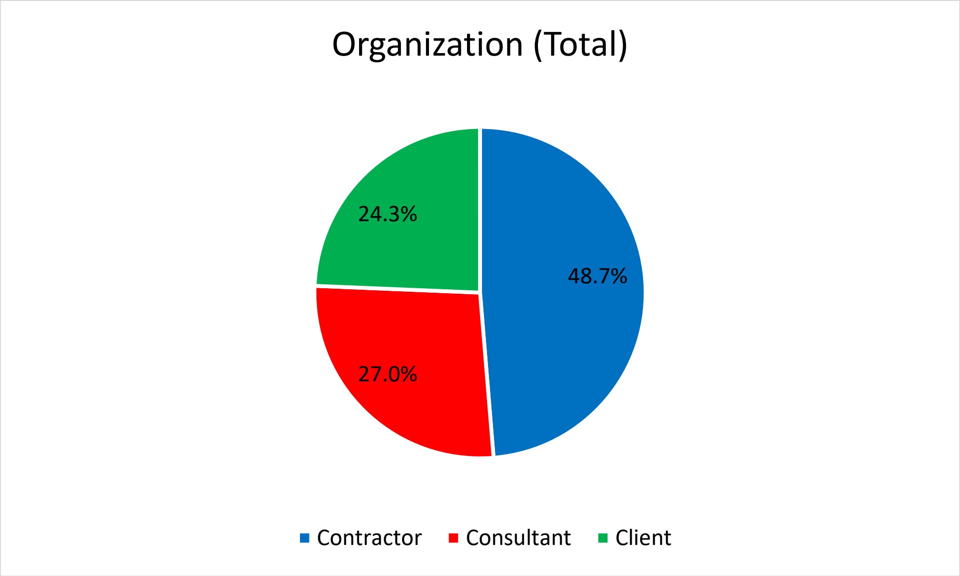


**Fig 4.16. Data for Organizational Distribution (Total)**

The breakdown of work organization responses of 25 pilot survey responses is as follows:

- Contractor: 10 responses
- Consultant: 9 responses
- Client: 6 responses

The breakdown of work organization responses of 90 main survey responses is as follows:

- Contractor: 46 responses
- Consultant: 22 responses
- Client: 22 responses

The breakdown of work organization responses of 115 main survey responses is as follows:

- Contractor: 56 responses
- Consultant: 31 responses
- Client: 28 responses

## 4.3 Statistical Analysis

### 4.3.1 Reliability Analysis – Cronbach's Alpha

To test the reliability of the data gathered by the questionnaire survey a reliability test (Cronbach's Alpha) was carried out. The reliability test was conducted separately for both the 6 main factors and 20 subfactors. The results of the analysis for main factors are shown in the Table 4.1.

**Table 4.1. Cronbach's Alpha value for Main Factors**

Case Processing Summary

| | | N | % |
|---|---|---|---|
| Cases | Valid | 115 | 100.0 |
| | Excluded[a] | 0 | .0 |
| | Total | 115 | 100.0 |

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
|---|---|---|
| .693 | .695 | 6 |

According to (Pallant 2013), the values of Cronbach's alpha can be quite sensitive to the number of items, therefore for a fewer than 10 items a Cronbach's alpha value greater than 0.5 is considered reliable. As there are 6 items in the reliability analysis for the main factors, the data is reliable.

**Table 4.2. Cronbach's Alpha Value for Subfactors**

Case Processing Summary

| | | N | % |
|---|---|---|---|
| Cases | Valid | 115 | 100.0 |
| | Excluded[a] | 0 | .0 |
| | Total | 115 | 100.0 |

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
|---|---|---|
| .918 | .918 | 20 |

The results of the analysis of sub factors are shown in Table 4.2 above. According to (George and Mallery 2016) the value of 0.918 is excellent and the data can easily be considered reliable.

## 4.4 Quantification of Rework Factors

### 4.4.1 Relative Importance Index

#### 4.4.1.1 Main Factors

The following results, as shown in Table 4.3, were obtained after the relative importance index was calculated for the main factors causing reworks in road infrastructure projects in Pakistan.

**Table 4.3. RII Values and Ranks of Main Factors**

| Main Factor | RII Value | Rank |
|---|---|---|
| Planning & Design Management | 0.86 | 1 |
| Project Communication | 0.85 | 2 |
| Field management | 0.82 | 3 |
| Contract Management | 0.81 | 4 |
| Client Management | 0.75 | 5 |
| External Environment | 0.70 | 6 |

According to the relative importance index value calculated from the 115 survey responses, Planning & Design Management was found to be the most critical factor in reworks with the highest RII score of 0.86 followed by Project Communication and Field Management with scores 0.85 and 0.82 respectively. However, there is a little difference between the RII values of the main factors and the minimum RII value of 0.70 indicates that all the main factors are crucial towards reworks in road infrastructure projects in Pakistan.

#### 4.4.1.2 Sub Factors

The following results, as shown in Table 4.4, were obtained after the relative importance index was calculated for the sub factors causing reworks in road infrastructure projects in Pakistan.

**Table 4.4. RII Values and Ranks of Sub Factors**

| Sub Factors | RII Value | Rank |
|---|---|---|
| Lack of funds | 0.50 | 1 |
| Substandard material and quality management | 0.46 | 2 |
| Poor management and supervision | 0.45 | 3 |
| Design errors and unrealistic schedules | 0.42 | 4 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.42 | 5 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.42 | 6 |
| Poor quality of construction technology used and machinery breakdown | 0.40 | 7 |
| Poor communication/Misinformation | 0.40 | 8 |
| Poor coordination of design team | 0.40 | 9 |
| Lack of design knowledge & experience of client | 0.39 | 10 |
| Poor and adverse site conditions | 0.38 | 11 |
| Insufficient time for design stage | 0.38 | 12 |
| Lack of constructability because of separation between design and construction conditions | 0.37 | 13 |
| Poor coordination between client and end user | 0.37 | 14 |
| Poor briefing and coordination with client | 0.35 | 15 |
| Poor contract documentation | 0.35 | 16 |
| Non-Availability of construction materials/equipment in market | 0.33 | 17 |
| Poor procurement method and untimely deliveries | 0.33 | 18 |
| Delay in providing site conditions e.g. water and electricity etc. | 0.32 | 19 |
| Changes in government regulations, laws, and policy | 0.31 | 20 |

### 4.4.2 Respondents' Perspective and Percentage Rank Agreement

#### 4.4.2.1 Main Factors

**Table 4.5. Respondents' Distribution of Main Factors**

| Main Factors | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Planning & Design Management | 0.86 | 1 | 0.85 | 1 | 0.89 | 1 | 0.84 | 2 |
| Project Communication | 0.85 | 2 | 0.84 | 2 | 0.88 | 2 | 0.84 | 3 |
| Field management | 0.83 | 3 | 0.80 | 3 | 0.83 | 4 | 0.86 | 1 |
| Contract Management | 0.82 | 4 | 0.78 | 4 | 0.83 | 3 | 0.84 | 4 |
| Client Management | 0.76 | 5 | 0.70 | 5 | 0.75 | 5 | 0.84 | 5 |
| External Environment | 0.70 | 6 | 0.69 | 6 | 0.69 | 6 | 0.71 | 6 |

The overall analysis of the responses towards the main factors of reworks, as shown in Table 4.5, indicate that the 'Planning & Design Management' is the foremost factor, leading with a high RII value of 0.86, which causes reworks in road infrastructure projects in Pakistan. The respondents were of the opinion that poor planning and inaccurate design lead towards problems during the construction of roads which eventually results in reworks. 'Poor project communication' falls just short with a close RII value of 0.85, indicating that poor project communication and misinformation can have huge negative implications towards the project. Poor site management result in catastrophic results towards the quality, life and cost of a project. 'Field management' comes in third with a RII value of 0.82, showing the importance of experience and professionalism required for the construction of a project.

Contractor's Perspective

The contractor's perspective was found to be similar to the overall response from the respondents with a slightly lower values of the RII for all the factors. This indicates that, relative to the consultants the contractors do not find the factors to have such huge impact.

Consultant's Perspective

The consultant's perspective was found to be almost similar to the overall response with a slightly higher values of RII for all the main factors. This indicate that the consultants believe that the main factors are likely to have a greater impact on reworks as compared to contractors. However, in consultant's view the contract management is rather slightly more important than field management.

Client's Perspective

The client's perspective was found to be a little different from the overall response. However, the top 3 ranked factors remain the same there's a difference between their rankings. Field management was ranked the highest with a RII value of 0.86 followed by planning & design management and project communication respectively. The RII values of the clients were found to be evenly distributed and closely similar.

Rank Agreement Factor and Percentage Agreement

**Table 4.6. Group Agreement on Main Factors**

| Main Factors | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 0.33 | 3.00 | 88.89 % |
| Contractor & Client | 0.67 | 3.00 | 77.78 % |
| Consultant & Client | 1.00 | 3.00 | 66.67 % |

The Table 4.6 shows that the different groups were in large agreement towards the ranking of the main factors causing reworks in road infrastructure projects in Pakistan.

#### 4.4.2.2 Field Management

**Table 4.7. Respondents' Distribution of Factors Related to Field Management**

| Field management | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Substandard material and quality management | 0.45 | 1 | 0.48 | 1 | 0.45 | 1 | 0.42 | 4 |
| Poor management and supervision | 0.44 | 2 | 0.47 | 2 | 0.41 | 2 | 0.44 | 2 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.42 | 3 | 0.42 | 3 | 0.39 | 4 | 0.45 | 1 |
| Poor quality of construction technology used and machinery breakdown | 0.40 | 4 | 0.38 | 4 | 0.40 | 3 | 0.43 | 3 |
| Poor procurement method and untimely deliveries | 0.33 | 5 | 0.32 | 5 | 0.31 | 5 | 0.37 | 5 |

The overall analysis of the responses towards the sub factors of field management, as shown in Table 4.7, indicate that the 'Substandard material and quality management' is the foremost factor, leading with a highest RII value of 0.46. The respondents were of the opinion that among the factors concerning field management the most recurring and cost impactful was the usage of low standard construction material subsequently causing quality issues. With a large amount of unskilled and uneducated labor in the country, heavy supervision is required to ensure proper management of the project. Most of the workers are unfamiliar with the latest technology and methods of construction. Therefore, 'poor management and supervision' is believed to be the second most important sub factor of field management with a RII value of 0.45. Due to incompetency of site personnel or unclear working documents, misunderstanding is observed many times which causes incorrect and faulty construction eventually leading to reworks. ‘Construction errors due to misunderstanding of design and unclear instructions to workers’ is found to be the third most important sub factor of field management with a RII value of 0.42.

Contractor’s perspective

The contractor’s perspective was found to be similar to the overall response from the respondents with a slightly higher values of the RII for almost all the sub factors. This indicates that, relative to the consultants the contractors find the sub factors to have a much bigger impact.

Consultant’s perspective

The consultant’s perspective was found to be almost similar to the overall response with a slightly lower values of RII for sub factors. This indicate that the consultants believe that the sub factors are likely to have a lower impact on reworks as compared to contractors. However, in consultant’s view the ‘poor construction technology and machinery’ used by contractors occur often and have a higher impact on the cost of the project rather than any misunderstanding due to complexity of design.

Client’s perspective

The client’s perspective was found to be a little different than the overall response. According to the client’s perspective the foremost sub factor for reworks is ‘Construction errors due to misunderstanding of design and unclear instructions to workers’ with a RII value of ‘0.45’ followed by ‘Poor management and supervision’ (RII 0.44) and ‘Poor quality of construction technology used and machinery breakdown’ (RII 0.43).

Rank Agreement Factor and Percentage Agreement

**Table 4.8. Group Agreement on Factors Related to Field Management**

| Field Management | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 0.40 | 2.40 | 83.33 % |
| Contractor & Client | 1.20 | 2.40 | 50.00 % |
| Consultant & Client | 1.20 | 2.40 | 50.00 % |

The Table 4.8 shows that a large agreement was found between the contractors and consultants with a high value 83.3%. However, a moderate agreement was found between both contractor/client and consultant/client with a percentage agreement of 50% each.

