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THESIS

ANALYSIS OF DELAYS IN HIGHWAY CONSTRUCTION PROJECTS IN SRI LANKA

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A Thesis Submitted in Partial Fulfilment of
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Delay is a critical issue in highway construction in Sri Lanka as half of the projects in past decades were delayed. The objective of this study is to identify various causes of delay on Sri Lankan highway construction. A structured questionnaire was developed to gather project participant's opinion on highway construction delays. The questionnaire focused on delay factors in pre-construction and construction phases. Sixty questionnaires were distributed to project owners and contractors while fifty one completed questionnaires were returned. The respondents were asked about the frequency and severity of each delay factor. Relative importance index and standard deviation were used to prioritize the delay factors according to their adverse impacts as well as frequency of occurrence. The different perception between the owner and the contractor was also examined by using rank agreement factor, percentage agreement and percentage disagreement. The results show that frequent changes of design, delays in acquisition of construction site, funding delay and incomplete design have significant impacts in pre-construction phase while contractor's cash flow problems, increased price of construction materials, scarcity of skilled labour, lack of resources and owner's cash flow problems are critical issues in construction phase. In addition, the project owner and contractor strongly agree on causes of delay in pre-construction phase but they are disagreed on several delay factors in construction phase.

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Panahatipola Mudiyanselage Sethsiri Bandara Kandegedera

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADB	=	Asian Development Bank
BOQ	=	Bills of Quantities
EIA	=	Environmental Impact Assessment
FOI	=	Frequency of Occurrence Index
GDP	=	Gross Domestic Product
ICB	=	International Competitive Bidding
ICTAD	=	Institute of Construction Training, Administration and Development
IMF	=	International Monitory Fund
IRR	=	Internal Rate of Return
JBIC	=	Japan Bank for International Cooperation
JICA	=	Japan International Cooperation Agency
LCB	=	Local Competitive Bidding
NCASL	=	National Contractors Association in Sri Lanka
NPA	=	National Procurement Agency
PA	=	Percentage Agreement
PD	=	Percentage Disagreement
PRDA	=	Provincial Road Development Authority
RAF	=	Rank Agreement Factor
RDA	=	Road Development Authority
RII	=	Relative Importance Index
SD	=	Standard Deviation
SFI	=	Severity and Frequency Index
TICA	=	Thailand International Cooperation Agency
WB	=	World Bank

ANALYSIS OF DELAYS IN HIGHWAY CONSTRUCTION PROJECTS IN SRI LANKA

INTRODUCTION

Highway construction industry in Sri Lanka is in a developing stage in terms of technology compared to other developed countries. Road development authority (RDA) is the premier highway agency, which is responsible for execution of constructing and maintenance of major highways and expressways. Most of the contractors are private sectors, and only few of them are in a government agency. Any private firm newly entering to the contraction industry, shall be registered to the National Contractors Association in Sri Lanka (NCASL), as well as the Institute of Construction Training, Administration and Development (ICTAD), which classifies the contractor based on its past construction experiences, technical and financial capability, ownership of heavy construction machinery in the firm and average annual turnover, and issues a grade between M1 to M10, which represents a ranking of the contractors. M1 represents the highest ranking, whereby the company with M1 grade can perform all types of construction, while M10 represents the lowest ranking, whereby the company with M10 grade can perform only certain types of construction work. At present, less than 10 reputed construction companies are classified as M1, and the others are varied up to M10.

Even though contractors are classified according to the above mentioned criteria, some of them are still suffering from lack of qualified staff, new machinery, and financial, technical and management skills. Sri Lankan construction industry is highly competitive among the contractors. Therefore, all of them are trying to win a contract by reducing their bid price down to the minimum limit for their survival purpose in the construction industry because all are facing difficulties of maintaining their staff, machinery and settlement of their bank loans without having a contract. According to the government contracting policy, a contract can be awarded to the minimum thirty percent below the engineer's estimate. If the contractor quotes the bid

price within the minimum limit, there is a high probability of wining the contract. After awarding the contract, the contractor is in a difficult situation to perform the contract according to the specified time period and standard quality level due to under-bidding .These factors cause a detrimental effect to the contract in terms of schedule delays and cost overrun.

Furthermore, contractors are facing difficulties to find skilled labour force, quality construction materials and professional staff to deploy in the construction work. Most of the professional engineers are migrating to the developed countries to improve their living standards and others are employed in foreign countries, gaining higher salaries and fringe benefits compared to work in Sri Lanka. This creates a vacuum of professionals in the construction industry. Especially, highly skilled labourers are going to work in Middle-East countries, which also create the same problem.

Nowadays, Sri Lankan government has been taken some necessary steps to minimize damage to the environment by enforcing environmental rules and regulations, which are helping to protect the environment, but on the other hand directly affecting to the low production of sand mining and rock blasting processes. If the supply of sand and aggregates is low, then the demand for those materials is very high, inevitably prices of those materials are dramatically increased in the construction industry. In this situation, if the contractor quoted a low bid price for the construction materials to win the contract, then the contractor encounters various problems to proceed with the contact according to the standard quality level, given project budget and schedule. This causes unnecessary delays and cost overrun of the contract.

Statement of the problem

Highway construction industry plays a key role in the country's infrastructural development as approximately 15% of the annual budget is allocated for the infrastructure construction and development projects.

Table 1 shows the statistical data of past highway construction projects in Sri Lanka. It can be observed that delay is a critical issue of the domestic and foreign funded projects as can be seen from Table 1, more than fifty percent of the domestic and World Bank funded projects are delayed and this delay causes a detrimental effect of the country's economy as well as the growth rate of gross domestic product (GDP).

Table 1 Highway projects delay situation in Sri Lanka

Source of fund	Projects (No :)	Projects completed on time (No :)	Projects delayed (No :)	Project delayed (%)
ADB	73	48	25	34
JBIC	208	110	98	47
Domestic	28	12	16	57
Kuwait	8	5	3	38
World bank	20	10	10	50

Hence, through this study, an effort shall be made to identify the influencing factors that cause delay in highway construction projects and recommend ways to minimize delay for better project performance of future highway projects in Sri Lanka**.**

OBJECTIVES

1. Identify the various causes of delays at pre-construction and construction phases of highway projects.

2. To prioritize delays according to the relative importance of causes of delays.

3. To recommend ways to minimize delays.

Scope

This study focuses on the pre-construction and construction phases of highway construction projects in Sri Lanka. Special attention is focused on highway construction projects in north central province, central province, north western province and western province.

LITERATURE REVIEW

1. Introduction to Sri Lanka

Sri Lanka is a small island with an area of 65,525 square kilometers and the total population is about 20 million people. It is also called the pearl of the Indian Ocean because it is situated in the Indian Ocean to the south of India. The country consists of various topographical regions including flat-lands and mountains, and has two climatic seasons: summer and rainy seasons. Figure 1 shows a map of Sri Lanka.

Figure 1 Topography of Sri Lanka

Source: Asia Society (2007)

Sri Lanka remained a British colony until 1948. Primary infrastructure facilities of the country including roads and railway lines connected to the hilly and coastal regions were developed to support the transportation of agricultural products from plantation areas to the Colombo harbour and for civil administration and defence. Furthermore, primary income gained for the country by exporting of crops such as tea, coffee, rubber and coconut were introduced during the British period.

Basically, Sri Lankan construction industry still adheres to the British standard codes of practices for any construction work.

During the period of 1948 to 1976, the country's economic policy was closed to the world and most of the needs of the nation were produced by our own production. In 1977 the new government strategically changed the country's economy and introduced open economic policies to the nation. Hence, this liberalized economic policy contributed to flow of foreign investments into the country. This led to the drastic development of infrastructure facilities of the country such as high-rise buildings, dams for irrigation and generation of hydroelectric power, highways and expressways, free-trade zones, air-ports and garment factories. Therefore, the country's Gross Domestic Product (GDP) dramatically increased.

At present, allocation of funds to the construction industry can be divided into two, government budgetary allocation (domestic fund) and foreign fund, which is coming through many donor agencies such as Asian Development bank (ADB), Japan International Cooperation Agency (JICA), Japan Bank for International Cooperation (JBIC), World Bank (WB) and International Monetary Fund (IMF). These agencies are providing financial and technical support to uplift the infrastructure development. This directly affects the growth of GDP of the country. Most of the foreign funding is given as loans and aid. These are very helpful to alleviate poverty and improve the quality of life among poor people by providing their basic needs such as food, health, shelter, education, social welfare facility and also financial assistance to carry out their own business in an effective and efficient manner.

However, sustainable development of infrastructure facilities in the country is mainly achieved by contribution of government sector as well as private sector. During the economic feasibility study stage of the project, government is only concerned about benefit / cost ratio rather than internal rate of return (IRR), capital recovery and payback period. Sometimes it is impossible to evaluate some social benefits in terms of money. For considering the future project benefits to the public, government agencies are more flexible and trying to implement the projects as much

as possible for the betterment of society. By comparing with the government agencies, private agencies mainly focus and are strict on the monetary return of their potential investment while manipulating capital recovery, payback period and IRR, they find out an unfavourable result of their investment, if that project is more favourable to the public, it will not come into reality.

2. Delays in the construction industry.

A successful project can be defined as meeting its goals and objectives as prescribed in the project plan, to evaluate the success of the project which has accomplished its technical performance, maintain its schedule and remained within its budgetary cost.

Project management tools and techniques play an important role in the effective management of the project. Hence good project management lies in the management tools and techniques used to manage the project. Project management involves managing the resources such as man, money, methods, materials and machinery. Some projects are effectively and efficiently managed while others are mismanaged, incurring much delay and cost overrun (Yaw Frimpong *et al.* 2002).

However, it is seldom that a project is accomplished within the schedule and given budgetary allocation, because various unforeseen factors are encountered during the construction phase. These unforeseen factors directly affect the schedule variance called delays, which may or may not incur cost overrun.

2.1 Definition of delay

"A delay is the time during which some part of the construction project has been extended or not performed due to an unanticipated circumstance". An incident of delay can originate from within the contractor's organization or from any of the other factors interfacing upon the construction project (Bramble and Callahan 1987).

2.2 Classification of delay

Delays can be classified into three parts, namely, excusable delay, non-excusable delay and concurrent delay. Furthermore, excusable delays can be subdivided into two parts: one is compensatory delays and the other is non-compensatory delay (Bramble and Callahan *et al.* 1987). Figure 2 shows the classification of delay.

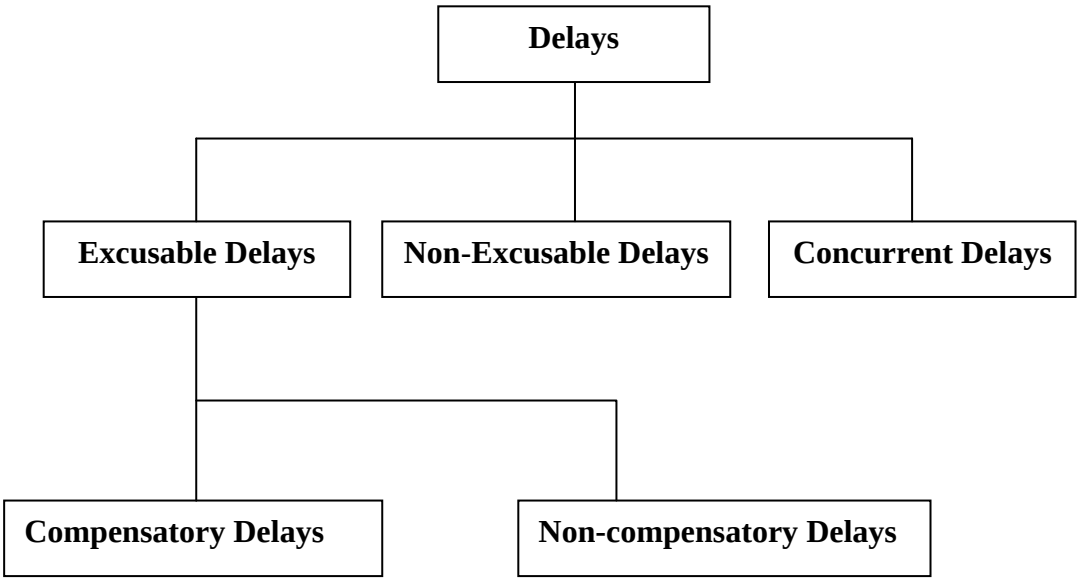

Figure 2 Classification of delay

Source: Bramble and Callahan, (1987)

2.2.1 Excusable / Compensable delay

Excusable and compensable delays normally occur when extra work orders are issued by the owner. It can also happen by suspension or interruption to all or part of work caused by the act or failure to act by the owner. In the condition of contract, it is described as an owner's breach of contract. In this situation the contractor is entitled to get an extension of time and additional payment for the extra work quantity.

2.2.2 Excusable / Non-compensable delay

Excusable and non-compensable delays are caused by factors that are unforeseeable and may be due to unforeseen ground conditions, unexpected weather conditions, strikes or acts of god. In such situations neither party is responsible for the delay and they share the risk. In this case, the contractor is entitled to get extension of time to complete the work but is not compensated for this delay in terms of money.

2.2.3 Non-Excusable delay

The contractor is fully responsible for non-excusable delays. This can be caused by the action and inaction of the contractor, sub-contractor, or material supplier. These delays could be the result of mismanagement of resources, low productivity, lack of planning and programming, rework, break-down of equipment, or shortage of professional staff and labours, etc. Such delays are within the contractor's control, which is entitled to neither compensation nor extension of time. According to the condition of the contract, the owner is entitled to claim liquidated damages against the contractor, if the contractor prolonged the contract beyond the contract period.

2.2.4 Concurrent delay

When two or more delays occur at the same time or overlap to some degree, they are called concurrent delays. These delays can occur when the owner and contractor are at fault.

3. Past studies on construction delays

3.1 Delays in the pre-construction phase.

It is very important to consider pre-construction delays of the projects because any delay which occurs during the pre-construction stage could be easily propagated to the construction phase of the project. Hence, pre-construction delays have significant impact on the physical and economic environment of the project. For instance, the owner fails to acquire the land for the project in the required time period, after that the implementation of the project is delayed. If the owner cannot utilize the funds within the given period of time, meaning that the donor agency would withdrawn those funds to invest in another project in another country. Later, it is very difficult to find a funding agency and get funds to implement this project.

Nowadays, countries throughout the world are more concerned about their environment. Hence, the donor agencies are also concerned about this matter, and give their funding with stricter rules and regulations than before. The submission of environmental impact assessment (EIA) report of the project is very important to get funds from the donor agency. If the owner is delayed in submitting EIA report to the donor agency, the funds are delayed to start the project that will directly effect to the increase of construction cost and schedule slippage of the project. However, the inflation rate increases day by day, conversely power of purchasing is gets lower. Therefore, to match these situations the owner has to revise the cost estimates up to the bidding stage of the contract. This may lead to delay in the pre-construction phase.

During the pre-construction phase the owner’s involvement is higher than the contractor. Hence, the owner is the most responsible for the delays in this phase. Such delays can happen during the bidding stage including: preparation of bid documents, funding delays, bid evaluation, contract awarding and land acquisition

Most of the time, bidding stage delays occurred due to mistakes in preparation of drawings, specifications and bill of quantities (BOQ). Although, submission of a large amount of disqualified bids would increase the time period of pre-qualification, post-qualification and bid evaluation processes. If the lowest evaluated bidder is refused to accept the contact because the under-bidding of the contract, it means that the bidder cannot perform the contact according to the quoted rates being fairly in the BOQ. By checking the other quoted values of the bids and found that they are extremely higher than the engineer's estimate, and they would not agree to do the contract at the engineer's estimate. Then the owner cannot proceed with the contract beyond that condition, so the only option is that the owner has to cancel the bid and re-invite of the bid for the same contract. This causes a considerable amount of delay in pre-construction phase of the project.

It is noticed that, most of the delays in the contract awarding phase may occur due to the funding problems, land acquisition problems and political influence. In developing countries politicians are more concerned about construction contracts. The politicians are trying to favour their supportive contractors by enforcing their political powers to violate the rules and regulations of the contracts by seeking some benefits from the contractors.

3.2 Delays in the construction phase.

During the construction phase, the contractor's involvement is higher than the owner's involvement. Thus, the contractor is the most responsible for delays in the construction phase. The owner also has some responsibility in the construction phase but not as much as the contractor. Many authors and researchers have done their research on delays in construction phase, and found some important reasons which contributed to the delays in the construction phase of the project and suggested ways of avoiding or minimizing the detrimental impact on the project.

It is vital to consider the causes of delays in Sri Lankan highway construction projects. As per the condition of the contract, the contract shall be legally bound between owner and contractor after signing of the contract agreement. After that the owner has to hand over the site to the contractor to carry out construction work without any difficulty, meaning without any land acquisition and other external problems. If the owner fails to handover the site to the contractor by clearing all problems within the time period or if the contractor fails to mobilize to the site within the specified time period, this situation is the starting point of the cause of delay. After that, in any situations the delay can occur during the construction phase. Most common causes of delays that are the contractor's responsibility during the highway construction are slow mobilization to the site, shortage of construction materials and machines, lack of professional staff, shortage of skilled labours, poor resources management, lack of planning and scheduling, financial problems of the contractor, etc. The causes of delays that are the owner's responsibility during in construction phase are delay to hand over the site to the contractor, issuing instructions, approving interim payments, issuing variation orders, extra works, decision-making, errors in contract documents and drawings, etc.

Ogunlana *et al.* (1996) did the research on the construction delays in Thailand, and found that most of the projects suffered delays due to shortage of construction materials, equipment and manpower at all levels. However, their research was carried out during the boom years which were not like the normal situation at present.

Another research done by Chan and Kumaraswamy (1997) evaluated the relative importance of 83 potential delay factors in Hong Kong construction industry and found five principle factors: poor risk management and supervision, unforeseen site condition , slow decision-making, client initiated variation and work variation. Lo *et al*. (2006) carried out a similar study in Hong Kong and found out that inclement weather, unforeseen ground condition, inaccurate bills of quantities and delays in providing design information were the major factors causing delays in construction projects.

Most delays in construction phase occurred, as the result of contractor failure to meet their contractual obligation. The delays that are common in construction phase are under-bidding, slow mobilization at site, late delivery of materials and machines, shortage of professional staff and labours, poor communication and coordination of work, lack of management of resources, poor planning and scheduling of work, shortage of material and machines, increase of rework, etc.

The results of the research carried out by Ogunlana *et al*. (1996) can be summarized in Table 2.

Table 2 Major causes of construction delays in Thailand (Ogunlana *et al*. 1996)

Reasons for Delay	**Source**	**Relative weightage of delay**
Change orders	Owner	41.7
Slow decision making		33.3
Incomplete drawings	Designer	75.0
Slow responses		66.7
Deficiencies in organization	Construction manager	33.3
Deficiencies in co-ordination		25.0
Uncompromising attitude		25.0
Delays in work approval		16.7
Material management problem	Contractor	75.0
Deficiencies in organization		75.0
Co-ordination deficiencies		66.7
Planning and scheduling problem		58.3
Equipment allocation problem		41.7
Financial difficulties		33.3
Inadequate site inspection		33.3
Shortage of construction materials		91.7
Late delivery of materials		41.7
Price escalation		16.7
Low quality of materials		8.3
Shortage of site work		75.0
Shortage of technical personnel		41.7
Insufficient amount of equipment		58.3
Frequent equipment break down		25.0
Confined site	Other	41.7

Kinley *et al*. (2007) carried out research on project performance in Bhutan construction industry and found that major causes of delays occurred during construction phase due to contractor's cash flow problem, poor site management and supervision of the contractor, ineffective project planning and scheduling of the contractor, unqualified workforce, shortage of materials and late delivery of materials were attributed to the contractor. Table 3 shows the outcome of the research carried on Bhutan construction industry.

Table 3 Reasons of delay in Bhutan construction industry (Kinley *et al*. 2007)

Reasons of delay due to contractor	**RII**	**Rank**
Contractor's cash flow problem	0.816	1
Ineffective project planning and scheduling by contractor	0.792	2
Poor site management and supervision by contractor	0.736	3
Inadequate contractor's experience	0.680	4
Improper construction methods implemented by contractor	0.672	5
Inadequate construction experience of contractors staff	0.672	6
Co-ordination between contractor and other parties	0.632	7
Scheduling conflict between general and sub- contractor	0.576	8
Delay in sub contractors work	0.560	9
Re-work due to mistakes during construction	0.560	10
Conflicts between contractor and other parties	0.552	11
Frequent change of sub-contractors	0.496	12

Al Momani *et al*. (2000) carried out a quantitative analysis in Jordan construction industry and found that main causes of delays occurred due to site conditions, weather, economic condition, late delivery and increase in quantity of work.

In Turkey, public construction projects frequently encountered delays in shortages of resources, financial difficulties in public agencies and contractors, delays in design work, changing orders and organizational deficiencies. Since this research was conducted two decades ago by Ariti *et al.* (1985), at present the problems may be different than previous.

