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FACTORS INFLUENCING THE DURATION OF ROAD CONSTRUCTION PROJECTS IN SRI LANKA

BY

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Supervised by

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This dissertation was submitted to the Department of Civil Engineering of the University of Moratuwa in partial fulfilment of the requirement for the Degree of Master of Science in Construction Project Management.

DEPARTMENT OF CIVIL ENGINEERING
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MORATUWA SRI LANKA

2010

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Abstract

One of the most important problems in the construction industry is delays. Delays occur in every construction project and the magnitude of these delays varies considerably from project to project. Hence, the duration of construction projects right from inception to completion is assumed great importance in the construction industry. Further, in many instances it is most cost-effective to complete a project within the shortest possible time.

Most of Road Construction Projects in Sri Lanka are experienced larger delays, and hence it's badly affected to the economy in many ways. Further, this has been identified as a socio-economic problem, and therefore an urgent rectification is required.

This study attempted to reveal the Factors Influencing the Duration of Road Construction Projects in Sri Lanka, and to identify how delays can be mitigated. The emphasis here was limited to study the Contractor's point of view. The main concern of the study was to Predict the nature of the Population using Statistical Inference - Identify the Confidence Interval for Population Mean of Percentage Delay via sample analysis. The other focusing areas were, Main Causes of Delay & Delay Diversification - Identify the Probable Reasons, which affect the Duration of Road Construction Projects, and Highlight the key / dominant factors of delay and identify how they are distributed, and Delay Mitigation - Identify how the effects of delays can be minimised.

The preliminary data for this research have been collected through a literature review and the use of a questionnaire survey targeted at local contractors of Road Construction. The data acquired were yielded a high reliability coefficient (90%).

This study defines the Percentage Delay parameter, and the Relative Significance Index (RSI) model, which are the new concepts introduced by the author this study.

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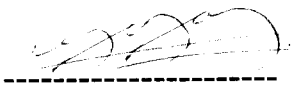
This study found that the local road construction projects are experienced 56 % - 88 % of average time overrun compared to the original (planned) project duration. The findings further revealed that the financial problems of the Owner as well as of the Contractor, is the most influencing factor in causing delay in road construction projects in Sri Lanka. Poor site management by the Contractor, followed by poor weather conditions that is an External Factor, contract modifications by the Owner, incomplete documents, delayed and slow supervision in making decisions and giving instructions by both the Consultant and the Owner are appeared to be the next critical factors in causing delays in local road constructions. Further, the responsibilities of the Contractor such as, shortage of site labour and materials, lack of subcontractor's skills, construction mistakes and defective work, poor skills and experience of labour, and finally delay in delivery of materials to site were revealed as the factors with significant probability of causing delays.

DECLARATION

I hereby certify that this dissertation does not incorporate any material without acknowledgement, and material previously submitted for a degree or diploma in any university to the best of my knowledge, and further I believe it does not contain any material previously published, written or orally communicated by another person except where due reference is made in the text.



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25/01/2010
Date

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This is to certify that this thesis submitted by Yasas L. Pathiranage is a record of the candidate's own work carried out by him under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree.

UOM Verified Signature

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25/01/2010
Date

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to the Department of Civil Engineering, University of Moratuwa for offering me this valuable opportunity to conduct an empirical study on Duration of Road Construction Projects in Sri Lanka.

I deeply appreciate my research supervisor Dr. R. U. Halwatura, *Senior Lecturer, Department of Civil Engineering, University of Moratuwa*, for his continuous support and guidance rendered during the period of this study.

My respect goes to Prof. J. M. S. J. Bandara, *Head, Highway & Transportation Engineering Division, Department of Civil Engineering, University of Moratuwa*, Dr. A. A. D. A. J. Perera, *Head, Construction Engineering & Management Division, Department of Civil Engineering, University of Moratuwa*, Eng. D. N. H. Liyanage, *Project Engineer, Road Development Authority*, and Eng. K. Chandramohan, *Chief Engineer, Department of Buildings*, for the expert comments given pertaining to this study area.

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I express my sincere thanks to all professionals who contributed to the questionnaire survey by sacrificing their precious time and energy.

My special respect and gratitude goes to my workplace management, especially to my immediate superior Eng. C. Wickramasinghe, *Local Project Manager, SIEMENS AG* for the numerous support and courage extended during the whole period of this engagement.

Last, but not least, I am greatly indebted to my wife and parents for their endless patience, support, and encouragement given throughout this study in order to make this event a success.

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LIST OF SYMBOLS

d_i	- Percentage Delay
$t_{ActuallyElapsed}$	- Actual Time Elapsed for the Completion
$t_{Planned}$	- Planned Project Duration
n	- Sample Size
$\bar{x}$	- Sample Mean
s^2	- Sample Variance
μ	- Population Mean
σ^2	- Population Variance
α	- Significance Level
μ_{d_i}	- Population Mean of Percentage Delay
W	- Weighting given to each Delay Factor
A	- Highest Weight
N	- Total number of respondents

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ABBREVIATIONS AND ACRONYMS

GR	- Group Rank
GW	- Group Weightage
OR	- Overall Rank
OW	- Overall Weightage
RII	- Relative Importance Index
RSI	- Relative Significance Index

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Chapter 1

INTRODUCTION

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1.1 Background & Problem Definition

The time duration of construction projects right from inception to completion is assumed great importance in the construction industry. Further, in many instances it is most cost-effective to complete a project within the shortest possible time.

One of the most important problems in the construction industry is delays. Delays occur in every construction project and the magnitude of these delays varies considerably from project to project. Some projects are only a few days behind schedule; some are delayed by over a year. So it is essential to define the actual causes of delay in order to minimize and avoid delays in any construction project. The successful execution of construction projects and keeping them within estimated cost and prescribed schedules depends on a methodology that requires sound engineering judgment (Al-Moumani, 2000).

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Delay is a common source of dispute in construction projects cause severe losses to the parties of the construction contract. For employers, delays mean loss of revenues due to the inability to run the new facilities, and/or depending on the present inefficient facilities, in addition to the high cost of investment and interest during construction. For contractors, the losses due to delays are attributed to: (1) increasing overhead costs because of the longer construction period; (2) increasing material costs and labour wages due to escalation; and (3) applying liquidated damage or penalty clauses (Marzouk et al., 2008).

Further, completing projects on time is an indicator of efficiency, but the construction process is subject to many variables and unpredictable factors, which result from many sources. These sources include the performance of parties, resources availability, environmental conditions, involvement of other parties, and contractual relations. However, it is rarely happen that a project is completed within the specified time (Sadi A. Assaf et al., 2006).

Most of Road Construction Projects in Sri Lanka are experienced larger delays, and hence it's badly affected to the economy in many ways. Further, this has been identified as a socio-economic problem, and therefore an urgent rectification is required.

This study will attempt to reveal the Factors Influencing the Duration of Road Construction Projects in Sri Lanka, and to identify how delays can be mitigated. Further, a prediction about the nature of the population (Road Projects in Sri Lanka) will be expected via sample analysis. The emphasis here is limited to study the Contractor's point of view. As the data collection will be done via a questionnaire survey, the accuracy of the findings and as well as the analysis merely depend on the quality of the responses.

1.2 Research Objectives

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The main objectives of the study are to be revealed the following with respect to the Road Construction Projects in Sri Lanka.

- Predict the nature of the Population using Statistical Inference – Identify the Confidence Interval for Population Mean of Percentage Delay via sample analysis

- Main Causes of Delay & Delay Diversification – Identify the Probable Reasons, which affect the Duration of Road Construction Projects, and Highlight the key / dominant factors of delay and identify how they are distributed

- Delay Mitigation – Identify how the effects of delays can be minimised

1.3 Conceptual Framework & Research Design / Methodology

The preliminary data for this research will be collected through a literature review and the use of a questionnaire survey targeted at local contractors of Road Construction.

The literature review will be conducted through books, conference proceedings, the internet, and construction management and engineering journals.

An unbiased random sample of Road Construction Delay Cases will be studied in order to predict the nature of the Population (General Circumstance) using Statistical Inference. Later the possible actions for Delay Mitigation will be discussed with the output revealed.

1.4 Main Findings

This study found that the local road construction projects are experienced ***56 % ~ 88 %*** of average time overrun compared to the original (planned) project duration.

The findings further revealed that the ***financial problems*** of the Owner as well as of the Contractor, is the most influencing factor in causing delay in road construction projects in Sri Lanka. ***Poor site management*** by the Contractor, followed by **poor weather conditions** that is an External Factor, ***contract modifications*** by the Owner, ***incomplete documents***, ***delayed and slow supervision in making decisions and giving instructions*** by both the Consultant and the Owner are appeared to be the next critical factors in causing delays in local road constructions. Further, the responsibilities of the Contractor such as, ***shortage of site labour and materials***, ***lack of subcontractor's skills***, ***construction mistakes and defective work***, ***poor skills and experience of labour***, and finally ***delay in delivery of materials to site*** were revealed as the factors with significant probability of causing delays.

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1.5 Guide to the Report

This section discusses the structure and the flow of the report. The report consists of following five chapters.

- Chapter 1 – Introduction
- Chapter 2 – Literature Review

- Chapter 3 – Methodology of Study
- Chapter 4 – Analysis and Discussion of Results
- Chapter 5 – Conclusions and Recommendations

Chapter 1 provides an introduction to the study. It describes *Background & Problem Definition*, *Research Objectives*, *Conceptual Framework & Research Design / Methodology*, and *Main Findings*. Further, it provides a *Guide to the Report* summarising each chapter to follow.

Chapter 2 illustrates the prevailing literature of the focused study area. Further, this chapter is to broaden the knowledge of reader on importance of *Time Delays in Construction*, *Delays of Road Construction Projects*. Further, this chapter gives a broad understanding about *Types and Causes of delay* highlighting the *responsible parties* for delays in road construction projects.

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Chapter 3 rationalises the *Methodology of Study*. It discusses the parameter identification with regard to model the *Conceptual Framework*, *Sample Size Justification* including *Reliability of Collected Data*, *Development of Hypothesis* and *Statistical Inference* in order to obtain the *Confidence Interval for Population Mean*. Further, this chapter describes about the *Percentage Delay* parameter and the *Relative Significance Index (RSI)* model, which are the new concepts introduced by the author this study.

Chapter 4 describes the detailed analysis of the collected data for the research. The chapter aims to details the main objectives of data analysis namely, *Confidence Interval for Population Mean of Percentage Delay*, *Relative Significance Index (RSI)*, and *Ranking of Delay Factors*. In addition to that, *Respondents' Background* is also broadly analysed in this chapter. Finally, the *Results* are discussed, and consequently highlighted the *Factors Influencing the Duration of Road Construction Projects in Sri Lanka*.

Chapter 5 explains and discusses the findings of the research in concise manner referring to the objectives defined in the first chapter. Moreover, the author attempts

to comprehend some guidelines and best practices in terms of *Recommendations* for mitigate the effects of delays in road construction projects in Sri Lanka. Finally, the author discusses some potential extensions of this study that can be incorporated for any further research activities.

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Chapter 2

LITERATURE REVIEW

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2.1 Introduction

The duration of construction projects right from inception to completion is assumed great importance in the construction industry. Clients or consumers are no longer content merely with minimal cost and adequate functional performance for their projects. Increasing interest rates, inflation and other commercial pressures, among other factors, mean that it is in many instances most cost-effective to complete a project within the shortest possible time.

Delay is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects. Because of the overriding importance of time for both the owner (in terms of performance) and the contractor (in terms of money), it is the source of frequent disputes and claims leading to lawsuits.

Delays occur in every construction project and the magnitude of these delays varies considerably from project to project. Some projects are only a few days behind schedule; some are delayed by over a year. So it is essential to define the actual causes of delay in order to minimize and avoid delay in any construction project (Ahmed et al., 2003).