#### 4.4.2.3 Planning & Design Management

**Table 4.9. Respondents' Distribution of Factors Related to Field Management**

| Planning & Design Management | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Design errors and unrealistic schedules | 0.41 | 1 | 0.46 | 1 | 0.40 | 3 | 0.39 | 1 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.41 | 2 | 0.44 | 2 | 0.40 | 2 | 0.38 | 2 |
| Poor coordination of design team | 0.38 | 3 | 0.44 | 3 | 0.37 | 4 | 0.33 | 4 |
| Insufficient time for design stage | 0.37 | 4 | 0.40 | 4 | 0.35 | 5 | 0.36 | 3 |
| Lack of constructability because of separation between design and construction conditions | 0.36 | 5 | 0.39 | 5 | 0.40 | 1 | 0.30 | 5 |

The overall analysis of the responses towards the sub factors of Planning & Design Management, as shown in Table 4.9, indicate that the 'Design errors and unrealistic schedules' is the foremost factor, leading with a highest RII value of 0.42. The respondents were of the opinion that among the factors concerning planning and design management the most frequent and cost impactful was the 'design errors and unrealistic schedules' which eventually lead to reworks. Due to unforeseen circumstances and uncertain environments, 'plan changes' are not uncommon. These changes may cause acceleration, deceleration and even compression of projects. Therefore, 'plan changes' is believed to be the second most important sub factor of planning and design management with a RII value of 0.42. Due to lack of coordination of design teams, design issues occur which later cause problems during the construction and lead towards rework of design and construction as well. 'Poor coordination of design team' is found to be the third most important sub factor of planning and design management with a RII value of 0.40.

Contractor's perspective

The contractor's perspective was found to be similar to the overall response from the respondents with a slightly higher values of the RII for all the sub factors. This indicates that, relative to the consultants the contractors find the sub factors to have a much bigger impact.

Consultant's perspective

The consultant's perspective was found to be different than the overall response with a slightly lower values of RII for sub factors. This indicate that the consultants believe that the sub factors are likely to have a lower impact on reworks as compared to contractors. The consultants believed that 'Lack of constructability because of separation between design and construction conditions' was the most important sub factor which is completely opposite to the contractor's and client's perspective who believe that it is the least important sub factor. The consultants argue that the major flaw is not in the design of the structure but mainly because of the difference between the existing site conditions and design.

Client's perspective

The client's perspective was found to be almost similar to the overall response with lower values of RII for sub factors. This indicate that the clients believe that the sub factors are likely to have a lower impact on reworks as compared to contractors and consultants. However, in client's view 'insufficient time for design stage' takes precedence and have a higher impact on the cost of the project rather than poor coordination of design team.

Rank Agreement Factor and Percentage Agreement

**Table 4.10. Group Agreement on Factors Related to Planning and Design Management**

| Planning & Design Management | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.60 | 2.40 | 33.33 % |
| Contractor & Client | 0.40 | 2.40 | 83.33 % |
| Consultant & Client | 1.60 | 2.40 | 33.33 % |

The Table 4.10 shows that a large agreement was found between the contractors/clients with a high value 83.3%. However, low agreement was found between both contractor/consultant and consultant/client with a percentage agreement of 33.3% each.

#### 4.4.2.4 Client Management

**Table 4.11. Respondents' Distribution of Factors Related to Client Management**

| Client Management | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Lack of funds | 0.50 | 1 | 0.48 | 1 | 0.53 | 1 | 0.51 | 1 |
| Lack of design knowledge & experience of client | 0.38 | 2 | 0.42 | 2 | 0.40 | 2 | 0.31 | 5 |
| Poor coordination between client and end user | 0.36 | 3 | 0.37 | 3 | 0.38 | 3 | 0.34 | 3 |
| Poor briefing and coordination with client | 0.36 | 4 | 0.32 | 4 | 0.38 | 4 | 0.37 | 2 |
| Delay in providing site conditions e.g. water and electricity etc. | 0.33 | 5 | 0.31 | 5 | 0.35 | 5 | 0.32 | 4 |

The overall analysis of the responses towards the sub factors of Client Management, as shown in Table 4.11, indicate that the 'Lack of funds' is the foremost factor, leading with a highest RII value of 0.50. Not only was the sub factor found to be the highest in client management, but the sub factor has scored the highest value of RII among all the 20 sub factors which lead towards reworks in road infrastructure projects in Pakistan. Being a developing nation and a third world country many public projects in Pakistan suffer from financial instability causing delays, poor quality and poor machinery etc. resulting in reworks. A huge decrease is observed in the RII value of the second most important sub factor of client management as 'Lack of design knowledge & experience of client' scores a RII value of 0.39. Little to no involvement of client in the design process in Pakistan leads to lesser issues that might occur from this sub factor. However, experts believe that active participation of an experienced client lead towards smooth and timely construction. Due to involvement of several stakeholders and poor stakeholder management, sometimes projects are delayed eventually causing reworks of completed tasks due to deterioration and damage to the existing structure. This usually involves the clients and the end user not being on the same page. 'Poor coordination between client and end user' is found to be the third most important sub factor of client management with a RII value of 0.37.

Contractor's Perspective

The contractor's perspective was found to be similar to the overall response from the respondents with a slightly lower values of the RII for all the sub factors. This indicates that, relative to the consultants the contractors find the sub factors to have a lower impact.

Consultant's Perspective

The consultant's perspective was found to be similar to the overall response from the respondents with a slightly higher values of the RII for all the sub factors. This indicates that, relative to the contractors the consultants find the sub factors to have a higher impact.

Client's Perspective

The client's perspective was found to be almost similar to the overall response from the respondents with a slightly lower values of the RII for almost all the sub factors. The clients agree to the fact that 'Lack of funds' is the foremost issue leading to reworks in construction. However, the clients disagree that the 'Lack of design knowledge and experience of client' is the second most important factor. Instead they consider it to be the least important factor of client management. In client's perspective 'Poor briefing and coordination with client' by consultants and contractors causes problems later in the project and is the second most important sub factor leading towards reworks with a RII value of 0.37.

Rank Agreement Factor and Percentage Agreement

**Table 4.12. Group Agreement on Factors Related to Client Management**

| Client Management | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 0.00 | 2.40 | 100.00 % |
| Contractor & Client | 1.20 | 2.40 | 50.00 % |
| Consultant & Client | 1.20 | 2.40 | 50.00 % |

The Table 4.12 shows that total agreement was found between the contractors/consultants with a perfect value of 100%. However, moderate agreement was found between both contractor/client and consultant/client with a percentage agreement of 50% each.

#### 4.4.2.5 External Environment

**Table 4.13. Respondents' Distribution of Factors Related to External Environment**

| External Environment | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Poor and adverse site conditions | 0.37 | 1 | 0.42 | 1 | 0.35 | 3 | 0.35 | 1 |
| Non-Availability of construction materials/equipment in market | 0.34 | 2 | 0.30 | 2 | 0.41 | 1 | 0.33 | 2 |
| Changes in government regulations, laws, and policy | 0.31 | 3 | 0.29 | 3 | 0.36 | 2 | 0.30 | 3 |

The overall analysis of the responses towards the sub factors of External Environment, as shown in Table 4.13, indicate that the 'Poor and adverse site conditions' is the foremost factor, leading with a highest RII value of 0.38. Pakistan being one of the top 10 countries to be affected by climate change faces extreme climatic conditions throughout the year. In addition to it, lack of basic infrastructure facilities in rural and high population density in urban areas creates a harsh and difficult working environment. Although most of the construction material is locally available for the construction of roads, yet problems occur in remote areas where sometimes construction material must be transported from a long way. However, almost all the heavy construction machinery and equipment is not manufactured locally and must be imported. According to the respondents 'Non-Availability of construction materials/equipment in market' is the second most important sub factor with a RII value of 0.33. Last and the least important factor was found to be 'Changes in government regulations, laws, and policy' which seldom occur and have little to no impact on the construction.

Contractor's Perspective

The contractor's perspective was found to be similar to the overall response from the respondents. The contractors being the focal personnel on site, agree that 'poor and adverse site conditions' seriously impede their performance.

Consultant's Perspective

The consultant's perspective was found to be a little different than the overall response as they disagree that 'Poor and adverse site conditions' is the most important sub factor and consider 'Changes in government regulations, laws and policy' to affect them and the project the highest.

Client's Perspective

The client's perspective was found to be similar to the overall response and the contractor's perspective. The clients considered the changes in government (mostly clients) regulations to be of the least importance.

Rank Agreement Factor and Percentage Agreement

**Table 4.14. Group Agreement on Factors Related to External Environment**

| External Environment | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.33 | 1.33 | 0.00 |
| Contractor & Client | 0.00 | 1.33 | 100.00 |
| Consultant & Client | 1.33 | 1.33 | 0.00 |

Table 4.14 shows that total agreement was found between the contractors/clients with a perfect value of 100%. However, zero agreement was found between both contractor/consultant and consultant/client with a percentage agreement of 0% each. This is

because there are only 3 sub factors involved and a mere one difference in rank leads to zero agreement.

#### 4.4.2.6 Overall ranking of sub factors

Table 4.15 below shows the overall ranking of all the 20 sub factors that lead towards reworks in road infrastructure projects in Pakistan. The factors were ranked according to the value of RII based upon the occurrence and cost impact of said factors.

**Table 4.15. Overall Ranking of Sub Factors**

| Sub Factors | RII | Rank | Group related |
|---|---|---|---|
| Lack of funds | 0.505 | 1 | Client Management |
| Substandard material and quality management | 0.450 | 2 | Field Management |
| Poor management and supervision | 0.442 | 3 | Field Management |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.417 | 4 | Field Management |
| Design errors and unrealistic schedules | 0.414 | 5 | Planning & Design Management |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.409 | 6 | Planning & Design Management |
| Poor quality of construction technology used and machinery breakdown | 0.405 | 7 | Field Management |
| Poor communication/Misinformation | 0.389 | 8 | Project Communication |
| Poor coordination of design team | 0.383 | 9 | Planning & Design Management |
| Lack of design knowledge & experience of client | 0.377 | 10 | Client Management |

| | | | |
|---|---|---|---|
| Insufficient time for design stage | 0.371 | 11 | Planning & Design Management |
| Poor and adverse site conditions | 0.370 | 12 | External Environment |
| Poor coordination between client and end user | 0.364 | 13 | Client Management |
| Lack of constructability because of separation between design and construction conditions | 0.364 | 14 | Planning & Design Management |
| Poor briefing and coordination with client | 0.357 | 15 | Client Management |
| Poor contract documentation | 0.349 | 16 | Contract Management |
| Non-Availability of construction materials/equipment in market | 0.345 | 17 | External Environment |
| Poor procurement method and untimely deliveries | 0.335 | 18 | Field Management |
| Delay in providing site conditions e.g. water and electricity etc. | 0.326 | 19 | Client Management |
| Changes in government regulations, laws, and policy | 0.315 | 20 | External Environment |

## 4.5 Cost Impact of Rework Factors

### 4.5.1 Multiple Regression Analysis

The estimated cost impact of the main factors on the project was calculated using multiple regression analysis as used by (Kim, An et al. 2004)for cost estimation. For the analysis, the data collected by the 115 respondents was entered into the SPSS software and an empirical relationship was developed between the 6 main factors and percentage rework cost in a project. Multiple regression analysis can be generally represented as:

$$Y = b_1X_1 + b_2X_2 + \cdots + b_nX_n$$

**Equation 4.1**

where Y is the total estimated cost, and $X_1$, $X_2$,…,$X_n$ are measures of independent predictors to estimate dependent variable Y. C is the estimated constant, and $b_1$, $b_2$,…,$b_n$ are the coefficients estimated by regression analysis.

A multiple regression analysis of the 6 main factors and percentage rework cost in a project using SPSS yielded the following results. The values for coefficients can be found in Table 4.17.