Odeh and Battaineh (2002) have done research by considering different aspects of delays in construction industry. Firstly, they considered the cause of delay that the contractors limited to get extension of time. This analysis did not cover the causes of delays that contractors are responsible for, some of them are related to the labour and equipment, planning and site management, construction methods, adequacy and capability of contractors etc. Secondly, their study based on the reported number of time extensions and not the extent of delay attributed to the different causes of delay. By carrying out that research they came across that most of delays in Jordan construction industry occurred due to owners interference, inadequate contract experience, financial problems, improper planning, labour productivity, slow decision-making, etc. The findings of delays in Jordan and Turkey construction industry are summarised in Table 4.

Table 4 Reasons of delay in Jordan and Turkey

Reasons of delay	Country	Researcher
Unforeseen site condition	Jordan	Al-Momani *et al.* (2000)
Bad weather condition		
Economic condition		
Late delivery of material		
Increase work quantity		
Shortage of resources	Turkey	Arditi *et al.* (1985)
Financial difficulties faced by public agencies and contractors		
Delays in design work		
Frequent change order / design		
Deficiencies in organization		
Owner interferences	Jordan	Odeh and Battaineh (2002)
Inadequate contractor experience		
Financial problems		
Improper planning		
Labour productivity		
Slow decision-making		

Dlakwa and Culpin (1990) suggested that major effects of delays are cost and time overrun due financial problems of agencies to make adequate payments to contractor on time and fluctuation of prices of materials, labour and plant in Nigeria.

Elinwa and Buba (1993) said that major factors for the delays and high construction cost was due to shortage and fluctuation in prices of materials, mode of finance and payments for completed works, poor contract management and improper planning.

Causes of delays and cost overrun in Nigerian construction projects were identified by Mnsfield *et al*. (1994). According to them, human resources and management were the main problems in Nigerian construction industry. Taking remedial measures in advance would minimize the delays and cost overrun. External factors can be identified as usually being responsible for project delays and increase of cost due to excessive bureaucratic checking and approval of procedures, unclear project definition and insufficient geological investigation at feasibility stage of the project. Reasons of delays in Nigerian construction industry can be summarized in Table 5.

Table 5 Reasons of delays in Nigerian construction industry.

Reasons of delay	**Researcher**
Financial problems of the owner	Dlakwa and Culpin (1990)
Cash flow problems of the contractor	
Fluctuation of cost of materials	
Fluctuation of cost of labour	
Fluctuation of cost of plant	
Shortages of materials	Elinwa and Buba(1993)
Improper planning	
Poor contract management	
Lack of human resources	Mnsfield *et al*. (1994)
Unclear project definition	
Insufficient geological investigations	

It is very important to consider the delays of construction industry in developed countries, and compare with the delay in developing countries. Sullivan and Harris (1986) found that the major factors leading to unanticipated delays and extra cost on large UK construction projects were late receipt of information, variation, mechanical and electrical construction and procurement delays, unforeseen ground condition and bad weather.

Ahmed *et al*. (2002) conducted an empirical study on construction delays in Florida. The objective of the research was to identify the major causes of delays in construction projects in Florida. The researcher concluded that the delays were obtaining the building permit approval, change orders, change in drawings and incomplete documents.

Semple *et al*. (1994) conducted research to find out causes of delays in construction industry in Canada, especially focusing on the civil, institutional, high-rise apartments buildings, and petrochemical projects. To identify critical elements in construction contracts, the researchers investigated the process to determine causes of claims, categories of compensation of claims and conduct clauses quoted in claims. Finally, they concluded the research with the following outcomes as critical element in construction contracts relates to delays, soil/ site condition, disputes, changes /extras. Growth of scope of work, restricted access and inclement weather condition were identified as causes of delays. The outcome of the researches are summarised in Table 6.

Table 6 Major reasons of delay in United States and Canada

Major reasons of delay	**Country**	**Researcher**
Building permits approval	U.S	Ahmed *et al*. (2002)
Change order		
Change in drawings		
Incomplete documents		
Increase in the scope of works	Canada	Semple *et al*. (1994)
Inclement weather conditions		
Restricted access		

Ogunlana *et al*. (1996) conducted research on construction delays in Thailand and compared the results with developed countries, by using causes of delays and relative weightings. It was observed that waiting for the information,

change orders, unforeseen ground condition, site inspection, bad weather and design complexity were the most effective factors responsible for delays in UK. Table 7 gives a clear idea about reasons of delays and relative weightings of each reason related to the developed and developing countries.

Table 7 Reasons of delays with relative weightage in developed and developing countries (Ogunlana *et al*. 1996).

Major reasons of delay	**U.K Rel.wt %**	**Turkey Rel.wt %**	**Nigeria Rel. wt.%**	**Thailand Rel.wt%**
Waiting for information	51.0	32.0	47.0	75.0
Change orders	49.0	40.0	71.0	41.7
Ground problem / site inspection	21.0	9.0	52.0	33.3
Bad weather	19.0	4.0	52.0	
Design complexity	19.0	14.0		
M & E sub-contractors	17.0	17.0		
Obstructions	14.0	9.0		
M & E plant procurement	14.0	26.0		
Material procurement	13.0	35.0	93.0	91.7
Civil sub contractors	7.0	6.0	55.0	
Claims /disputes	6.0	11.0	55.0	
Labour shortages	5.0	17.0	65.0	75.0
Construction plant shortages	5.0	12.0		58.3
Break downs	5.0	8.0		25.0
Monthly payment difficulties		10.67	92.0	
Contractors financial difficulties		10.59		33.3
Owner's deficiencies		6.30		33. 7
Additional works		5.39	79.0	
Design delays		4.57		66.70
Plang: and Sche: deficiencies		4.54		58.30
Contract negotiations		48.0		
Owner's unrealistic project duration		2.68	71.0	
Disagreement on contract clauses		1.28	67.0	
Disagreement on specification		0.48		25.0
Transportation problems		0.31	54.0	
Poor contract management		8.25	86.0	75.0
Imported materials			73.0	
Mistakes during construction			57.0	

Finally, it is very important to make some conclusions by comparing the results of the above researches. By considering the results of Table7, performance of the construction in developed countries is much better than in developing countries. A

few reasons of delays are common among developed and developing countries. Others are common in developing countries. In developed countries, common reasons of delays are due to incomplete documents, drawings and contact specifications. These causes of delays can occur in any contact and in any country. Hence, it is vital to take preventive measures to avoid causes of delays at the initial stage of the project.

3.3 Practices and prevention of delay.

Ahuja and Nandakumar (1985) said that a project is considered successful, if it is completed within its schedule duration and estimated cost. The most critical parameter affecting the cost is the project schedule. To keep the project on schedule, according to them, it is the responsibility of project management to make an accurate forecast of project duration for establishing the pace of performance and also revise it at regular intervals according to the dynamic nature of the project. According to them variables affecting activity duration are learning curve, weather, space congestion, crew absenteeism, regulatory requirements, design change and rework, economic activity level, labour unrest, crew interfacing, project complexity, foundation conditions, design data collection schedule, drawing approval schedule, inspection schedule, ineffective supervision, ineffective consultant, building code, transportation schedule, construction material delivery schedule, legal problems and union problems.

Schumacher (1995) prepared four questions which are related to the delay and appear to be very straightforward. What was supposed to happen? What did happen? What were the differences? How did they affect the project schedule? Schumacher also stated that, delays occur in complex construction projects should be analyzed with the context of overall project schedule as it existed when the delays occurred.

Zafar (1996) said that the most important aspect of delay analysis is to find the delay that affected the activities in the critical path and consequently the completion of the project.

Adriti *et al.* (1985) suggested that public agency must make sure that sufficient time and effort are allocated to the feasibility study and design process. The researchers mentioned that the ways to be improved are the authority structure and decision-making mechanism in the organization. For the improvement of the contractors, they suggested to be aware of stock control problems with materials and use effective scheduling techniques, furthermore the contractor's company must be compatible with size and type of the job that they undertake.

Mansfield *et al*. (1994) proposed that the reduction of poor contract management skills can be done by providing sufficient training facilities from senior and middle management levels. The local contractor's technical knowledge can be improved by giving more opportunities to the local's to work with international contractors. Lack of availability of materials can be avoided by giving higher priority to improve local material stocks and supply.

Ogunlana *et al*. (1996) recommended that the ways to minimize project delay in Thailand construction industry, especially in low technical and managerial skills of contractor can be avoided by giving necessary training.

Scott *et al*. (1993) mentioned some common remedies for delays, as summarized in Table 8.

Table 8 Common remedies for delays. (Scott *et al*. 1993)

Responsible party	Example	Remedy
Employer's responsibility	Variations, failure to provide site / information	Extension of time with recovery of overhead costs
Contractor's responsibility	Insufficient labour/plant remedial work	No compensation either time or cost
Neither party responsible	Strikes, riot, exceptional adverse weather, force majeure	Extension of time to defray deduction of liquidated damages but no cost

To prevent delays in construction phase, change orders require rapid approval. (Ehrenreich–Hansen 1994). Construction projects are bound to encounter change orders. If this is identified by the owner and contractor alike, necessary planning is required at the inception of the project, and unproductive time and effort can be prevented.

4. Project management background in construction Industry.

It is vital to measure the success of the project by means of project management tools and techniques which play an important role in effective management of a project. The project can be favourably accomplished under budget and behind the schedule. This is the situation that prevents delays and cost overrun. In order to achieve the favourable accomplishment of the project, it is required to introduce the management of resources, planning and programming the schedule from the implementation stage of the project. Murphy's law, "If anything can go wrong, it will go wrong", is true in the case of construction projects also, otherwise at the secondary stage it is very hard to make it correct.

4.1 Participants in construction industry

Many participants are involved in the construction industry. The most important participants are owner, contractor and architect – engineer.

4.1.1 Owner (Client or Employer)

The object of the project management is to accomplish a project to meet the needs of the owner. The process of setting the owner's objective involves an optimization of quality, cost and schedule. The owner's objectives must be clearly communicated and understood by all the participants and serves as a benchmark for the numerous decisions that are made throughout the duration of the project. However, for the successful project accomplishment, the owner must have well defined project objectives and needs, minimum requirement of quality and performance, an approved maximum budget and required project completion date. Failure to provide any of above items starts a project in the wrong direction and leads to future problems with delays and cost overrun (Oberlender 2000). Knowing the relative importance of three types of objectives is essential for effective project management. The owner's objectives are shown in Figure 3.

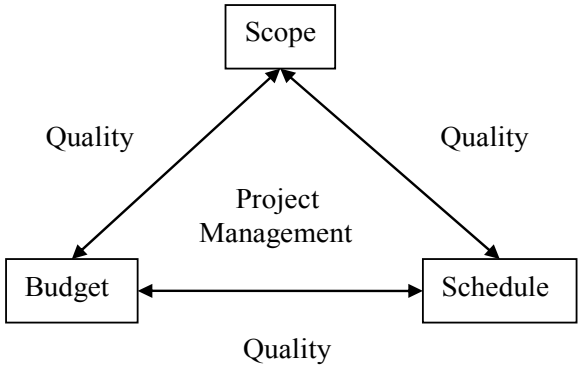

Figure 3 Owner's Objectives

Source: Oberlender, (2000)

A project is in continual state of change as it starts from the owners needs, goes through feasibility studies, design development, construction and finally

finishes in project closeout phase. Figure 4 shows the various phases during the life of the project. As a project moves from one phase to another, additional parties are involved in the project and more information can be obtained to better identify project scope, budget and schedule.

Especially in technical feasibility studies of highway construction projects, they are carried out by considering different aspects, such as geology and topographical conditions, environmental impact assessment, social impact assessments, highway design, construction method, availability of construction materials and quarry locations, and by considering those aspects and trying to find several alternative proposals with their cost estimates.

During the economic feasibility study stage, the owner mainly concerns about monetary return of his investment. In government organizations economic feasibility is done by using benefit/cost ratio method. It is impossible to evaluate social benefits to the public in terms of money. Hence, most of the government organizations try to implement the project for betterment of the public. Private organizations are mainly focused on monetary return of their investment. The common methods of evaluation of economic feasibility in private organizations are IRR, payback period and capital recovery.

After that the owner reviews each alternative proposal in terms of technical and economic feasibility. One proposal is selected that satisfies all or the most important aspects with favourable cost. Most of the time, least cost alternative doesn't satisfy all or the most important aspects in technical and economic study. Hence, they make some important comments in each alternative and carry out further studies to select the most favourable proposal.

The owner's authorizations are obtained for the most favourable proposal and proceed to select suitable project delivery method. After selecting the project delivery method, preparation of contract documents and detailed design work can be done by the supervision of the owner.

Thereafter, the construction phase can be started by selecting a contractor. During the construction phase, all plans and drawings can be converted to their physical form. After completion of the construction phase, the project is considered to be closed out by handing over the completed project to the owner with as-built drawings, required testing and inspections. Figure 4 shows the various phases during the life of the project.

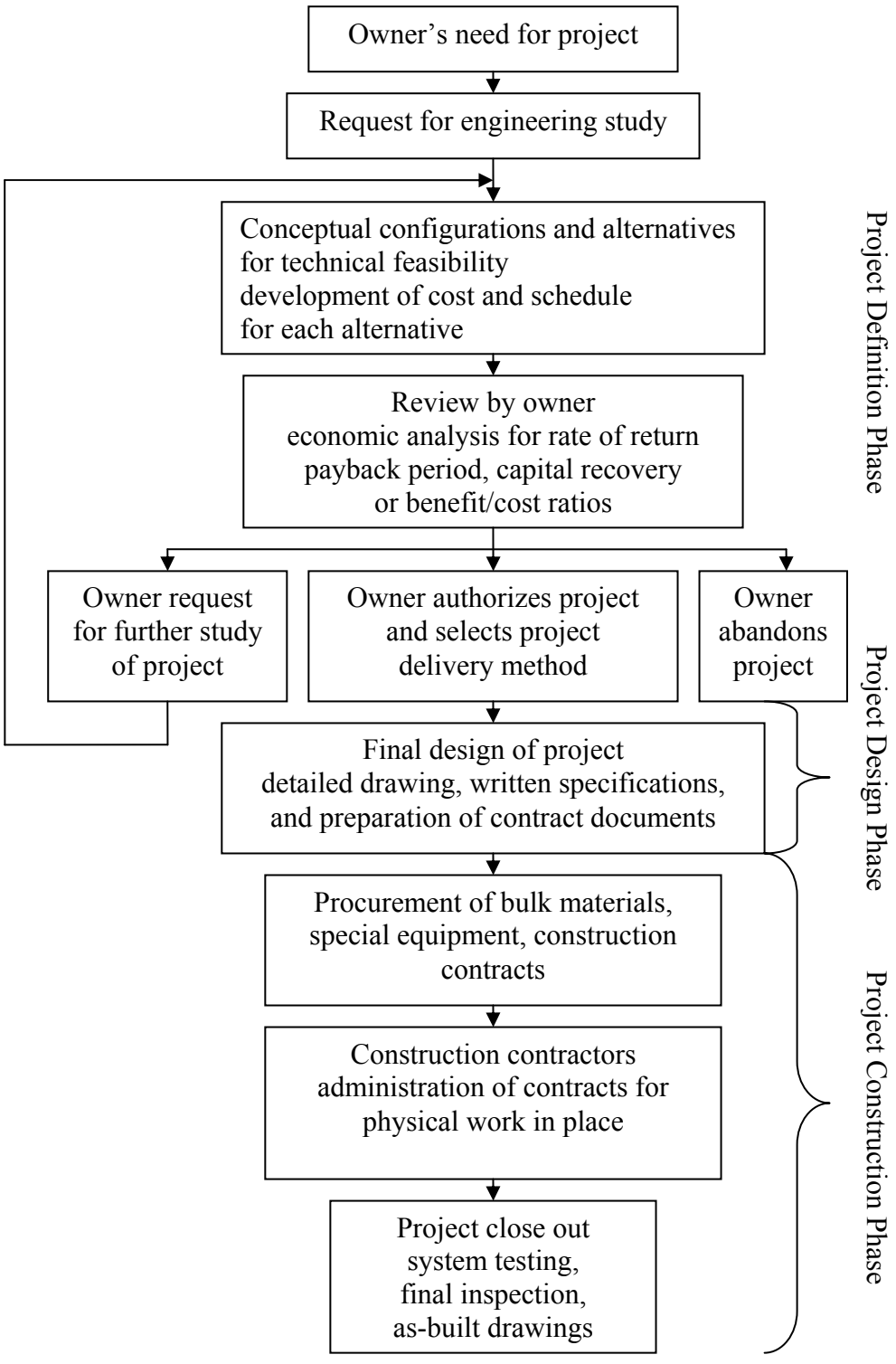

Figure 4 Phases of a Project

Source: Oberlender, (2000)

4.1.2 Contractor.

The prime contractor is also called a general contractor who signs a contract agreement with the owner to proceed with the construction work according to the conditions of the contract. During the construction phase, the contractor's responsibility is higher than the owner's. The prime contractor brings together all the diverse elements and inputs of the construction process into a single, coordinated effort. The essential function of the prime contractor is close management control of construction (Clough and Sears1994). The prime contractor may be selected on the basis of competitive bidding, the owner may negotiate the contract with selected contractor or another combination of methods can be used.

A sub-contractor is a construction firm that signs a contract agreement with the prime contractor to perform some aspect of the prime contractor's work. When the prime contractor engages a specialty firm to execute a particular portion of overall construction program, the two parties enter into an agreement called a sub-contract. No contractual relationship is established there by between the owner and the sub- contractor (Clough and Sears 1994).

After signing a contract agreement with the owner, the contractor's obligation is to finish the contract within an agreed period of time specified by the owner. If the contractor is unable to finish the contract within that period of time, it means that extra time is required to finish the contract, called the contract is delayed. Due to this delay the contractor's over-head cost is increased. Neither contractor justifies the cause of delay to the owner nor extension of time. Hence, the contractor has to pay the penalty fee or liquidated damages for compensation of delay to the owner.

4.1.3 Architect – Engineer.

The architect-engineer, also called the design professionals, is the party, organization or the firm that designs the project (Clough and Sears 1994).

Acting for the owner, the architect – engineer tends to minimize the value of work changed and delays (Antill and Woodhead 1990). The A/E or construction manager who has responsibility for time, cost and quality control must have an agreement with the owner that will allow him or her to do the following (Herry *et al*. 1975):

1. Have adequate personnel assigned during the construction phase at the job site, fabrication location, testing sites and in the office.

2. Utilize construction management personnel who are familiar with the contract documents.

3. Utilize construction management personnel who are regular staff members of the A/E or CM firm or who have been brought in sufficiently in advance to have been trained in the specific type of contract administration and to have been oriented to the details of the project.

4.2 Project management.

4.2.1 Definition of project management.

Project management may be defined as the art and science of coordinating people, equipment, materials, money and schedules to complete a specific project on time and within approved cost. (Oberlender 2000)

Another definition of project management is the process of managing, allocating and timing of resources to achieve a specific goal in an efficient and expedient manner. Alternatively, it could be defined as the systematic integration of technical, human and financial resources to achieve goals and objectives. Bairu *et al*. (1995)

4.2.2. Principles of Project Management

A fundamental principle of project management is to organize the project around the work to be accomplished. The work environment focuses on what must be performed, when it must be accomplished and how much it will cost. (Oberlender 2000)

The project management body of knowledge identifies eight major functional areas: scope, quality, time, cost, risk, human resources, contract/procurement and communications. Bairu *et al*. (1995)

Scope management is the process of directing and controlling the entire project scope with respect to specific goals. The need for establishment of a clear definition of project goals and objectives form the baseline for monitoring and controlling the changes or deviations.

Quality management means that the project performance should conform to the specifications. The main objective of quality management is to minimize deviation from the actual project plans. It should be noted that quality management should be performed throughout the project life cycle.

Time management involves the use of time effectively and efficiently to facilitate the execution of a project in a sound manner. Time is the most noticeable aspect of a project; hence, effective time management is of utmost importance for a project to be successful.

Cost management is the primary function project management. Cost management involves effectively controlling project costs with the use of reliable techniques of estimation, forecasting, budgeting and reporting.

Risk management involves identifying, analyzing, and recognizing the various risks and uncertainties that might affect the project. Risk analysis outlines possible future events and their likelihood of occurrence.

Human resources management signifies the importance of people in executing a project. Human resources management involves directing people throughout the project life cycle. The active participation of all the key participants is of utmost importance for achieving the quality objectives of a project.

Contract/procurement management is the process of acquiring the necessary equipments, tools, goods, services, and resources for successful accomplishment of project goals.

Communications management refers to the functional interface among individuals and groups within the project environment. This involves proper organization, routing, and control of information needed for the project. Good communication is in effect when there is a common understanding between the communicator and the target groups on a specific issue.

4.3 Project performance

Commonly project performance is measured by using time, cost, quality target and participant satisfaction. The construction projects are multidisciplinary in nature involving owners, designers, contractors, subcontractors, specialists, construction managers and consultants. The basics indicators used to measure project performance are time and cost.