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There is a wide range of views on the causes of time delays for engineering and construction projects. Some are attributed to a single party, others can be ascribed to several quarters, and many relate more to systemic faults or deficiencies rather than to a group or groups (Hancher and Rowings, 1981).

2.2 Time Delays in Construction

Many studies have been carried out to assess the causes of delay in construction projects. Mansfield et al. (1994) studied the causes of delay and cost overrun in construction projects in Nigeria. The results showed that the most important factors are financing and payment for completed works, poor contract management, changes in site conditions, shortage of materials, and improper planning.

Ogunlana and Promkuntong (1996) identified the causes of delays in construction projects in Bangkok, Thailand and compared these with other delays and cost overruns to determine whether there are special problems that generate delays. They summarized the causes of delay in the construction industry as being in three problem areas: (1) problems of shortages or inadequacies in the industry infrastructure (mainly supply of resources); (2) problems caused by clients and consultants; and (3) problems caused by contractor incompetence/inadequacy.

Mezher and Tawil (1998) conducted a survey of the causes of delays in the construction industry in Lebanon from the viewpoint of owners, contractors and architectural/engineering firms. Owners had more concerns with regard to financial issues, contractors regarded contractual relationships as being the most important, and consultants considered project management issues to be the most important cause of delays.

Al-Moumani (2000) investigated the causes of delays on 130 public projects in Jordan, and the results indicated that the main causes of delay in construction of public projects relate to designers, user changes, weather, site conditions, late deliveries, and economic conditions.

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2.3 Delays of Road Construction Projects

There is no consensus in the literature on the identification of factors that affect stipulated, planned or achieved construction times of Road Projects in Sri Lanka. One reason for this is that researchers have largely viewed the subject from diverse prospective. Such view points include identification of discrete factors that affect productivity on site and taking a systems view of the construction process and end product.

Delays happen in most construction projects, whether simple or complex. Construction delay could be defined as the time overrun either beyond the contract date or beyond the date that the parties agreed upon for delivery of a project (Sadi A. Assaf et al., 2006).

Manavazhia and Adhikarib (2002) conducted a survey to investigate material and equipment procurement delays in highway projects in Nepal. Delay in the delivery of materials and equipment to construction sites is often a contributory cause to cost overruns in construction projects in developing countries. An assessment of the causes of the delays and the magnitude of their impact on project costs were also made. The survey method was used in conducting this research involving 22 highway projects. The main causes of material and equipment procurement delays were found to be (in rank order) organizational weaknesses, suppliers' defaults, governmental regulations and transportation delays. However, the actual impact of these delays on project costs was found to be on average, only about 0.5% of the total budgeted cost of the projects. Among materials, delays in the supply of aggregates and equipment were found to occur most frequently.

Noulmanee et al. (1999) investigated causes of delays in highway construction in Thailand and concluded that delays can be caused by all parties involved in projects; however, main causes come from inadequacy of sub-contractors, organization that lacks of sufficient resources, incomplete and unclear drawings and deficiencies between consultants and contractors. The study suggested that delay can be minimized by discussions that lead to understanding.

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Hancher and Rowings (1981) provided a concise summary of the methodologies used by transportation agencies to establish the contract duration used for highway construction projects, and also provide a schedule guide for field engineers during construction.

2.4 Types of delay

Delays can be grouped in the following four broad categories according to how they operate contractually (Ahmed et al., 2003):

(1) Non-excusable delays;
(2) Excusable non-compensable delays;
(3) Excusable compensable delays;
(4) Concurrent delays.

Generally, delays can be divided into three major types, namely:

(1) Excusable and non-excusable;
(2) Compensable and non-compensable;
(3) Concurrent.

2.4.1 Compensable delays

Compensable delays are those that are generally caused by the owner or its agents. The most common form of compensable delay is inadequate drawings and specifications, but compensable delays can also arise from the owner's failure to respond in a timely fashion to requests for information or shop drawings, owner's changes in design or materials, and owner's disruption and/or change in the sequence of the work. The contractor is entitled to both additional money and additional time resulting from compensable delays (Alaghbari, 2005).

2.4.2 Non-excusable delays

Basically, these delays are caused by contractors or subcontractors or materials suppliers, through no fault of the owner. The contractor might be entitled to compensation from the delaying subcontractor or supplier, but no compensation is due from the owner. Therefore, non-compensable delays usually result in no additional money and no additional time being granted to the contractor (Alaghbari, 2005).

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2.4.3 Excusable delays

Excusable delays, also known as "Force Majeure" delays, are the third general category of delay. These delays are commonly called "Acts of God" because they are not the responsibility or fault of any particular party. Most contracts allow for the contractor to obtain an extension of time for excusable delays, but not additional money (Alaghbari, 2005).

2.4.4 Concurrent delays

If only one factor is delaying construction, it is usually fairly easy to calculate both the time and money resulting from that single issue. A more complicated – but also more typical – situation is one in which more than one factor delays the project at the same time or in overlapping periods of time. These are called concurrent delays (Alaghbari, 2005).

2.4.5 Delay responsibility

Ahmed et al. (2003) claimed that the issue of responsibility for delay is related to whether the contractor is awarded or is liable for costs and additional time to complete the project. The categories of responsibilities are:

- Owner (or agent) responsible – contractor will be granted a time extension and additional costs (indirect), where warranted;

- Contractor (or subcontractor) responsible – contractor will not be granted time or costs and may have to pay damages/penalties;

- Neither party (e.g. "Act of God") responsible – contractor will receive additional time to complete the project but no costs will be granted and no damages/penalties assessed;

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- Both parties responsible – contractor will receive additional time to complete the project but no costs will be granted and no damages/penalties assessed.

2.5 Causes of delay

There are two kinds of cause for delay in construction projects:

(1) External causes;

(2) Internal causes.

Internal causes of delay include the causes arising from four parties involved in the project. These parties include the owner, designers, contractors, and consultants. Other delays, which do not arise from these four parties, are based on external causes for example from the government, materials suppliers, or the weather (Ahmed et al., 2003).

Ahmed et al. (2003) and Alaghbari (2005) mentioned the possible following factors causing delays in construction projects:

(1) Contractor's responsibility:

- Delay in delivery of materials to site;
- Shortage of materials on site;
- Construction mistakes and defective work;
- Poor skills and experience of labour;
- Shortage of site labour;
- Low productivity of labour;
- Financial problems;
- Coordination problems with others;
- Lack of subcontractor's skills;
- Lack of site contractor's staff;
- Poor site management;
- Equipments and tool shortage on site.

(2) Consultant's responsibility:

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- Absence of consultant's site staff;
- Lack of experience on the part of the consultant;
- Lack of experience on the part of the consultant's site staff; (managerial and supervisory personnel);
- Delayed and slow supervision in making decisions;
- Incomplete documents;
- Slowness in giving instructions.

(3) Owner's responsibility:

- Lack of working knowledge;
- Slowness in making decisions;
- Lack of coordination with contractors;
- Contract modifications (replacement and addition of new work to the project and change in specifications);
- Financial problems (delayed payments, financial difficulties, and economic problems).

(4) External factors:

- Lack of materials on the market;
- Lack of equipment and tools on the market;
- Poor weather conditions;
- Poor site conditions (location, ground, etc.);
- Poor economic conditions (currency, inflation rate, etc.);
- Changes in laws and regulations;
- Transportation delays;
- External work due to public agencies (roads, utilities and public services).

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Chapter 3

METHODOLOGY OF STUDY

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3.1 Introduction

The impacts and causes of project delays were first examined and identified through a relevant international literature review and by conducting a pilot study that sought advice from experienced highway construction practitioners (specialists) in Sri Lanka. The basic purpose of the pilot study was to verify the completeness of the questionnaire in capturing the factors relevant to Sri Lankan situation.

A questionnaire (***Appendix-A: Survey Form***) was developed based on Ahmed et al. (2003) and Alaghbari (2005) to assess the perceptions of contractors on the ***Percentage Delay*** and the ***Relative Significance Index*** of *Factors Influencing the Duration of Road Construction Projects in Sri Lanka*. All the practitioners (specialists) agreed that the questionnaire, which based on Ahmed et al. (2003) and Alaghbari (2005), was merely sufficient to capture the causes of delays in Sri Lankan Road Construction sector.

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The questionnaire was divided into three parts. The first part requested ***Background Information*** about the ***Respondents***. The second part of the questionnaire captured the ***Project Information*** in order to estimate the ***Percentage Delay***. The third part of the questionnaire focused on ***Causes of Road Construction Delay***. The respondents were asked to indicate their response category based on 31 well-recognized construction delay factors (causes of delay). These causes were categorized into the following four major groups:

(1) Contractor's responsibility
(2) Consultant's responsibility
(3) Owner's responsibility
(4) External factors

3.2 Justification of Sample Size and Reliability of Data

As per the ***Central Limit Theorem*** (Please refer *Section 3.4* for the detailed theorem), when the ***Sample Size*** approaches ***30***, the ***Distribution of Sample Mean*** is approximately ***Normal*** in spite of the ***Distribution of Population***. Therefore, in this study a ***Random Sample*** of ***30 projects*** has been considered for the analysis in order to predict the nature of the ***Population*** (Confidence Interval for Population Mean).

The ***reliability of a measure*** illustrates its stability and consistency, which assists in evaluating the "goodness" of a measure. The ***reliability coefficient*** obtained with ***the repetition of an identical measure on a second occasion*** is called ***test-retest reliability*** (Sekaran, 1992). The reliability and stability of the measure would increase with a greater reliability coefficient. In this regard, the same set of blanked questionnaires were resent with a self stamped return envelope to 6 respondents (20%) who had completed and returned their questionnaire previously, in order to test the reliability. A total of 5 completed questionnaires were eventually received in the resending process. After crosschecking the results, 90% of the answers were the same as in the previous survey, thus yielding a ***high reliability coefficient (90%)***. The data, therefore, were considered to be reliable. It is also noted that the ***demographic statistics about the respondents*** (Table 4.1 & Figure 4.1 ~ 4.3) suggest sufficient exposure to make the information acquired reliable, and thus the opinions are thought to reflect the real situation in the prevailing context of the Road Construction Projects in Sri Lanka.

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3.3 Percentage Delay

In this study, we introduce a new parameter called ***Percentage Delay*** ($\mathbf{d}_i$) as a ***parameter of the Magnitude of Delay***, which yields from the equation,

$$d_i = \frac{t_{\text{Actually Elapsed}} - t_{\text{Planned}}}{t_{\text{Planned}}} \qquad \text{- - - Equation 3.1}$$

Where,

- $t_{\text{Actually Elapsed}}$ = Actual Time Elapsed for the Completion
- t_{Planned} = Planned Project Duration

$\mathbf{d}_i$ is a ***measure of actual impact of the delay with respect to the time*** for a particular project. Further, in practical perspective, $\mathbf{d}_i$ is the ***time overrun compared to the original (planned) project duration***.

In this study, a Random Sample of 30 projects has been examined and then the ***Statistical Inference*** is used to predict the nature of the Population (Road Construction Projects in Sri Lanka).