**Table 4.16. Multiple Regression Model Summary**

| Model Summary | | | |
|---|---|---|---|
| R | R Square | Adjusted R Square | Std. Error of the Estimate |
| .883[a] | 0.780 | 0.768 | 1.95529 |
| a. Predictors: (Constant), PC, CLM, PDM, EE, COM, FM | | | |

**Table 4.17. Coefficients' Summary for Main Factors**

| | Unstandardized Coefficients | | Standardized Coefficients |
|---|---|---|---|
| | B | Std. Error | Beta |
| (Constant) | -16.220 | 1.374 | |
| FM | 0.944 | 0.233 | 0.210 |
| PDM | 1.022 | 0.253 | 0.205 |
| CLM | 1.415 | 0.242 | 0.306 |
| EE | 1.169 | 0.232 | 0.254 |
| COM | 1.189 | 0.235 | 0.257 |
| PC | 0.832 | 0.270 | 0.171 |
| a. Dependent Variable: Rework | | | |

Where;

FM = Field Management

PDM = Planning & Design Management

CLM = Client Management

EE = External Environment

COM = Contract Management

PC = Project Communication

The value of Adjusted R-Square, as shown in Table 4.16, is defined as the total sample change of the dependent variable y that is explained by the model after adjusting for the sample size and the number of independent variables. Both $R^2$ and $R^2_{adj}$ are indicators of how well the prediction equation fits the data (Ngo and La Puente 2012). (Chin 1998) recommended $R^2$ values for endogenous latent variables based on: 0.67 (substantial), 0.33 (moderate), 0.19 (weak). Considering this, the value of $R^2$ was found to be substantial.

# CASE STUDIES

## 5.1 Introduction

In order to validate and apply the findings of this research, 6 case studies were undertaken. A variety of case studies were conducted to incorporate effects of factors like size, location and duration etc. of different projects. Experienced personnel who actively participated in their respective project were interviewed and feedback was collected based on the framework extracted from the research. Candidates from all the major stakeholder categories; Contractor, Consultant and Client, were interviewed and a weighted average was calculated to eliminate biasedness towards any specific category. The objective of case studies is to quantify the main factors and sub factors, in terms of RII, and to determine the cost impact of these factors, in terms of percentage rework cost. A comparative analysis of all the case studies is also calculated at the end of this chapter.

## 5.2 Lahore Ring Road (Southern Loop)

The first case was selected from the capital city of the province of Punjab and is located on the outskirts of the major city, Lahore. Starting from the M-2 junction at Babu Sabu interchange, the road forms a ring around the city and is divided into Northern Loop and Southern Loop. However, a part of southern loop is not yet complete due to issues pertaining to its route and land acquisition. The SL-1 and SL-2 parts of the southern loop are complete amounting to a total length of 22.4 km, were taken up for this study. The completed part of southern loop starts from Kamahan (DHA Ph V) and ends at Adda Plot, Raiwand Road. The salient features of the study are shown in the Table 5.1.

**Table 5.1. Project Details of Lahore Ring Road Pakistan (SL-1 & SL-2)**

| | |
|---|---|
| **Project Name** | LRRP (SL-1 &SL-2) |
| **Scope** | Construction of 6 Lane Expressway provision of Intelligent Transportation System (ITS) for Northern & Southern Loop, Construction of 9.60 Km Svc Road, 6x Interchanges, 22 x Bridges & 66 x Culverts. |
| **Project Length** | 22.4 Km |
| **Client** | LRRA |
| **Consultant** | NESPAK, ZEERAK/BNA |
| **Contractor** | FWO |
| **Commencement Date** | Aug 2016 |
| **Completion Date** | Jan 2020 |
| **Project Cost** | Rs 23,476 Mn |

### 5.2.1 Quantification of factors

The results obtained from the analysis of main factors of the subject case are shown in the Table 5.2.

**Table 5.2. RII Values and Ranks of Main Factors (Lahore Ring Road)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Field management | 0.92 | 1 | 0.95 | 2 | 0.80 | 3 | 1.00 | 2 |
| Planning & Design Management | 0.90 | 2 | 0.85 | 3 | 0.84 | 1 | 1.00 | 1 |
| Client Management | 0.81 | 3 | 1.00 | 1 | 0.74 | 4 | 0.70 | 4 |
| Project Communication | 0.78 | 4 | 0.80 | 4 | 0.84 | 2 | 0.70 | 3 |
| Contract Management | 0.75 | 5 | 0.80 | 5 | 0.74 | 5 | 0.70 | 5 |
| External Environment | 0.68 | 6 | 0.70 | 6 | 0.74 | 6 | 0.60 | 6 |

Despite not being the top ranked factor by any, the weighted average of RII revealed Field Management as the leading main factor for rework in the project. The contractor personnel believed the main factor was poor client management. However, Client and Consultant agreed that major problems occurred due to poor planning and design management. Moderate agreement was found between Contractor/Consultant and Contractor/Client responses. However, large agreement was found between Consultant/Client as shown in the Table 5.3.

**Table 5.3. Group Agreement on Main Factors (Lahore Ring Road)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.33 | 3.00 | 55.56 % |
| Contractor & Client | 1.00 | 3.00 | 66.67 % |
| Consultant & Client | 0.33 | 3.00 | 88.89 % |

A detailed analysis incorporating the sub factors of reworks was carried out. The results are shown in the Table 5.4.

**Table 5.4. RII Values and Ranks of Sub Factors (Lahore Ring Road)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Poor management and supervision | 0.45 | 1 | 0.04 | 16 | 0.64 | 2 | 0.68 | 1 |
| Poor quality of construction technology used and machinery breakdown | 0.42 | 2 | 0.31 | 1 | 0.60 | 3 | 0.36 | 6 |
| Substandard material and quality management | 0.39 | 3 | 0.12 | 3 | 0.66 | 1 | 0.40 | 4 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.38 | 4 | 0.12 | 4 | 0.52 | 6 | 0.50 | 2 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.34 | 5 | 0.07 | 12 | 0.56 | 4 | 0.38 | 5 |
| Poor and adverse site conditions | 0.33 | 6 | 0.26 | 2 | 0.44 | 11 | 0.30 | 9 |
| Insufficient time for design stage | 0.31 | 7 | 0.04 | 17 | 0.48 | 9 | 0.42 | 3 |
| Lack of constructability because of separation between design and construction conditions | 0.31 | 8 | 0.12 | 5 | 0.51 | 8 | 0.30 | 8 |
| Poor coordination of design team | 0.31 | 9 | 0.11 | 10 | 0.52 | 7 | 0.30 | 7 |
| Design errors and unrealistic schedules | 0.29 | 10 | 0.05 | 15 | 0.54 | 5 | 0.28 | 11 |
| Poor communication/Misinformation | 0.26 | 11 | 0.12 | 6 | 0.36 | 18 | 0.30 | 10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Poor procurement method and untimely deliveries | 0.25 | 12 | 0.12 | 7 | 0.43 | 12 | 0.20 | 12 |
| Lack of funding | 0.22 | 13 | 0.07 | 13 | 0.46 | 10 | 0.14 | 17 |
| Lack of design knowledge & experience of client | 0.22 | 14 | 0.04 | 18 | 0.42 | 13 | 0.20 | 13 |
| Non-Availability of construction materials/equipment in market | 0.21 | 15 | 0.12 | 8 | 0.32 | 20 | 0.20 | 14 |
| Delay in providing site conditions like water and electricity | 0.21 | 16 | 0.09 | 11 | 0.35 | 19 | 0.18 | 15 |
| Poor coordination between client and end user | 0.20 | 17 | 0.04 | 19 | 0.41 | 14 | 0.16 | 16 |
| Changes in government regulations, laws, and policy | 0.20 | 18 | 0.12 | 9 | 0.38 | 16 | 0.10 | 20 |
| Poor contract documentation | 0.19 | 19 | 0.07 | 14 | 0.40 | 15 | 0.10 | 19 |
| Poor briefing and coordination with client | 0.18 | 20 | 0.04 | 20 | 0.36 | 17 | 0.14 | 18 |

Little to moderate agreement was found between Contractor/Consultant and Contractor/Client responses. However, large agreement was found between Consultant/Client as shown in the Table 5.5.

**Table 5.5. Group Agreement on Sub Factors (Lahore Ring Road)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 6.10 | 10.00 | 39.00 % |
| Contractor & Client | 5.50 | 10.00 | 45.00 % |
| Consultant & Client | 3.10 | 10.00 | 69.00 % |

Comments

From the data collected and further analysis of the study it was concluded that the following factors had the highest impact towards reworks in the project:

- Poor management and supervision
- Poor quality of construction technology used and machinery breakdown
- Substandard material and quality management
- Plan changes by client (Acceleration/Deceleration/Compression)
- Construction errors due to misunderstanding of design and unclear instructions to workers

### 5.2.2 Cost Impact of Factors

To determine the cost impact of main rework factors on the subject study project, an analysis was performed using the multiple regression equation derived from the research. The results are displayed in the Table 5.6.

**Table 5.6. Cost Impact of Main Factors (Lahore Ring Road)**

| Project | Category | % Rework |
|---|---|---|
| LRRP (SL-1 & SL-2) | Client | 9.14 % |
| | Consultant | 9.30 % |
| | Contractor | 11.86 % |
| | Weighted Average | 10.10 % |

Comments

The multiple regression analysis of the data collected concluded that an estimated 10.10% of project cost was directly or indirectly expended on reworks.

## 5.3 BRT Lahore

The second case was also selected from the capital city of the province of Punjab and is in the heart of the major city, Lahore. Starting from the outskirts of the city at Shahdara terminal, the project continues through the highly populated and dense areas of the city and ends at the Gajjumata terminal, also located at the far end of the city. The completed Ferozpur road corridor is a 27 Km long two-lane corridor, consisting of an 8.4 Km elevated portion. The salient features of the study are shown in the Table 5.7 below.

**Table 5.7. Project Details of BRT Lahore**

| | |
|---|---|
| **Project Name** | BRT Lahore |
| **Scope** | Design and build of 27 Km long two-lane corridor with 27 stations and 8.3 Km elevated portion |
| **Project Length** | 27 Km |
| **Client** | TEPA, LDA |
| **Consultant** | NESPAK |
| **Contractor** | NLC, HCS |
| **Commencement Date** | March 2012 |
| **Completion Date** | February 2013 |
| **Project Cost** | Rs 29,650 Mn |

### 5.3.1 Quantification of factors

The results obtained from the analysis of main factors of the subject case are shown in the Table 5.8.

**Table 5.8. RII Values and Ranks of Main Factors (BRT Lahore)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Field management | 0.91 | 1 | 1.00 | 1 | 0.84 | 2 | 0.90 | 1 |
| Project Communication | 0.85 | 2 | 1.00 | 2 | 0.90 | 1 | 0.65 | 4 |
| Planning & Design Management | 0.78 | 3 | 0.60 | 4 | 0.84 | 3 | 0.90 | 2 |
| Client Management | 0.75 | 4 | 0.80 | 3 | 0.80 | 4 | 0.65 | 5 |
| External Environment | 0.70 | 5 | 0.60 | 5 | 0.76 | 6 | 0.75 | 3 |
| Contract Management | 0.67 | 6 | 0.60 | 6 | 0.80 | 5 | 0.60 | 6 |

The weighted average of RII revealed Field Management as the leading main factor for rework in the project. The contractor and client personnel believed the main challenge during the construction phase was field management and eventually caused a lot of reworks. However, Consultant opinioned that major problems occurred due to poor project communication. Moderate agreement was found between Contractor/Consultant, Contractor/Client and Consultant/Client as shown in the Table 5.9.

**Table 5.9. Group Agreement on Main Factors (BRT Lahore)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.00 | 3.00 | 66.67 % |
| Contractor & Client | 1.33 | 3.00 | 55.56 % |
| Consultant & Client | 1.67 | 3.00 | 44.44 % |

A detailed analysis incorporating the sub factors of reworks was carried out. The results are shown in the Table 5.10.