Kumaraswamy *et al*. (1997) says that the overall success of the project can be achieved by its technical performance, maintaining its schedule and remaining within budgetary cost. First order project performance can be computed by using time and cost indicators as follows,

$$Time\ Index = \frac{Actual\_duration}{Scheduled\_duration} \times 100$$

$$Cost\ Index = \frac{Actual\_cost}{Estimated\_cost} \times 100$$

A time index exceeding 100 indicates that the project exceeded schedule time and less than 100 means that the project is completed before the schedule time. Similarly for cost index, exceeding 100 indicates that the project exceeded budget or cost overrun and less than 100 means that the project is in under budget. Time and cost indices of exactly 100 mean that the project is completed on schedule and budget, respectively.

Finally, a successful project can be achieved by its technical performance, maintaining its schedule and remaining within budgetary cost (Kumaraswamy *et al*. 1997). It is a very difficult task to accomplish the project on schedule and budget because numerous unforeseen factors are involved during construction phase, which affect to the schedule delays of the projects.

4.4 Project delivery systems

The highway construction industry in Sri Lanka is in its developing stage in terms of technology compared to the other developed countries. Road Development Authority (RDA) is the premier highway agency, which is responsible for executing construction and maintenance of major highways and expressways. There are various combinations of contract arrangements for handling a project. Figure 5 illustrates the fundamental arrangements in their simplest form.

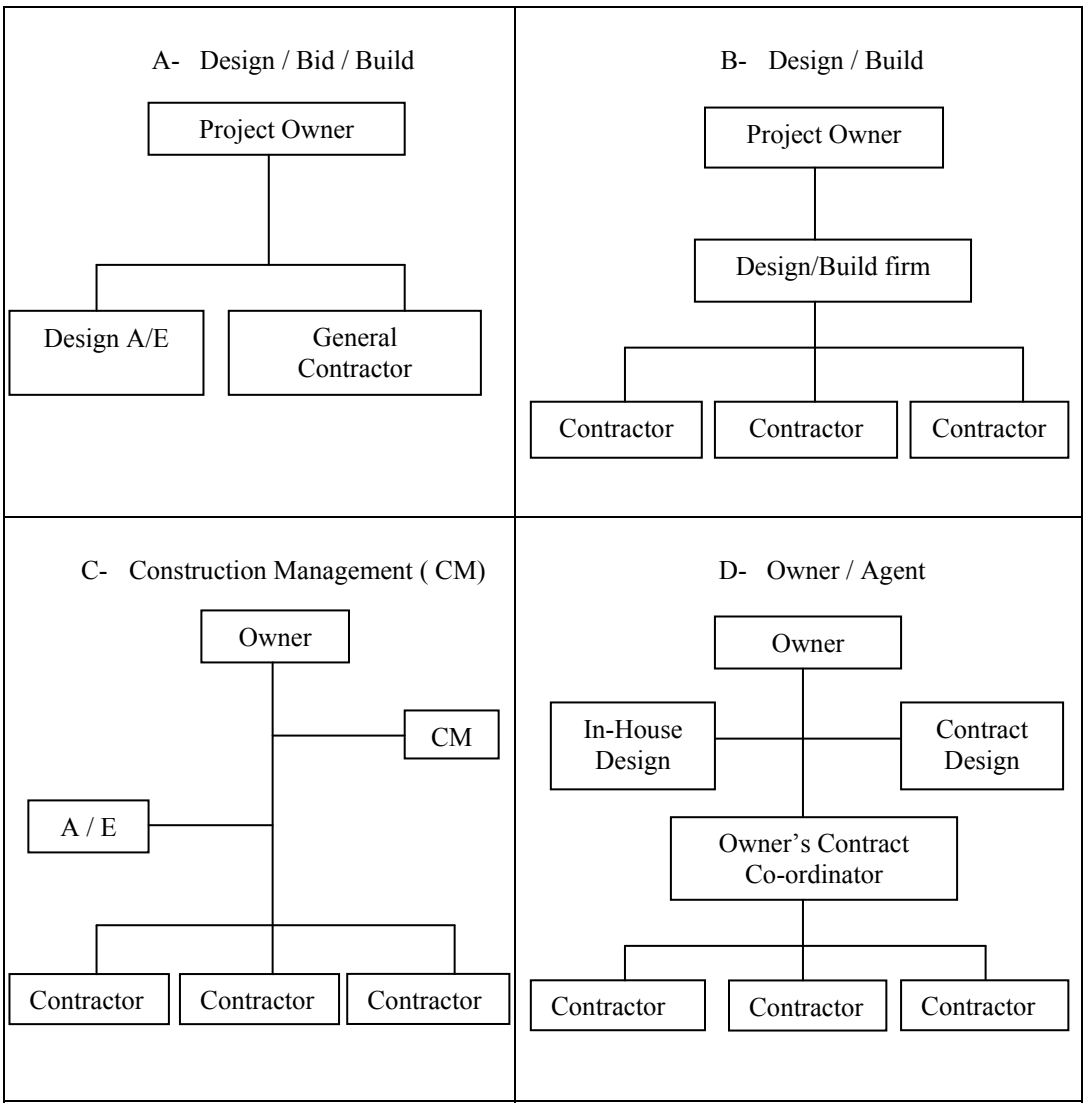

Figure 5 Contracting arrangements

Source Oberlender**,** (2000)

A design/ bid/ build contract is commonly used for projects that have no unusual features and well-define scope. It is a three party arrangement involving the owner, designer and contractor. A complete design is prepared, followed by solicitation of competitive bids from contractors and award of a contract to a construction contractor to build the project. Two separate contracts are awarded, one to the selection of designer and other one to the selection of contractor. Since complete design is prepared before construction. The project owner must have an idea about the project configuration and approximate cost before commencing

construction. Considerable time can be required because each step must be complete before starting the next step. Also changes during construction can be expensive because the award of the construction contract is usually based on Lump-sum, fixed-price bid before construction rather than during construction Oberlender (2000).

A design/ build contract is also called the Turnkey contract is often used to shorten the time required to complete the project or provide flexibility for the owner to make changes in the projects during construction. It is a two party arrangement between the owner and the design/ build firm. Since the contract with the design build firm is awarded before starting any design or construction, a cost-reimbursable arrangement is normally used instead of a lump-sum, fixed-cost arrangement. In this method requires the higher involvement of the owners for the decisions that are made during selections of design alternatives and the monitoring of cost and schedule during construction Oberlender, (2000).

A construction management (CM) contract can be assigned to a CM firm to a co- ordinate the project for the owner. The CM contract consists of four-party arrangement involving the owner, designer, CM firm and the contractor. The owner assigns a contract to a firm that is knowledgeable and capable of coordinating all aspects of the project to meet the intended use of the project by the owner Oberlender, (2000).

An owner/ agent arrangement is also used for handling the projects. The owners perform part of the design with in-house personal and contract balance of the design to one or more outside design consultants. Construction contracts may be assigned to one contractor or multiple contractors. If the project owner performs all design and construction activities with in-house personnel, in this method called force-account method Oberlender, (2000).

Most of the highway construction projects in Sri Lanka are executed through semi-government and private contractors. Design/ bid/ build, design/ build and owner/ agent contract arrangements are practiced in highway construction

projects in Sri Lanka. Foreign funded mega-scaled projects most commonly used design/ bid/ build or design/ build project delivery systems because according to the donor guidelines project design and consultancy parts have to separate from the client agency and given to foreign expertise. Most of expressways designing, consultancy and construction companies are selected from the foreign expertise by international competitive bidding (ICB) system. Although, locally funded highway projects are practicing owner/ agent contract arrangements because executing agency (RDA) has own in-house design personnel to do the project design and after that consultancy of construction works are done by the RDA and only construction contract is given to the local contractors by selecting local competitive bidding (LCB) system. Unit price contract is the most widely used in local and foreign funded highway construction projects in Sri Lanka. Cost reimbursable and fixed price contract systems are practiced for the designing and consultancy work in the foreign funded expressway projects.

As stated earlier, design/ bid/ build and design/ build are commonly used project delivery systems for foreign funded mega-scaled highway projects. Locally funded projects commonly use owner/ agent project delivery system. Pre-construction phase is mainly involved in preparation of design, drawings and bid documents. The invitations to bid are normally called through advertising in the national media including: newspapers, radio, television and RDA website.

Standard bidding documents and all procurement guidelines for the ICB and LCB contracts are prepared by the national procurement agency (NPA) in Sri Lanka and distributed to the various government agencies. The cost estimates are prepared based on the highway schedule of rates for the purpose of budgeting of the project. The contract is normally awarded based on the lowest evaluated substantially responsive bidder.

The contract duration is fixed based on the experience of the similar work, climatic condition, material and labour availability, equipment productivity, distance to the quarry location, haulage road condition and accessibility to the project location.

Most of the time, actual project duration is longer than the estimated duration due to various reasons such as using hired equipment, unforeseen ground condition, natural disasters and negligence of the owner and contractor.

The bids are evaluated based on procurement guidelines issued by the NPA in Sri Lanka. Basically, a contract is awarded to the lowest evaluated substantially responsive bidder. Earlier guidelines stated that the lowest evaluated bidder can go a minimum 30% below the engineer's estimate and the engineer's estimate amount is kept confidential and not disclosed to the bidders. However, under-bidding causes too many problems to the project performance in highway construction industry in Sri Lanka. Furthermore, many times the contractors are not able to perform the contract due to unworkable rates, the contracts had to be cancelled and bids re-invited, which accounted for enormous delay in project completion. To minimize the under-bidding situations in the present guidelines that clause has been revised and the lowest evaluated bidder can go a minimum 20% below the engineer's estimate and the engineer's estimate amount is also published to bidders with the invitations to the bid in the national media.

The present bid evaluation guidelines take into consideration the technical and financial capacity of the contracting firm on one part and the bid amount on the other part. The bidder who secures the maximum point is considered as the lowest evaluated substantially responsive bidder and awarded the contract. The evaluation of the bid is normally done by the bid evaluating committee and the recommendations are forwarded to the procurement committee for review and subsequent approval to award the contract to the lowest evaluated bidder. Nevertheless, the following merits and demerits have been observed in this system and are discussed below:

According to the guidelines bidder's technical capacity was evaluated by the bidders past working experience in similar projects. This system is unfavourable for the new contractor who lost points because of no past experience. This clause directly affected the development of the new contractors in the highway construction industry. This system favoured the well experienced and well established contractors

and they are getting more contracts in different places of the country beyond their limit of control which causes significant impact on project delays.

The guidelines requested the bidders to submit past work experience certificate, ICTAD registration book, NCASL registration, equipment ownership certificates, and curriculum vitae of technical personnel to prove their technical performance, and produce a letter of credit or bank guarantee to prove their financial capacity, etc for bid evaluation purposes. Nonetheless, it became a difficult task to ascertain the authenticity of the document submitted by the bidders. There are some cases where the work experience certificates were fake, enclosing curriculum vitae of non-existent technical personal, etc. This led to problems during project execution normally resulting in delays.

RESEARCH METHODOLOGY

1. General

Delays are predominant in road construction industry in Sri Lanka. For analysis purposes these delays can be mainly divided into two parts:

1. Pre-construction delays

2. Construction delays

Pre-construction delays can occur during the implementation stages of the projects. Such delays can happen in during bidding stage including pre-qualification, post-qualification, bid evaluation, contract awarding and land acquisitions stages of the project. In this situation the owner's responsibility in delay is higher than the contractor's. In this stage, pre-construction work is mainly done by the involvement of the owner, the contractor is only involved for submission of bid documents and accepting of the contract when it is awarded.

Construction delays can occur during the construction phase of the project. Such delays can happen in due to the violent weather conditions, shortage of construction materials and machines, lack of professional engineers and technical staff, shortage of labour etc. The contractor plays a major role during the execution of the project. Hence, the contractor's responsibility in delay is higher than the owner's and owner is involved for giving approval of following work such as extra work, variation and interim payments, quality control and quality assurance , settle disputes between other parties, etc.

The above mentioned causes are significant to carry out research study to analyze the delay factors and evaluate the contribution of the owner and the contractor for each delay factor that directly affects to the project schedule variance. Hence, through this study, an effort shall be made to minimize the delays and try to develop

some guidelines which shall be of benefit to take proactive action against the schedule variance at the beginning stage of the project. The outcome of this research will be vital for the betterment of future highway construction projects in Sri Lanka.

2. Literature review

As much literature as possible related to the topic was reviewed and knowledge acquired about the research topic and specified research boundaries. The literature review found that, most of the research was done by focusing delays on the construction phase. It was identified that most delays in construction phase occurred due to the high involvement of the contractor and low involvement of the owner. Past research was considered as a foundation of new research, which was helpful to improve the new research by investigating the construction project in different scenarios. The review of past research provided some idea about delays of construction industry in developed and developing countries. Furthermore, common delays of developed and developing countries were identified. In the literature review, no research was found related to the delays in Sri Lankan construction industry. In general, most of the literature elaborated that the contractor first tasted bad experience of delays due to their own deficiencies.

3. Questionnaire Survey

A structured questionnaire was developed based on findings from a relevant international literature review including Thailand, Bhutan, Hong Kong, Jordan, Saudi Arabia and Nigeria as well as the researcher's extensive construction experience gathered from highway construction in Sri Lanka.

The questionnaire was used to gather project participant's opinions on causes of delay in highway construction. Twenty questionnaires were distributed to project managers, design engineers and project engineers who were working under various project divisions in Sri Lanka Road Development Authority (RDA), which is the premier highway agency responsible for execution of construction and maintenance of

highways and expressways. Ten questionnaires were distributed to the Provincial Road Development Authority (PRDA), which is responsible for development of the rural road network in Sri Lanka and thirty questionnaires were distributed to project managers, design engineers and project engineers who were working in the leading construction companies in Sri Lanka. Fifty one completed questionnaires were returned. The results of the questionnaire survey can be summarized as shown in Table 9.

Table 9 Details of distributed and responded questionnaires

Target group	No: distributed	No: responded
Owner of the national highways (RDA)	20	20
Owner of the rural roads (PRDA)	10	10
Contractors	30	21

The questionnaire was mainly divided into two parts: pre-construction and construction phases as illustrated in Figure 6.

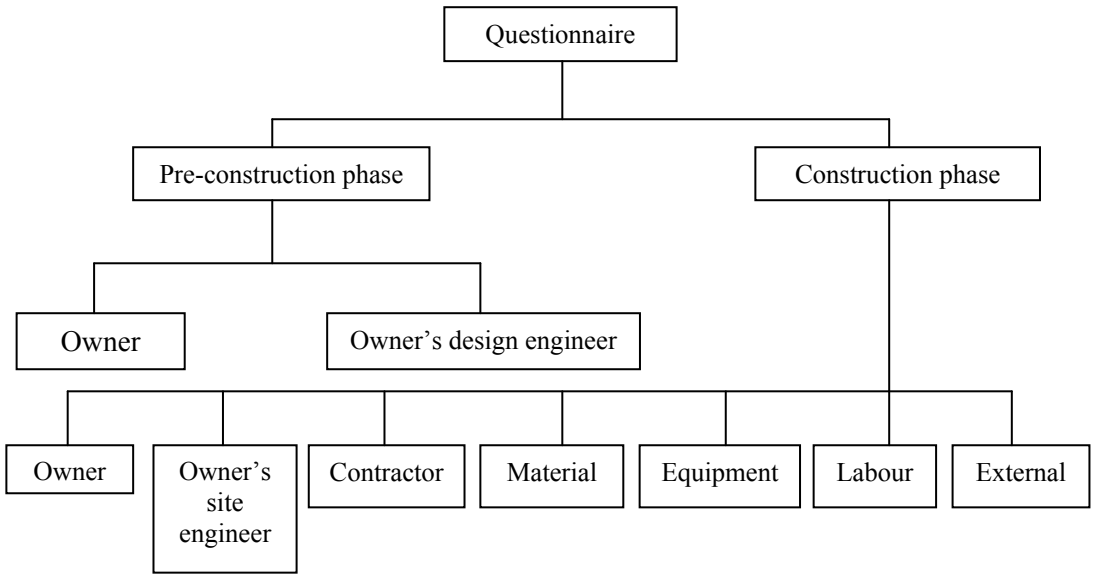

Figure 6 Structure of the questionnaire

The questionnaire consisted of nine delay categories that were divided into two categories in the pre-construction phase and another seven categories are in the construction phase. All nine categories comprised of seventy seven delay factors.

3.1 Category of delays in pre-construction phase

3.1.1 Owner category

During the pre-construction phase the owner's involvement is higher than the contractor. The owner's duties include: preparation of bid documents, bid evaluation, contract awarding and land acquisition. The contractor is only involved in submitting the completed bid document. If the project owner fails to do one of his duties on time, it could have a significant effect on project delays.

3.1.2 Owner's design engineer

In pre-construction phase, the owner's design engineer plays a key role in project success as several causes of delays including: designs not being matched with actual site conditions, frequent changes of design and lack of review of all designs and drawings before submission to the contractor have considerable impact on project delays.

3.2 Category of delays in construction phase

3.2.1 Owner category

The owner plays a vital role for the execution of a construction project by timely handing over the site to the contractor. In addition, the project owner is responsible for issuing mobilization advance at the beginning of the contract, making interim payments on time, minimizing the scope growth during construction and taking prompt action on contractual matters which could have a significant effect in minimizing project delays.

3.2.2 Owner's site engineer category

The owner's site engineer is responsible for inspection and testing of materials, issuing instructions and approvals of shop drawings, maintaining contractual documents and informing additional scope growth to the owner on time, so that the owner can take prompt action with minimum effect on project delays. Hence, factors included in this category are related to the functions of the site engineer in the construction phase.

3.2.3 Contractor category

In the construction phase, the contractor plays a vital role for the timely completion of the project. Hence, a contractor's cash flow problem, lack of resources, poor planning and scheduling, lack of professional engineer's and other technical staff could have a significant effect on project delays.

3.2.4 Material category

Materials are one of the most important components of construction projects. Thus, scarcities of materials, increased price of materials and environmental restrictions for mining materials have a significant effect on material related delays.

3.2.5 Equipment category

In the equipment category, some of the factors which could have considerable impact on project delays include: hiring of main equipment, inability to mobilize required equipment on time, break-down of equipment and lack of skilled operators to operate particular equipment.

3.2.6 Labour category

Labour is the vital resource in the construction industry which has encountered a threat of finding skilled labour force in Sri Lanka. In addition, labour rules and regulations, mismanagement of labour and conflict among labourers are some of the factors included in this category which have a significant effect on project delays.

3.2.7 External category

External factors can be divided into two categories: acts of man and acts of god. Some of the delay factors which are considered as acts of man include strikes, traffic jams, riots and terrorist attacks and curfew situations. Violent weather, landslides and flood conditions are considered as delay factors due to acts of god.

4. Data analysis

Evaluation of degree of variation in opinion among respondents can be done by calculating the mean and standard deviation. The following expressions can be used to calculate mean and standard deviations.

$$\text{Mean } \overline{X} = \frac{\sum w}{N}$$

Where,

$\overline{X}$ = mean value

W= score given to each factor by the respondents and ranges from1to 5
Where '1' is 'very low significance' and '5' is 'very high significance'

N= Total number of respondents

The level of significance of each cause of delay factor which affects to the highway construction delay was evaluated and ranked by using the following criteria.

Level of significance:

Mean of 4.51 – 5.00 Very high significance
Mean of 3.51 – 4.50 High significance
Mean of 2.51 – 3.50 Moderate significance
Mean of 1.51 – 2.50 Low significance
Mean of 1.00 – 1.50 Very low significance

The value of mean = 1.00 would be obtained if all respondents marking their opinion on 1st position in frequency of occurrence or severity and combined severity and frequency of each cause of delay. The mean= 1.5 would be obtained by half of the respondents marking their opinion on 1st position and others marking their opinion on 2nd position in frequency of occurrence or severity and combined severity and frequency of each cause of delay. In addition to that the value of mean =5.00 would be obtained by all respondents marking their opinion on 5th position in frequency of occurrence or severity and combined severity and frequency of each cause of delay in pre-construction and construction phases of the highway projects.

$$SD = \sqrt{\frac{\sum (w - \bar{x})^2}{N - 1}}$$

Where,

SD = Standard deviation

$\bar{x}$ = Mean value

W = Score given to each factor by respondents and ranges from 1 to 5

Where ‘1’ is ‘very low effect’ and ‘5’ is ‘adverse effect’

N = Total number of respondents

The relative importance index (RII) and standard deviations (SD) and were used to prioritize delay factors according to their adverse impact to the project delays. Highest RII gives the most significant delay factor in highway construction. SD is used to prioritize the delay factors which have the same RII. A delay factor which has low SD has high priority, while high SD indicates low priority.

The relative importance index (RII) was used to determine the relative importance of each cause of delay. The RII is simply a weighted average of scores given by the respondents on each causes of project delays. The relative importance index method is best suited to determine the relative importance of the delay factors (Chan and Kumaraswamy, 1997). The relative importance index (RII) was calculated by using the following equation:

$$\text{RII} = \frac{\sum_{i}^{n} S_i}{AxN}, (0.2 \leq \text{index} \leq 1)$$

Where,

S_i = Severity given to each factor by the respondents and ranges from 1 to 5 where 1 is ‘very low’ and 5 is ‘very high’

A = highest severity (i.e. 5 in this case)

N = total number of respondents

The level of severity of each cause of delay factor which affects to the highway construction delay was evaluated and ranked based on the following criteria.