3.4 Confidence Interval for Population Mean of Percentage Delay

The ***Central Limit Theorem*** is illustrated as follows,

- Let x_i $(i = 1,2,3,....,n)$ be a Random Sample from a Population with Mean μ and Variance σ^2.
- The distribution of Sample Mean $\bar{x}$ is approximately $N\left(\mu, \frac{\sigma}{\sqrt{n}}\right)$ for large values of n.
- When $n \geq 30$, approximation is good for any population. When $n < 30$, approximation will be good only if the population is approximately normal.
- When $n \geq 30$, Sample Variance $s^2 = \sigma^2$, and $n = \frac{c^2.\sigma^2}{|\bar{x} - \mu|^2}$
- Further, $(1-\alpha)$ Confidence Interval for Population Mean μ is $\left(\bar{x} - c\frac{\sigma}{\sqrt{n}}, \bar{x} + c\frac{\sigma}{\sqrt{n}}\right)$

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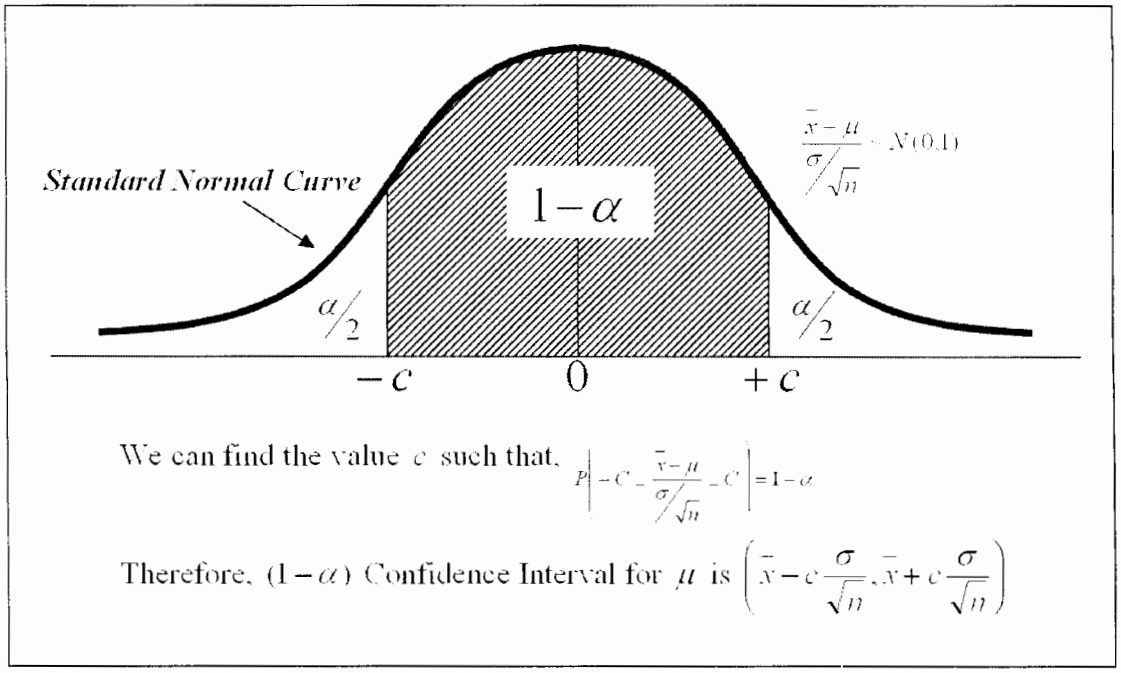

Figure 3.1 – Standard Normal Curve and the Confidence Interval for Population Mean

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Therefore, $(1-\alpha)$ ***Confidence Interval*** for ***Population Mean*** (μ) of ***Percentage Delay*** (d_i) is,

$$\mu_{d_i} = \left(\bar{x} - c\frac{\sigma}{\sqrt{n}}, \bar{x} + c\frac{\sigma}{\sqrt{n}}\right) \quad \text{- - - Equation 3.2}$$

Where,

- $\bar{x}$ = Sample Mean = $\dfrac{\sum_{i=1}^{n} d_i}{n}$
- $\sigma = s$ = Sample Standard Deviation = $\sqrt{\dfrac{\sum_{i=1}^{n} d_i^2}{n} - \left(\dfrac{\sum_{i=1}^{n} d_i}{n}\right)^2}$
- $c = 1.96$ for 95% Confidence, and n = Sample Size = 30 in this case

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3.5 Relative Importance Index (RII)

Kometa et al. (1994) used the ***Relative Importance Index (RII)*** method to determine the relative importance of the various causes of delays. The five-point scale ranged from 1 (not significant) to 5 (extremely significant) was adopted and transformed to relative importance indices (RII) for each cause as follows:

$$RII = \frac{\sum W}{A * N} \qquad \text{- - - Equation 3.3}$$

Where,

- "**W**" is the weighting given to each factor by the respondents (ranging from 1 to 5),
- "**A**" is the highest weight (i.e. 5 in this case), and
- "**N**" is the total number of respondents.

The RII value had a range from 0 to 1, higher the value of RII, more important was the cause or effect of delays. The RII was used to rank the different causes.

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3.6 Relative Significance Index (RSI)

The *Relative Importance Index (RII)* method suggested by Kometa et al. (1994) had focused merely on the ***weighting given by the respondents (frequency)*** despite the ***amount of delay (magnitude)*** that the relevant project was undergone. That means, RII model assumes, ***all the projects*** are undergone the ***similar impact*** in the context of amount of delay, when the delays are ranked. But, in real practice we know that most frequent delay causes may not always be the most significance delay causes, in the context of the actual impact.

In order to supplement the above draw back, more sophisticated method (a new equation) has been introduced in this study with the new input parameter of ***Percentage Delay*** (a parameter of the ***Magnitude of Delay***) in order to reveal the ***Relative Significance*** of the various causes of delays. The five-point scale ranged

from 1 (not significant) to 5 (extremely significant) was adopted and transformed to ***Relative Significance Indices (RSI)*** for each cause as follows:

$$RSI = \frac{\sum_{i=1}^{n}(W_i * d_i)}{A * \sum_{i=1}^{n} d_i}$$ - - - Equation 3.4

Where,

- "$\mathbf{W}_i$" is the weighting given to the particular cause for i^{th} project by the respondents (ranging from 1 to 5),
- "$\mathbf{d}_i$" is the Percentage Delay of i^{th} project,

$$d_i = \frac{t_{\text{Actually Elapsed}} - t_{\text{Planned}}}{t_{\text{Planned}}}$$

$t_{\text{Actually Elapsed}}$ = Actual Time Elapsed for the Completion

t_{Planned} = Planned Project Duration

- "**A**" is the highest weight (i.e. 5 in this case), and
- "**n**" is the total number of projects (number of respondents, i.e. 30 in this case).

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The RSI value had a range from 0 to 1, higher the value of RSI, more significant is the cause or effect of delays. The RSI was used to ***Rank (R)*** the different causes. These rankings made it possible to reveal the ***Relative Significance*** of the ***Delay Factors*** as perceived by the Contractors of Road Construction in Sri Lanka.

Chapter 4

ANALYSIS AND DISCUSSION OF RESULTS

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4.1 Introduction

In this section, the detailed Analysis of the following items is illustrated with regard to the survey carried out based on the Duration of Road Construction Projects in Sri Lanka that targeted at the local road construction Contractors.

- Respondents' Background with respect to Education, Occupational level, and Number of years working experience
- Confidence Interval for Population Mean of Percentage Delay
- Relative Significance Index (RSI)
- Ranking of Delay Factors based on RSI

Finally, based on the analysis, the Results will be discussed upon the Factors Influencing the Duration of Road Construction Projects in Sri Lanka.

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4.2 Respondents' Background

In this study, 30 respondents were participated representing distinct Road Construction Projects. Their Background was analysed with respect to the ***Education***, the ***Occupational level***, and the ***Number of years of working experience***. The result were analysed using MS-Excel Statistical Package.

The Table 4.1 below illustrates the detailed analysis of ***Respondents' Background***, and the different cases (Education, Occupational level, and Number of years of working experience) were again further analysed upon the percentages via charts depicted in Figure 4.1, 4.2, and 4.3, respectively.

Table 4.1 – Analysis of Respondents' Background

	Responder # 01	Responder # 02	Responder # 03	Responder # 04	Responder # 05	Responder # 06	Responder # 07	Responder # 08	Responder # 09	Responder # 10	Responder # 11	Responder # 12	Responder # 13	Responder # 14	Responder # 15	Responder # 16	Responder # 17	Responder # 18	Responder # 19	Responder # 20	Responder # 21	Responder # 22	Responder # 23	Responder # 24	Responder # 25	Responder # 26	Responder # 27	Responder # 28	Responder # 29	Responder # 30	Total	Percentage
Education																															
Diploma	√			√			√		√		√			√		√		√			√		√			√			√		12	**40%**
Degree		√	√		√			√		√		√	√		√		√			√		√		√	√		√		√	16	**53%**
Post graduate						√													√												2	**7%**
Occupational level																															
Non-executive				√					√							√					√					√			√		6	**20%**
Executive	√	√			√		√	√			√			√	√			√		√		√	√	√			√	√			15	**50%**
Managerial			√			√				√		√	√				√		√						√					√	9	**30%**
Number of years of working experience																															
Less than 2 years								√							√						√					√					4	**13%**
2–5 years				√					√											√		√							√		5	**17%**
6–10 years		√			√		√			√	√	√		√		√	√		√					√				√			12	**40%**
More than 10 years	√		√			√							√					√				√		√		√			√	9	**30%**

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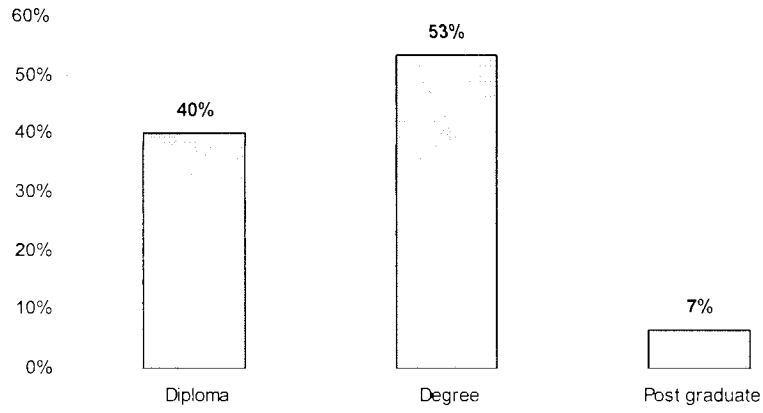

Figure 4.1 – Respondents' Background with respect to the **Education**

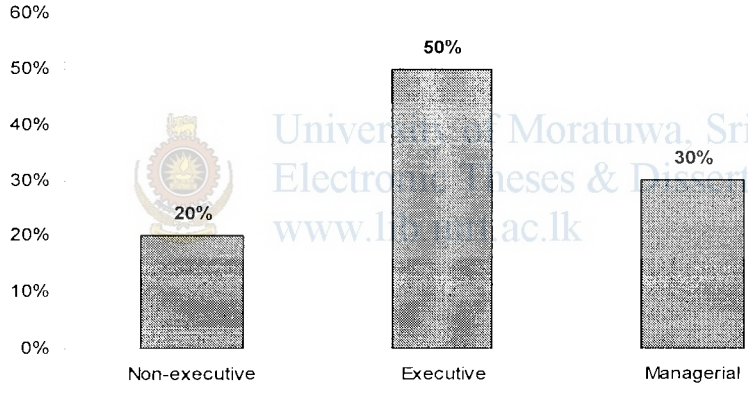

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Figure 4.2 – Respondents' Background with respect to the **Occupational level**

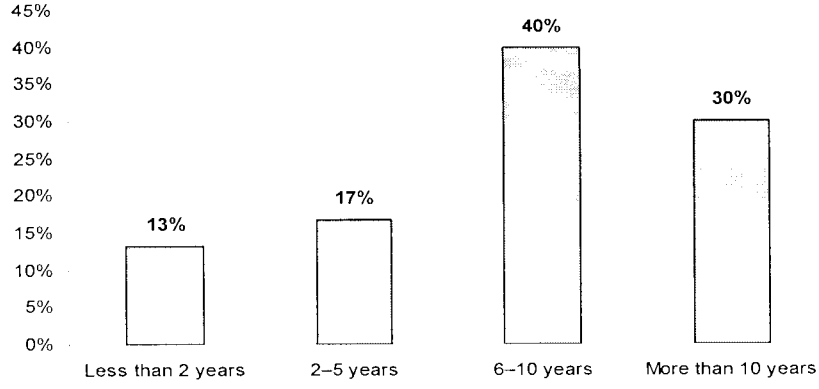

Figure 4.3 – Respondents' Background with respect to the **Number of years of working experience**