**Table 5.10. RII Values and Ranks of Sub Factors (BRT Lahore)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Insufficient time for design stage | 0.44 | 1 | 0.24 | 4 | 0.53 | 1 | 0.54 | 2 |
| Poor and adverse site conditions | 0.44 | 2 | 0.16 | 7 | 0.46 | 2 | 0.69 | 1 |
| Design errors and unrealistic schedules | 0.39 | 3 | 0.36 | 3 | 0.35 | 4 | 0.45 | 3 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.33 | 4 | 0.16 | 8 | 0.45 | 3 | 0.37 | 7 |
| Poor management and supervision | 0.32 | 5 | 0.48 | 1 | 0.18 | 12 | 0.31 | 11 |
| Substandard material and quality management | 0.30 | 6 | 0.48 | 2 | 0.10 | 19 | 0.33 | 9 |
| Delay in providing site conditions like water and electricity | 0.28 | 7 | 0.24 | 5 | 0.29 | 6 | 0.32 | 10 |
| Lack of constructability because of separation between design and construction conditions | 0.27 | 8 | 0.24 | 6 | 0.20 | 10 | 0.37 | 8 |
| Poor coordination between client and end user | 0.22 | 9 | 0.16 | 9 | 0.20 | 11 | 0.30 | 13 |
| Poor contract documentation | 0.21 | 11 | 0.04 | 15 | 0.20 | 8 | 0.38 | 5 |
| Poor coordination of design team | 0.21 | 10 | 0.08 | 11 | 0.16 | 13 | 0.38 | 6 |
| Poor communication/Misinformation | 0.20 | 13 | 0.04 | 16 | 0.33 | 5 | 0.23 | 18 |
| Poor procurement method and untimely deliveries | 0.20 | 12 | 0.12 | 10 | 0.27 | 7 | 0.21 | 19 |
| Changes in government regulations, laws, and policy | 0.20 | 14 | 0.04 | 17 | 0.15 | 15 | 0.40 | 4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.18 | 15 | 0.04 | 18 | 0.20 | 9 | 0.30 | 12 |
| Lack of design knowledge & experience of client | 0.17 | 16 | 0.08 | 12 | 0.16 | 14 | 0.28 | 15 |
| Poor briefing and coordination with client | 0.16 | 17 | 0.08 | 13 | 0.13 | 18 | 0.27 | 16 |
| Poor quality of construction technology used and machinery breakdown | 0.16 | 18 | 0.08 | 14 | 0.14 | 17 | 0.26 | 17 |
| Lack of funding | 0.14 | 19 | 0.04 | 19 | 0.10 | 20 | 0.29 | 14 |
| Non-Availability of construction materials/equipment in market | 0.13 | 20 | 0.04 | 20 | 0.15 | 16 | 0.21 | 20 |

Moderate agreement was found between Contractor/Consultant and Contractor/Client and Consultant/Client as shown in the Table 5.11.

**Table 5.11. Group Agreement of Sub Factors (BRT Lahore)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 4.90 | 10.00 | 51.00 % |
| Contractor & Client | 4.80 | 10.00 | 52.00 % |
| Consultant & Client | 4.40 | 10.00 | 56.00 % |

Comments

From the data collected and further analysis of the study it was concluded that the following factors had the highest impact towards reworks in the project:

- Insufficient time for design stage
- Poor and adverse site conditions
- Design errors and unrealistic schedules
- Plan changes by client (Acceleration/Deceleration/Compression)
- Poor management and supervision

### 5.3.2 Cost Impact of Factors

To determine the cost impact of main rework factors on the subject study project, an analysis was performed using the multiple regression equation derived from the research. The results are displayed in the Table 5.12.

**Table 5.12. Cost Impact of Main Factors (BRT Lahore)**

| Project | Category | % Rework |
|---|---|---|
| BRT LHR | Client | 7.88 % |
| | Consultant | 10.64 % |
| | Contractor | 8.46 % |
| | Weighted Average | 8.99 % |

Comments

The multiple regression analysis of the data collected concluded that an estimated 8.99% of project cost was directly or indirectly expended on reworks.

## 5.4 BRT Rawalpindi-Islamabad

The third case was selected from the Rawalpindi-Islamabad cities, also known as twin-cities with Rawalpindi being a city of province Punjab and Islamabad being the capital city of Pakistan. Starting from the city of Rawalpindi at Saddar terminal, the project continues through the highly populated and dense areas of the city, enters the capital city of Pakistan (Islamabad) and ends at the Pak Secretariat terminal in Islamabad. The completed corridor is a 22 Km long two-lane corridor, consisting of the entire length covering the Rawalpindi city of around 8.6 Km as elevated portion. The salient features of the study are shown in the Table 5.13.

**Table 5.13. Project Details of BRT Rawalpindi-Islamabad**

| **Project Name** | BRT Rawalpindi-Islamabad |
|---|---|
| **Scope** | Design and build of 22.5 Km long two-lane corridor with 24 stations and 8.6 Km elevated portion |
| **Project Length** | 22.5 Km |
| **Client** | RDA |
| **Consultant** | NESPAK |
| **Contractor** | NLC, HCS |
| **Commencement Date** | April 2014 |
| **Completion Date** | March 2015 |
| **Project Cost** | Rs 44,310 Mn |

### 5.4.1 Quantification of factors

The results obtained from the analysis of main factors of the subject case are shown in the Table 5.14.

**Table 5.14. RII Values and Ranks of Main Factors (BRT Rawalpindi-Islamabad)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Field management | 0.93 | 1 | 1.00 | 1 | 0.80 | 1 | 1.00 | 1 |
| Planning & Design Management | 0.90 | 2 | 1.00 | 2 | 0.70 | 3 | 1.00 | 2 |
| External Environment | 0.80 | 3 | 0.80 | 3 | 0.80 | 2 | 0.80 | 4 |
| Client Management | 0.73 | 4 | 0.80 | 4 | 0.60 | 4 | 0.80 | 5 |
| Contract Management | 0.60 | 5 | 0.40 | 5 | 0.40 | 5 | 1.00 | 3 |
| Project Communication | 0.53 | 6 | 0.40 | 6 | 0.40 | 6 | 0.80 | 6 |

All the major project participants believe Field Management to be the leading cause of reworks in the project. The contractor and client personnel believed the second biggestfactor was poor planning and design management. However, Consultant opinioned that major problems occurred due to adverse site conditions. Large agreement was found between the responses of all the project participants as shown in the Table 5.15.

**Table 5.15. Group Agreement on Main Factors (BRT Rawalpindi-Islamabad)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 0.33 | 3.00 | 88.89 % |
| Contractor & Client | 0.67 | 3.00 | 77.78 % |
| Consultant & Client | 1.00 | 3.00 | 66.67 % |

A detailed analysis incorporating the sub factors of reworks was carried out. The results are shown in the Table 5.16.

**Table 5.16. RII Values and Ranks of Sub Factors (BRT Rawalpindi-Islamabad)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Insufficient time for design stage | 0.27 | 1 | 0.24 | 1 | 0.24 | 3 | 0.32 | 2 |
| Poor and adverse site conditions | 0.27 | 2 | 0.16 | 2 | 0.40 | 1 | 0.24 | 3 |
| Design errors and unrealistic schedules | 0.25 | 3 | 0.08 | 3 | 0.26 | 2 | 0.40 | 1 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.15 | 4 | 0.08 | 4 | 0.20 | 4 | 0.16 | 4 |
| Lack of constructability because of separation between design and construction conditions | 0.09 | 7 | 0.04 | 10 | 0.16 | 8 | 0.08 | 8 |
| Poor communication/Misinformation | 0.09 | 9 | 0.04 | 11 | 0.20 | 5 | 0.04 | 12 |
| Poor coordination between client and end user | 0.09 | 8 | 0.08 | 5 | 0.16 | 6 | 0.04 | 13 |
| Poor management and supervision | 0.09 | 5 | 0.04 | 8 | 0.12 | 9 | 0.12 | 6 |
| Poor quality of construction technology used and machinery breakdown | 0.09 | 6 | 0.04 | 9 | 0.16 | 7 | 0.08 | 7 |
| Delay in providing site conditions like water and electricity | 0.09 | 10 | 0.04 | 12 | 0.06 | 13 | 0.16 | 5 |
| Poor contract documentation | 0.08 | 11 | 0.04 | 13 | 0.12 | 10 | 0.08 | 9 |
| Poor coordination of design team | 0.07 | 12 | 0.08 | 6 | 0.06 | 12 | 0.08 | 10 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.05 | 14 | 0.04 | 14 | 0.08 | 11 | 0.04 | 14 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Poor procurement method and untimely deliveries | 0.05 | 15 | 0.04 | 15 | 0.04 | 17 | 0.08 | 11 |
| Substandard material and quality management | 0.05 | 13 | 0.08 | 7 | 0.04 | 16 | 0.04 | 17 |
| Lack of design knowledge & experience of client | 0.05 | 16 | 0.04 | 16 | 0.06 | 14 | 0.04 | 15 |
| Lack of funding | 0.05 | 17 | 0.04 | 17 | 0.06 | 15 | 0.04 | 16 |
| Changes in government regulations, laws, and policy | 0.04 | 19 | 0.04 | 19 | 0.04 | 19 | 0.04 | 19 |
| Non-Availability of construction materials/equipment in market | 0.04 | 20 | 0.04 | 20 | 0.04 | 20 | 0.04 | 20 |
| Poor briefing and coordination with client | 0.04 | 18 | 0.04 | 18 | 0.04 | 18 | 0.04 | 18 |

Large agreement was found between Contractor/Consultant and Contractor/Client and Consultant/Client as shown in the Table 5.17.

**Table 5.17. Group Agreement on Sub Factors (BRT Rawalpindi-Islamabad)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 2.20 | 10.00 | 78.00 |
| Contractor & Client | 2.50 | 10.00 | 75.00 |
| Consultant & Client | 2.20 | 10.00 | 78.00 |

Comments

From the data collected and further analysis of the study it was concluded that the following factors had the highest impact towards reworks in the project:

- Insufficient time for design stage
- Poor and adverse site conditions
- Design errors and unrealistic schedules
- Plan changes by client (Acceleration/Deceleration/Compression)
- Lack of constructability because of separation between design and construction conditions

### 5.4.2 Cost Impact of Factors

To determine the cost impact of main rework factors on the subject study project, an analysis was performed using the multiple regression equation derived from the research. The results are displayed in the Table 5.18.

**Table 5.18. Cost Impact of Main Factors (BRT Rawalpindi-Islamabad)**

| Project | Category | % Rework |
|---|---|---|
| BRT RWP-ISB | Client | 7.99 % |
| | Consultant | 4.10 % |
| | Contractor | 13.22 % |
| | Weighted Average | 8.43 % |

Comments

The multiple regression analysis of the data collected concluded that an estimated 8.43% of project cost was directly or indirectly expended on reworks.

## 5.5 BRT Peshawar

The fourth case was selected from the capital city Peshawar of province Khyber Pakhtunkhwa. The designed project consists of 31 stations spread all over the city and is divided into three major routes extending from Chamkani to east end of Karkhano market. The proposed corridor is 30.8 Km long, consisting of 23.3 Km at-grade section,4.1 Km elevated section and 3.5 Km tunnel section. The salient features of the study are shown in the Table 5.19.

**Table 5.19. Project Details of BRT Peshawar**

| **Project Name** | BRT Peshawar |
|---|---|
| **Scope** | Design and construction of a 30.8 Km long corridor with 31 stations, 4.1 Km elevated portion and 3.5 Km tunnel section |
| **Project Length** | 30.8 Km |
| **Client** | PDA |
| **Consultant** | MMP |
| **Contractor** | SGEC-Maqbool-Calsons |
| **Commencement Date** | November 2017 |
| **Completion Date** | August 13, 2020 |
| **Project Cost** | Rs 70,000 Mn |

### 5.5.1 Quantification of factors

The results obtained from the analysis of main factors of the subject case are shown in the Table 5.20.

**Table 5.20. RII Values and Ranks of Main Factors (BRT Peshawar)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Planning & Design Management | 0.88 | 1 | 1.00 | 1 | 0.84 | 2 | 0.80 | 1 |
| Field management | 0.84 | 2 | 1.00 | 2 | 0.84 | 3 | 0.69 | 2 |
| Project Communication | 0.83 | 3 | 1.00 | 3 | 0.98 | 1 | 0.51 | 6 |
| Contract Management | 0.78 | 4 | 1.00 | 4 | 0.78 | 4 | 0.57 | 5 |
| Client Management | 0.76 | 5 | 1.00 | 5 | 0.67 | 6 | 0.60 | 4 |
| External Environment | 0.70 | 6 | 0.80 | 6 | 0.69 | 5 | 0.60 | 3 |

A weighted average of the RII values indicated that poor Planning & Design Management is the foremost factor causing reworks in the project. However, Consultant opinioned that major problems occurred due to poor project communication. Moderate agreement was found between Contractor/Consultant and Contractor/Client. Little agreement was found between Consultant/Client as shown in the Table 5.21.