Level of severity:

RII of 0.91 – 1.00 Very high
RII of 0.71 – 0.90 High
RII of 0.51 – 0.70 Moderate
RII of 0.31 – 0.50 Low
RII of 0.20 – 0.30 Very low

The value of RII =0.2 would be obtained if all respondents marking their opinion on 1st position i.e. 'very low' in severity and RII= 0.3 would be obtained if half of respondents marking their opinion on 1st position and other half of respondents marking on 2nd position i.e. 'low' in severity. The value of RII = 1.00 would be obtained if all respondents marking their opinion on 5th position i.e. 'very high' in severity of each cause of delay in pre-construction and construction phase of the highway projects.

The following equation represents the formulation of frequency of occurrence index (FOI), and was used to calculate the degree of occurrence of delay factors (Chan and Kumaraswamy, 1997).

$$\text{FOI} = \frac{\sum_{i}^{n} F_i}{AxN}, (0.2 \leq \text{index} \leq 1)$$

Where,

F_i = frequency given to each factor by the respondents and ranges from 1 to 5 where 1 is 'very low' and 5 is 'very often'

A = highest frequency (i.e. 5 in this case)

N = total number of respondents

The degree of occurrence of each cause of delay factor which affects to the highway construction delay was evaluated and ranked based on the following criteria.

Degree of occurrence:

FOI of 0.91 – 1.0 Very often
FOI of 0.71 – 0.90 Often
FOI of 0.51 – 0.70 Moderate
FOI of 0.31 – 0.50 Low
FOI of 0.20 – 0.30 Very low

The value of FOI= 0.2 would be obtained if all respondents marking their opinion on 1st position i.e. 'very low' in frequency of occurrence of the each cause of delay. The value of FOI=0.3 would be obtained if half of the respondents marking their opinion on 1st position and other half of respondents marking on 2nd position i.e. 'low' in frequency of occurrence of each cause of delay of highway projects. The value of FOI= 1.0 would be obtained if all respondents marking their opinion on 5th position i.e. 'very often' in frequency of occurrence of each cause of delay during pre-construction and construction phases of the highway projects.

The following equation was derived by using the combination of above two equations, severity and frequency index (SFI) was calculated as follows,

$$\text{SFI} = \frac{\sum_{i=1}^{n} \sqrt{(S_i F_i)}}{AxN}, (0.2 \leq \text{index} \leq 1)$$

Where,

S_i = Severity given to each factor by the respondents and ranges from 1 to 5 where 1is 'very low' and 5 is 'very high'

F_i = frequency given to each factor by the respondents and ranges from 1 to 5 where 1 is 'very low' and 5 is 'very often'

A = highest severity and frequency (i.e. 5 in this case)

N = total number of respondents

The level of severity and frequency of each cause of delay factor which affects to the highway construction delay was evaluated and ranked based on the following criteria.

Level of severity and frequency:

SFI of 0.91 – 1.00 Very high
SFI of 0.71 – 0.90 High
SFI of 0.51 – 0.70 Moderate
SFI of 0.31 – 0.50 Low
SFI of 0.20 – 0.30 Very low

The value of SFI = 0.2 would be obtained if all respondents marking their opinion on 1st position i.e. 'very low' in severity and frequency and the value of SFI= 0.3 would be obtained if half of the respondents marking their opinion on 1st position i.e. 'very low' and others marking their opinion on 2nd position i.e. 'low' in severity and frequency of each cause of delay. The highest value of SFI =1 would be obtained if all respondents marking their opinion on 5th position i.e. 'very high' in severity and frequency of each cause of delay in pre-construction and construction phases of the highway projects.

In order to quantitatively measure the agreement in ranking between two different groups of participants, following equation was used to evaluate a rank agreement factor (RAF) for any two groups Okpala and Aniekuw, (1998). This shows the average absolute differences in rank of the factors. For any two groups, let the rank of the ith items in Group 1 be R_{i1} and in Group 2 be R_{i2}, N be the number of items and $j = N - i + 1$. Then, the 'Rank Agreement Factor' is defined as:

$$RAF = \frac{\left[\sum_{i=1}^{N} \left| R_{i1} - R_{i2} \right|\right]}{N}$$

With a maximum RAF:

$$RAF_{\max} = \frac{\left[\sum_{i=1}^{N} \left| R_{i1} - R_{j2} \right|\right]}{N}$$

The level of RAF between two groups of respondents was evaluated by using the following criteria.

Level of RAF:

RAF of 19.10 – 20.00 Very high
RAF of 13.10 – 19.00 High
RAF of 7.10 – 13.00 Moderate
RAF of 1.10 – 7.00 Low
RAF of 0.00 – 1.00 Very low

The value of RAF=0 would be obtained by there is no difference of perceptions between two group of respondents i.e. both respondents are equally agreed or highest agreement between two groups and the value of RAF= 20 would be obtained by both respondents have totally disagreed on each cause of delay in pre-construction and construction phases of the highway projects.

The 'Percentage Disagreement' is defined as:

$$PD = \frac{\sum_{i=1}^{N} \left(\left| R_{i1} - R_{i2} \right| \right)}{\sum_{i=1}^{N} \left(\left| R_{i1} - R_{j2} \right| \right)} \text{ x } 100$$

The ‘Percentage Agreement’ is then given as:

$$PA = 100 - PD$$

The level of PA and PD between two different groups of respondents were evaluated by using the following criteria.

Level of PA:

PA of 95.10 – 100.0 Very high agreement
PA of 65.10 – 95.0 High agreement
PA of 35.10 – 65.0 Moderate agreement
PA of 5.10 – 35.0 Less agreement
PA of 0.00 – 5.0 Very less agreement

Level of PD:

PD of 95.10 – 100.0 Very high disagreement
PD of 65.10 – 95.0 High disagreement
PD of 35.10 – 65.0 Moderate disagreement
PD of 5.10 – 35.0 Less disagreement
PD of 0.00 – 5.0 Very less disagreement

The values of PA= 0 and PD= 100 would be obtained if both respondents have totally disagreed i.e. very large difference of perception between two respondents on each cause of delay. Conversely, the values of PA= 100 and PD= 0 would be obtained if both respondents have equally agreed or there is no difference between perceptions of two respondents on each cause of delay in pre-construction and construction phases of the highway projects.

RESULTS AND DISCUSSION

1. Introduction

Three methods were performed to analyze collected data from the questionnaire survey. Firstly, all delay factors were ranked according to their frequency of occurrence index (FOI) and the frequency of occurrence of delay factors during the project life evaluated based on the criteria as explained in the data analysis by considering the top ten delay factors in pre-construction and construction phases of the project. Standard deviation was used to prioritize the delay factors which had the same FOI. Secondly, all delay factors were ranked according to their severity by using the relative importance index (RII) and the level of impact on the project evaluated based on the criteria as explained in the data analysis by considering the top ten delay factors in pre-construction and construction phases of the project. Standard deviation was used to prioritize the delay factors which had the same RII. Finally, all delay factors were ranked according to their severity and frequency index (SFI) and the level of impact on the project evaluated based on the criteria as explained in the data analysis by combining frequency and severity effect of the top ten delay factors in pre-construction and construction phases. Standard deviation was used to prioritize the delay factors which had the same SFI.

Frequency of occurrence index (FOI) method gives a degree of occurrence of delay factors in pre-construction and construction phases of the project. The FOI is simply a weighted average of scores given by the respondents on each cause of project delay. The delay factors which have high value of FOI may have less significance in project delay. Conversely, the delay factors which have low value of FOI may have high significance in project delay.

Relative importance index (RII) method gives a severity of delay factors in pre-construction and construction phases of the project. The RII is simply a weighted average of scores given by the respondents on each cause of project delay. The delay

factors which have high value of RII have high significance in project delay. Conversely, low value of RII has less significance in project delay.

Severity and frequency of occurrence index (SFI) method gives a realistic approach to analyze delay factors in pre-construction and construction phases of the project. Finally, ranking of delay factors was done according to the SFI of each delay factor. In order to minimize delays, recommendations were made based on the top ten delay factors in pre-construction and construction phases of the project for the better project performance in highway construction industry.

2. General ranking of causes of delays in pre-construction phase as postulated by all respondents

2.1 Rank according to the highest frequency of occurrence

Table 10 shows the top 10 delay factors having highest frequency of occurrence and arranged according to their frequency of occurrence index (FOI), ranks and standard deviations (SD) of the delay factors as postulated by respondents. Standard deviations are used to rank the factors having the same FOI. According to Table 10, the majority of the factors causing delays including: frequent changes of design, funding delays, delays in acquisition of construction site, designs not matched with actual site condition and incomplete design were mainly attributed to the pre-construction phase.(Detail analysis of all delay factors is attached in appendix B)

Table 10 Top ten delay factors by frequency of occurrence

Delay factor	Category	FOI	Meaning	Mean and SD	Meaning	Rank
Frequent changes of design	Owner's design engineer	0.658	Moderate	3.290 ± 0.944	Moderate	1
Funding delays	Owner	0.624	Moderate	3.120 ± 1.243	Moderate	2
Delay in acquisition of construction site	Owner	0.608	Moderate	3.040 ± 1.148	Moderate	3
Designs not matched with actual site conditions	Owner's design engineer	0.560	Moderate	2.800 ± 0.939	Moderate	4
Incomplete designs	Owner's design engineer	0.556	Moderate	2.780 ± 0.986	Moderate	5
Lack of review of all designs and drawings before issuing to the contractor	Owner's design engineer	0.546	Moderate	2.730 ± 0.896	Moderate	6
Delay in review and approval of bid documents and designs	Owner	0.514	Moderate	2.570 ± 0.900	Moderate	7
Inexperienced design engineer	Owner's design engineer	0.490	Low	2.450 ± 0.857	Low	8
Delay in awarding of contract and issuing of letter of acceptance	Owner	0.490	Low	2.450 ± 0.987	Low	9
Incomplete bid documents	Owner	0.490	Low	2.450 ± 1.045	Low	10

2.2 Rank according to the severity

Table 11 shows the top 10 delay factors having severity and arranged according to their relative importance index (RII), ranks and standard deviations (SD) of the delay factors as postulated by respondents. Standard deviations are used to rank the factors having the same RII. According to Table 11, the majority of the factors causing delays including: delays in acquisition of construction site, frequent changes of design, funding delays, incomplete design and bid documents were mainly attributed to the pre-construction phase.(Detail analysis of all delay factors is attached in appendix C)

Table 11 Top ten delay factors by severity

Delay factor	Category	RII	Meaning	Mean and SD	Meaning	Rank
Delay in acquisition of construction site	Owner	0.749	High	3.745 ± 1.111	High	1
Frequent changes of design	Owner's design engineer	0.710	High	3.549 ± 1.026	High	2
Funding delays	Owner	0.702	High	3.510 ± 1.332	High	3
Incomplete designs	Owner's design engineer	0.678	Moderate	3.392 ± 1.133	Moderate	4
Incomplete bid documents	Owner	0.655	Moderate	3.275 ± 1.281	Moderate	5
Designs not matched with actual site conditions	Owner's design engineer	0.651	Moderate	3.255 ± 1.036	Moderate	6
Lack of review of all designs and drawings before issuing to the contractor	Owner's design engineer	0.600	Moderate	3.000 ± 0.849	Moderate	7
Delay in awarding of contract and issuing of letter of acceptance	Owner	0.573	Moderate	2.863 ± 1.000	Moderate	8
Delay in review and approval of bid documents and designs	Owner	0.561	Moderate	2.804 ± 1.077	Moderate	9
Inexperienced design engineer	Owner's design engineer	0.545	Moderate	2.725 ± 1.060	Moderate	10

2.3 Rank according to the severity and frequency

Table 12 shows the top 10 delay factors arranged according to their severity and frequency index (SFI) and ranks of the delay factors as postulated by respondents. According to Table 12, the majority of the factors causing delays including: funding delays, delays in acquisition of construction site, frequent changes of design, incomplete design and designs are not matched with actual site condition were mainly attributed to the pre-construction phase.(Detail analysis of all delay factors is attached in appendix D)

Table 12 Top ten delay factors by severity and frequency

Delay factor	Category	FOI	Meaning	RII	Meaning	SFI	Meaning	Rank
Frequent changes of design	Owner	0.658	Moderate	0.710	High	0.676	Moderate	1
Delay in acquisition of construction site	Owner	0.608	Moderate	0.749	High	0.666	Moderate	2
Funding delays	Owner's design engineer	0.624	Moderate	0.702	High	0.654	Moderate	3
Incomplete designs	Owner's design engineer	0.556	Moderate	0.678	Moderate	0.604	Moderate	4
Designs not matched with actual site conditions	Owner's design engineer	0.560	Moderate	0.651	Moderate	0.596	Moderate	5
Lack of review of all designs and drawings before issuing to the contractor	Owner's design engineer	0.546	Moderate	0.600	Moderate	0.566	Moderate	6
Incomplete bid documents	Owner	0.490	Low	0.655	Moderate	0.552	Moderate	7
Delay in review and approval of bid documents and designs	Owner	0.514	Moderate	0.561	Moderate	0.529	Moderate	8
Delay in awarding of contract and issuing of letter of acceptance	Owner	0.490	Low	0.573	Moderate	0.525	Moderate	9
Inexperienced design engineer	Owner's design engineer	0.490	Low	0.545	Moderate	0.510	Moderate	10

Lack of communication between the owner and the design engineer will leads to frequent change of design. All design work must be finished according to the site conditions and owner's requirements before the start of the contract. If the designs are changed in several times, eventually other contract documents such as drawings, BOQs and specifications have to be changed to suit the designs. Subsequently, this causes significant impact to starting the contract on schedule. In order to minimize this delay, both parties should have a proper channel of communication and the designer must be convinced of the actual site condition and the owner's requirements before starting the project design.

Delay in acquisition of the construction site is the highest significant impact on project delays, although according to the severity and frequency it has ranked in 2nd position. Sri Lankan road construction industry has commonly faced land acquisition problems, during the implementation stages of projects. Most foreign funds as well as domestic funds get accumulated without executing the specific projects during the given time period. These land acquisition problems, which are always dealing with legal issues, most of the time they are prolonged and take a minimum of over one year to get settled. This causes a detrimental effect to the development of the road construction industry because the donor agencies are withdrawing their funds without utilization for more than one year period. Consequently, to get maximum benefits of those funds, executing agency must take necessary actions to hand over the site to the contractor, section by section to perform the contract until it gets settlement of the problematic section. Unfortunately, in certain situations these land acquisition problems cannot settle before the construction work of the sections given to the contractor is finished. In this situation, the contractor finished the work in assigned sections and waits to take over the balance section to perform the construction work. Suppose the executing agency is unable to hand over section to the contractor by settling the legal disputes within the stipulated time period, the contractor makes use of this opportunity to go for the extra claim situation by providing some facts for idling of construction machineries and staff. This causes significant impact on the executing agency because the contractor's additional claim

situation without any physical progress of the site directly affects the cost and time overrun of the project.

Funding problem has been identified as the most severe impact on project delays in pre-construction phase. Nowadays, countries throughout the world are more concerned about their environment. Hence, the donor agencies are also concerned about this matter and make their funding rules and regulations stricter than before. The submission of environmental impact assessment (EIA) and social impact assessment (SIA) reports of the project is very important to get funding from the donor agencies. If the owner is delayed in submitting EIA and SIA reports to the donor agency, the funding gets delayed to start the project that will directly affect the increase of construction cost and schedule slippage of the project.

Incomplete designs can occur in the pre-construction phase and if found out before starting the contract bidding, as making corrections and it tends to delay the bidding process. If those errors in the designs are found out after awarding the contract, it has a more significant impact to the project delay in the construction phase because most design errors can be easily found during construction phase. At that time corrections of designs are time consuming and sometimes document corrections are impossible. For instance, errors in the quantities in BOQs cannot be corrected after awarding the contract. The only possible solution is that, the owner has to issue variation orders to the contractor for the items which have errors in quantities. This may affect the smooth flow of construction which tends to get delayed**.**

Design not matched with actual site condition is a predominant delay factor because most designers are reluctant to visit the site, while they are doing their designs in the office. If the designers make a habit of frequent site visits, it helps to minimize the delays in pre-construction phase. Otherwise this may cause a significant effect in construction phase also.

Designer's responsibility is the review of all designs and drawings before the start of the contract bidding. However, the designer is failed to review all designs before bidding stage of the contract, all errors and missing details of the designs and drawings can be found during the construction phase. At that time correction of designs has significant effect to the project delay in the construction phase. If the errors and missing details of the designs are found after issuing bid documents to the respective bidders, the designer's duty is to correct those mistakes as early as possible and issue bid addendum to the bidders by convincing the relevant corrections. Sometimes the errors and mistakes are found before issuing to the bid documents to the bidders and those mistakes could not be corrected within a short period of time, so this may affect to the delays in pre-construction phase.

Incomplete bid documents have significant impact on project delays in pre-construction and construction phases because most of the vital data are included to perform the contract in these contract documents. The bid documents in pre-construction phase and also called as contract documents in construction phase. These documents comprise of drawings, BOQs, specifications and conditions of contract which have a correlation in each other, if any error or mistakes occur in one of these documents that tends to be a series of corrections in all documents except conditions of contract. Making all corrections in documents are time consuming and this tends to make a delay the pre-construction phase.

Duties of a designer are preparations of all designs, drawings, specifications, BOQs and conditions of contracts. After preparation all mentioned documents shall be handed over to the owner for further review and approval before finalizing the bid documents. The owner has to take expertise help to review all those documents as per the owner's requirement. If the project owner takes more time for reviewing and approving the documents and re-submission to the designer for further corrections and modifications of documents, there would be delay in the pre-construction phase.

It is a project owner's responsibility to award the contract and issue a letter of acceptance on time to a contractor. However, the owner cannot award the contract due to various problems such as land acquisition, funding delay and political interferences that may lead to project delays in pre-construction phase. In Sri Lanka political intervene of awarding contract is a predominant issue which has significant impact on project delay. After awarding the contract, the owner has to issue a letter of acceptance and hand over the site to the contractor within a specified time period as per the conditions of the contract.

Success of the project design mainly depends on the experience of the designer. Also the designer has an ability to understand the intended needs of the project owner as well as the actual site condition of the project location. An experienced designer knows how to match these two conditions to make success of the project and complete all designs to meet the project goal within given budget and schedule.

3. General ranking of causes of delays in construction phase as postulated by respondents

3.1 Rank according to the highest frequency of occurrence

Table 13 shows the top 10 delay factors having highest frequency of occurrence and arranged according to their frequency of occurrence index (FOI), ranks and standard deviations (SD) of the delay factors as postulated by respondents. Standard deviations are used to rank the factors having the same FOI. According to Table 13, the majority of the factors causing delays including: increase price of materials, scarcity of skilled labour, contractor's cash flow problem, owner's cash flow problem, lack of resources and scarcity of materials were mainly attributed to the construction phase**.**(Detail analysis of all delay factors is attached in appendix B)

Table 13 Top ten delay factors by frequency of occurrence

Delay factor	Category	FOI	Meaning	Mean and SD	Meaning	Rank
Increased price of materials	Material	0.761	Often	3.804 ± 0.722	High	1
Scarcity of skilled labour	Labour	0.745	Often	3.725 ± 0.961	High	2
Contractor's cash flow problem	Contractor	0.722	Often	3.608 ± 0.961	High	3
Owner's cash flow problem	Owner	0.710	Often	3.550 ± 1.101	High	4
Lack of resources	Contractor	0.702	Often	3.510 ± 0.903	High	5
Scarcity of materials	Material	0.698	Moderate	3.490 ± 0.925	Moderate	6
Environmental restrictions for mining materials	Material	0.694	Moderate	3.471 ± 1.027	Moderate	7
Extra work apart from the scope	Owner	0.686	Moderate	3.430 ± 0.781	Moderate	8
Lack of professional engineer's and other technical staff	Contractor	0.671	Moderate	3.353 ± 0.868	Moderate	9
Poor planning and scheduling	Contractor	0.663	Moderate	3.314 ± 0.927	Moderate	10

Lack of professional engineers and other technical staff was identified as a common delay factor in highway construction. Most works in the construction phase such as designing, budgeting, planning, scheduling and tracking work are done by professional engineers. If a contractor doesn't have sufficient professional and technical staff it means that it is very difficult to finish the contract within the given budget and schedule.