4.3 Confidence Interval for Population Mean of Percentage Delay

As per the ***Equation 3.2***, $(1-\alpha)$ ***Confidence Interval*** for ***Population Mean*** (μ) of ***Percentage Delay*** (d_i) is,

$$\mu_{d_i} = \left(\bar{x} - c\frac{\sigma}{\sqrt{n}}, \bar{x} + c\frac{\sigma}{\sqrt{n}} \right)$$

Let's calculate the elementary items as follows for n = Sample Size = 30,

- $\bar{x}$ = Sample Mean = $\frac{\sum_{i=1}^{n} d_i}{n} = \frac{21.69}{30} = 0.72$
- $\sigma = s$ = Sample Standard Deviation = $\sqrt{\frac{\sum_{i=1}^{n} d_i^2}{n} - \left(\frac{\sum_{i=1}^{n} d_i}{n} \right)^2} = \sqrt{\frac{21.64}{30} - \left(\frac{21.69}{30} \right)^2} = 0.45$
- $c = 1.96$ for 95% Confidence Interval (Significance Level $\alpha = 0.05$)

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Therefore,

$$\mu_{d_i} = \left(0.72 - 1.96 * \frac{0.45}{\sqrt{30}}, 0.72 + 1.96 * \frac{0.45}{\sqrt{30}} \right)$$
$$\mu_{d_i} = (0.56, 0.88)$$

Thus, it can be concluded that the mean ***Percentage Delay*** lies between **0.56** and **0.88** with respect to the ***Road Construction Projects in Sri Lanka*** (with 95% Confidence).

4.4 Relative Significance Index (RSI) and Ranking of Delay Factors

As per the ***Equation 3.4***, Relative Significance Index (RSI) is given by,

$$RSI = \frac{\sum_{i=1}^{n}(W_i * d_i)}{A * \sum_{i=1}^{n} d_i}$$

Let's calculate the elementary items as follows,

- "$\mathbf{W_i}$" is the weighting given to the particular cause for i^{th} project by the respondents (ranging from 1 to 5),
- "$\mathbf{d_i}$" is the Percentage Delay of i^{th} project,

$$d_i = \frac{t_{\text{Actually Elapsed}} - t_{\text{Planned}}}{t_{\text{Planned}}}$$

$t_{\text{Actually Elapsed}}$ = Actual Time Elapsed for the Completion

t_{Planned} = Planned Project Duration

- "**A**" is the highest weight (i.e. 5 in this case), and
- "**n**" is the total number of projects (number of respondents i.e. 30 in this case).

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The out put of the survey carried out was analysed using MS-Excel Statistical Package.

The Table 4.2 and 4.3 below illustrate the detailed analysis of ***Relative Significance Index (RSI)*** and ***Rank (Group & Overall)*** of various ***Causes of Delays (Delay Factors)***. Further, the ***Proportionate Significances*** of ***Delay Factors*** were identified via ***Weightages (Group & Overall)***. After that, ***Most Significance Delay Factors*** were highlighted.

The different groups (Contractor, Consultant, Owner, and External factors) were further analysed upon the ***Group Rank***, and the ***Proportionate Significances*** of ***Delay Factors*** were depicted in Figure 4.4, 4.5, 4.6, and 4.7 respectively.

Finally, in Table 4.4, all the ***Causes of Delays*** were again ranked upon the ***Overall Rank***, and the relevant ***responsibilities*** of each cause (Delay Factor) were highlighted. The ***Proportionate Significances*** of ***Road Construction Delay Factors*** (for all 4 groups) were identified via ***Weightages (Overall)***, and depicted in Figure 4.8.

Table 4.2 – Analysis of Relative Significance Index (RSI)