**Table 5.21. Group Agreement on Main Factors (BRT Peshawar)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.00 | 3.00 | 66.67 % |
| Contractor & Client | 1.33 | 3.00 | 55.56 % |
| Consultant & Client | 2.00 | 3.00 | 33.33 % |

A detailed analysis incorporating the sub factors of reworks was carried out. The results are shown in the Table 5.22.

**Table 5.22. RII Values and Ranks of Sub Factors (BRT Peshawar)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Design errors and unrealistic schedules | 0.74 | 1 | 1.00 | 1 | 0.69 | 1 | 0.54 | 1 |
| Lack of constructability because of separation between design and construction conditions | 0.63 | 2 | 1.00 | 2 | 0.55 | 5 | 0.34 | 7 |
| Poor coordination of design team | 0.63 | 3 | 1.00 | 3 | 0.60 | 3 | 0.29 | 10 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.63 | 4 | 1.00 | 4 | 0.48 | 8 | 0.41 | 5 |
| Insufficient time for design stage | 0.54 | 5 | 0.60 | 8 | 0.56 | 4 | 0.47 | 4 |
| Poor procurement method and untimely deliveries | 0.52 | 6 | 1.00 | 5 | 0.35 | 14 | 0.22 | 16 |
| Poor management and supervision | 0.51 | 7 | 0.80 | 6 | 0.50 | 6 | 0.24 | 15 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.49 | 8 | 0.36 | 10 | 0.64 | 2 | 0.47 | 3 |
| Poor communication/Misinformation | 0.44 | 9 | 0.80 | 7 | 0.34 | 15 | 0.18 | 18 |
| Poor coordination between client and end user | 0.38 | 10 | 0.48 | 9 | 0.27 | 18 | 0.39 | 6 |
| Lack of design knowledge & experience of client | 0.32 | 11 | 0.08 | 14 | 0.41 | 10 | 0.48 | 2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Substandard material and quality management | 0.30 | 12 | 0.16 | 12 | 0.49 | 7 | 0.26 | 13 |
| Poor contract documentation | 0.29 | 13 | 0.36 | 11 | 0.28 | 17 | 0.22 | 17 |
| Poor briefing and coordination with client | 0.26 | 14 | 0.12 | 13 | 0.38 | 12 | 0.28 | 11 |
| Poor quality of construction technology used and machinery breakdown | 0.26 | 15 | 0.08 | 15 | 0.43 | 9 | 0.26 | 14 |
| Poor and adverse site conditions | 0.25 | 16 | 0.04 | 16 | 0.41 | 11 | 0.30 | 8 |
| Lack of funding | 0.24 | 17 | 0.04 | 17 | 0.38 | 13 | 0.30 | 9 |
| Delay in providing site conditions like water and electricity | 0.20 | 18 | 0.04 | 18 | 0.29 | 16 | 0.27 | 12 |
| Non-Availability of construction materials/equipment in market | 0.15 | 19 | 0.04 | 19 | 0.23 | 19 | 0.17 | 19 |
| Changes in government regulations, laws, and policy | 0.12 | 20 | 0.04 | 20 | 0.23 | 20 | 0.09 | 20 |

Moderate to large agreement was found between Contractor/Consultant and Consultant/Client and Consultant/Client as shown in the Table 5.23.

**Table 5.23. Group Agreement on Sub Factors (BRT Peshawar)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 3.90 | 10.00 | 61.00 % |
| Contractor & Client | 5.10 | 10.00 | 49.00 % |
| Consultant & Client | 3.50 | 10.00 | 65.00 % |

Comments

From the data collected and further analysis of the study it was concluded that the following factors had the highest impact towards reworks in the project:

- Design errors and unrealistic schedules
- Lack of constructability because of separation between design and construction conditions
- Poor coordination of design team
- Construction errors due to misunderstanding of design and unclear instructions to workers
- Insufficient time for design stage

### 5.5.2 Cost Impact of Factors

To determine the cost impact of main rework factors on the subject study project, an analysis was performed using the multiple regression equation derived from the research. The results are displayed in the Table 5.24.

**Table 5.24. Cost Impact of Main Factors (BRT Peshawar)**

| Project | Category | % Rework |
|---|---|---|
| BRT Peshawar (Reach-1) | Client | 15.47 % |
| | Consultant | 9.52 % |
| | Contractor | 4.39 % |
| | Weighted Average | 9.79 % |

Comments

The multiple regression analysis of the data collected concluded that an estimated 9.79% of project cost (Reach-1) was directly or indirectly expended on reworks.

## 5.6 Jaglot-Skardu Highway

The fifth case was selected from the northern mountainous area of Gilgit-Baltistan. The Jaglot-Skardu Highway is a major link between Karakorum Highway and Skardu. In 1984 a track was constructed with a length of 164 Km and 3.66 meters width. The road is now being upgraded to a width of 7.3 meters with less sharp curves. The salient features of the study are shown in the Table 5.25.

**Table 5.25. Project Details of Jaglot-Skardu Highway**

| | |
|---|---|
| **Project Name** | Upgradation, Improvement, Widening &Construction of Jaglot-Skardu Highway |
| **Scope** | Construction of Road, Retaining & Breast Wall, Culvert & Bridges |
| **Project Length** | 164 Km |
| **Client** | PSDP |
| **Consultant** | FWO (FINIT, CPM) |
| **Contractor** | FWO |
| **Commencement Date** | August 2017 |
| **Completion Date** | Continued (97 Km Completed) |
| **Project Cost** | Rs 31,000 Mn (Estimated) |

### 5.6.1 Quantification of factors

The results obtained from the analysis of main factors of the subject case are shown in the Table 5.26.

**Table 5.26. RII Values and Ranks of Main Factors (Jaglot-Skardu Highway)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Field management | 1.00 | 1 | 1.00 | 1 | 1.00 | 1 | 1.00 | 1 |
| Contract Management | 0.94 | 2 | 1.00 | 2 | 0.90 | 3 | 0.93 | 3 |
| Project Communication | 0.93 | 3 | 0.93 | 3 | 0.90 | 4 | 0.95 | 2 |
| Planning & Design Management | 0.91 | 4 | 0.87 | 4 | 1.00 | 2 | 0.85 | 5 |
| External Environment | 0.83 | 5 | 0.80 | 6 | 0.80 | 5 | 0.88 | 4 |
| Client Management | 0.79 | 6 | 0.87 | 5 | 0.70 | 6 | 0.80 | 6 |

A weighted average of the RII values indicated that Field Management is the utmost factor to be catered for in this project to avoid reworks. However, differing views were obtained regarding the following factors involved as shown in the table. Moderate to large agreement was found between Contractor/Consultant, Contractor/Client and Consultant/Client as shown in the Table 5.27.

**Table 5.27. Group Agreement on Main Factors (Jaglot-Skardu Highway)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.00 | 3.00 | 66.67 % |
| Contractor & Client | 1.00 | 3.00 | 66.67 % |
| Consultant & Client | 1.00 | 3.00 | 66.67 % |

A detailed analysis incorporating the sub factors of reworks was carried out. The results are shown in the Table 5.28.

**Table 5.28. Group Agreement on Sub Factors (Jaglot-Skardu Highway)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Poor quality of construction technology used and machinery breakdown | 0.79 | 1 | 0.71 | 2 | 0.80 | 4 | 0.86 | 3 |
| Lack of funding | 0.77 | 2 | 0.61 | 7 | 1.00 | 1 | 0.71 | 10 |
| Poor management and supervision | 0.75 | 3 | 0.65 | 5 | 0.62 | 9 | 0.98 | 1 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.73 | 4 | 0.49 | 15 | 0.90 | 2 | 0.80 | 4 |
| Non-Availability of construction materials/equipment in market | 0.72 | 5 | 0.72 | 1 | 0.54 | 11 | 0.89 | 2 |
| Poor and adverse site conditions | 0.71 | 6 | 0.57 | 11 | 0.82 | 3 | 0.75 | 6 |
| Poor coordination between client and end user | 0.71 | 7 | 0.69 | 3 | 0.70 | 7 | 0.74 | 7 |
| Design errors and unrealistic schedules | 0.68 | 8 | 0.53 | 12 | 0.74 | 5 | 0.77 | 5 |
| Lack of constructability because of separation between design and construction conditions | 0.66 | 9 | 0.68 | 4 | 0.72 | 6 | 0.59 | 15 |
| Substandard material and quality management | 0.61 | 10 | 0.59 | 8 | 0.62 | 10 | 0.61 | 14 |
| Delay in providing site conditions like water and electricity | 0.56 | 11 | 0.53 | 13 | 0.52 | 12 | 0.64 | 12 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Poor coordination of design team | 0.55 | 12 | 0.64 | 6 | 0.46 | 14 | 0.56 | 17 |
| Poor contract documentation | 0.54 | 13 | 0.59 | 9 | 0.50 | 13 | 0.53 | 18 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.54 | 14 | 0.45 | 17 | 0.66 | 8 | 0.50 | 19 |
| Poor procurement method and untimely deliveries | 0.52 | 15 | 0.45 | 18 | 0.38 | 16 | 0.73 | 9 |
| Poor communication/Misinformation | 0.51 | 16 | 0.59 | 10 | 0.22 | 19 | 0.73 | 8 |
| Insufficient time for design stage | 0.50 | 17 | 0.53 | 14 | 0.34 | 17 | 0.62 | 13 |
| Changes in government regulations, laws, and policy | 0.48 | 18 | 0.31 | 20 | 0.42 | 15 | 0.71 | 11 |
| Poor briefing and coordination with client | 0.42 | 19 | 0.48 | 16 | 0.22 | 20 | 0.57 | 16 |
| Lack of design knowledge & experience of client | 0.39 | 20 | 0.40 | 19 | 0.34 | 18 | 0.44 | 20 |

Moderate agreement was found between Contractor/Consultant, Consultant/Client and Consultant/Client as shown in the Table 5.29.

**Table 5.29. Group Agreement on Sub Factors (Jaglot-Skardu Highway)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 5.20 | 10.00 | 48.00 % |
| Contractor & Client | 4.90 | 10.00 | 51.00 % |
| Consultant & Client | 4.80 | 10.00 | 52.00 % |

Comments

From the data collected and further analysis of the study it was concluded that the following factors had the highest impact towards reworks in the project:

- Poor quality of construction technology used and machinery breakdown
- Lack of funding
- Poor management and supervision
- Construction errors due to misunderstanding of design and unclear instructions to workers
- Non-Availability of construction materials/equipment in market

### 5.6.2 Cost Impact of Factors

To determine the cost impact of main rework factors on the subject study project, an analysis was performed using the multiple regression equation derived from the research. The results are displayed in the Table 5.30.

**Table 5.30. Cost Impact of Main Factors (Jaglot-Skardu Highway)**

| Project | Category | % Rework |
|---|---|---|
| Jaglot-Skardu Highway | Client | 13.56 % |
| | Consultant | 12.33 % |
| | Contractor | 13.07 % |
| | Weighted Average | 12.99 % |

Comments

The multiple regression analysis of the data collected concluded that an estimated 12.99% of project cost is expected to be directly or indirectly expended on reworks if the rework factors are not mitigated.

## 5.7 G-14/4 Islamabad

The sixth case was selected from the capital city Islamabad of Pakistan. The G-14/4 sector is located next to the main Kashmir Highway of the city. Although the road works of the local area had been completed earlier, due to poor workmanship and wear and tear the road network of the area is under rehabilitation. This local road network was selected as part of this research to study the findings on areas other than major highways. The salient features of the study are shown in the Table 5.31 below.

**Table 5.31. Project Details of Infra Development Rehabilitation of Sector G-14/4 Islamabad**

| | |
|---|---|
| **Project Name** | Infra Development and Rehabilitation of Sector G-14/4 Islamabad |
| **Scope** | Construction/ Rehabilitation of road network |
| **Project Length** | Mesh Road Network of around 1 × 1 Km |
| **Client** | FGEHA |
| **Consultant** | NESPAK |
| **Contractor** | AXS Pak |
| **Commencement Date** | February 2019 |
| **Completion Date** | December 2020 (Tentative) |
| **Project Cost** | Under Construction |

### 5.7.1 Quantification of factors

The results obtained from the analysis of main factors of the subject case are shown in the Table 5.32.