3.2 Rank according to the highest severity

Table 14 shows the top 10 delay factors having highest severity and arranged according to their relative important index (RII), ranks and standard deviations of the delay factors as postulated by respondents. Standard deviations are used to rank the factors having the same RII. According to Table 14, the majority of the factors causing delays including: contractor's cash flow problem, lack of resources to the contractor, owner's cash flow problem, scarcity of skilled labor, scarcity of construction materials and increased price of materials were attributed to the construction phase.(Detail analysis of all delay factors is attached in appendix C)

Table 14 Top ten delay factors by severity

Delay factor	Category	RII	Meaning	Mean and SD	Meaning	Rank
Contractor's cash flow problem	Contractor	0.812	High	4.059 ± 1.085	High	1
Lack of resources	Contractor	0.792	High	3.961 ± 0.958	High	2
Owner's cash flow problem	Owner	0.780	High	3.902 ± 1.171	High	3
Scarcity of skilled labour	Labour	0.773	High	3.863 ± 1.114	High	4
Scarcity of materials	Material	0.769	High	3.843 ± 1.155	High	5
Increase price of materials	Material	0.757	High	3.784 ± 0.808	High	6
Contractor failure to mobilize required equipment on time	Equipment	0.733	High	3. 667 ± 1.077	High	7
Contractor delay in site mobilization	Contractor	0.725	High	3.627 ± 1.280	High	8
Extra work apart from the scope	Owner	0.722	High	3.608 ± 1.002	High	9
Environmental restrictions for mining of materials	Material	0.718	High	3.588 ± 1.214	High	10

Most delay factors which are ranked in Table 14 are almost the same in Table 13, but they are ranked in different positions according to the frequency of occurrence and severity index as postulated by respondents. In addition, two new delay factors are introduced by the respondents in Table 14 according to their severity

index: contractor failure to mobilize required equipment on time and contractor's delay in site mobilization.

Contractor's delay in mobilization to the site has been identified as high severity but less frequency of occurrence because of the contractor purposely delaying mobilization to the site in a considerable period of time that delay may have high severity. Otherwise very short period of time, the contractor could crash the original schedule by increasing the resources and working overtime hours and trying to avoid the delay.

3.3 Rank according to the severity and frequency

Table 15 shows the top 10 delay factors ranked according to their severity and frequency index (SFI) as postulated by respondents. According to Table 15, the majority of the factors causing delays including: contractor's cash flow problem, scarcity of skilled labour, increase price of material, owner's cash flow problem, lack of resources to the contractor, scarcity of construction materials and environmental restriction for mining of materials were attributed to delays in construction phase. (Detail analysis of all delay factors is attached in appendix D)

In Table 15, all delay factors are ranked by calculating the SFI which gives the combined effect of severity and frequency. The combined effect or SFI represents the most realistic ranking of delay factors which have significant impact on highway construction industry in Sri Lanka.

Table 15 Top ten delay factors by severity and frequency

Delay factor	Category	FOI	Meaning	RII	Meaning	SFI	Meaning	Rank
Contractor's cash flow problem	Contractor	0.722	Often	0.812	High	0.757	High	1
Increased price of materials	Material	0.761	Often	0.757	High	0.754	High	2
Scarcity of skilled labour	Labour	0.745	Often	0.773	High	0.752	High	3
Lack of resources	Contractor	0.702	Often	0.792	High	0.739	High	4
Owner's cash flow problem	Owner	0.710	Often	0.780	High	0.738	High	5
Scarcity of materials	Material	0.698	Moderate	0.769	High	0.726	High	6
Environmental restrictions for mining of materials	Material	0.694	Moderate	0.718	High	0.708	High	7
Extra work apart from the scope	Owner	0.686	Moderate	0.722	High	0.697	Moderate	8
Poor planning and scheduling	Contractor	0.663	Moderate	0.714	High	0.680	Moderate	9
Lack of professional engineers and other technical staff	Contractor	0.671	Moderate	0.702	High	0.678	Moderate	10

Contractor's cash flow problem also has the highest significant effect on project delays. At the beginning of the contract, the owner releases the mobilization advance to the contractor to perform the contract without further delay. However, most of the contractors misuse this money in different ways such as foreign tours, to settle their banks loans and procurement of machinery. Finally, the contractor cannot progress according to the original schedule due to the cash flow problem. In addition to that, the contractor is failure to submit the interim payment to the owner in regular time period due to insufficient work done during that period, and at the same time the owner is failure to release the interim payment to the contractor within the required time period. Both cases directly affected by the contractor's cash flow problem.

Increased in the price of construction materials was identified as the second severity and frequency of delay factor in Sri Lankan highway construction industry because most of the contractors are trying to win the contract by reducing their bid price down to the minimum level due to high competition among the contractors. It is vital to mention that most contractors quote the material prices at the time of the bidding stage without considering the risk of future price fluctuations in the market. After awarding the contract, the original contract duration of the project minimum is more than one year, in this situation the contractor fails to perform the work according to the schedule due to the increased price of material and tries to delay the contract. Inflation rate of the country and world crude oil price are the factors governing the increase of the price of road construction materials. Especially the price of bitumen has drastically increased within the last two to three years due to increased world crude oil price. That has detrimentally affected projects with delays due to shortage of bitumen as well as price increase. Even though every contract BOQs are allocated 10 % of the contract amount for the price fluctuations of materials, this is not sufficient to cope with the increased price of materials in the market. Hence, under-bidding is the major problem which cannot cope with the increase price of materials.

Scarcity of skilled labour force was the third highest severity and frequency of delay factor in highway construction because most of the skilled workers

are going to work in Middle-East countries to gain higher salaries compared to work in Sri Lanka. Nowadays, young generations are reluctant to work as blue-collar employees in construction sector due to low job security, low wages, and lack of social status and post-retirement benefit. In addition, the country mainly consists of flat lands which have an agricultural economic base. Hence, the main income of people in that area is gained from paddy cultivation. It is very hard to find labors for highway construction work in that area during paddy cultivation and harvesting periods because most of the laborers are attending those works and gaining higher wages compared to work in construction field. It is necessary to increase the skilled labor force in the highway construction by providing higher wages according to their working capacity, and capability, and increasing their job security.

Lack of resources also has some considerable impact on project delays. Most of the contractors hire the main construction equipment to avoid high ownership cost, maintenance cost and insurance cost. During peak construction time the contractor's failure to hire the right machine and deploy it correctly that may affect the required quality of work and leads to an increase of rework**.**

Owner's cash flow problem causes high impact on project delays because this can happen due to the allocated funds of the project getting used for another purposes such as to settle urgent payments of other ongoing projects, to initiate new projects without having proper budgetary allocations and settling compensation payments for relocation of affected people. As a result, misuse of allocated budget of a particular project causes high severity of project delay. Nowadays, most donor agencies are releasing their funds for different phases of a particular project, such as pre-feasibility studies, feasibility studies, preliminary engineering designs, detailed engineering designs and project execution phases. Before starting project execution phase, the owner has to submit Environmental Impact Assessment (EIA) report and, Social Impact Assessment (SIA) report to the donor agency by confirming that the project will not give any detrimental effect to the surrounding environment and people in the project location. After that, the donor agency releasing funds for the project execution. If the owner fails to submit EIA and SIA reports according to the donor's

satisfactory standard level that may lead to funding delays for project execution which also affects to the pre-construction phase.

Scarcity of the required quality of materials in project location surrounding has a significant impact on project delays. During the bidding stage of the contract, before completing the bid document, it is the contractor's responsibility to visit the project location and carry out a preliminary survey such as, available quarry locations, that the required quantity of materials can be collected within the given distances in the BOQ and the condition of the haul road from the quarry to the site. All important available details and future uncertainty has to be considered to rate and add the mark up of the BOQ. In reality most of the contractors rated their BOQs without knowing the actual site conditions, and availability of materials in that project location, and at the same time underbidding the contract, this will tend to create a great problem for the contractor while performing the contract.

Environmental restrictions for mining of materials are the new influencing factors to the construction industry. These rules are newly imposed by the government to protect the environment due to excessively mining of river sand, which is a very important material for road construction work. Controlling the mining of river sand has made the price of sand tremendously increase. Although after introducing other alternatives, this problem has less severity on project delay.

Extra works apart from the scope means that during the construction phase, various essential works accumulate in the scope. If those works are not included in the original scope, they are considered as extra works. Every BOQ is allocated 10% of contract amount as a contingency which can be used to perform essential work apart from the scope during construction. This delay factor also has high frequency of occurrence but it has less severity of project delay.

Poor planning and scheduling of contractors has a significant effect on project delays. It can be attributed due to the lack of professional engineers and other technical staff or contractor's having unqualified technical staff. Most of the

contractors are recruiting unqualified staff by paying low salaries. This may cause a severe impact on project delays

Lack of professionals and other technical staff in the contractor's party is another delay factor which has high severity and often frequency of occurrence in highway construction projects. Most of the contractors are recruiting unqualified technical staff by giving low salaries and benefits. That is directly affected to the poor performance of the contractor. As a result of saving money by paying low salaries for the unqualified technical staff, a huge amount of money could be lost from the contracts due to rework and schedule slippage.

4. Differences in perceptions of the project owner and the contractor

4.1 Different perceptions of delays in pre-construction phase

It is vital to evaluate the significant differences and agreement on the perceptions of the project owner and the contractor during pre-construction phase. The rank assigned for each individual cause of delay with respect to their frequency of occurrence by the owner and the contractor are presented in Table 16 and discussed below:

Table 16 Comparison between project owner's and contractor's perceptions in frequency of occurrence

Delay factor	Owner's perception			Contractor's perception		
	FOI	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**
Delay in acquisition of construction site	0.633	Moderate	1	0.571	Moderate	6
Funding delays	0.627	Moderate	2	0.619	Moderate	3
Frequent changes of design	0.607	Moderate	3	0.733	Often	1
Incomplete designs(with errors and missing details)	0.520	Moderate	**4**	0.610	Moderate	**4**
Lack of review of all designs and drawings before issuing to the contractor	0.519	Moderate	**5**	0.581	Moderate	**5**
Designs not matched with actual site condition	0.500	Low	6	0.648	Moderate	2
Delay in review and approval of bid documents	0.498	Low	7	0.533	Moderate	8
Incomplete bid documents (specifications, BOQs, drawings)	0.480	Low	8	0.504	Moderate	10
Delays in awarding contract and issuing of letter of acceptance	0.473	Low	**9**	0.505	Moderate	**9**
Delay in evaluation of bid documents.	0.467	Low	10	0.476	Low	12

Note: Ranks in bold indicate strong agreement in the perceptions of the project owner and the contractor.

According to Table 16, both parties strongly agreed three causes of delays: incomplete designs, lack of review of all designs and drawings before issuing to the contractor and delays in awarding contract and issuing letter of acceptance. It can be seen from Table 16 that other delay factors have less agreement. However, it is observed that both respondents have been shown higher agreement on their perceptions of project delays.

It is surprising to see that the delay factor which is ranked in number seven of contractor's perception has missed in the content of Table 16 because in owner's perception it is ranked in 11th position. In Table 16 only considered that top ten delay factors in owner's perception.

In order to measure the agreement in perception between the project owner and the contractor rank agreement factor (RAF), percentage agreement (PA) and percentage disagreement (PD) were calculated and it was found that RAF= 1.7 (i.e. less), PA= 68% (i.e. high agreement) and PD = 32% (i.e. less disagreement). By considering these values, it was observed that a smaller value of RAF gave higher agreement in perception between project participants and percentage agreement was 68%. It was revealed that the project participants were highly agreed on cause of delays which were ranked by frequency of occurrence in pre-construction phase.

Table 17 shows the different perceptions of the project participants for each cause of delay ranked by severity. The owner and the contractor strongly agreed to the funding delays and less agreed in other causes of delays in pre-construction phase.

According to the contractor's perception, the delay factor which was ranked in number 8th position was ranked in number 12th position by owner's perception and thereby missed in Table 17 because Table 17 only considered the top ten delay factors in owner's perception.

Table 17 Comparison between project owner's and contractor's perception in severity

Delay factor	Owner's perception			Contractor's perception		
	RII	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**
Delay in acquisition of construction site	0.733	High	1	0.819	High	3
Funding delays	0.633	Moderate	**2**	0.820	High	**2**
Frequent changes of design	0.600	Moderate	3	0.867	High	1
Incomplete designs	0.580	Moderate	4	0.800	High	5
Designs not matched with actual site condition	0.567	Moderate	5	0.771	High	6
Lack of review of all designs before issuing to the contractor	0.553	Moderate	6	0.667	Moderate	7
Delay in award of contract and issue of letter of acceptance	0.552	Moderate	7	0.610	Moderate	10
Incomplete bid documents	0.547	Moderate	8	0.810	High	4
Inexperience design engineer	0.527	Moderate	9	0.571	Moderate	12
Delays in review and approval of bid document and designs	0.520	Moderate	10	0.619	Moderate	9

Note: Ranks in bold indicate strong agreement in the perceptions of the project owner and the contractor

According the owner's point of view, most significant delay factors which were identified as having a detrimental impact on project delays were funding delays, delay in acquisition of construction site, frequent changes of designs, incomplete designs and designs are not matched with actual site conditions. Although in the contractor's point of view, significant impact on project delays were frequent changes of designs, funding delays, delay in acquisition of construction site, incomplete bid documents and incomplete designs.

Delay in acquisition of construction site is the highest impact on project delay and the project owner is most responsible for this delay factor. If the owner fails to acquire the land for starting the project in the required time that may have a significant impact on project delay. Hence, the owners gave it high priority and ranked it in first position. In the contractor's point of view, it has a less significant impact on project delay because it is the sole responsibility of the owner to hand over the site to the contractor without any land acquisition problem. Therefore, the contractors ranked it in third position.

Funding delay was equally important to both parties because without sufficient funding the owner cannot execute the contract as well as the contractor cannot perform the contract. Hence, both respondents gave equal importance to the funding delays and ranked them in second position.

Frequent changes of design were of high importance to the contractor because it has significant impact on delays in the pre-construction phase, which is directly related to the delay in starting the construction phase of the project. The construction industry has high competition for winning the contract among the contractors. Most of the contractors are eagerly waiting for bidding and winning the contract to fulfil their demands in the construction field. Thus, the contractor gave high priority and ranked it in the first position while the owner gave it less priority and ranked it in third position.

Incomplete designs have significant impact on delays with responsibility of the owner. Most errors and mistakes of the designs can be easily found during the construction phase. Making corrections may increase the quantities of the BOQ, which can be compensated by issuing the variation orders to the contractor. That is beneficial to the contractor and cost overrun to the owner because if any new work item comes or quantity increases more than 1% of the contact contract sum due to the corrections of the designs, the contractor has the authority to decide the rate of that particular item, which is obviously higher than other quoted rates in the BOQ. Therefore, the owners gave it high priority and ranked it in 4th position, while the contractors gave it low priority and ranked it in 5th position.

Designs not matched with site conditions are a common delay factor that will leads to prolonging the pre-construction phase due to negligence of the owner's design engineer. Hence, the owners ranked it in higher position than the contractors.

Lack of review of all designs and drawings before issuing to the contractor is another delay factor, which can occur due to negligence of the owner's design engineer. This also has significant impact on delay and cost overrun of the project. Therefore, the owners identified those mistakes by previous experience and ranked it in higher position than the contractors.

It is a project owner's sole responsibility to award the contract and issue of letter of acceptance on time to the contractor. Sometimes, the owner fails to award the contract due to various reasons such as funding delays, land acquisition delays and political interferences. This delay factor directly affects to the owner and has less impact to the contractor.

Incomplete bid documents have significant effect to the contractor or bidder because after receiving the bid documents from the owner, the contractor has to complete the document and re-submit it to the owner within a given time period. During that period if the owner finds some mistakes in the bid documents, the owner can correct those mistakes in the pre-bid meeting by issuing a bid addendum to the

respective bidders. Most contractors or bidders had bad experience of the incomplete bid documents in pre-construction phase and gave it higher priority to rank in 4th position.

The designer has a key role in pre-construction phase because the main duties of the designer include: preparation of all designs and drawings, specifications, BOQs and conditions of contracts. If the owner is selected a well experienced designer to carry out all design work, the owner is able to complete all project designs and bid documents within budget and schedule of the project. Otherwise if the design engineer is inexperienced to perform project design work, the owner could encounter schedule delays and cost overrun of the project. Hence, the project owners gave higher ranking to this than the contractors.

Delay in review and approval of bid documents and design is the last delay factor, which could occur due to negligence of the owner. The owner has to take prompt action to avoid this delay factor and try to speed up this process according to the schedule. This delay factor has a significant impact on the pre-construction phase because the bidding process may get delayed. Therefore, the contractors or bidders gave higher priority in ranking it than the owners.

Finally, in order to measure the agreement in perceptions of project participants RAF, PA and PD were calculated and it was found that RAF= 1.8 (i.e. less), PA= 64% (i.e. moderate agreement) and PD= 36% (i.e. moderate disagreement). It was revealed that both participants were moderately agreed on cause of delays which were ranked by severity in the pre-construction phase.

Table 18 shows difference perceptions of the project participants are ranked according to their severity and frequency.

Table 18 Comparison between project owner's and contractor's perceptions in severity and frequency

Delay factor	Owner's perception			Contractor's perception		
	SFI	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**
Delay in acquisition of construction site	0.659	Moderate	1	0.676	Moderate	5
Funding delays	0.623	Moderate	2	0.699	Moderate	3
Frequent changes of designs	0.594	Moderate	3	0.793	High	1
Incomplete designs	0.538	Moderate	**4**	0.698	Moderate	**4**
Lack of review of all designs and drawings before issuing to the contractor	0.529	Moderate	5	0.618	Moderate	7
Designs not matched with actual site conditions	0.521	Moderate	6	0.703	High	2
Delays in awarding of contract and issuing of letter of acceptance	0.507	Moderate	7	0.552	Moderate	10
Delay in review and approval of bid documents and designs	0.501	Moderate	**8**	0.569	Moderate	**8**
Incomplete bid documents (BOQs, specifications, drawings etc)	0.499	Low	9	0.626	Moderate	6
Inexperienced design engineer	0.480	Low	10	0.551	Moderate	11

Note: Ranks in bold indicate strong agreement in the perceptions of the project owner and the contractor.

It was amazing to see that strong agreement between project owner and contractor on incomplete designs and delay in review and approval of bid documents and designs. Both delay factors occur due to the sole responsibility of the project owner. Surprisingly, the project owner gives the equal priority as same as the contractor to these delay factors occur due to the weakness of the project owner.

In order to measure the agreement between the perceptions of the project participants RAF, PA and PD were calculated and it was found that RAF= 2.0 (i.e. less), PA= 60% (i.e. moderate agreement) and PD= 40% (i.e. moderate disagreement). It was observed that moderate agreement between the project participants on cause of delays which were ranked by severity and frequency in pre-construction phase.

According to the Table 18, severity and frequency index gives the most realistic ranking order of delay factors in pre-construction phase because it shows the prevailing situation of delays in Sri Lankan construction industry. It can be observed that both the owner and the contractor have given equally importance to the incomplete designs and delay in review and approval of bid documents and designs while their perceptions of the remaining causes of delays have less disagreement.

4.2 Different perceptions of delays in construction phase and priority is given based on owner's ranking method

The rank assigned for each individual cause of delays by the project participants are presented in Table 19.

Table 19 Comparison between project owner's and contractor's perceptions in frequency of occurrence

Delay factor	Owner's perception			Contractor's perception		
	FOI	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**
Increase of the price of materials	0.787	Often	1	0.724	Often	5
Contractor's cash flow problem.	0.747	Often	2	0.686	Moderate	7
Lack of professional engineers and other technical staff	0.746	Often	**3**	0.562	Moderate	**35**
Lack of resources.	0.727	Often	4	0.667	Moderate	9
Poor planning and scheduling	0.720	Often	**5**	0.581	Moderate	**31**
Contractor unable to mobilize required equipment on time	0.687	Moderate	**6**	0.590	Moderate	**23**
Idling of equipment	0.686	Moderate	**7**	0.533	Moderate	**46**
Scarcity of skilled labour	0.673	Moderate	8	0.848	Often	1
Extra work apart from the scope	0.672	Moderate	9	0.705	Often	6
Owner's cash flow problem	0.667	Moderate	10	0.771	Often	3

Note: Ranks in bold indicate strong disagreement in the perceptions of the project owner and the contractor.

Contractor must be equipped with sufficient professional engineers and other technical staff to perform the contract within given budget and schedule. Most contractors do not have minimum requirement of professional and technical staff to perform contract in construction industry. By identifying the contractor's weakness during the construction period the project has given higher priority but the contractor dishonestly given lower priority while ranking of delay factors as shown in Table 19.

One of the main secret of successful completion of the project within given budget and schedule is achieved by good practicing of project planning and scheduling techniques. Even though contractors are failure to follow these techniques for successfully completion of their project because most of them do not equipped with technically sound staff. Nowadays, most contractors are recruiting unqualified staff for the construction works by paying low salaries but they could not perform well during the construction. Hence, the project owner has given the higher priority for the contractor's faults but the contractor dishonestly given the lower priority as shown in Table 19.

Contractor failures to mobilize required equipment on time is predominant delay factor in construction industry because most contractors do not have an ownership of required machineries for performing the construction work due to avoid high ownership cost, insurance cost and maintenance cost. Most of the time the contractors are used to hire the required machines on required time but during the peak construction time the contractor could not select the required machine for required work, because the particular machine may not be available in that equipment hiring company. The contractor is sole responsible for this cause of delay. Thus, the project owner has given higher priority to highlight the contractor's fault but the contractor has given lower priority as shown in the Table 19.