	Project # 01	Project # 02	Project # 03	Project # 04	Project # 05	Project # 06	Project # 07	Project # 08	Project # 09	Project # 10	Project # 11	Project # 12	Project # 13	Project # 14	Project # 15	Project # 16	Project # 17	Project # 18	Project # 19	Project # 20	Project # 21	Project # 22	Project # 23	Project # 24	Project # 25	Project # 26	Project # 27	Project # 28	Project # 29	Project # 30	RSI
Percentage Delay (d_i)	1.11	1.59	0.75	1.00	1.00	0.25	0.67	0.33	0.67	0.25	0.20	0.50	1.00	1.67	0.67	1.00	2.00	0.25	0.33	0.31	0.67	0.17	0.33	1.22	0.83	0.67	0.69	0.33	0.83	0.50	
Road Construction Delay Factors	Respondent's Score = 01 (W_{i1}) (W_{i1} . d_i)	Respondent's Score = 02 (W_{i2}) (W_{i2} . d_i)	Respondent's Score = 03 (W_{i3}) (W_{i3} . d_i)	Respondent's Score = 04 (W_{i4}) (W_{i4} . d_i)	Respondent's Score = 05 (W_{i5}) (W_{i5} . d_i)	Respondent's Score = 06 (W_{i6}) (W_{i6} . d_i)	Respondent's Score = 07 (W_{i7}) (W_{i7} . d_i)	Respondent's Score = 08 (W_{i8}) (W_{i8} . d_i)	Respondent's Score = 09 (W_{i9}) (W_{i9} . d_i)	Respondent's Score = 10 (W_{i10}) (W_{i10} . d_i)	Respondent's Score = 11 (W_{i11}) (W_{i11} . d_i)	Respondent's Score = 12 (W_{i12}) (W_{i12} . d_i)	Respondent's Score = 13 (W_{i13}) (W_{i13} . d_i)	Respondent's Score = 14 (W_{i14}) (W_{i14} . d_i)	Respondent's Score = 15 (W_{i15}) (W_{i15} . d_i)	Respondent's Score = 16 (W_{i16}) (W_{i16} . d_i)	Respondent's Score = 17 (W_{i17}) (W_{i17} . d_i)	Respondent's Score = 18 (W_{i18}) (W_{i18} . d_i)	Respondent's Score = 19 (W_{i19}) (W_{i19} . d_i)	Respondent's Score = 20 (W_{i20}) (W_{i20} . d_i)	Respondent's Score = 21 (W_{i21}) (W_{i21} . d_i)	Respondent's Score = 22 (W_{i22}) (W_{i22} . d_i)	Respondent's Score = 23 (W_{i23}) (W_{i23} . d_i)	Respondent's Score = 24 (W_{i24}) (W_{i24} . d_i)	Respondent's Score = 25 (W_{i25}) (W_{i25} . d_i)	Respondent's Score = 26 (W_{i26}) (W_{i26} . d_i)	Respondent's Score = 27 (W_{i27}) (W_{i27} . d_i)	Respondent's Score = 28 (W_{i28}) (W_{i28} . d_i)	Respondent's Score = 29 (W_{i29}) (W_{i29} . d_i)	Respondent's Score = 30 (W_{i30}) (W_{i30} . d_i)	
Contractor's responsibility:																															
1 Delay in delivery of materials to site	2 2.22	4 6.00	5 3.75	5 5.00	5 5.00	4 1.00	1 0.67	3 1.00	3 2.00	3 0.75	4 0.80	2 1.00	3 3.00	3 5.00	4 2.67	3 3.00	2 4.00	3 0.75	3 1.00	3 1.17	3 2.00	4 0.67	3 1.00	3 3.67	2 1.67	1 2.67	3 1.80	3 1.00	5 4.17	4 2.00	0.6492
2 Shortage of materials on site	3 3.33	3 4.50	4 3.00	4 4.00	4 4.00	4 1.00	1 0.67	5 1.67	4 2.67	4 1.00	3 0.60	3 1.50	4 4.00	4 6.67	3 2.00	4 4.00	4 8.00	4 1.00	4 1.33	4 1.56	5 3.33	4 0.67	5 1.67	5 3.67	4 3.33	4 2.67	4 2.40	4 1.33	4 3.33	4 2.00	0.7459
3 Construction mistakes and defective work	2 2.22	2 3.00	2 1.50	2 2.00	3 3.00	5 1.25	1 0.67	1 0.33	3 2.00	1 0.25	4 0.80	5 2.50	5 5.00	4 6.67	3 2.00	3 3.00	4 8.00	5 1.25	4 1.33	4 1.56	4 2.67	1 0.50	5 1.67	5 4.11	4 3.33	4 2.67	5 3.00	4 1.33	3 2.50	5 2.50	0.6972
4 Poor skills and experience of labour	1 1.11	2 3.00	3 2.25	2 2.00	4 4.00	4 1.00	3 2.00	4 1.33	4 2.67	4 1.00	4 0.80	4 2.00	4 4.00	4 6.67	4 2.67	4 4.00	4 8.00	5 1.25	4 1.33	4 1.56	3 2.00	4 0.67	4 1.33	4 4.89	3 2.50	5 3.33	4 2.40	4 1.33	4 3.33	3 1.50	0.6842
5 Shortage of site labour	4 4.44	3 4.50	3 2.25	3 3.00	4 4.00	3 0.75	1 0.67	1 0.33	4 2.67	4 1.00	4 0.80	3 1.50	5 5.00	4 6.67	4 2.67	4 4.00	4 8.00	5 1.25	4 1.33	4 1.56	4 2.67	3 0.50	5 1.67	5 4.11	4 3.33	4 2.67	4 2.40	3 1.00	5 4.17	4 2.00	0.7705
6 Low productivity of labour	2 2.22	1 1.50	3 2.25	4 4.00	3 3.00	3 0.75	2 1.33	3 1.00	3 2.00	2 0.50	3 0.60	3 1.50	3 3.00	2 3.33	4 2.67	3 3.00	4 8.00	3 0.75	3 1.00	3 1.17	3 2.00	3 0.50	4 1.33	4 4.89	3 2.50	3 2.00	3 1.80	4 1.33	3 2.50	3 1.50	0.5664
7 Financial problems	4 4.44	1 1.50	5 3.75	4 4.00	5 5.00	5 1.25	1 0.67	5 1.67	5 3.33	5 1.25	4 0.80	5 2.50	4 4.00	5 8.33	5 3.33	5 5.00	5 10.00	5 1.25	4 1.33	4 1.56	5 3.33	5 0.83	5 1.67	5 6.11	5 4.17	4 2.67	5 3.00	5 1.67	4 3.33	5 2.50	0.8598
8 Coordination problems with others	5 5.56	3 4.50	3 2.25	2 2.00	4 4.00	2 0.50	3 2.00	3 1.00	2 1.33	3 0.75	3 0.60	3 1.50	3 3.00	2 3.33	3 2.00	3 3.00	3 6.00	4 1.00	3 1.17	3 1.33	4 0.67	3 1.00	3 3.67	3 2.50	2 1.33	4 2.40	3 1.00	3 2.50	3 1.50	0.5938
9 Lack of subcontractor's skills	3 3.33	3 4.50	3 2.25	2 2.00	3 3.00	5 1.25	4 2.67	4 1.33	4 2.67	4 1.00	4 0.80	4 2.00	4 4.00	4 6.67	4 2.67	3 3.00	4 8.00	4 1.00	4 1.33	5 1.94	4 2.67	4 0.67	3 1.00	2 2.44	4 3.33	4 2.67	4 2.40	3 1.00	5 4.17	4 2.00	0.7276
10 Lack of site contractor's staff	4 4.44	3 4.50	4 3.00	2 2.00	2 2.00	4 1.00	4 2.67	4 1.33	1 0.67	1 0.25	2 0.40	1 0.50	1 1.00	1 1.67	3 0.67	2 2.00	1 2.00	1 0.25	1 0.33	2 0.78	1 0.67	1 0.17	1 0.33	1 1.22	1 0.83	1 0.67	2 1.20	1 0.33	1 0.83	1 0.50	0.3431
11 Poor site management	1 1.11	2 3.00	4 3.00	3 3.00	5 5.00	4 1.00	4 2.67	5 1.67	5 3.33	5 1.25	5 1.00	5 2.50	5 5.00	4 6.67	5 3.33	5 5.00	5 10.00	5 1.25	5 1.67	5 1.94	5 3.33	4 0.67	5 1.67	5 6.11	5 4.17	5 3.33	5 3.00	5 1.67	5 4.17	5 2.50	0.8668
12 Equipments and tool shortage on site	4 3.33	1 1.50	2 1.50	3 3.00	4 4.00	5 1.25	1 0.67	3 1.00	3 2.00	3 0.75	5 1.00	3 1.50	3 3.00	2 3.33	3 2.00	3 3.00	3 6.00	3 0.75	3 1.00	3 1.17	3 2.00	3 0.50	4 1.33	3 3.67	3 2.50	3 2.00	2 1.20	3 1.00	2 1.67	3 1.50	0.5414
Consultant's responsibility:																															
13 Absence of consultant's site staff	3 3.33	2 3.00	2 1.50	5 5.00	5 5.00	5 1.25	4 2.67	1 0.33	1 0.67	1 0.25	2 0.40	3 1.50	2 2.00	3 5.00	1 0.67	1 1.00	3 6.00	1 0.25	1 0.33	1 0.39	1 0.67	1 0.17	1 0.33	1 1.22	2 1.67	1 0.67	1 0.60	1 0.33	1 0.83	1 0.50	0.4383
14 Lack of experience on the part of the consultant	3 3.33	4 6.00	3 2.25	3 3.00	3 3.00	5 1.25	4 2.67	3 1.00	2 1.33	2 0.50	2 0.40	2 1.00	4 4.00	3 5.00	2 1.33	2 2.00	2 4.00	2 0.50	2 0.67	2 0.78	2 1.33	2 0.33	2 0.67	2 2.44	3 2.50	2 1.33	2 1.20	2 0.67	3 2.50	3 1.50	0.5209
15 Lack of experience on the part of the consultant's site staff (managerial and supervisory personnel)	2 2.22	3 4.50	3 2.25	3 3.00	3 3.00	5 1.25	4 2.67	1 0.33	1 0.67	1 0.25	1 0.20	2 1.00	1 1.00	1 1.67	1 0.67	1 1.00	2 4.00	1 0.25	1 0.33	1 0.39	1 0.67	1 0.17	1 0.33	2 2.44	1 0.83	1 0.67	1 0.60	1 0.33	1 0.83	1 0.50	0.3506
16 Delayed and slow supervision in making decisions	4 4.44	2 3.00	3 2.25	5 5.00	5 5.00	4 1.00	5 3.33	4 1.33	4 2.67	4 1.00	4 0.80	4 2.00	4 4.00	3 5.00	4 2.67	5 5.00	4 8.00	4 1.00	4 1.33	4 1.56	3 2.00	3 0.67	4 1.33	4 4.89	5 4.17	4 2.67	4 2.40	4 1.33	4 3.33	4 2.00	0.7854
17 Incomplete documents	1 1.11	5 7.50	1 0.75	2 2.00	2 2.00	2 0.50	5 3.33	5 1.67	5 3.33	5 1.25	4 0.80	5 2.50	5 5.00	5 8.33	5 3.33	5 5.00	5 10.00	4 1.00	5 1.67	5 1.94	5 3.33	5 0.83	5 1.67	4 4.89	3 2.50	2 1.33	5 3.00	5 1.67	5 4.17	4 2.00	0.7958
18 Slowness in giving instructions	2 2.22	3 4.50	3 2.25	3 3.00	3 3.00	3 0.75	4 2.67	4 1.33	4 2.67	4 1.00	5 1.00	4 2.00	4 4.00	4 6.67	3 2.00	4 4.00	4 8.00	5 1.25	4 1.33	4 1.56	4 2.67	4 0.67	4 1.33	4 4.89	5 4.17	5 3.33	4 2.40	4 1.33	4 3.33	5 2.50	0.7545
Owner's responsibility:																															
19 Lack of working knowledge	4 4.44	3 4.50	3 2.25	3 3.00	3 3.00	4 1.00	5 3.33	1 0.33	1 0.67	1 0.25	1 0.20	2 1.00	1 1.00	1 1.67	1 0.67	1 1.00	1 2.00	1 0.25	1 0.33	1 0.39	1 0.67	2 0.33	1 0.33	1 1.22	1 0.83	1 0.67	1 0.60	1 0.33	2 1.67	1 0.50	0.3545
20 Slowness in making decisions	3 3.33	1 6.00	5 3.75	4 4.00	4 4.00	3 0.75	3 2.00	5 1.67	4 2.67	3 0.75	3 0.60	3 1.50	4 4.00	4 6.67	5 3.33	5 5.00	4 8.00	4 1.00	4 1.33	4 1.56	4 2.67	4 0.67	3 1.00	4 4.89	4 3.33	4 2.67	5 3.00	5 1.67	5 4.17	4 2.00	0.7847
21 Lack of coordination with contractors	3 3.33	3 4.50	5 3.75	2 2.00	2 2.00	3 0.75	4 2.67	2 0.67	3 2.00	3 0.75	4 0.80	3 1.50	3 3.00	3 5.00	3 2.00	2 2.00	3 6.00	3 0.75	3 1.00	3 1.17	3 2.00	3 0.50	4 1.33	3 3.67	2 1.67	2 1.33	3 1.80	3 1.00	3 2.50	4 2.00	0.5849
22 Contract modifications (replacement and addition of new work to the project and change in specifications)	5 5.56	5 7.50	1 0.75	3 3.00	2 2.00	1 0.25	4 2.67	5 1.67	5 3.33	5 1.25	5 1.00	5 2.50	4 4.00	5 8.33	5 3.33	5 5.00	5 10.00	5 1.25	5 1.67	5 1.94	5 3.33	5 0.83	5 1.67	4 4.89	5 4.17	4 2.67	4 2.40	5 1.67	5 4.17	5 2.50	0.8510
23 Financial problems (delayed payments, financial difficulties, and economic problems)	3 3.33	1 6.00	5 3.75	1 4.00	4 4.00	5 1.25	2 1.33	5 1.67	5 3.33	5 1.25	5 1.00	4 2.00	5 5.00	5 8.33	4 2.67	5 5.00	4 8.00	5 1.25	5 1.67	5 1.94	5 3.33	5 0.83	5 1.67	5 6.11	4 3.33	5 3.33	5 3.00	5 1.67	5 4.17	5 2.50	0.8781
External factors:																															
24 Lack of materials on the market	2 2.22	1 1.50	3 2.25	2 2.00	2 2.00	5 1.25	4 2.67	2 0.67	2 1.33	2 0.50	2 0.40	2 1.00	1 1.00	3 5.00	2 1.33	2 2.00	2 4.00	3 0.75	2 0.67	2 0.78	2 1.33	2 0.33	3 1.00	2 2.44	3 2.50	2 1.33	2 1.20	2 0.67	1 0.83	2 1.00	0.4238
25 Lack of equipment and tools on the market	2 2.22	1 1.50	3 2.25	2 2.00	2 2.00	5 1.25	4 2.67	1 0.33	1 0.67	1 0.25	1 0.20	1 0.50	2 2.00	1 1.67	1 0.67	1 1.00	2 2.00	1 0.25	1 0.33	1 0.39	1 0.67	1 0.17	1 0.33	1 1.22	1 0.83	1 0.67	1 0.60	1 0.33	2 1.67	1 0.50	0.2871
26 Poor weather conditions	5 5.56	5 7.50	5 3.75	3 3.00	4 4.00	5 1.25	5 3.33	4 1.33	4 2.67	4 1.00	4 0.80	4 2.00	4 4.00	4 6.67	5 3.33	4 4.00	4 8.00	4 1.00	4 1.33	4 1.56	4 2.67	4 0.67	4 1.33	5 6.11	4 3.33	4 2.67	4 2.40	4 1.33	5 4.17	4 2.00	0.8517
27 Poor site conditions (location, ground, etc.)	4 4.44	5 7.50	2 1.50	4 4.00	3 3.00	5 1.25	5 3.33	5 1.67	4 2.67	2 0.50	3 0.60	3 1.50	3 3.00	3 5.00	3 2.00	2 2.00	4 8.00	3 0.75	3 1.00	3 1.17	3 2.00	3 0.50	3 1.00	4 4.89	3 2.50	3 2.00	3 1.80	3 1.00	3 2.50	3 1.50	0.6815
28 Poor economic conditions (currency, inflation rate, etc.)	4 4.44	3 4.50	2 1.50	3 3.00	3 3.00	5 1.25	2 1.33	1 0.33	2 1.33	1 0.25	1 0.20	1 0.50	1 1.00	1 1.67	1 0.67	2 2.00	2 4.00	1 0.25	1 0.33	1 0.39	1 0.67	1 0.17	2 0.67	1 2.22	1 0.83	1 0.67	1 0.60	1 0.33	1 0.83	1 0.50	0.3360
29 Changes in laws and regulations	1 1.11	1 1.50	1 0.75	3 3.00	1 1.00	5 1.25	3 2.00	2 0.67	1 0.67	1 0.25	2 0.40	2 1.00	1 1.00	1 1.67	1 0.67	1 1.00	2 4.00	1 0.25	1 0.33	1 0.39	1 0.67	1 0.17	1 0.33	1 1.22	1 0.83	2 1.33	1 0.60	1 0.33	1 0.83	1 0.50	0.2587
30 Transportation delays	2 2.22	5 7.50	3 2.25	1 1.00	3 3.00	5 1.25	3 2.00	1 0.33	1 0.67	1 0.25	1 0.20	1 0.50	2 2.00	1 1.67	1 0.67	1 1.00	2 4.00	1 0.25	1 0.33	1 0.39	1 0.67	1 0.17	1 0.33	1 1.22	2 1.67	1 0.67	1 0.60	1 0.33	1 0.83	2 1.00	0.3432
31 External work due to public agencies (roads, utilities and public services)	1 1.11	2 3.00	1 0.75	2 2.00	2 2.00	5 1.25	4 2.67	1 0.33	1 0.67	2 0.50	1 0.20	1 0.50	1 1.00	2 3.33	1 0.67	1 1.00	2 4.00	1 0.25	1 0.33	2 0.78	2 1.33	1 0.17	1 0.33	1 1.22	1 0.83	1 0.67	1 0.60	2 0.67	1 0.83	1 0.50	0.3212

Table 4.3 – Ranking of Delay Factors based on Relative Significance Index (RSI)