**Table 5.32. RII Values and Cost Impact of Main Factors (G-14/4 Islamabad)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Field management | 0.73 | 1 | 0.60 | 3 | 0.60 | 4 | 1.00 | 1 |
| Planning & Design Management | 0.73 | 2 | 0.80 | 1 | 0.60 | 3 | 0.80 | 2 |
| External Environment | 0.71 | 3 | 0.80 | 2 | 0.80 | 1 | 0.53 | 4 |
| Client Management | 0.68 | 4 | 0.60 | 4 | 0.70 | 2 | 0.73 | 3 |
| Contract Management | 0.51 | 5 | 0.40 | 5 | 0.60 | 5 | 0.53 | 5 |
| Project Communication | 0.46 | 6 | 0.40 | 6 | 0.50 | 6 | 0.47 | 6 |

A weighted average of the RII values indicated that Field Management is the utmost factor to be mitigated in this project to avoid reworks. However, differing views were obtained regarding the factors involved as shown in the table. Moderate to large agreement was found between Contractor/Consultant, Contractor/Client and Consultant/Client as shown in the Table 5.33.

**Table 5.33. Group Agreement on Main Factors (G-14/4 Islamabad)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 1.00 | 3.00 | 66.67 % |
| Contractor & Client | 1.00 | 3.00 | 66.67 % |
| Consultant & Client | 1.33 | 3.00 | 55.56 % |

A detailed analysis incorporating the sub factors of reworks was carried out. The results are shown in the Table 5.34.

**Table 5.34. RII Values and Ranks of Sub Factors (G-14/4 Islamabad)**

| | Weighted Average | | Contractor | | Consultant | | Client | |
|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Lack of constructability because of separation between design and construction conditions | 0.41 | 1 | 0.16 | 2 | 0.52 | 1 | 0.56 | 5 |
| Design errors and unrealistic schedules | 0.29 | 2 | 0.08 | 7 | 0.04 | 15 | 0.75 | 1 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.28 | 3 | 0.12 | 6 | 0.14 | 6 | 0.59 | 4 |
| Insufficient time for design stage | 0.28 | 4 | 0.08 | 8 | 0.14 | 7 | 0.61 | 3 |
| Delay in providing site conditions like water and electricity | 0.24 | 5 | 0.04 | 12 | 0.04 | 17 | 0.65 | 2 |
| Poor and adverse site conditions | 0.20 | 6 | 0.24 | 1 | 0.18 | 5 | 0.17 | 16 |
| Poor contract documentation | 0.19 | 8 | 0.16 | 3 | 0.04 | 13 | 0.36 | 8 |
| Poor management and supervision | 0.19 | 7 | 0.08 | 9 | 0.08 | 10 | 0.40 | 6 |
| Poor coordination between client and end user | 0.17 | 9 | 0.04 | 13 | 0.22 | 2 | 0.25 | 11 |
| Poor briefing and coordination with client | 0.16 | 11 | 0.04 | 15 | 0.20 | 3 | 0.24 | 13 |
| Poor procurement method and untimely deliveries | 0.16 | 10 | 0.04 | 14 | 0.04 | 18 | 0.40 | 7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lack of design knowledge & experience of client | 0.16 | 12 | 0.04 | 16 | 0.10 | 8 | 0.33 | 9 |
| Poor coordination of design team | 0.16 | 13 | 0.16 | 4 | 0.04 | 14 | 0.27 | 10 |
| Poor communication/Misinformation | 0.13 | 14 | 0.08 | 10 | 0.06 | 11 | 0.25 | 12 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.12 | 15 | 0.16 | 5 | 0.08 | 9 | 0.12 | 18 |
| Non-Availability of construction materials/equipment in market | 0.11 | 16 | 0.04 | 17 | 0.20 | 4 | 0.08 | 19 |
| Poor quality of construction technology used and machinery breakdown | 0.10 | 17 | 0.04 | 18 | 0.06 | 12 | 0.19 | 14 |
| Changes in government regulations, laws, and policy | 0.09 | 18 | 0.04 | 19 | 0.04 | 19 | 0.19 | 15 |
| Substandard material and quality management | 0.09 | 19 | 0.08 | 11 | 0.04 | 16 | 0.15 | 17 |
| Lack of funding | 0.04 | 20 | 0.04 | 20 | 0.04 | 20 | 0.04 | 20 |

Little to moderate agreement was found between Contractor/Consultant, Consultant/Client and Consultant/Client as shown in the Table 5.35.

**Table 5.35. Group Agreement on Sub Factors (G-14/4 Islamabad)**

| Project Participants | RA | RA Max | Percentage Agreement |
|---|---|---|---|
| Contractor & Consultant | 5.20 | 10.00 | 48.00 % |
| Contractor & Client | 5.20 | 10.00 | 48.00 % |
| Consultant & Client | 6.30 | 10.00 | 37.00 % |

Comments

From the data collected and further analysis of the study it was concluded that the following factors had the highest impact towards reworks in the project:

- Lack of constructability because of separation between design and construction conditions
- Design errors and unrealistic schedules
- Plan changes by client (Acceleration/Deceleration/Compression)
- Insufficient time for design stage
- Delay in providing site conditions like water and electricity

### 5.7.2 Cost Impact of Factors

To determine the cost impact of main rework factors on the subject study project, an analysis was performed using the multiple regression equation derived from the research. The results are displayed in the Table 5.36.

**Table 5.36. Cost Impact of Main Factors (G-14/4 Islamabad)**

| Project | Category | % Rework |
|---|---|---|
| Infra Development and Rehabilitation of Sector G-14/4 Islamabad | Client | 3.66 % |
| | Consultant | 4.95 % |
| | Contractor | 6.01 % |
| | Weighted Average | 4.87 % |

Comments

The multiple regression analysis of the data collected concluded that an estimated 4.87% of project cost is expected to be directly or indirectly expended on reworks if the rework factors are not mitigated.

## 5.8 Comparative Analysis of Case Studies

To determine the effects of reworks and the application of the findings of this research on the case studies, a comparative analysis was conducted. For this purpose, a comparison of main factors and sub factors was made based upon their RII values and ranking in each project. The results are discussed below.

### 5.8.1 Main Factors

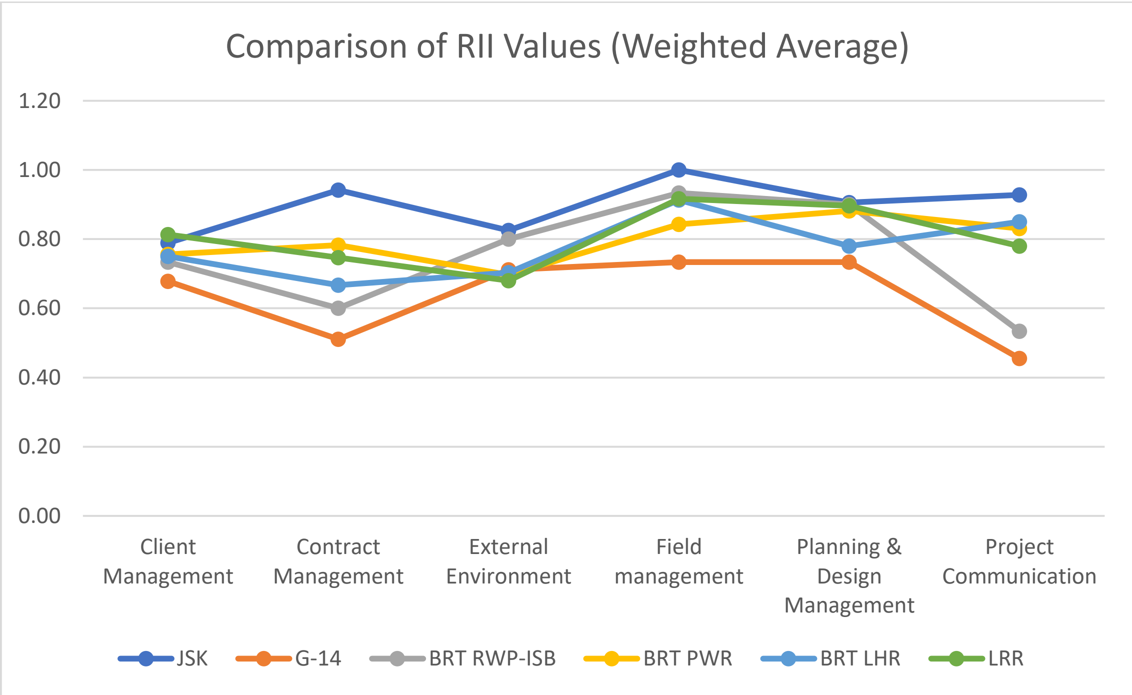


**Fig 5.1. Comparison of RII Values of Main Factors (Comparative Analysis)**

**Table 5.37. Comparison of RII Values and Ranks of Main Factors (Comparative Analysis)**

| | JSK | | G-14 | | BRT RWP-ISB | | BRT PWR | | BRT LHR | | LRR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Client Management | 0.79 | 6 | 0.68 | 4 | 0.73 | 4 | 0.76 | 5 | 0.75 | 4 | 0.81 | 3 |
| Contract Management | 0.94 | 2 | 0.51 | 5 | 0.60 | 5 | 0.78 | 4 | 0.67 | 6 | 0.75 | 5 |
| External Environment | 0.83 | 5 | 0.71 | 3 | 0.80 | 3 | 0.70 | 6 | 0.70 | 5 | 0.68 | 6 |
| Field management | 1.00 | 1 | 0.73 | 1 | 0.93 | 1 | 0.84 | 2 | 0.91 | 1 | 0.92 | 1 |
| Planning & Design Management | 0.91 | 4 | 0.73 | 2 | 0.90 | 2 | 0.88 | 1 | 0.78 | 3 | 0.90 | 2 |
| Project Communication | 0.93 | 3 | 0.46 | 6 | 0.53 | 6 | 0.83 | 3 | 0.85 | 2 | 0.78 | 4 |

A comparative analysis of the weighted average values of RII, as shown in Fig 5.1 and Table 5.37, showed that almost all the main factors scored a higher RII value in the Jaglot-Skardu Highway project with the exception of Client Management. The weighted average RII value of Client Management was found to be higher in Lahore Ring Road project. The higher values of RII in Jaglot-Skardu Highway project also indicate towards a higher estimated percentage rework cost of 12.99% than any other subject study project. Higher values of RII do not mean that the respective main factors were poorly dealt with. However, these values signify that in comparison the Jaglot-Skardu project faced and is likely to face more challenges regarding these rework factors than other subject study projects. On the contrary, the Infrastructure development and rehabilitation of G-14/4 project has the lowest RII values (weighted average) of all the main factors with the exception of External Environment. Thus, the corresponding expected percentage rework cost value of the project is also the lowest at 4.87 %.