Idling of contractor's equipment is a common problem in the construction industry, the main reason of this delay is identified as the contractor does not maintain proper equipment management plan with material management plan because both plans must be linked together. For an example, if the contractor is receiving less quantity of materials to the site in that case the contractor could deploy less number of machines. Conversely, if the contractor is receiving more material to the site in that case the contractor could deploy more machinery for the construction works. By adopting proper equipment management plan with link to the material management plan for the construction works the contractor could timely assign work in each machine without idle the machines. The project owner has observed the contractors

weakness of equipment management capabilities during the construction period, the owner has given higher priority of this cause of delay rather than the contractor.

However, it is important to check the agreement between the perceptions of project participants on cause of delays which were ranked by frequency of occurrence in construction phase. The RAF, PA and PD were calculated to measure the agreement between the project owner and the contractor and found that the RAF= 14.5 (i.e. high), PA= 0% (i.e. very less agreement) and PD= 100% (i.e. very high disagreement). It was surprising to see that both participants highly disagreed with each cause of delay due to higher values of RAF, and PD and very lower values of PA gave the strong disagreement between the project participants because both participants tried to give the least priority for their own faults and higher priority to others faults in the construction phase.

Table 20 shows the different perceptions of the project participants for each cause of project delay ranked by severity in construction phase.

Table 20 Comparison between project owner's and contractor's perceptions in severity

Delay factor	Owner's perception			Contractor's perception		
	RII	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**
Contractor's cash flow problem.	0.760	High	1	0.886	High	5
Lack of resources	0.747	High	2	0.857	High	6
Lack of professional engineers and other technical staff	0.720	High	**3**	0.676	Moderate	**29**
Poor planning and scheduling	0.707	High	**4**	0.724	High	**20**
Increase of the price of materials	0.706	High	5	0.829	High	9
Contractor failures to mobilize required equipments on time	0.705	High	**6**	0.771	High	**14**
Owner's cash flow problem	0.680	Moderate	7	0.924	Very high	2
Poor site management of contractor	0.673	Moderate	**8**	0.686	Moderate	**27**
Scarcity of material	0.660	Moderate	9	0.923	Very high	3
Scarcity of skilled labour	0.653	Moderate	10	0.943	Very high	1

Note: Ranks in bold indicate strong disagreement in the perceptions of the project owner and the contractor.

By comparing the results of Table 19 and Table 20, it is observed that out of the top ten delay factors of each table they contain seven common delay factors for both parties without considering their ranks: increase price of materials, contractor's cash flow problems, lack of resources, lack of professional engineers and other technical staff, poor planning and scheduling, scarcity of skilled labour and contractor

unable to mobilize required equipment on time. Other remaining factors of delays have their own significance for the owner and the contractor.

According to the Table 20, only four factors have recognized as strong disagreement between the project owner and the contractor including: lack of professional engineers and other technical staff, poor planning and scheduling, contractor failures to mobilize required equipment on time and poor site management of contractor. The main reasons of this strong disagreement of first three delay factors have already explained by referring the Table 19. Only new delay factor which is found that strong disagreement, poor site management of the contractor.

Poor site management of the contractor is identified as a predominant delay factor in the construction phase. Main reason of this delay is observed that the contractor does not have professional engineers to perform site management; furthermore without having technically sound staff for the site management the contractor could not achieve the target profit margin due to increase loss during the construction period. Therefore, by observing the contractors faults the project owner has given high significant for this cause of delay rather than the contractor.

In order to measure the agreement between perceptions of project participants on cause of delays which were ranked by severity in construction phase, the RAF, PA and PD were calculated and it was found that RAF= 10.0 (i.e. moderate), PA= 0% (i.e. very less agreement), PD= 100% (i.e. very high disagreement). The results show that the project participants highly disagreed on each cause of delay in construction phase due to the higher values of RAF, and PD and lower value of PA.

The ranks assigned for each cause of project delay by the project participants in severity and frequency are presented in Table 21 and discussed below:

Table 21 Comparison between project owner's and contractor's perceptions in severity and frequency

Delay factor	Owner's perception			Contractor's perception		
	SFI	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**
Contractor's cash flow problem.	0.746	High	1	0.773	High	5
Increase of the price of materials	0.741	High	2	0.772	High	6
Lack of resources	0.730	High	3	0.751	High	8
Lack of professional engineers& other technical staff	0.727	High	**4**	0.612	Moderate	**32**
Poor Planning & Scheduling.	0.708	High	**5**	0.639	Moderate	**24**
Contractor unable to mobilize required equipment on time	0.684	Moderate	**6**	0.667	Moderate	**15**
Owners Cash flow problem	0.667	Moderate	7	0.838	High	3
Idling of equipment	0.659	Moderate	**8**	0.534	Moderate	**52**
Scarcity of skilled labour	0.656	Moderate	**9**	0.889	High	**1**
Poor site management of contractor.	0.651	Moderate	**10**	0.609	Moderate	**34**
Extra work apart from the scope.	0.650	Moderate	**11**	0.764	High	**7**
Scarcity of material.	0.643	Moderate	**12**	0.845	High	**2**

Note: Ranks in bold indicate strong disagreement in the perceptions of the project owner and the contractor.

It was amazing to see that contractor's cash flow problem is highest significant impact on project delays. In most of the contracts, contractors misuse their mobilization advance and suffer from cash flow problem to carry out the contact. By giving it 5th rank, the contractor tries to give less importance to the contractor's mistakes. The owner's ranking substantiates the importance of this cause of delay in highway construction.

Increased price of materials was given as the second cause of delay in highway construction because the world crude oil price had tremendously increased in the last two years. This directly affects the increase of production cost of road construction materials, such as aggregate, steel, bitumen and cement. Ultimately the market price of materials also increased. As a main road construction material, increased price of bitumen and shortage of bitumen in the market caused a detrimental effect to the project delays because the bitumen is a by product of crude oil refining process. During the crude oil price increase time, limited consumption and importing of crude oil directly affected bitumen production. It is very important to analyze why the owners ranked it as 2nd, while contractors ranked it as 6th position because both parties are responsible for completing the project within given time and allocated budget. During the construction period, if the material price is drastically increased beyond the allocated amount of price escalation given in the BOQ, in order to compensate the additional amount for the contractor by requesting special approval of payment from the higher officials in the executing agency. This process may not be easy to get approved, and sometimes allocations are not available to make the additional payments. Hence, the owners ranked it as 2nd position by severity and frequency in construction industry. At the same time the contractors ranked in as 6th position because the original BOQ already included some percentage of contract amount as an escalation. Thus, the contractor could be compensated some extent of the price increase of material within that specified escalation amount.

Lack of resources for the contractor to carry out the contract was another important factor for the owners and ranked in third position, while contractors ranked it in 8th position. Most of the contractors are used to hiring the main construction

equipment due to avoiding high ownership cost, maintenance cost and insurance cost. During peak construction time the contractor's failure to hire the right machine and deploy it correctly may affect to the required quality of work and lead to increase of rework. Therefore, owners ranked it in 3rd position but contractors gave it less priority and ranked in 8th position.

Lack of professionals and other technical staff in the contractor's party was ranked in 4th position by the owners but contractors gave it less importance by ranking it in 32nd position. Most of the contractors are recruiting unqualified technical staff by giving low salaries and facilities. That directly affects the poor performance of the contractor. As a result of saving money by paying low salaries for the unqualified technical staff, a huge amount of money could be lost from the contracts due to rework and schedule slippage. This caused significant impact to the contractor as well as to the owner, by identifying the significance of the delay factor owners ranked it in 4th position but contractors tried to hide his faults and ranked it in 32nd position.

Contractor's poor planning and scheduling is ranked by the owners in 5th place, but contractor ranked it in 24th position. This can happen due to lack of qualified staff in the contractor's party. Hence, the contractor is highly responsible to causes of delay but in an irresponsible way contractors gave less significance for this delay factor.

Contractor's failure to mobilize required equipment on time was ranked in 6th position by the owners but contractors ranked in 15th position. Most of the contractors have insufficient machinery of their own. Hence, major equipment that are needed for construction work are deployed to site by renting from other equipment rent companies. During the peak construction time, the contractor might not select the required machine for required work, because the particular machine may not be available in that company. This cause of delay occurred due to the responsibility of the contractor. Thus, the project owners identified this problem and ranked it as in 6th position while the contractors gave it less priority for their own responsibilities.

Owner's cash flow problem is ranked in 7th position by the owners but the contractors gave it high significance and ranked it in 3rd position. Most of the time this can occur due to the allocated budget of the project getting used for another purpose such as to settle urgent payments of other ongoing projects, to initiate new projects without having proper budgetary allocations and settling compensation payments for relocation of affected people. As a result of misuse of allocated budget of a particular project it causes high significance of project delay which directly affects to the contractor. Hence, the project owner is highly responsible for this cause of delay but the owners gave it less significance in an irresponsible manner while contractors gave it high significance and ranked it in 3rd position.

It is observed that idling of equipment in construction sites mainly occurred due to negligence of the contractors. The reason of this delay is failure to maintain the equipment management plan for assigning tasks to each machine. Most of the time, the contractor is highly responsible for this cause of delay but sometimes it can occur due to delay of issuing necessary instructions to the contractor by the owner. Thus, idling of equipment was ranked 8th and 52nd positions by the project owners and the contractors respectively.

Scarcity of skilled labour was ranked as the 9th and 1st important factor by the project owner and the contractor respectively contributing to the delayed completion of a project. Most of the skilled workers are going to work in Middle-East countries to gain higher salaries compared to work in Sri Lanka. Nowadays, young generations are reluctant to work as a blue-collar employee in the construction sector due to less job security, low wages, and lack of social status and post-retirement benefit. The contractors are encountering difficulties in finding skilled labour force to perform construction throughout the project period. Hence, the contractors gave it high significance and ranked it 1st position but the project owners gave it less significance because the owners decided that contractors can deploy more machinery to perform work instead of labour.

Poor site management of contractor is another important delay factor ranked in 10th position by the owners but contractors gave it the least importance and ranked it in 34th position because the project owner identified the poor management skills of the contractor by working with different contractors in various construction projects. Most of the contractors do not have sufficient knowledge of management skills which has a significant effect on managing their money, time and resources because some owners of the construction companies have less management and technical knowledge. Therefore, the project owners gave high priority to this cause of delay which is highly responsible for the contractor and ranked it in 10th position but the contractors responded in an irresponsive manner and gave it less importance.

Extra work apart from the scope was ranked 11th position by the project owners and 7th position by the contractors because the project owner is highly responsible for this cause of delay but ranked it in an irresponsible way by giving less priority. The contractors identified the owner's mistakes and ranked it by giving high priority.

Scarcity of required quality of materials surrounding the project location is a significant impact on project delays. After awarding the contract, it is the responsibility of the contractor to collect all required quality and quantity of materials and carry out the project in the given budget and schedule. It is observed that scarcity of materials is a predominant delay factor in construction industry. Hence, the contractors gave high significance to this problem and ranked in 2nd position but the project owners gave it less priority and ranked it in 12th position.

Nonetheless, it is necessary to measure the agreement between the perceptions of project participants on cause of delays which were ranked by severity and frequency in construction phase. The RAF, PA and PD were used to measure the agreement between perceptions and calculated values and were found to be RAF= 13.6 (i.e.high), PA= 0% (i.e. very less agreement) and PD= 100% (i.e. very high disagreement). It was surprising to see such high disagreement between the project participants on cause of delays in construction phase due to higher values of RAF and

PD, and lower value of PA. In reality, it is human nature of the project participants to point out others' faults without considering their own faults and blaming the other party.

4.3 Different perceptions of delays in construction phase and priority is given based on contractor's ranking method

Table 22 shows the different perceptions of the project participants for each cause of delays are ranked by frequency of occurrence. Especial attention is paid for the contractor's view of ranking, based on that the owner's view of ranking could be done as shown in Table 22.

Table 22 Comparison between contractor's and project owner's perceptions in frequency of occurrence

Delay factors	Contractor's perception			Owner's perception		
	FOI	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**
Scarcity of skilled labour	0.848	Often	**1**	0.673	Moderate	**8**
Scarcity of material	0.781	Often	**2**	0.640	Moderate	**15**
Owner's cash flow problem	0.771	Often	**3**	0.667	Moderate	**10**
Environmental restrictions of mining materials	0.762	Often	**4**	0.647	Moderate	**13**
Increased the price of materials	0.724	Often	5	0.787	Often	1
Extra work apart from the scope	0.705	Often	6	0.672	Moderate	9
Contractor's cash flow problem	0.686	Moderate	7	0.747	Often	2
Delay in approval of interim payments and variation orders	0.685	Moderate	**8**	0.573	Moderate	**26**
Lack of resources	0.667	Moderate	9	0.727	Often	4
Break down of equipment	0.648	Moderate	**10**	0.613	Moderate	**21**

Note: Ranks in bold indicate less agreement in the perceptions of the project participants.

According to the Table 22, it is surprising to see that contractor's and owner's views have large difference on the perception of delay factors including: Scarcity of skilled labour, scarcity of materials, owner's cash flow problem, delay in approval of interim payments and variation orders and break down of equipment.

Contractor's point of view, scarcity of skilled labour and materials are highly important delay factors for the contractor because it is very difficult to perform the contract within given budget and schedule without having sufficient skilled labour force and required quality of materials. Hence, the contractor has given a high priority for these causes of delays but these delay factors are not directly related to the owner's work due to this owner has given less priority.

Owner's cash flow problem is vital for the contractor because progress of construction is mainly depend on cash flowing process through the owner to the contractor. Moreover, end of each month the contractor submits monthly interim payment to the owner for the relevant work done for each month. So the owner must have sufficient amount of cash to reimburse these monthly interim payments. If the owner suffers from cash flow problem that is directly effect to the contractor's working progress. Therefore, the contractor has given the higher priority than the owner. Although the project owner has identified the own faults and ranked in irresponsible way by giving low priority.

An environmental restriction of mining of material has newly imposed rules by the government. So this is directly effect to the progress of construction work because materials are the main ingredients of the construction process. The contractor could not proceed the construction works without having required quality and quantity of material. By suddenly enforcing these rules without properly introducing the alternative material for the construction work is the great impact to the construction industry. Hence, the contractor has realized this problem and ranked it by giving high priority than the project owner.

Timely approval of interim payments and variation orders are sole responsibility of the owner. If the project owner is purposely delay to issue interim payments and variation orders have detrimental effect to the working progress of the contractor. The contractor always suffers from the owner related delays and taking some efforts to highlight those delay factors by giving higher rank but the project

owner tries to devalue his responsibilities by giving the lowest rank as shown in the Table 22.

Break down of equipment is a common delay factor in construction industry because most contractors are using obsolete machines for the construction work instead of using new machines. As a result of frequent break down of equipment makes more vulnerable for the project delay. This delay factor occurs due to high contribution of the contractor. Hence, by realizing the own faults the contractor gives a higher priority than the owner.

Nevertheless, it is vital to measure the agreement between the perceptions of project participants on causes of delays which were ranked by frequency of occurrence in construction phase. The RAF, PA and PD were used to measure the agreement between the perceptions of the participants. The calculated values were RAF= 8.2 (i.e. moderate), PA= 0% (i.e. very less agreement) and PD= 100% (i.e. very high disagreement). The results show that both parties highly disagreed in each cause of project delay due to higher values of RAF and PD and the low value of PA.

Table 23 shows the different perceptions of the project participants are ranking by severity. Relative importance index (RII) was used to prioritize the delay factors according to the contractor's and owner's views in severity.

Table 23 Comparison between contractor's and project owner's perceptions in severity

Delay factors	Contractor's perception			Owner's perception		
	RII	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**
Scarcity of skilled labour	0.943	Very high	**1**	0.653	Moderate	**10**
Owner's cash flow problem	0.924	Very high	2	0.680	Moderate	7
Scarcity of material	0.923	Very high	3	0.660	Moderate	9
Environmental restriction of mining of material	0.905	Very high	**4**	0.613	Moderate	**18**
Contractor's cash flow problem	0.886	High	5	0.760	High	1
Lack of resources	0.857	High	6	0.747	High	2
Contractor delay in site mobilization	0.838	High	7	0.647	Moderate	12
Extra work apart from the scope	0.837	High	8	0.640	Moderate	13
Increased the price of material	0.829	High	9	0.706	High	5
Delay in approval of variation orders and interim payments	0.819	High	**10**	0.567	Moderate	**28**

Note: Ranks in bold indicate less agreement in the perceptions of the contractor and the project owner.

It is surprising to see less disagreement between the contractor and the owner by severity compared to the frequency of occurrence of delay factors in Table 22. Only three delay factors show high disagreement: scarcity of skilled labour, environmental restrictions of mining of materials and delay in approval of variation orders and interim payments.

Scarcity of skilled labour is high significant causes of delay as ranked by the contractor but the project owner has different perception of this delay factor by giving low ranking as shown in the Table 23. The project owner may think that the contractor could easily overcome this cause of delay by deploying more machinery instead of labours.

In contractor's perception, environment restrictions for mining of material have been identified as high impact on project delays in construction phase. Although in owner's perception, the project owner doesn't concerned much intention of this delay factor and ranked it by giving less priority because the contractor could use the alternative materials for the construction instead of excessive mining of materials.

Delay in approval of interim payments and variation orders are critical delay factors which have significant impact on the contractor's cash flow program as well as working progress of the project. Hence, the contractor has given high priority rather than the project owner.

Nevertheless, it is important to measure the agreement between the perceptions of project participants on causes of delays which were ranked by severity in construction phase. The RAF, PA and PD were used to measure the agreement between the project participants. The calculated values were RAF= 7.4(i.e. moderate), PA= 0% (i.e. very less agreement) and PD= 100% (i.e. very high disagreement). The results show strong disagreement between the perceptions of project participants in construction phase due to the higher values of RAF, and PD, and the low value of PA.

Table 24 shows the different perceptions of the project participants are ranked by its severity and frequency. Severity and frequency index (SFI) was used to prioritize the delay factors based on the contractor's and the project owner's views ranked as shown in Table 24.

Table 24 Comparisons between contractor's and project owner's perceptions in severity and frequency

Delay factors	Contractor's perception			Owner's perception		
	SFI	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**
Scarcity of skilled labour	0.889	High	1	0.656	Moderate	9
Scarcity of materials	0.845	High	**2**	0.643	Moderate	**12**
Owner's cash flow problem	0.838	High	3	0.667	Moderate	7
Environmental restrictions of mining of materials	0.827	High	**4**	0.624	Moderate	**15**
Contractor's cash flow problem	0.773	High	5	0.746	High	1
Increased of the price of materials	0.772	High	6	0.741	High	2
Extra work apart from the scope	0.764	High	7	0.650	Moderate	11
Lack of resources	0.751	High	8	0.730	High	3
Delay in approval of interim payments and variation orders	0.746	High	**9**	0.564	Moderate	**27**
Procurement delay in special kind of materials	0.693	Moderate	**10**	0.611	Moderate	**19**

Note: Ranks in bold indicate less agreement in the perceptions of the project participants.

According to the Table 24, only four delay factors have high disagreement between the contractor and the owner but both parties have less disagree for remaining other delay factors.

Scarcity of material for the construction work has been identified as significant impact on delays in the construction phase. Hence, the contractor gave higher priority rather than the project owner because the contractor encounters scarcity of materials in surrounding project location during the construction phase. This problem could be overcome by transporting materials from other locations and stockpile closer to the site to carry out the construction work without any delay.

Environmental restrictions for mining of material are newly enforced rules by the government to protect the environment for the excessive mining of river sand. By suddenly imposing this type of rules are significant impacts on contractors work schedule because the contractor has to find alternative materials instead of the river sand. Before using this alternative material for construction work, the contractor has to obtain the prior approval of the material testing laboratory to use this material for highway construction works. This delay factor is highly important for the contractor rather than the project owner. Hence, the contractor gives higher priority than the owner.

It was surprising to see that the project owner devalues sole responsibility by giving the low priority for the delay in approval of interim payments and variation orders but the contractor is highlighted weakness of the project owner by giving high priority to this cause of delay.

Procurement delay in special kind of material has a significant impact on project delay. Especially in bridge construction project, contractor has to order all required sizes of pre-cast bridge beams from suppliers at the beginning stage of the project that is very helpful to carry out smooth flow of construction work without any delay because when the contractor finished construction of bridge piers, after that construction of bridge deck can be easily done by launching bridge beams due to timely ordered and procured all required sizes of bridge beams. Otherwise after construction of bridge piers contractor has to wait for long time to installation of bridge deck due to delay for procurement of pre-cast bridge beams. In highway construction projects also contractor has to order all required materials including:

required sizes of aggregates, sand and bitumen at early stage of the project to carry out smooth flow of construction work without any delay. By considering all these facts the contractor honestly gave higher priority rather than project owner.

Nonetheless, it is necessary to measure agreement between the perceptions of project participants on causes of delays which were ranked by severity and frequency in construction phase. The RAF, PA and PD were used to measure the agreement between the perceptions of project participants. The calculated values were RAF= 7.7 (i.e. moderate), PA= 0% (i.e. very less agreement) and PD= 100% (i.e. very high disagreement). The results show that the project participants highly disagreed on causes of delays in construction phase due to the higher values of RAF, and PD and the low value of PA.