	Road Construction Delay Factors	RSI	Rank		Weightage	
			Group	Overall	Group	Overall
(1) Contractor's responsibility:						
11	Poor site management	**0.8668**	**1**	**2**	**10.8%**	**4.650%**
7	Financial problems	**0.8598**	**2**	**3**	**10.7%**	**4.612%**
5	Shortage of site labour	**0.7705**	**3**	**9**	**9.6%**	**4.133%**
2	Shortage of materials on site	**0.7459**	**4**	**11**	**9.3%**	**4.001%**
9	Lack of subcontractor's skills	**0.7216**	**5**	**12**	**9.0%**	**3.871%**
3	Construction mistakes and defective work	**0.6972**	**6**	**13**	**8.7%**	**3.740%**
4	Poor skills and experience of labour	**0.6832**	**7**	**14**	**8.5%**	**3.665%**
1	Delay in delivery of materials to site	**0.6492**	**8**	**16**	**8.1%**	**3.483%**
8	Coordination problems with others	0.5938	9	17	7.4%	3.185%
6	Low productivity of labour	0.5664	10	19	7.0%	3.039%
12	Equipments and tool shortage on site	0.5414	11	20	6.7%	2.904%
10	Lack of site contractor's staff	0.3431	12	27	4.3%	1.841%
(2) Consultant's responsibility:						
17	Incomplete documents	**0.7968**	**1**	**6**	**21.9%**	**4.274%**
16	Delayed and slow supervision in making decisions	**0.7854**	**2**	**7**	**21.5%**	**4.213%**
18	Slowness in giving instructions	**0.7545**	**3**	**10**	**20.7%**	**4.047%**
14	Lack of experience on the part of the consultant	0.5209	4	21	14.3%	2.794%
13	Absence of consultant's site staff	0.4383	5	22	12.0%	2.351%
15	Lack of experience on the part of the consultant's site staff (managerial and supervisory personnel)	0.3506	6	25	9.6%	1.881%
(3) Owner's responsibility:						
23	Financial problems (delayed payments, financial difficulties, and economic problems)	**0.8781**	**1**	**1**	**25.4%**	**4.710%**
22	Contract modifications (replacement and addition of new work to the project and change in specifications)	**0.8510**	**2**	**5**	**24.6%**	**4.565%**
20	Slowness in making decisions	**0.7847**	**3**	**8**	**22.7%**	**4.209%**
21	Lack of coordination with contractors	0.5849	4	18	16.9%	3.138%
19	Lack of working knowledge	0.3545	5	24	10.3%	1.901%
(4) External factors:						
26	Poor weather conditions	**0.8517**	**1**	**4**	**24.3%**	**4.569%**
27	Poor site conditions (location, ground, etc.)	**0.6815**	**2**	**15**	**19.5%**	**3.656%**
24	Lack of materials on the market	0.4238	3	23	12.1%	2.273%
30	Transportation delays	0.3432	4	26	9.8%	1.841%
28	Poor economic conditions (currency, inflation rate, etc.)	0.3360	5	28	9.6%	1.802%
31	External work due to public agencies (roads, utilities and public services)	0.3212	6	29	9.2%	1.723%
25	Lack of equipment and tools on the market	0.2871	7	30	8.2%	1.540%
29	Changes in laws and regulations	0.2587	8	31	7.4%	1.388%

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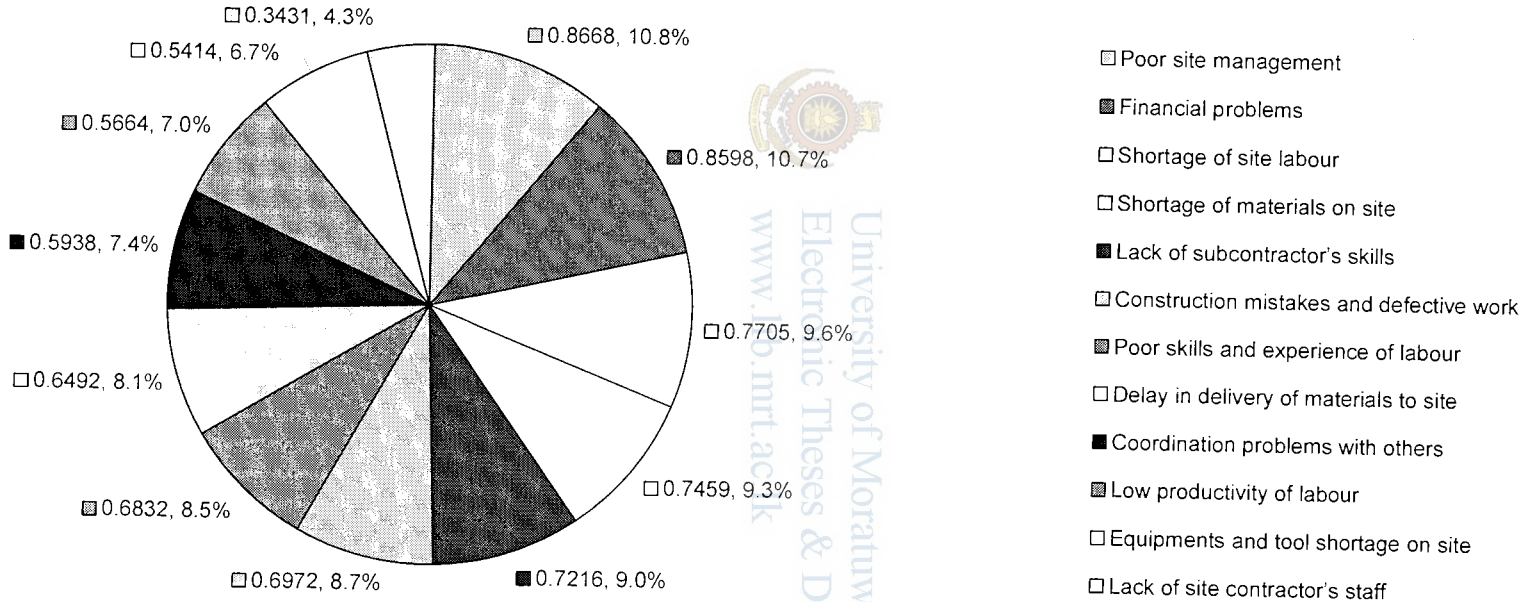

Figure 4.4 – Road Construction Delay Factors with respect to the **Contractor's responsibility**

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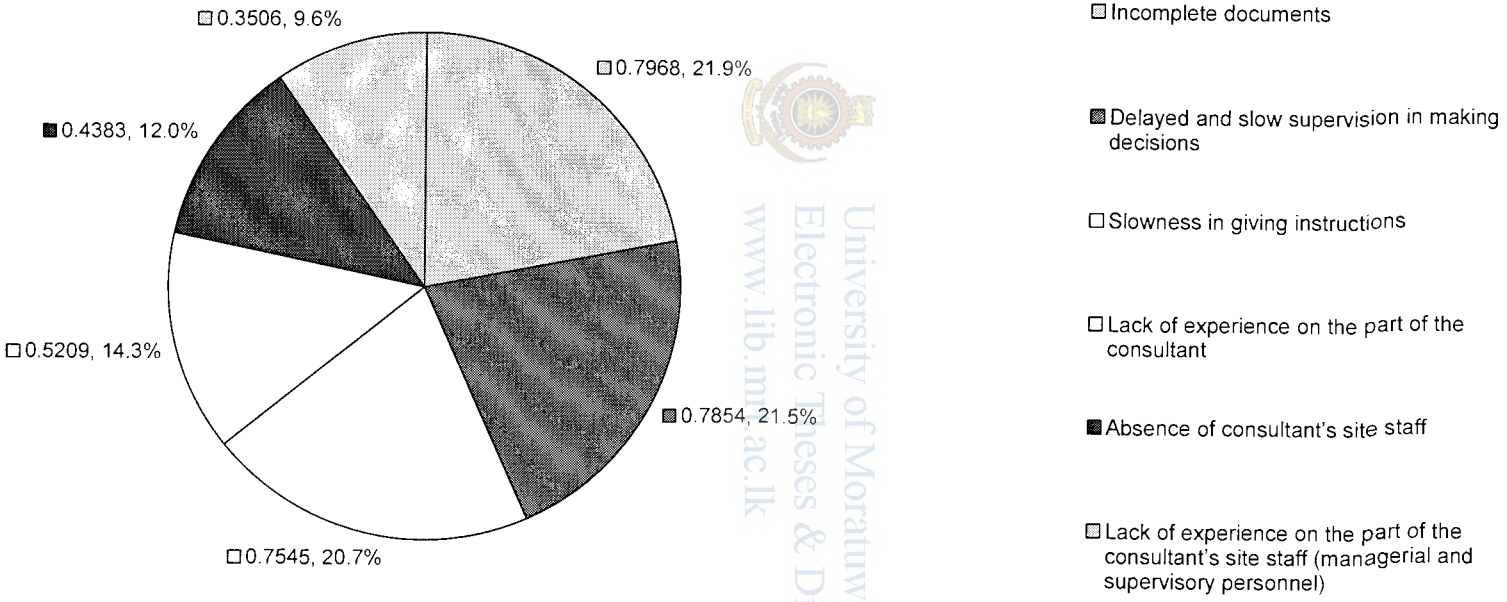

Figure 4.5 – Road Construction Delay Factors with respect to the **Consultant's responsibility**

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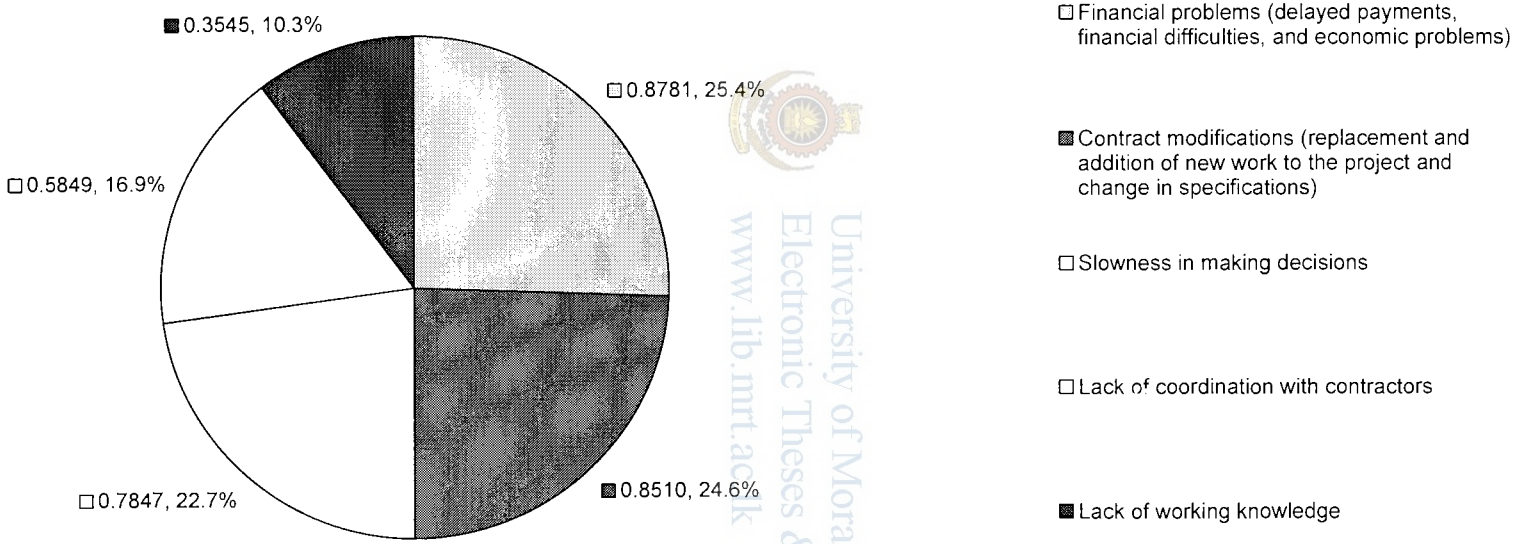

Figure 4.6 – Road Construction Delay Factors with respect to the **Owner's responsibility**