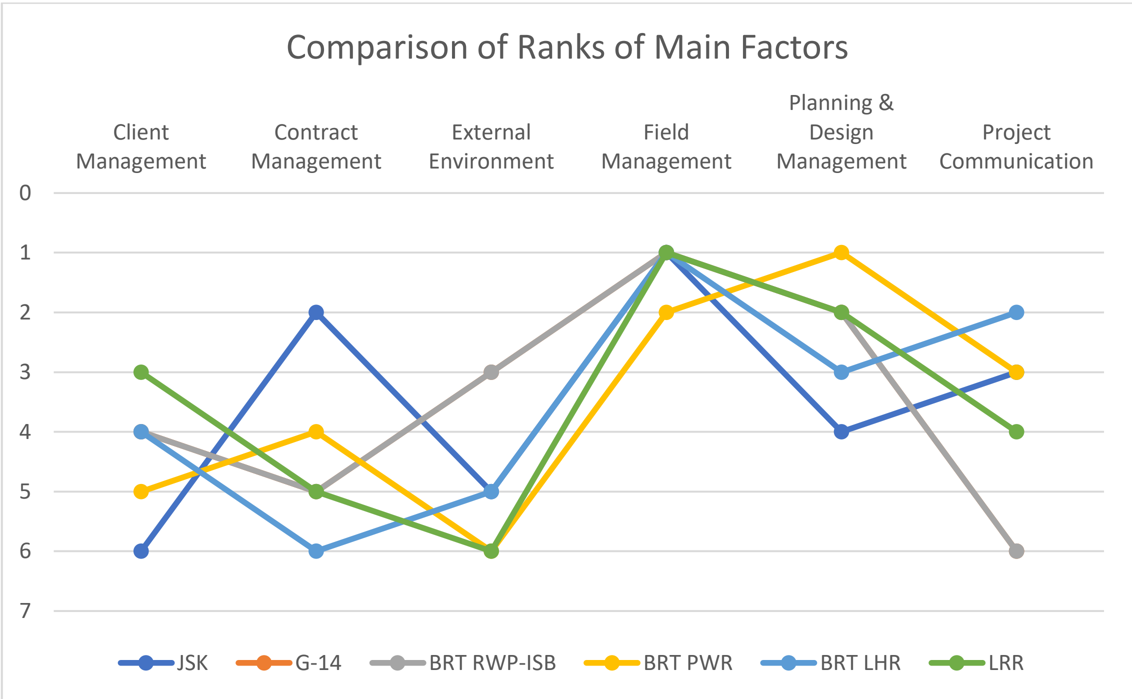


**Fig 5.2. Comparison of Ranks of Main Factors (Comparative Analysis)**

A comparative analysis of the ranks of main factors of reworks in the subject study projects, as shown in Fig 5.2, concludes that in almost all the projects, Field Management was found to be the highest ranked main factor contributing towards reworks. A single exception of the project of BRT Peshawar was found in which, Planning and Design Management was found to be highest ranked main factor. It was also noted that the rankings of main factors in the projects of BRT Rawalpindi-Islamabad and Infrastructure Development and Rehabilitation of

G-14/4 were similar. However, this does not mean that the factors had the same impact on both the projects. As it can be seen in the RII analysis and MRA that both projects had been impacted differently and have different estimated percentage rework cost values.

### 5.8.2 Sub Factors

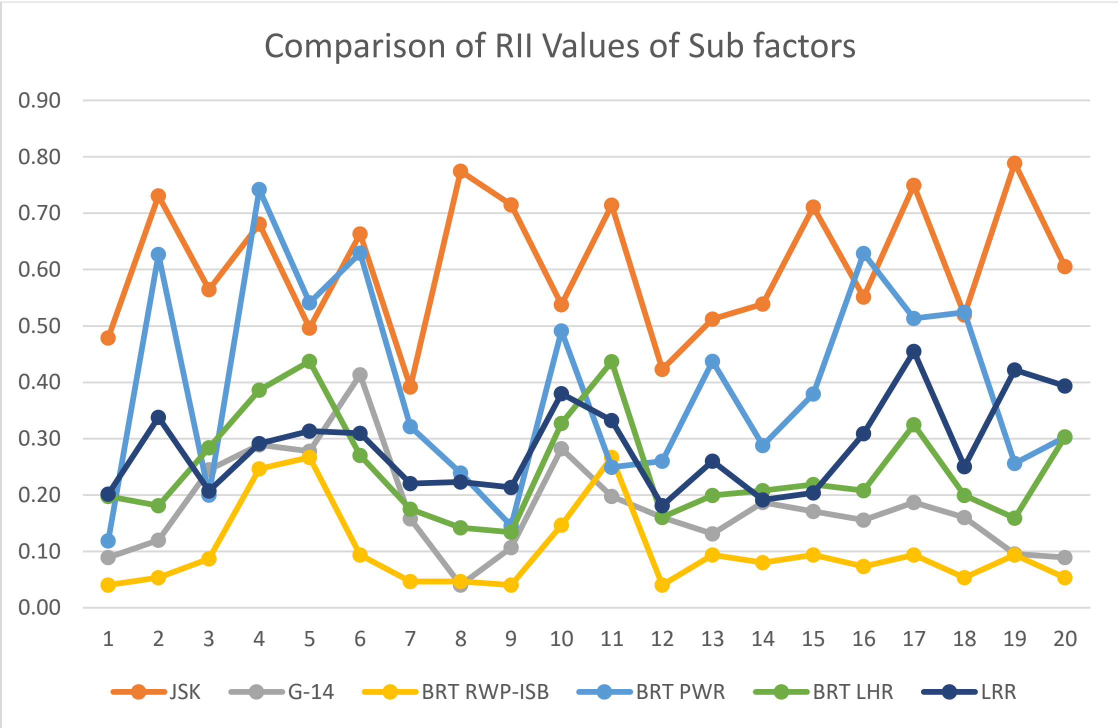


**Fig 5.3. Comparison of RII Values of Sub Factors (Comparative Analysis)**

1. Changes in government regulations, laws, and policy
2. Construction errors due to misunderstanding of design and unclear instructions to workers
3. Delay in providing site conditions like water and electricity
4. Design errors and unrealistic schedules
5. Insufficient time for design stage
6. Lack of constructability because of separation between design and construction conditions

7. Lack of design knowledge & experience of client
8. Lack of funding
9. Non-Availability of construction materials/equipment in market
10. Plan changes by client (Acceleration/Deceleration/Compression)
11. Poor and adverse site conditions
12. Poor briefing and coordination with client
13. Poor communication/Misinformation
14. Poor contract documentation
15. Poor coordination between client and end user
16. Poor coordination of design team
17. Poor management and supervision
18. Poor procurement method and untimely deliveries
19. Poor quality of construction technology used and machinery breakdown
20. Substandard material and quality management

A comparative analysis of the weighted average of RII values of sub factors, as shown in Fig 5.3, concluded that much like the trend of main factors, almost all the sub factors scored a higher RII value in Jaglot-Skardu Highway project. The ongoing Jaglot-Skardu Highway project is located in the mountainous region of Gilgit. The site is in a tough terrain and is far away from the urban areas. Although, the construction is under the supervision of a highly competitive, skilled and disciplined organization, the challenges cannot be ignored. On the contrary, the weighted average RII values of BRT RWP-ISB project were found to be the lowest for almost all the sub factors.

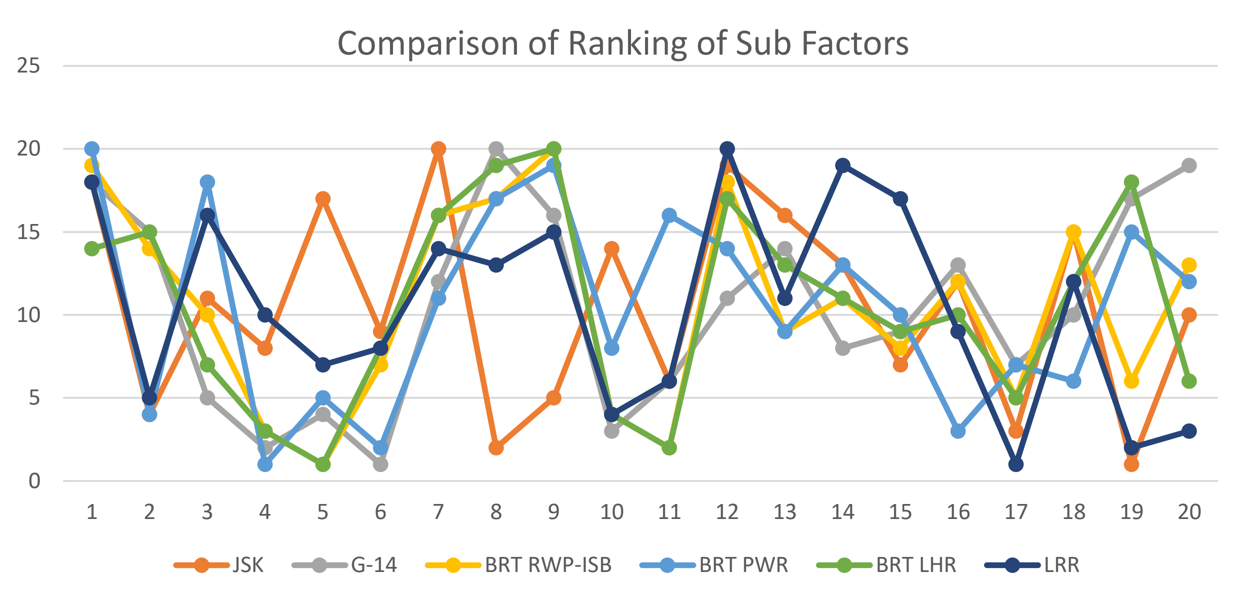


**Fig 5.4. Comparison of Ranks of Sub Factors (Comparative Analysis)**

A comparative analysis of the ranks of sub factors for all the subject study projects, as shown in Fig 5.4, display a scatter of values, pointing towards the fact that every project is unique and faces unique challenges. However, a cluster of data points can be seen on a few occasions. For example, a cluster of sub factors 4 to 6 indicate that 4 out of 6 projects recorded these sub factors in the top 5 ranks. Similarly, sub factor 17 i.e. “Poor management and supervision” was ranked in top 10 for all the projects. A detailed analysis of RII values and ranks of sub factors of subject studies can be seen in Table 5.38.

**Table 5.38. Comparison of RII Values and Ranks of Sub Factors (Comparative Analysis)**

| | JSK | | G-14 | | BRT RWP-ISB | | BRT PWR | | BRT LHR | | LRR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub Factors | RII | Rank | RII | Rank | RII | Rank | RII | Rank | RII | Rank | RII | Rank |
| Changes in government regulations, laws, and policy | 0.48 | 18 | 0.09 | 18 | 0.04 | 19 | 0.12 | 20 | 0.20 | 14 | 0.20 | 18 |
| Construction errors due to misunderstanding of design and unclear instructions to workers | 0.73 | 4 | 0.12 | 15 | 0.05 | 14 | 0.63 | 4 | 0.18 | 15 | 0.34 | 5 |
| Delay in providing site conditions like water and electricity | 0.56 | 11 | 0.24 | 5 | 0.09 | 10 | 0.20 | 18 | 0.28 | 7 | 0.21 | 16 |
| Design errors and unrealistic schedules | 0.68 | 8 | 0.29 | 2 | 0.25 | 3 | 0.74 | 1 | 0.39 | 3 | 0.29 | 10 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insufficient time for design stage | 0.50 | 17 | 0.28 | 4 | 0.27 | 1 | 0.54 | 5 | 0.44 | 1 | 0.31 | 7 |
| Lack of constructability because of separation between design and construction conditions | 0.66 | 9 | 0.41 | 1 | 0.09 | 7 | 0.63 | 2 | 0.27 | 8 | 0.31 | 8 |
| Lack of design knowledge & experience of client | 0.39 | 20 | 0.16 | 12 | 0.05 | 16 | 0.32 | 11 | 0.17 | 16 | 0.22 | 14 |
| Lack of funding | 0.77 | 2 | 0.04 | 20 | 0.05 | 17 | 0.24 | 17 | 0.14 | 19 | 0.22 | 13 |
| Non-Availability of construction materials/equipment in market | 0.72 | 5 | 0.11 | 16 | 0.04 | 20 | 0.15 | 19 | 0.13 | 20 | 0.21 | 15 |
| Plan changes by client (Acceleration/Deceleration/Compression) | 0.54 | 14 | 0.28 | 3 | 0.15 | 4 | 0.49 | 8 | 0.33 | 4 | 0.38 | 4 |
| Poor and adverse site conditions | 0.71 | 6 | 0.20 | 6 | 0.27 | 2 | 0.25 | 16 | 0.44 | 2 | 0.33 | 6 |
| Poor briefing and coordination with client | 0.42 | 19 | 0.16 | 11 | 0.04 | 18 | 0.26 | 14 | 0.16 | 17 | 0.18 | 20 |
| Poor communication/Misinformation | 0.51 | 16 | 0.13 | 14 | 0.09 | 9 | 0.44 | 9 | 0.20 | 13 | 0.26 | 11 |
| Poor contract documentation | 0.54 | 13 | 0.19 | 8 | 0.08 | 11 | 0.29 | 13 | 0.21 | 11 | 0.19 | 19 |
| Poor coordination between client and end user | 0.71 | 7 | 0.17 | 9 | 0.09 | 8 | 0.38 | 10 | 0.22 | 9 | 0.20 | 17 |
| Poor coordination of design team | 0.55 | 12 | 0.16 | 13 | 0.07 | 12 | 0.63 | 3 | 0.21 | 10 | 0.31 | 9 |
| Poor management and supervision | 0.75 | 3 | 0.19 | 7 | 0.09 | 5 | 0.51 | 7 | 0.32 | 5 | 0.45 | 1 |
| Poor procurement method and untimely deliveries | 0.52 | 15 | 0.16 | 10 | 0.05 | 15 | 0.52 | 6 | 0.20 | 12 | 0.25 | 12 |
| Poor quality of construction technology used and machinery breakdown | 0.79 | 1 | 0.10 | 17 | 0.09 | 6 | 0.26 | 15 | 0.16 | 18 | 0.42 | 2 |
| Substandard material and quality management | 0.61 | 10 | 0.09 | 19 | 0.05 | 13 | 0.30 | 12 | 0.30 | 6 | 0.39 | 3 |