5. Summary of rank of delay categories in pre-construction and construction phases

5.1 Rank of delay categories in pre-construction phase

Table 25 shows the summary of two delay categories ranked by frequency of occurrence index (FOI) for highway construction. The frequency of occurrence index of each of delay category was calculated from the mean of the individual delay factors under the same category, which were then used to assess the frequency of occurrence of the major factor categories. The same method was used to calculate the weighted average of frequency of occurrence index for each factor category.

According to Table 25, first priority by frequency of occurrence of the project delay was given to the owner's design engineer category and second priority was given to the project owner category.

Table 25 Rank of delay categories by frequency

Factor category	Owner's view			Contractor's view			Weighted average		
	FOI	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**
Owner	0.528	Moderate	1	0.545	Moderate	2	0.537	Moderate	2
Owner's design engineer	0.502	Moderate	2	0.603	Moderate	1	0.553	Moderate	1

From the owner's point of view, top rank was given to the owner and second rank was given to the owner's design engineer because the owner's category mainly consists of land acquisition and project funding, which have high frequency of project delay in pre- construction phase.

From the contractor's point of view, top rank was given to the owner's design engineer and second priority was given to the owner category because the design related issues have high frequency of occurrence of delays to the contractor in pre-construction phase. Therefore, the owner's design engineer category was ranked in the first position and the owner category was ranked in second position by weighted average.

Table 26 shows the summary of two delay categories ranked by relative importance index (RII), which is used to evaluate the severity of each delay category. The relative important index of each delay category was calculated from the mean of the individual delay factors under the same category, which were then used to assess the relative importance index of the major factor category. The same method was used to calculate the weighted average of RII for each factor category.

Table 26 Rank of delay categories by severity

Factor category	Owner's view			Contractor's view			Weighted average		
	RII	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**
Owner	0.573	Moderate	1	0.725	High	1	0.649	Moderate	1
Owner's design engineer	0.544	Moderate	2	0.701	High	2	0.623	Moderate	2

According to the owner's point of view, the project owner category was ranked as the first priority of project delay and second priority was given to the owner's design engineer category by severity because the role and responsibility of the owner for initiating of the project such as project funding and land acquisition have high significance of project delay in pre-construction phase.

From the contractor's point of view, the highest priority was given to the owner's category by identifying the significant cause of project delay and the second priority was given to the owner's design engineer category.

Finally, the weighted average was given equal priority by ranking the owner category in the first position and the owner's design engineer category in the second position.

Table 27 shows the summary of two delay categories ranked by severity and frequency index (SFI), which is used to evaluate the significance impact on project delay in each category. The severity and frequency index of each delay category was calculated from the mean of the individual delay factors under the same category, which were then used to assess the SFI of the major factor category. The same method was used to calculate the weighted average of SFI for each factor.

Table 27 Ranking of delay categories by severity and frequency

Factor category	Owner's view			Contractor's view			Weighted average		
	SFI	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**
Owner	0.542	Moderate	1	0.621	Moderate	2	0.582	Moderate	1
Owner's design engineer	0.513	Moderate	2	0.644	Moderate	1	0.579	Moderate	2

Moreover, Table 27 shows the most realistically ranked delay factor categories in pre-construction phase. The project owner category is ranked the first priority and owner's design engineer category is ranked as the second priority of project delays in pre-construction phase because the roles and responsibilities of the owner in the project initiation phase is higher than the owner's design engineer.

5.2 Rank of delay categories in construction phase

Table 28 shows the seven delay categories ranked by frequency occurrence index (FOI), which is used to measure the significant impact on each delay category in construction phase. The FOI of each of delay category was calculated from the mean of the individual delay factors under the same category, which were then used to assess the frequency of occurrence of the major factor categories. The same method was used to calculate the weighted average of frequency of occurrence index for each factor category.

Table 28 Ranking of delay categories by frequency

Factor category	Owner's view			Contractor's view			Weighted average		
	FOI	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**	**FOI**	**Meaning**	**Rank**
Owner	0.527	Moderate	4	0.608	Moderate	2	0.567	Moderate	4
Owner's site engineer	0.495	Low	6	0.542	Moderate	5	0.519	Moderate	5
Contractor	0.618	Moderate	2	0.572	Moderate	4	0.595	Moderate	3
Material	0.613	Moderate	3	0.632	Moderate	1	0.622	Moderate	1
Equipment	0.650	Moderate	1	0.588	Moderate	3	0.619	Moderate	2
Labour	0.504	Moderate	5	0.493	Low	6	0.498	Low	6
External	0.458	Low	7	0.470	Low	7	0.464	Low	7

Table 29 shows the seven delay categories ranked by relative important index (RII), which is used to measure the severity of each delay category in construction phase. The RII of each of delay category was calculated from the mean of the individual delay factors under the same category, which were then used to assess the relative importance of the major factor categories. The same method was used to calculate the weighted average of relative importance index for each factor category.

Table 29 Ranking of delay by severity

Factor category	Owner's view			Contractor's view			Weighted average		
	RII	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**	**RII**	**Meaning**	**Rank**
Owner	0.573	Moderate	4	0.724	High	2	0.649	Moderate	4
Owner's site engineer	0.529	Moderate	5	0.596	Moderate	5	0.563	Moderate	5
Contractor	0.628	Moderate	1	0.677	Moderate	3	0.652	Moderate	2
Material	0.598	Moderate	3	0.732	High	1	0.665	Moderate	1
Equipment	0.626	Moderate	2	0.676	Moderate	4	0.651	Moderate	3
Labour	0.471	Low	7	0.557	Moderate	7	0.514	Moderate	7
External	0.494	Low	6	0.590	Moderate	6	0.542	Moderate	6

The following Table 30 shows the seven delay categories ranked by severity and frequency index (SFI), which is used to measure the significant impact on each delay category in construction phase. The RII of each of delay category was calculated from the mean of the individual delay factors under the same category, which were then used to assess the relative importance of the major factor categories. The same method was used to calculate the weighted average of relative importance index for each factor category.

Table 30 Ranking of delay by severity and frequency

Factor category	Owner's view			Contractor's view			Weighted average		
	SFI	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**	**SFI**	**Meaning**	**Rank**
Owner	0.541	Moderate	5	0.658	Moderate	2	0.600	Moderate	4
Owner's site engineer	0.506	Moderate	6	0.564	Moderate	6	0.535	Moderate	6
Contractor	0.616	Moderate	2	0.616	Moderate	4	0.616	Moderate	3
Material	0.599	Moderate	3	0.676	Moderate	1	0.638	Moderate	1
Equipment	0.630	Moderate	1	0.625	Moderate	3	0.628	Moderate	2
Labour	0.560	Moderate	4	0.607	Moderate	5	0.584	Moderate	5
External	0.466	Low	7	0.518	Moderate	7	0.492	Low	7

It can be observed from Table 30, that owners and contractors views of ranking were in different aspects according to their experience and judgment of the construction industry. The realistic method of ranking delay categories can be done by calculating the weighted average of each delay category.

According to the weighted average of SFI in Table 30, the first priority was given to the material category because material has a significant effect on project delays. During the construction period contractors frequently encountered material related delays such as scarcity of required quality of materials, environmental restriction of mining of materials and increased price of materials. Hence, the contractors and the project owners gave it first and third priorities, respectively.

The equipment category was ranked in 2nd position by weighted average of SFI, because most of the highway project encountered equipment related delays during the construction period. Most of the contractors do not have the ownership of required equipment for highway construction due to avoiding the high ownership cost, insurance and maintenance costs. They are used to hiring main equipment for carrying out construction work but during peak construction time, the contractor may fail to

hire required equipment for particular work due to lack of availability of special equipment. Sometimes the contractor uses low quality equipment to carry out construction and cannot achieve the required quality of work. Therefore, this causes a significant effect on project delay in construction phase. The contractor is highly responsible for the occurrence of equipment category of delay and high significance of project delays to the owner. Thus, the project owners ranked the equipment category of delay in 1st position and contractors ranked it in 3rd position.

Contractor category of delay was ranked in 3rd position by weighted average of SFI. The contractors are highly responsible for occurrence of this delay category rather than the project owners but this causes significant impact on project delays for the owner. Hence, this category of delay was ranked in 2nd position by the owner and the contractor was ranked it in 4th position. It is important to note that the person who is highly responsible of delay category gave it less priority for ranking and conversely, less responsibility of a delay category was given the high priority for ranking the delay category.

Owner category of delay was ranked in 4th position by weighted average of SFI. This category consists of several delay factors such as owner's cash flow problem, delay in release of mobilization advance and delay in approval of interim payments and variation orders. The project owner is highly responsible for occurrence of this delay category and ranked it in 5th position but the contractor is less responsible for occurrence of this delay category and it has high significant effect on the project delays for the contractor. Hence, the contractors ranked it in the 2nd position while the owners ranked it in the fourth position.

Labour category was ranked in 5th position by weighted average of SFI. It consists of various delay factors such as scarcity of skilled labour, idling of labour and conflicts among labours. This delay category was also important to both respondents and ranked it in 4th and 5th positions by the project owner and the contractor respectively.

Owner's site engineer category was ranked in 6th position and it consists of several delay factors such as delay in inspection and testing, delay in issuing instructions and approvals to the contractor and delay to inform scope growth to the owner. This category of delay is equally important to the project owner and the contractor. Therefore, both respondents ranked it in 6th position.

External category of delay was ranked in 7th position by weighted average of SFI. This delay category is divided in two sub-categories: act of man and act of god. The act of man category has several delay factors such as strikes, curfew situations and terrorist attacks. The act of god category consists of several delay factors such as violent weather conditions, landslides and flood conditions. External category of delay is equally important to the project owner and the contractor because both respondents are ranked in 7th position. On the other hand external factor categories have moderate impact on project delays.

6. Rank agreement factor (RAF) of delay category in pre-construction and construction phases.

6.1 Rank agreement factor (RAF) of delay category in pre-construction phase.

According to Table 31, there was a high agreement between the owner and the contractor on the owner category of delay but less agreement with them on the owner's design engineer category.

Table 31 Rank agreement factor (RAF) and percentage agreement (PA) of delay category in pre-construction phase.

Category	RAF	Meaning	PA	Meaning
Owner	11	Moderate	66%	High agreement
Owner's design engineer	17	High	35%	Less agreement

The owner category consists of seven delay factors. Out of them both parties agreed on four delay factors and disagreed on three factors because the delay factors, which are included in owner category mainly occurred due to responsibility of the owner. Therefore, the project owner identified his weakness and marked the delay factors by giving them high priority.

The owner's design engineer category comprises of five delay factors. One out of five of the delay factors both parties agreed on and disagreed on other factors. The owner's design engineer is highly responsible for occurring of this delay factors but the project owner has given less priority to his subordinate weakness and marked them in an irresponsible manner. The contractor has identified the design engineer's weakness and marked them by giving high priority.

As shown in Table 32, there is a high degree of agreement between the project owners and the contractors on the material, labour and external categories, as the agreement is more than 60%. Less degree of agreement is observed on the owner, owner's site engineer, contractor and equipment categories, where the agreement is less than 40%.

Table 32 Rank agreement factor (RAF) and percentage agreement (PA) of delay category in construction phase.

Category	RAF	Meaning	PA	Meaning
Owner	16	High	22%	Less agreement
Owner's site engineer	18	High	9%	Less agreement
Contractor	19	High	34%	Less agreement
Material	9	Moderate	67%	High agreement
Equipment	20	Very high	2%	Very less agreement
Labour	12	High	60%	Moderate agreement
External	7	Less	75%	High agreement

The contractor plays a vital role during the construction phase of the project compared to the owner and owner's site engineer. The results in Table 32 show that both parties tried to highlight the other's weaknesses without honestly highlighting their own weaknesses. As a result, percentage agreement between both parties was less than 40% in owner and contractor categories. Other delay categories including: material, labour and external showed high agreement, which was more than 60% of agreement between the project owner and contractor because those categories have moderate impact on project delays. Therefore, both respondents mostly agreed with the delay factors of each category.

Owner's site engineer is mostly dealing with contractor during construction phase of the project. Obviously, both parties may have contradiction of opinion or disputes between each other relating to the contractual matters. The condition of contract helps both parties, to reach amicable settlement of those raised contradiction of opinion or disputes between each party. Hence, it can be seen that the less agreement (PA= 9%) between the contractor and owner for this owner's site engineer category of delay.

The contractor is being highly responsible for the equipment category of delay due to lack of ownership of required equipment for the contractor is highlighted by the owners and the contractors gave the least priority for the equipment related delays. Hence, the very less agreement (PA = 2%) between the owner and the contractor for this equipment category of delay can be seen.

CONCLUSION AND RECOMMENDATIONS

1. Conclusion

Delays are predominant in Sri Lankan highway construction. A structured questionnaire was developed to gather project participant's opinions on highway construction delays. The questionnaire focused on delay factors in pre-construction and construction phases. Through this study an effort was taken to determine the frequency and severity of delay factors in pre-construction and construction phases in highway construction. Finally, in order to get a fair ranking method of delay factors in highway construction, a realistic ranking method was obtained by ranking all delay factors based on their severity and frequency index (SFI).

In the pre-construction phase, critical delay factors, which were observed according to the respondent's perceptions were frequent changes of design, delay in acquisition of construction site and funding delays respectively. Moreover, further ranking was done based on the delay category, it found that the project owner and the owner's design engineer had the most significant impact on delays in this project phase. Some of the impacts on the pre-construction phase including: difficult to timely start the project as planned, increase additional re-design cost, risk of lost of project fund from donor agency and increase of construction cost. It is the responsibility of the owner to minimize those delays at the pre-construction phase of the project rather than let them accumulate to the construction phase.

In the construction phase, most significant delay factors, which were identified from the respondent's perceptions were contractor's cash flow problem, increased price of materials, scarcity of skilled labour, lack of resources and owner's cash flow problems respectively. Furthermore, ranking was done by considering the category of delays and found that materials, equipment and contractors were more prominent categories of delays in construction phase. Some of the impacts on the construction phase including: increase of the labour rate, increase of the price of materials, low quality of work, increase the construction cost and could not finish the contract on

schedule time. It was revealed that the contractor's performance is the most significant impact on delays in construction phase. However, scarcity of skilled labour, increased price of materials and owner's cash flow problem makes it more vulnerable for the project delays.

In order to determine the different perceptions between owner and contractor rank agreement factor (RAF), percentage agreement (PA) and percentage disagreement (PD) were calculated and found strong agreement in pre-construction phase while less agreement in construction phase because in construction phase both participants tried to hide their own weakness to put blame on the other party.

2. Recommendations

Delay is a critical issue in highway construction in Sri Lanka as half of the projects are delayed and consequently, cost overrun. In order to mitigate construction delays and improve the project performance in highway construction industry, the following recommendations are made on the research's own opinion for the pre-construction and construction phases of the highway projects.(Delay and remedy matrix is attached in appendix E)

2.1 Recommendations for the pre-construction phase

2.1.1 Enhance timely funding for the projects

It has been found that funding delays have a significant impact on project delays in pre-construction and construction phases. Most of the funding for highway constructions is obtained through donor agencies, such as Asian Development Bank (ADB), World Bank (WB) and Japan Bank for International Co-operation (JBIC). These donor agencies have especial guidelines and strategies of funding for construction projects in Asian countries. Thus, the countries have to be fulfilling the donor's minimum requirement for getting funds for the project. Nowadays the donor agencies are more concerned about the Environmental Impact

Assessment (EIA) and Social Impact Assessment (SIA) reports of construction projects. By using expertise knowledge for preparation of required reports in each particular field and timely submission of all required documents according to the donor's expected standards, the timely funding for the projects can be enhanced.

2.1.2 Improve efficiency of land acquisition process of construction industry

Sri Lankan highway construction industry has commonly faced land acquisition problems, during the implementation stages of projects. Most foreign funds as well as domestic funds get accumulated without executing the specific projects during the given time period. These land acquisition problems, which are always dealing with legal issues, most of the time are prolonged and take a minimum of over one year to get settled. It is identified that the main reason of this issue is the government compensation package for acquiring the lands are not sufficient enough compared with the present market value of the same acquired land. Therefore, most of the affected people are protesting against the government for acquiring their own lands for the construction site. This can be minimized by introducing an attractive compensation package equal to the present market value of the land, and in addition to that by giving some attractive ex-gratia payment for the affected people those who early vacate their lands for starting the construction work. Most of the land acquisition problems can be minimized during the design phase of the project by avoiding densely populated areas. Hence, the highway trace could be designed on bare land with less effect to public properties.

2.1.3 Enhancing the designer's efficiency and capacity by reducing mistakes and errors

It was observed that frequent changes of designs have a significant impact on project delays in pre-construction and construction phase. If the designs are changed several times, eventually other contract documents such as drawings, BOQs and specifications have to be changed to suit the designs. Subsequently, this causes

significant impact to starting the contract on schedule. The main reason for this delay is identified as lack of communication between the owner and the design engineer. In order to minimize this delay, both parties should have a proper channel of communication, and the same objective setting, and the designer must be convinced of the actual site condition and the owner's objectives and intended needs of the project before starting the project designs.

Incomplete designs can occur in pre-construction phase and if found out before starting for contract bidding, as making corrections and it tends to delay the bidding process. If those errors in designs are found out after awarding the contract, it has a more significant impact to the project delay in the construction phase because most design errors can be easily found during construction phase. This can be reduced by appointing another designer for re-checking the finished designs and making corrections before issuing them to the bidders.

Design not matched with actual site condition is a predominant delay factor because most designers prefer to stay in the design office and perform the project design works without having thorough knowledge about the site conditions. This can be minimized by motivating the designers for frequent site visits and in each site visit the project owner could introduce an attractive subsistence package for the designer to increase the habit of frequent site visits.

Designer's responsibility is the review of all designs and drawings before the start of the contract bidding. However, if the designer fails to review all designs before the bidding stage of the contract, all errors and missing details of the designs and drawings can be found during the construction phase. In that time correction of designs have a significant effect to the project delay in the construction phase. In order to minimize this cause of delay, after finishing some extent of the project design one or two of the designers in the same design group could be appointed for reviewing all finished designs and drawings for further corrections as fast as possible without delaying the bidding phase of the project.

Success of the project design mainly depends on the experience of the designer. Also the designer has the ability to understand the intended needs of the project owner as well as actual site condition of the project location. An experienced designer knows how to match these two conditions to make success of the project and complete all designs to meet the project goal within given budget and schedule. The selection procedure of an experienced designer is based on the special criteria, such as a minimum of 10 years of similar project experience, member of a professional institution and similar overseas project experiences.

2.1.4 Improve project owner's contract knowledge, efficiency and working capacity

Incomplete bid documents have a significant impact on delays in pre-construction and construction phases because most of the vital data are included to perform the contract in these contract documents. Most contract documents for International Competitive Bidding (ICB) are based on FIDIC conditions of contract and Local Competitive Bidding (LCB) is followed by the ICTAD condition of contract. It is very important to give additional training for the owner to improve the working knowledge of these two contract documents.

In order to minimize delays in approval of designs and bid documents, the project owner must have a group of expert professionals for reviewing and approving all bid documents as per the owner's requirement. This group of expert professionals comprises of contract document specialists, senior quantity surveyor, senior design engineer and senior Auto Cad operator. The project owner can delegate the approving authority of the documents to these professionals on behalf of the owner. Hence, the project owner can increase the working capacity as well as efficiency and timely re-submission of the approved documents for the bidding process.

It is a project owner's responsibility to award the contract and issue a letter of acceptance on time to a contractor. Sometimes, the owner cannot award the contract due to various problems such as land acquisition, funding delay and political interferences that may lead to project delays in pre-construction phase. These land acquisitions can be minimized by introducing attractive compensation packages for affected people and funding delays also can be minimized by timely submission of all required documents to the donor agency. It is very difficult to minimize the political interferences for the contractual matters. However, this problem can be minimized to a certain extend by conducting awareness and training programs for the politicians about the contractual matters.

2.2 Recommendations for the construction phase.

2.2.1 Improve cash flow capacity of contractor

In order to improve the cash flow capacity of the contractor, the owner has to issue the mobilization advance to the contractor at the beginning of the contract. After that, the owner can closely monitor the cash flow pattern of the contractor by requesting a monthly cash flow program. In addition to that the owner can issue mobilization advance in two stages, first half can be issued after the contractor mobilize to the site and the second half can be issued after all required equipment is mobilized to the site. Nowadays, the project owner practices these two methods to avoid misuse of the mobilization advance and improve cash flow capacity of the contractor. Furthermore, the project owner can insist to the contractor to submit interim payment at the end of each month to the owner for the relevant work done in the project.

2.2.2 Increased skilled labour force

In order to increase skilled labour force, government has to establish vocational training centres and try to expand up to the village level to provide more sufficient training for the young generations to improve their skills in the construction

industry. On the other hand, increasing labour wages according to their performance and providing high job security are other methods of retaining more labours within the construction sector.