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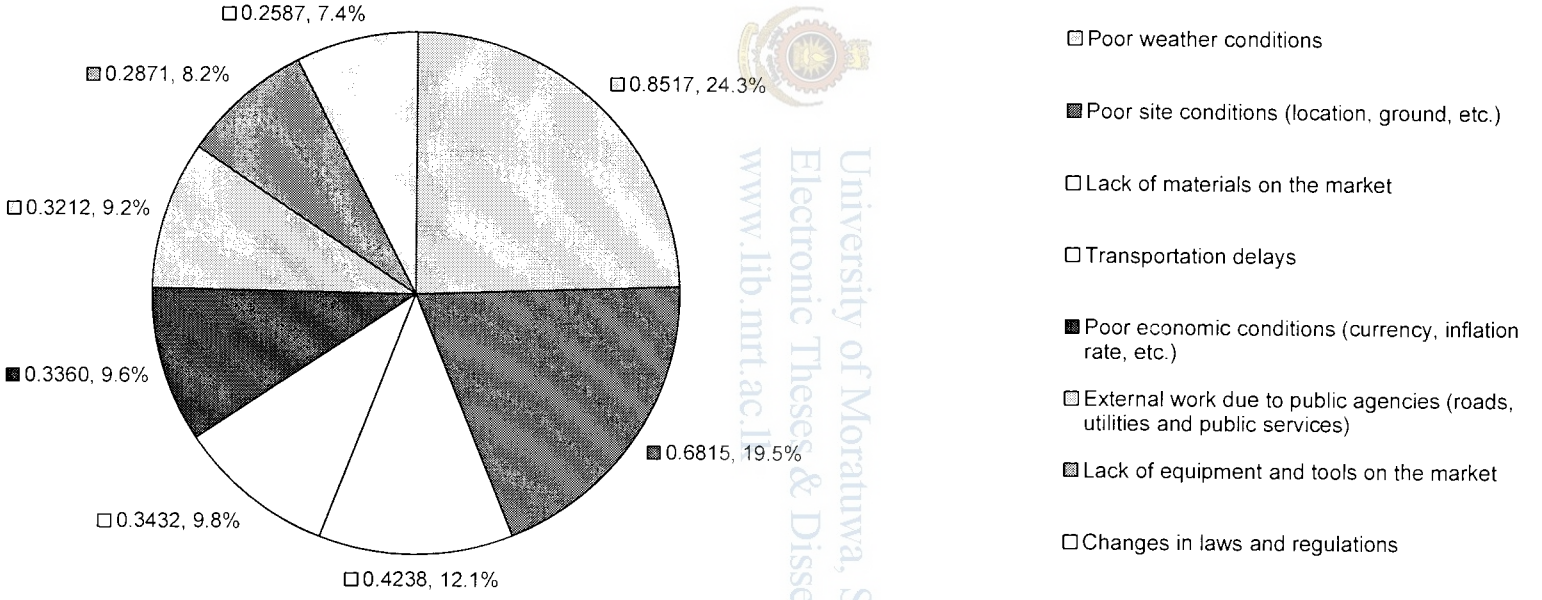

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Figure 4.7 – Road Construction Delay Factors with respect to the **External factors**

Table 4.4 – Overall Ranking of Delay Factors based on Relative Significance Index (RSI)

Road Construction Delay Factors	Responsibility	RSI	Rank (Overall)	Weightage (Overall)
Financial problems (delayed payments, financial difficulties, and economic problems)	Owner	0.8781	1	4.710%
Poor site management	Contractor	0.8668	2	4.650%
Financial problems	Contractor	0.8598	3	4.612%
Poor weather conditions	External Factor	0.8517	4	4.569%
Contract modifications (replacement and addition of new work to the project and change in specifications)	Owner	0.8510	5	4.565%
Incomplete documents	Consultant	0.7968	6	4.274%
Delayed and slow supervision in making decisions	Consultant	0.7854	7	4.213%
Slowness in making decisions	Owner	0.7847	8	4.209%
Shortage of site labour	Contractor	0.7705	9	4.133%
Slowness in giving instructions	Consultant	0.7545	10	4.047%
Shortage of materials on site	Contractor	0.7459	11	4.001%
Lack of subcontractor's skills	Contractor	0.7216	12	3.871%
Construction mistakes and defective work	Contractor	0.6972	13	3.740%
Poor skills and experience of labour	Contractor	0.6832	14	3.665%
Poor site conditions (location, ground, etc.)	External Factor	0.6815	15	3.656%
Delay in delivery of materials to site	Contractor	0.6492	16	3.483%
Coordination problems with others	Contractor	0.5938	17	3.185%
Lack of coordination with contractors	Owner	0.5849	18	3.138%
Low productivity of labour	Contractor	0.5664	19	3.039%
Equipments and tool shortage on site	Contractor	0.5414	20	2.904%
Lack of experience on the part of the consultant	Consultant	0.5209	21	2.794%
Absence of consultant's site staff	Consultant	0.4383	22	2.351%
Lack of materials on the market	External Factor	0.4238	23	2.273%
Lack of working knowledge	Owner	0.3545	24	1.901%
Lack of experience on the part of the consultant's site staff (managerial and supervisory personnel)	Consultant	0.3506	25	1.881%
Transportation delays	External Factor	0.3432	26	1.841%
Lack of site contractor's staff	Contractor	0.3431	27	1.841%
Poor economic conditions (currency, inflation rate, etc.)	External Factor	0.3360	28	1.802%
External work due to public agencies (roads, utilities and public services)	External Factor	0.3212	29	1.723%
Lack of equipment and tools on the market	External Factor	0.2871	30	1.540%
Changes in laws and regulations	External Factor	0.2587	31	1.388%

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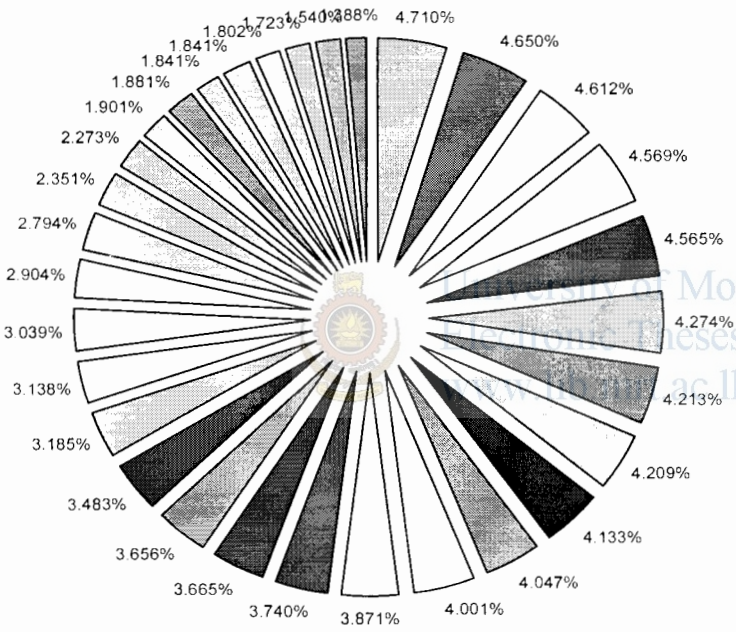

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Figure 4.8 – Road Construction Delay Factors (for all 4 cases)

4.5 Discussion of Results

A detailed analysis was performed, with regard to the survey carried out based on the Duration of Road Construction Projects in Sri Lanka, targeted at the local road construction Contractors, in order to reveal the factors influencing the Project Duration.

A random sample of 30 distinct projects has been considered for the survey, and 30 distinct responders from local road contactors were examined via a Survey Form. The data acquired were yielded a ***high reliability coefficient (90%)***.

The ***Respondents' Background*** was analysed with respect to the *Education*, the *Occupational level*, and the *Number of years of working experience*. With respect their education; ***40 %*** of them acquired a ***Diploma***, ***53 %*** of them acquired a ***Degree***, and ***7 %*** of them acquired ***Post graduate*** qualifications (Figure 4.1). With respect their occupational level; ***20 %*** of them were operated as ***Non-executives***, ***50 %*** of them were operated as ***Executives***, and ***30 %*** of them were operated as ***Managerial*** capacities (Figure 4.2). With respect their number of years of working experience; ***13 %*** of them had ***Less than 2 years***, ***17 %*** of them had ***2–5 years***, ***40 %*** of them had ***6–10 years***, and ***30 %*** of them had ***More than 10 years*** of working experience (Figure 4.3). These demographic statistics about the respondents suggest sufficient exposure to make the information acquired reliable, and thus the opinions are thought to reflect the real situation in the prevailing context of the Road Construction Projects in Sri Lanka.

A new parameter was introduced in this study as *Percentage Delay* in order to reflect the *Magnitude of Delay*. The *Statistical Inference* yielded that the mean ***Percentage Delay*** lies between ***0.56*** and ***0.88*** with respect to the ***Road Construction Projects in Sri Lanka*** (with 95% Confidence). This means that the local road construction projects are experienced ***56 % ~ 88 %*** of average time overrun compared to the original (planned) project duration.

Relative Significance Index (RSI) is a new concept introduced from this study, which has an input parameter of *Percentage Delay*. The survey data were analysed in order to obtain the ***Relative Significance Index (RSI)*** and ***Rank*** of Delay Factors. The different groups (Contractor, Consultant, Owner, and External factors) were further analysed upon their *Group Rank*, and the proportionate significance of *Delay Factors* were depicted in Pie Charts (Figures 4.4~4.7).

Most significant ***Contractor's responsibilities*** were: ***Poor site management*** (RSI = 0.8668, GW = 10.8%, OW = 4.650%), ***Financial problems*** (RSI = 0.8598, GW = 10.7%, OW = 4.612%), ***Shortage of site labour*** (RSI = 0.7705, GW = 9.6%, OW = 4.133%), ***Shortage of materials on site*** (RSI = 0.7459, GW = 9.3%, OW = 4.001%), ***Lack of subcontractor's skills*** (RSI = 0.7216, GW = 9.0%, OW = 3.871%), ***Construction mistakes and defective work*** (RSI = 0.6972, GW = 8.7%, OW = 3.740%), ***Poor skills and experience of labour*** (RSI = 0.6832, GW = 8.5%, OW = 3.665%), and ***Delay in delivery of materials to site*** (RSI = 0.6492, GW = 8.1%, OW = 3.483%).

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Most significant ***Consultant's responsibilities*** were: ***Incomplete documents*** (RSI = 0.7968, GW = 21.9%, OW = 4.274%), ***Delayed and slow supervision in making decisions*** (RSI = 0.7854, GW = 21.5%, OW = 4.213%), and ***Slowness in giving instructions*** (RSI = 0.7545, GW = 20.7%, OW = 4.047%).

Most significant ***Owner's responsibilities*** were: ***Financial problems (delayed payments, financial difficulties, and economic problems)*** (RSI = 0.8781, GW = 25.4%, OW = 4.710%), ***Contract modifications (replacement and addition of new work to the project and change in specifications)*** (RSI = 0.8510, GW = 24.6%, OW = 4.565%), and ***Slowness in making decisions*** (RSI = 0.7847, GW = 22.7%, OW = 4.209%).

Most significant ***External factors*** were: ***Poor weather conditions*** (RSI = 0.8517, GW = 24.3%, OW = 4.569%), and ***Poor site conditions (location, ground, etc.)*** (RSI = 0.6815, GW = 19.5%, OW = 3.656%).