# CONCLUSIONS & RECOMMENDATIONS

## 6.1 Introduction

This chapter covers the conclusions and recommendations that would help the road infrastructure industry of Pakistan to anticipate and consequently take effective action against the main and sub factors contributing towards reworks. The first objective of this study was to identify all the factors causing reworks in road infrastructure industry of Pakistan through literature review and input from highly experienced professionals of the industry. The second objective was to conduct a large-scale questionnaire survey in order to obtain feedback regarding the impact of these factors on road infrastructure projects. The third and final objective of this study was to perform statistical analysis on these responses to evaluate these factors with respect to the construction industry of Pakistan. After evaluation of said factors, case studies were conducted and finally recommendations were made to improve project performance.

## 6.2 Conclusions

The conclusions of the study are as follows:

### 6.2.1 Top 3 Main Factors:

According to the overall response it was determined that ‘Planning & Design Management’ is the most important main factor causing reworks. ‘Project Communication’ was found to be the second and ‘Field Management’ was ranked as the third most important main factor.

### 6.2.2 Top 5 Sub Factors:

Out of all the 20 sub factors, the study showed that ‘Lack of Funds’ was the highest ranked sub-factor causing reworks in road infrastructure industry of Pakistan. The study indicates that the lack of funds causes delays resulting towards wear and tear of the road project. ‘Substandard material and quality management’ was found to be the second most important sub factor followed by ‘Poor management and supervision’. Both sub factors belong to the same category of ‘Field management’. ‘Construction errors due to misunderstanding of design and unclear instructions to workers’ also belonging to the same category was ranked as the fourth most important sub factor. Finally, ‘Design errors and unrealistic schedules’ was ranked as the fifth most important sub factor out of 20 sub factors shortlisted in this study.

### 6.3 Cost Impact:

A multiple regression analysis was conducted to determine the empirical relationship between estimated percentage cost impact and main factors on the cost of project. The results of the analysis revealed the following equation:

$$Y = 0.944X_1 + 1.022X_2 + 1.415X_3 + 1.169X_4 + 1.189X_5 + 0.832X_6 - 16.22$$

**Equation 6.1**

Where;

Y = Estimated percentage rework cost

X1 = Field Management

X2 = Planning & Design Management

X3 = Client Management

X4 = External Environment

X5 = Contract Management

X6 = Project Communication

## 6.4 Agreement of Major Stakeholders

In general, large agreement was found between contractors, consultants and clients regarding the ranking of main factors and moderate agreement was found for ranking of sub factors causing reworks in road infrastructure projects of Pakistan.

## 6.5 Case Studies

Upon the application of the findings of this study on 6 subject studies it was revealed that every project is unique and has different challenges based upon factors like location, duration and pressure from the client etc. However, some similarity was found as 'Field Management' and 'Planning & Design Management' was found to be the key factors in these case study projects. Furthermore, it was also discovered that local and small projects are likely to incur lesser percentage rework costs in comparison to large-scale mega highway projects. A scatter of sub factors was found upon analysis of all the case studies revealing that all the 20 sub factors shortlisted earlier have their own relative importance. A cluster of sub factors was also found that shows that some sub factors are recurring in every project and are a threat to the road infrastructure industry of the country.

## 6.6 Recommendations

Based on the findings of this study, following recommendations are made:

- Proper funding of the project must be ensured before the start of the project in order to avoid any damage to progress made
- A detailed and thorough quality management plan must be implemented to assure use

of high-quality material and construction practices

- Proper site management and supervision must be ensured through experienced and qualified site personnel
- Placement of technically sound and skilled personnel on site to make sure that proper instructions are communicated to the construction workers
- Avoid giving unrealistic deadlines at all costs and ensure proper plan and design before the start of construction process
- Follow the initial plan and avoid making changes by altering the pace of project repeatedly
- Thoroughly vet the qualification of contractor in terms of finances and machinery, before the award of contract
- Develop a proper communication framework and chain of command. Ensure the awareness of these communication channels to all the personnel involved in the project
- Ensure proper coordination between all the major stakeholders so that everyone is on the same page
- Representation of equally experienced and knowledgeable professionals as part of clients' team for better participation and involvement of client in the project
- Provide sufficient time to design consultants for a flawless design to avoid design changes in critical stages of project
- Ensure clear and detailed contract documentation in order to avoid legal and responsibility issues in later stages of project

The methodology applied and findings of this research can also be used to determine the rework factors in other sectors of construction industry. The results of this study would help identify, quantify and take a proactive approach towards the factors causing reworks in road infrastructure projects in Pakistan. The inclusion of the findings of the study in feasibility reports would help improve project performance.

## 6.7 Future Study

The findings of this study are limited to road infrastructure industry of Pakistan. However, with the help of this study, future studies can be carried out in other sectors of the construction industry as well. The impacts of the factors highlighted in this study can be further improved and refined by application of these factors on a real-time project from its conception till its end date. Detailed analysis can also be performed with respect to all the major stakeholders. As all rework costs are not documented, calculation of these costs can be determined by presence of research team on site.

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# APPENDIX

| Quantification and Cost Impacts of Risk Factors Causing Reworks in Road Infrastructure Projects in Pakistan |
|---|

| |
|---|
| You are requested to kindly rate the factors as asked. You may also suggest any addition or subtraction of any main/sub factors as deemed appropriate. Your valuable contribution will go a long way in establishing a benchmark for good engineering practices and cost-effective measures for road infrastructure projects in Pakistan. |

| **Demographic Data** | |
|---|---|
| **Note: Following data is being compiled for academic purpose only. Personal information will not be shared.** | |
| **NAME:** | **AGE:** |
| **HIGHEST QUALIFICATION:** | **EXPERIENCE:**<br>**OVERALL: ____YEARS**<br>**ROAD CONSTRUCTION: ____YEARS** |
| **SECTOR:**<br>**PUBLIC ______ PRIVATE ______** | |
| **COMPANY/ORGANIZATION:** | **DESIGNATION:** |

| ORGANIZATIONAL MEASURES | | | |
|---|---|---|---|
| 1. | Have you ever received formal risk management training? | **Yes** | **No** |
| 2. | Does your company have formal risk management program? | **Yes** | **No** |
| 3. | Is this risk management program effective? | **Yes** | **No** |
| 4. | Is there any risk record mechanism in your organization? | **Yes** | **No** |
| 5. | Does your company have a separate risk management department? | **Yes** | **No** |
| 6. | Is risk management training provided to new workers? | **Yes** | **No** |
| 7. | Is the risk management policy displayed? | **Yes** | **No** |
| 8. | Does your company employ a full-time risk management officer on site? | **Yes** | **No** |
| 9. | In what category does your experience mainly fall?<br>**a. Consultant** **b. Contractor** **c. Client** | | |
| 10. | How frequently do you carry out risk management meetings on site?<br>**a. Weekly** **b. Fortnightly** **c. Monthly** **d. Never** | | |
| 11. | Does your company maintain a record of expenses incurred on reworks? | **Yes** | **No** |
| 12. | In your professional experience, what percentage of the project cost is expended on reworks in road infra projects in Pakistan? | **____%** | |

## Evaluation of Risk Factors/ Sub Factors Contributing TowardsReworks in Road Infrastructure Projects in Pakistan

Prime contributors to reworks in road infrastructure projects in Pakistan based on literature review are appended below. You may also add/subtract any factor(s) in the blank spaces provided. Kindly give them a weightage from 1-5 basing on their relative importance as given below. Use of check mark (✓) is appreciated:

1. **Irrelevant**
2. **Not so important**
3. **Important to some extent**
4. **Significant**
5. **Extremely important**

## PART-1

## MAIN FACTORS

| S/No. | MAIN FACTORS | Score based on significance | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1. | **Field management** | | | | | |
| 2. | **Planning and Design Management** | | | | | |
| 3. | **Client Management** | | | | | |
| 4. | **External Environment** | | | | | |
| 5. | **Contract management** | | | | | |
| 6. | **Project Communication** | | | | | |

# PART-2

## SUB-FACTORS

Irrespective of weightage assigned to above main factors, assign weightage to following sub factors in accordance to occurrence (1 being least and 5 being highest occurrence) and their cost impact. Use of check mark (✓) is appreciated:

| S/No. | Sub Factors for Field Management | Score based on occurrence | | | | | % Score based on cost impact to total cost of reworks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | <20% | 20-40% | 40-60% | 60-80% | >80% |
| 1. | Poor management and supervision | | | | | | | | | | |
| 2. | Substandard material and quality management | | | | | | | | | | |
| 3. | Construction errors due to misunderstanding of design and unclear instructions to workers | | | | | | | | | | |
| 4. | Poor quality of construction technology used and machinery breakdown | | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5. | Poor procurement method and untimely deliveries | | | | | | | | | | |

| S/No. | **Sub Factors for Planning and Design Management** | **Score based on occurrence** | | | | | **% Score based on cost impact to total cost of reworks** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **<20%** | **20-40%** | **40-60%** | **60-80%** | **>80%** |
| 1. | Poor coordination of design team | | | | | | | | | | |
| 2. | Insufficient time for design stage | | | | | | | | | | |
| 3. | Design errors and unrealistic schedules | | | | | | | | | | |
| 4. | Plan changes by client (Acceleration/ Deceleration/ Compression) | | | | | | | | | | |
| 5. | Lack of constructability because of separation between design and construction conditions | | | | | | | | | | |

| S/No. | **Sub Factors for Client Management** | **Score based on occurrence** | | | | | **Score based on percentage cost impact to total cost of reworks** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **<20%** | **20-40%** | **40-60%** | **60-80%** | **>80%** |
| 1. | Poor coordination between client and end user | | | | | | | | | | |
| 2. | Poor briefing and coordination with client | | | | | | | | | | |
| 3. | Delay in providing site conditions e.g. water and electricity etc. | | | | | | | | | | |
| 4. | Lack of design knowledge & experience of client | | | | | | | | | | |
| 5. | Lack of funds | | | | | | | | | | |

| S/No. | **Sub Factors for External Environment** | **Score based on occurrence** | | | | | **% Score based on cost impact to total cost of reworks** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **<20%** | **20-40%** | **40-60%** | **60-80%** | **>80%** |
| 1. | Poor and adverse site conditions | | | | | | | | | | |
| 2. | Changes in government regulations, laws, and policy | | | | | | | | | | |
| 3. | Non-Availability of construction materials/equipment in market | | | | | | | | | | |

| S/No. | **Sub Factors for Contract management** | **Score based on occurrence** | | | | | **% Score based on cost impact to total cost of reworks** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **<20%** | **20-40%** | **40-60%** | **60-80%** | **>80%** |
| 1. | Poor contract documentation | | | | | | | | | | |

| S/No. | **Sub Factors for Project Communication** | **Score based on occurrence** | | | | | **% Score based on cost impact to total cost of reworks** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **<20%** | **20-40%** | **40-60%** | **60-80%** | **>80%** |
| 1. | Poor communication/ Misinformation | | | | | | | | | | |

**COMMENTS/ SUGGESTIONS:**

Thank you for your precious time!