Finally, all the *Causes of Delays* were again ranked upon the *Overall Rank*, and the relevant responsibilities of each cause (Delay Factor) were highlighted. The proportionate significance of *Road Construction Delay Factors* for all 4 groups was depicted in one diagram (Figure 4.8). Therefore the ***Factors Influencing the Duration of Road Construction Projects in Sri Lanka***, can be tabulated as follows:

Table 4.5 – Factors Influencing the Duration of Road Construction Projects in Sri Lanka

Road Construction Delay Factors	Responsibility	RSI	Rank (Overall)	Weightage (Overall)
Financial problems (delayed payments, financial difficulties, and economic problems)	Owner	0.8781	1	4.710%
Poor site management	Contractor	0.8668	2	4.650%
Financial problems	Contractor	0.8598	3	4.612%
Poor weather conditions	External Factor	0.8517	4	4.569%
Contract modifications (replacement and addition of new work to the project and change in specifications)	Owner	0.8510	5	4.565%
Incomplete documents	Consultant	0.7968	6	4.274%
Delayed and slow supervision in making decisions	Consultant	0.7854	7	4.213%
Slowness in making decisions	Owner	0.7847	8	4.209%
Shortage of site labour	Contractor	0.7705	9	4.133%
Slowness in giving instructions	Consultant	0.7545	10	4.047%
Shortage of materials on site	Contractor	0.7459	11	4.001%
Lack of subcontractor's skills	Contractor	0.7216	12	3.871%
Construction mistakes and defective work	Contractor	0.6972	13	3.740%
Poor skills and experience of labour	Contractor	0.6832	14	3.665%
Foor site conditions (location, ground, etc.)	External Factor	0.6815	15	3.656%
Delay in delivery of materials to site	Contractor	0.6492	16	3.483%

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According to the above findings, it is obvious that the ***Contractor*** is the most liable for the Road Construction Delays in Sri Lanka, compared to the ***Consultant*** and the ***Owner***. But, however, the responsibility of ***Owner*** is perceived important than the ***Consultant*** as per the revealed facts. ***External factors*** have also been contributed to the delays, but not in very significant level.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

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5.1 Conclusions

This study focused on the Delays of Road Construction Projects, and a formal attempt made to reveal the ***Factors Influencing the Duration of Road Construction Projects in Sri Lanka*** from ***Contractor's Perspective***.

The data for the analysis were collected via a survey targeted at the ***Local Road Construction Contractors***. The data collected were yielded a ***reliability coefficient of 90%***.

This study found that the local road construction projects are experienced ***56 % ~ 88 %*** of average time overrun compared to the original (planned) project duration. This finding was yielded via ***Statistical Inference*** of ***Percentage Delay***, which is a new parameter introduced in this study.

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Another new concept that has been introduced in this study is the ***Relative Significance Index (RSI)***. The ***RSI*** is mainly adhered with the input parameters of ***Respondent's Weighting*** and ***Percentage Delay*** in order to measure the relative significance of ***Delay Factors***. The results of the analysis show that, from a total of 31 variables (Delay Factors) examined, separated into four categories by the responsibility, the major factors causing delay in road construction projects are factors due to the ***Contractor***, followed by factors due to the ***Owner***, factors due to the ***Consultant***, and finally due to ***External Factors***.

The findings revealed that the ***financial problems*** of the Owner as well as of the Contractor, is the most influencing factor in causing delay in road construction projects in Sri Lanka. ***Poor site management*** by the Contractor, followed by **poor weather conditions** that is an External Factor, ***contract modifications*** by the Owner, ***incomplete documents***, ***delayed and slow supervision in making decisions and giving instructions*** by both the Consultant and the Owner are appeared to be the next critical factors in causing delays in local road constructions. Further, the responsibilities of the Contractor such as, ***shortage of site labour and materials***, ***lack***

t subcontractor's skills, ***construction mistakes and defective work***, ***poor skills and xperience of labour***, and finally ***delay in delivery of materials to site*** were revealed the factors with significant probability of causing delays.

2 Recommendations

ased on the findings and discussions of the study, the following recommendations n be suggested in order to mitigate the effects of delays in road construction projects Sri Lanka.

2.1 Financial problems

- Cash flow problems / financial difficulties, and insufficient resources by the contractors can be eliminated by a ***good practice contractor selecting process***. It is therefore essential to take into account ***not only on the lowest bidding price, but also the previous working experience and reputation*** of the contractors and subcontractors.

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- ***Proper costing*** is essential in every road construction project. The ***initial cost estimates*** shall be as accurate as possible. This would allow Owners to ensure that the required funds for executing the project are sourced on time and made available when required. ***Cost and value engineering principles*** must be applied at all stages of the project.

- ***Financial Support*** as well as ***Technical Support*** is a very necessary and urgent step for road construction investments, since the results of the analysis show that financial problems are the most influencing factor causing delay. Further, ***Capacity Building*** is essential for sustainable development. Governments shall set up deliberate schemes that can help local contractors build their capacity by availing them credit facilities. This would ensure adequate equipment availability.

- Delayed payments due to complex financial processes in Owner organizations would cause financial difficulties to contractors, and consequently cause time overruns. Therefore, ***Owners shall ensure that they have sufficient funds available for projects before the commissioning***.

5.2.2 Poor site management

- Contractors shall have ***able site managers*** for plan their work properly, and for the smooth execution of work. During the execution stage of the project, site managers shall ensure that the ***contractual obligations*** are dealt with diligently within the stipulated ***Cost***, ***Time***, and the ***Quality*** of Works.

- Since there are many parties (Owner, Consultant, Contractor, and Sub-contractors etc.) involved in a project, the communication between the parties is very crucial for the success of the project. Any problem with communication can lead to severe misunderstanding and hence delays in the execution of the project. Therefore, ***proper communication channels*** between the various parties shall be established during the planning stage.

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- ***Effective communication*** can alleviate most of the factors that cause delays in road construction projects. Owners ought to promote ***team building communication processes***. Site managers need to deal with all project issues objectively and ensure that ***all communication is project issue based***.

5.2.3 Poor weather conditions

- The projects earmarked for construction shall be properly planned and timed in such a way that most of the works can be executed in ***seasons of clement weather***. Further, the Contractors have to expedite and complete the works as much as possible within that period since the weather conditions in Sri Lanka may not remain the same for a long period.

5.2.4 Contract modifications

- Excessive ***change orders*** (Contract modifications) have a tremendous effect on the financial performance of a road construction project. According to many experts, the average cost of change orders on road construction, as a percentage of the original project budget, is 5%~10%. Therefore, Owners shall draw more emphasis in this regard before initiate a modification in the contract. However, ***contingency allowances*** may be incorporated for inevitable variations.

- For any project, ***scope*** needs to be well defined from inception to completion. Scope changes often lead to claims, and some times to disruption of work due to inadequate analysis of the project in its initial stages. Further, it shall be borne in mind that ***contractors tend to claim over the price variations so as to cover up for any short falls in their initial bids***. This implies that the variations that result from scope enlargements are ***more costly*** hence compound cost escalation. Effective ***scope definition*** is therefore indispensable for a successful project delivery.

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5.2.5 Incomplete documents / Slowness in making decisions

- While drawing the contract between the Owner and Contractor, the Consultant must conspicuously include items such as ***duration of the contract***, ***mechanism to solve disputes*** including ***extra work and additional works***, ***mechanism to assess the causes of delay*** if there are any, and ***risk management plans*** etc.

- Consultants shall prepare and approve drawings ***on time*** according to a set ***schedule***, and shall monitor the work closely by making inspections at appropriate times.

- Consultants shall be ***flexible*** enough in evaluating contractor's works so that ***intuitive compromising*** to be assured between the ***cost*** and the ***quality***.

- Owners must make ***quick decisions*** to solve any problem that arise during the execution.

5.2.6 Shortage of site labour and materials

- The ***quality*** and ***quantity*** of labour supply can have major impacts on the progress of road construction projects. Therefore, Contractors shall assign ***enough number of capable labours on time***, and shall ***motivate them to improve productivity***.

- Contractors shall draw more emphasis in ***on time delivery*** of materials to the site, as in many local road projects the works are been held up due to materials shortages.

5.2.7 Lack of subcontractor's skills / Poor skills and experience of labour

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- ***Manpower***, at both the ***technical and the managerial levels***, shall have their own knowledge updated by ***continuous professional development schemes***.

- Effective project implementation requires ***competent personnel***. This would minimise errors, poor supervision and enhance coordination on sites.

- Wherever possible, construction professionals need to have experience and qualifications in ***Construction Project Management*** so that they can effectively utilise the project management tools that are available.

- Contractors shall not take up the job in which they do not have sufficient expertise.

5.2.8 Construction mistakes and defective work

- The mistakes during the construction stage can be due to ***accidents***, ***inadequate planning***, or ***miscommunication*** between the parties. Whatever

the reason, mistakes can have significant impacts on the project progress while the ***redoing work involves additional expenses.*** Therefore, it is worthwhile for Contractors to draw stern emphasis in order to minimise the probable mistakes that appeared during the construction stage.

5.2.9 Poor site conditions

- Although natural ground conditions sometimes cannot be thoroughly predictable, a ***sound preparations and investigations*** are required before commencement of construction in order to reduce the impact of any unforeseen ground conditions.

5.3 Recommendations for Future Research

RSI model, which is the new concept introduced in this study, can be utilised for any kind of ***Delay Analysis*** in order to measure the ***Relative Significances*** of ***Delay Factors*** (*Causes of Delay*).

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The focused area in this research can be broaden up to ***all the Civil Engineering Projects*** with the perspectives of ***Contractors***, ***Consultants***, and ***Owners***.

Moreover, similar studies can be performed for the ***different parts of the world*** in order to ***investigate the prevailing trends of construction delay in global context***.

Further, a ***Construction Time Delay Model*** for ***Civil Engineering Industry*** can be developed with the comprehensive investigation of such trends.

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APPENDICES

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Appendix A: Survey Form

SURVEY FORM

July, 2009

This Survey Form is to capture preliminary information for a study conducted by Department of Civil Engineering, University of Moratuwa. The facts are used to reveal the "**Factors influencing the Duration of Road Construction Projects in Sri Lanka**"

Kindly note that the respondents for this survey should be professionals only from **Contractors** of **Road Construction** in **Sri Lanka**

Please confine **One Survey Form** only for a **One Project** in order to furnish the particulars. Hence, **cases to be specific**, and general viewpoints are not encouraged

Further, kindly note that this study is merely for a non-commercial academic interest of a post graduate student, and the individual responses are treated in strictly confidential basis

For any further clarifications, please contact: Eng. Yasas L. Pathiranage (mobile: +94 (0) 71 6498752, email: yasas_pathiranage@yahoo.com)

Insert a "**X**" or a **Number** in the cages where appropriate

Respondents' Background

Education: Diploma _____, Degree _____, Post graduate _____

Level of operation: Non-executive _____, Executive _____, Managerial _____

Working experience: Less than 2 years _____, 2–5 years _____, 6–10 years _____, More than 10 years _____

Project Information

Planned Project Duration: _____ (Months)

Actual Time Elapsed for the Completion: _____ (Months)

Causes for the Delay

	Road Construction Delay Factors	Not Significant	Slightly Significant	Moderately Significant	Highly Significant	Extremely Significant
(1) Contractor's responsibility						
1	Delay in delivery of materials to site					
2	Shortage of materials on site					
3	Construction mistakes and defective work					
4	Poor skills and experience of labour					
5	Shortage of site labour					
6	Low productivity of labour					
7	Financial problems					
8	Coordination problems with others					
9	Lack of subcontractor's skills					
10	Lack of site contractor's staff					
11	Poor site management					
12	Equipments and tool shortage on site					
(2) Consultant's responsibility						
13	Absence of consultant's site staff					
14	Lack of experience on the part of the consultant					
15	Lack of experience on the part of the consultant's site staff (managerial and supervisory personnel)					
16	Delayed and slow supervision in making decisions					
17	Incomplete documents					
18	Slowness in giving instructions					
(3) Owner's responsibility						
19	Lack of working knowledge					
20	Slowness in making decisions					
21	Lack of coordination with contractors					
22	Contract modifications (replacement and addition of new work to the project and change in specifications)					
23	Financial problems (delayed payments, financial difficulties, and economic problems)					
(4) External factors						
24	Lack of materials on the market					
25	Lack of equipment and tools on the market					
26	Poor weather conditions					
27	Poor site conditions (location, ground, etc.)					
28	Poor economic conditions (currency, inflation rate, etc.)					
29	Changes in laws and regulations					
30	Transportation delays					
31	External work due to public agencies (roads, utilities and public services)					

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