2.2.3 Control under bidding situation and introduce material management plan

Increased price of construction materials has considerable impact on project delay because most of the contractors are trying to win the contract by under-bidding their bid values due to high competition among the contractors. It is vital to mention that most contractors quote the material prices at the time of the bidding stage, without considering the risk of future price fluctuations in the market. Even though in every contract BOQs are allocated 10 % of the contract amount for the price fluctuations of materials, this is not sufficient to cope with the increased price of materials in the market. Hence, under bidding is the major problem which cannot cope with the increase price of materials.

Scarcity of the required quality of materials in the project location surroundings has a significant impact on project delays. During the bidding stage of the contract, before completing the bid document, it is the contractor's responsibility to visit the project location and carry out a preliminary survey such as, available quarry locations, that the required quantity of materials can be collected within the given distances in the BOQ and the condition of the haulage road from quarry to the site. After the preliminary survey, if it is found that the required quantity of materials cannot be collected within the surrounding location of the project, another alternative is to transport materials from other locations. In this situation, the contractor has to maintain a material management plan. The main advantages of the material management plan include: minimize the wastage of material, total required quantity of material for the project, actual quantity of material for work done, optimum usage of material per day and minimum quantity of material needed per day for carrying out work without idle equipment and labour.

2.2.4 Improve cash flow capacity of owner and restrict the scope growth during construction

Owner's cash flow problem causes high impact on project delays because this can happen due to the allocated fund of the project being used for another purpose such as to settle urgent payments of other ongoing projects, to initiate new projects without having proper budgetary allocations and settling compensation payments for relocation of affected people. As a result, misuse of allocated budget of a particular project causes high severity of project delay. The project owner has to maintain strict financial discipline to control this misuse of project funds and timely submission of required documents to donor agency according to the standard level will leads to improve the cash flow capacity of the owner.

Extra works apart from the scope means that during the construction stage various essential works are accumulating to the scope. If those works are not included to the original scope, those are considered as an extra works. In every BOQ 10% of contract amount is allocated as a contingency which can be used for carrying out essential work apart from the scope during construction. However, the project owner has to pay more attention while deciding the original project scope and share the experience as well as the knowledge with other expert professionals working in the organization. This method of communication is vital for gathering all necessary information to develop the best scope of the project with minimum extra works. Hence, the allocated 10% contingency amount in the BOQ can be used for avoiding the unforeseen ground or weather condition that occurs during the construction.

2.2.5 Improve equipment resource availability

Most of the contractors have less ownership of necessary construction equipment because of high ownership cost, insurance cost and maintenance cost. This will directly affect the quality of the work carried out by the contractor. The government has to arrange some easy payment loan or tax free system for the contractors to purchase these special construction machineries and make some

arrangement for reducing the spare parts cost of these machines. This type of motivation from the government is necessary to uplift the contractor's status in the construction industry.

2.2.6 Proper planning and scheduling

It was identified that successful project completion depends on proper planning and scheduling of resources from the initial stage to the final stage of the project. This can be achieved by recruiting expert professional staff to the contractor's organization. Moreover, it can be easily done by using sophisticated computer software for the project management work including: MS Project and Primavera. In order to achieve continuous usage of resources with minimum idling time, it is vital to implement the new scheduling tools and techniques including: RSM (Repetitive Scheduling Techniques) and PERT (Program Evaluation and Review Techniques). These techniques can be used for effective project management work.

2.2.7 Protection of environment by reducing excessive mining of river sand

Environmental restrictions for mining of materials are new influence factors to the construction industry. These rules are newly imposed by the government to protect the environment due to excessive mining of river sand, which is a very important material for road construction. This environmental damage can be minimized by using alternative methods for river sand, such as manufacturing sand and sea sand. Sand can be manufactured during the rock blasting process, as during the blasting process small particles of remaining rocks are sent through a crusher and to make fine grain and coarse grain sand. Sea sand can be used for the highway construction work by removing salinity from the sand.

2.2.8 Insist to a contractor for timely mobilizing of required machineries to the site

Contractor failure to mobilize required equipment on time has a significant effect on the project delay. Most of the contractors have insufficient ownership of construction machinery. Hence, major equipment that is needed for construction work is deployed to site by renting from other equipment rent companies. During the peak construction time the contractor might not select the required machine for the required work, because the particular machine may not be available in that company. In order to minimize this delay, the project owner must be very strict to the contractor and half of the mobilization advance can be paid to the contractor after mobilizing all required equipment to the site. If the contractor fails to mobilize all the required equipment to the site, in this situation the project owner could stop payment of the contractor's half payment of mobilization advance.

2.2.9 Determine realistic contract time for fixing construction project duration

However, the project duration had not been considered to be a major problem, but the contractors often feel that adequate time is not given to perform the construction work. Therefore, it is vital to estimate realistic contract duration depending upon the various factors including construction material availability and quarry locations, prevailing weather condition, accessibility to the site, complexity of work, traffic condition and method of construction. If the contract duration is realistically estimated the possibilities of extra-claims situations could be minimized in the event of delay.

2.2.10 Introduce bonus clause to the condition of contract

It is noticed that lack of incentives to the contractor for completing the work ahead of the schedule has significant impact on project delay. Hence, it would be wise to include a bonus clause in the condition of contract to motivate the contractor to do the work diligently. However, the caution has to be taken to assign a

realistic contract time because if more time is allocated than required the owner would risk a loss. Likewise, if the contract duration allocated is less than the actual required for the construction the contractor could risk a loss. Furthermore, when a bonus clause is incorporated in the contract, the project owner may be reluctant to grant extension of time in the event of delay.

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APPENDICES

Appendix A

Questionnaire on cause of delays

Please fill in the following details

Personnel Details:

Name: ……..….

Organization: ……..

Email: …….

Tel. No: …….

Designation

□Site Engineer □Project Manager

□Project Engineer □Chief Engineer

Role in construction industry (You can √ only one of each)

□Owner □Designer

□Consultant □Contractor

How long have you been working in construction industry?

□0-5 years □10-20 Years

□5-10 Years □20-30 years

Project Details:

Project Size:

□Large scale □ Medium Scale □ Small scale

Contract Type:

□Unit price □ Lump sum □ Cost reimbursable

Note:

1. Please select and put **(X)** on the frequency of occurrence based on your experience and following criteria.

1 = Cause happening ≤ once in a year

2 = Cause happening once in a six month

3 = Cause happening once in three month

4 = Cause happening once in two month

5= Cause happening ≥once in a month

2. Please select and put **(X)** mark on the severity index based on your experience and judgment.

Appendix Table A1 Pre-construction phase: Project owner

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Incomplete bid document	1	2	3	4	5	1	2	3	4	5
2	Incomplete design	1	2	3	4	5	1	2	3	4	5
3	Funding delays	1	2	3	4	5	1	2	3	4	5
4	Delay in review and approval of bid documents and design	1	2	3	4	5	1	2	3	4	5
5	Delay in evaluation of bid documents	1	2	3	4	5	1	2	3	4	5
6	Delays in awarding of contract and issuing letter of acceptance	1	2	3	4	5	1	2	3	4	5
7	Delay in acquisition of construction site	1	2	3	4	5	1	2	3	4	5

Appendix Table A 2 Pre-construction phase: Project owner's design engineer

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Design not matched with actual site condition.	1	2	3	4	5	1	2	3	4	5
2	Lack of review of all designs and drawings before issue to the contractor	1	2	3	4	5	1	2	3	4	5
3	Frequent changes of design	1	2	3	4	5	1	2	3	4	5
4	Relocation of people due to construction not minimized during design stage	1	2	3	4	5	1	2	3	4	5
5	Inexperience design Engineer	1	2	3	4	5	1	2	3	4	5

Appendix Table A 3 Construction phase: Project owner

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Delay in handing over the Site to the contractor	1	2	3	4	5	1	2	3	4	5
2	Delay in release of mobilization advance	1	2	3	4	5	1	2	3	4	5
3	Lack of issuing of necessary instructions and approvals	1	2	3	4	5	1	2	3	4	5
4	Extra work apart from the scope	1	2	3	4	5	1	2	3	4	5
5	Delay in testing of materials and approvals	1	2	3	4	5	1	2	3	4	5
6	Actual site conditions are differing from the design condition	1	2	3	4	5	1	2	3	4	5
7	Lack of communication and team work	1	2	3	4	5	1	2	3	4	5
8	Delay in approval of variation orders and interim payments	1	2	3	4	5	1	2	3	4	5
9	Owners cash flow problem	1	2	3	4	5	1	2	3	4	5
10	Lack of ability of decision making	1	2	3	4	5	1	2	3	4	5
11	Suspension of work	1	2	3	4	5	1	2	3	4	5

Appendix Table A 4 Construction phase: Project owner's site engineer

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Less experience in construction work	1	2	3	4	5	1	2	3	4	5
2	Delay in issuing instructions and approvals	1	2	3	4	5	1	2	3	4	5
3	Lack of communication with contractor's technical and other staff	1	2	3	4	5	1	2	3	4	5
4	Delay in evaluation of interim payment and variation orders	1	2	3	4	5	1	2	3	4	5
5	By issuing of wrong instructions increase of rework	1	2	3	4	5	1	2	3	4	5
6	Delay in inspection and testing	1	2	3	4	5	1	2	3	4	5
7	Late approval of shop drawings	1	2	3	4	5	1	2	3	4	5
8	Delay to inform scope growth to the owner	1	2	3	4	5	1	2	3	4	5
9	Conflicts between site engineer and contractor	1	2	3	4	5	1	2	3	4	5
10	Lack of maintaining and follow up contract documentations	1	2	3	4	5	1	2	3	4	5

Appendix Table A 5 Construction phase: Contractor

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Delay in site mobilization	1	2	3	4	5	1	2	3	4	5
2	Lack of professional engineers and other technical staff	1	2	3	4	5	1	2	3	4	5
3	Cash flow problem	1	2	3	4	5	1	2	3	4	5
4	Lack of resources	1	2	3	4	5	1	2	3	4	5
5	Poor planning and scheduling	1	2	3	4	5	1	2	3	4	5
6	Poor communication, coordination and team work with other parties	1	2	3	4	5	1	2	3	4	5
7	Poor management	1	2	3	4	5	1	2	3	4	5
8	Actual site condition differing with specification and drawings	1	2	3	4	5	1	2	3	4	5
9	Difference of actual and BOQ's quantities	1	2	3	4	5	1	2	3	4	5
10	Increase amount of rework	1	2	3	4	5	1	2	3	4	5
11	Method of construction is differing with specification	1	2	3	4	5	1	2	3	4	5
12	Inadequate construction experience	1	2	3	4	5	1	2	3	4	5
13	Conflicts between the contactor and other parties	1	2	3	4	5	1	2	3	4	5

Appendix Table A 6 Construction phase: Material

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Approval of required quality of material	1	2	3	4	5	1	2	3	4	5
2	Actual transported material deferring with approved quality	1	2	3	4	5	1	2	3	4	5
3	Scarcity of material	1	2	3	4	5	1	2	3	4	5
4	Less transportation facility to transport material	1	2	3	4	5	1	2	3	4	5
5	Increase of the price of material	1	2	3	4	5	1	2	3	4	5
6	Lack of additional stocks of material	1	2	3	4	5	1	2	3	4	5
7	Protection of material from weather until it uses for the construction	1	2	3	4	5	1	2	3	4	5
8	Procurement delay in special kind of material	1	2	3	4	5	1	2	3	4	5
9	Environmental restriction for manufacturing and mining of material	1	2	3	4	5	1	2	3	4	5

Appendix Table A 7 Construction phase: Equipment

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Contractor unable to mobilize required equipments on time	1	2	3	4	5	1	2	3	4	5
2	Hiring of main equipment	1	2	3	4	5	1	2	3	4	5
3	Break down of equipment	1	2	3	4	5	1	2	3	4	5
4	Deploying less efficiency and old equipment	1	2	3	4	5	1	2	3	4	5
5	Due to lack of skill operators will increase rework	1	2	3	4	5	1	2	3	4	5
6	Lack of substitution of essential equipment	1	2	3	4	5	1	2	3	4	5
7	Idling of equipment	1	2	3	4	5	1	2	3	4	5

Appendix Table A 8 Construction phase: Labour

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Scarcity of Skilled Labour	1	2	3	4	5	1	2	3	4	5
2	Lack of supervision and not assign specific work to each labour	1	2	3	4	5	1	2	3	4	5
3	Mismanagement of labour	1	2	3	4	5	1	2	3	4	5
4	Labour laws and regulations	1	2	3	4	5	1	2	3	4	5
5	Idling of labour	1	2	3	4	5	1	2	3	4	5
6	Conflicts among labours	1	2	3	4	5	1	2	3	4	5

Appendix Table A 9 Construction phase: Act of Man

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Strikes	1	2	3	4	5	1	2	3	4	5
2	High traffic jams	1	2	3	4	5	1	2	3	4	5
3	Riots and terrorists attacks	1	2	3	4	5	1	2	3	4	5
4	Violations of acts, rules and regulations of other organizations	1	2	3	4	5	1	2	3	4	5
5	Curfew situation	1	2	3	4	5	1	2	3	4	5
6	Judicial actions	1	2	3	4	5	1	2	3	4	5

Appendix Table A 10 Construction phase: Act of God

SN	Delay factors	Frequency of occurrence					Severity index				
		No	Rare	Medium	Often	Very often	No	Very low	Medium	High	Very High
1	Violent weather condition	1	2	3	4	5	1	2	3	4	5
2	Land slides	1	2	3	4	5	1	2	3	4	5
3	Flood condition	1	2	3	4	5	1	2	3	4	5

Note: Please feel free to add any other factors which may have been missed out in the list

Appendix B

Ranking of all delay factors in frequency of occurrence

Appendix Table B1 Delay factors by frequency of occurrence in pre-construction phase

Delay factors	Mean	SD	FOI	Rank
Incomplete bid document	2.450	1.045	0.490	10
Incomplete design	2.780	0.986	0.556	5
Funding delays	3.120	1.243	0.624	2
Delay in review and approval of bid documents and designs	2.570	0.900	0.514	7
Delay in evaluation of bid documents.	2.350	0.913	0.470	11
Delays in awarding of contract and issuing letter of acceptance	2.450	0.987	0.490	9
Delay in acquisition of construction site	3.040	1.148	0.608	3
Design not matched with actual site condition	2.800	0.939	0.560	4
Lack of review of all designs and drawings before issuing to the contractor	2.730	0.896	0.546	6
Frequent changes of design	3.290	0.944	0.658	1
Relocation of people due to construction not minimized during design stage	2.310	0.927	0.462	12
Inexperience design engineer	2.450	0.857	0.490	8

Appendix Table B2 Delay factors by frequently happening in construction phase

Delay factors	Mean	SD	FOI	Rank
Delay in handing over the Site to the contractor	2.450	0.832	0.490	53
Delay in release of mobilization advance	2.690	1.029	0.538	41
Lack of issuing of necessary instructions and approvals	2.690	0.883	0.538	40
Extra work apart from the Scope	3.430	0.781	0.686	8
Delay in testing of materials and approvals	2.670	0.841	0.534	43
Actual site conditions are differing from the design condition	2.750	0.688	0.550	36
Lack of communication and team work	2.330	0.622	0.466	57
Delay in approval of variation orders and interim payments	3.100	0.878	0.620	18
Owners cash flow problem	3.550	1.101	0.710	4
Lack of ability of decision making	2.820	0.767	0.564	31
Suspension of work	2.350	0.716	0.470	55
Less experience in construction work	2.800	0.825	0.560	33
Delay in issuing instructions and approvals	2.820	0.684	0.564	30
Lack of communication with contractors technical and other staff	2.550	0.783	0.510	50

Appendix Table B2 (continued)

Delay factors	Mean	SD	FOI	Rank
Delay in evaluation of interim payment and variation orders	2.690	0.812	0.538	39
By issuing of wrong instructions increase of rework	2.310	0.905	0.462	59
Delay in inspection and testing	2.530	0.758	0.506	51
Late approval of shop drawings	2.570	0.781	0.514	49
Delay to inform scope growth to the owner	2.330	0.766	0.466	58
Conflicts between site engineer and contractor	2.470	0.946	0.494	52
Lack of maintaining and follow up contract documentations	2.650	0.770	0.530	45
Delay in site mobilization	2.882	0.846	0.576	25
Lack of professional engineers and other technical staff	3.353	0.868	0.671	9
Contractors cash flow problem	3.608	0.961	0.722	3
Lack of resources. (Man, Money, Material and Machines.)	3.510	0.903	0.702	5
Poor planning and scheduling	3.314	0.927	0.663	10
Poor communication, coordination and team work with other parties	2.824	0.775	0.565	29
Poor management. (Money, Time and Resources)	3.020	0.860	0.604	23

Appendix Table B2 (continued)

Delay factors	Mean	SD	FOI	Rank
Actual site condition differing with specification and drawings	2.765	0.737	0.553	35
Difference of actual and BOQ's quantities	3.137	0.849	0.627	16
Increase amount of rework	2.804	0.800	0.561	32
Method of construction is differing with specification	2.627	0.699	0.525	47
Inadequate construction experience	2.686	0.761	0.537	42
Conflicts between the contactor and other parties	2.431	0.671	0.486	54
Approval of required quality of material	2.863	0.825	0.573	28
Actual transported material deferring with approved quality	2.745	0.845	0.549	37
Scarcity of material	3.490	0.925	0.698	6
Less transportation facility to transport material	2.667	0.766	0.533	44
Increase of the price of material	3.804	0.722	0.761	1
Lack of additional stocks of material	3.157	0.784	0.631	13
Protection of material from weather until it uses for the construction	2.647	0.688	0.529	46
Procurement delay in special kind of material	3.078	0.926	0.616	20
Environmental restriction for manufacturing and mining of material	3.471	1.027	0.694	7
Contractor unable to mobilize required equipments on time	3.235	1.031	0.647	11
Hiring of main equipment	3.098	1.005	0.620	19
Break down of equipment	3.137	0.775	0.627	15

Appendix Table B2 (continued)

Delay factors	Mean	SD	FOI	Rank
Deploying less efficiency and old equipment	3.176	0.974	0.635	12
Due to lack of Skill operators will increase rework	3.020	0.786	0.604	22
Lack of substitution of essential equipment	3.020	0.969	0.604	24
Idling of equipment	3.118	0.952	0.624	17
Scarcity of skilled labour	3.725	0.961	0.745	2
Lack of supervision and assign specific work to each labour	3.039	0.692	0.608	21
Mismanagement of labour	2.706	0.666	0.541	38
Labour laws and regulations	2.784	0.879	0.557	34
Idling of labour	2.863	0.800	0.573	27
Conflicts among labours	2.333	0.683	0.467	56
Strikes	2.078	0.717	0.416	62
High traffic jams	2.882	0.864	0.576	26
Riots and terrorists attacks	2.176	0.932	0.435	60
Violations of acts, rules and regulations of other organizations	2.157	0.703	0.431	61
Curfew situation	1.092	1.095	0.218	65
Judicial actions	1.843	0.543	0.369	64
Violent weather condition	3.157	0.946	0.631	14
Land slides	2.039	0.999	0.408	63
Flood condition	2.588	0.831	0.518	48

Appendix Table B3 Different perceptions of project participants of delay category in pre-construction phase

Delay categories	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
Owner	0.528	1	0.545	2	0.537	2
Owner's design engineer	0.502	2	0.603	1	0.553	1

Appendix Table B4 Different perceptions of project participants of delay category in construction phase

Delay categories	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
Owner	0.527	4	0.608	2	0.567	4
Owner's site engineer	0.495	6	0.542	5	0.519	5
Contractor	0.618	2	0.572	4	0.595	3
Material	0.613	3	0.632	1	0.622	1
Equipment	0.650	1	0.588	3	0.619	2
Labour	0.504	5	0.493	6	0.498	6
External	0.458	7	0.470	7	0.464	7

Appendix Table B5 Different perceptions of project participants in pre-construction Phase

Delay factors	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
Incomplete bid document	0.480	8	0.504	10	0.492	9
Incomplete designs	0.520	4	0.610	4	0.565	5
Funding delays	0.627	2	0.619	3	0.623	2
Delay in review and approval of bid documents and designs	0.498	7	0.533	8	0.516	7
Delay in evaluation of bid documents	0.467	10	0.476	12	0.472	11
Delays in awarding of contract and issuing letter of acceptance	0.473	9	0.505	9	0.489	10
Delay in acquisition of construction site	0.633	1	0.571	6	0.602	3
Designs not matched with actual site condition	0.500	6	0.648	2	0.574	4
Lack of review of all designs and drawings before issue to the contractor	0.519	5	0.581	5	0.550	6
Frequently changes of design	0.607	3	0.733	1	0.670	1
Relocation of people due to construction not minimized during design stage	0.433	12	0.502	11	0.468	12
Inexperience design engineer	0.453	11	0.552	7	0.503	8

Appendix Table B 6 Different perceptions of project participants in construction Phase

Delay factors	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
Delay in handing over the Site to the contractor	0.440	60	0.562	34	0.501	52
Delay in release of mobilization advance	0.500	47	0.590	25	0.545	40
Lack of issuing of necessary instructions and approvals	0.467	55	0.638	12	0.553	37
Extra work apart from the scope	0.672	9	0.705	6	0.689	8
Delay in testing of materials and approvals	0.500	46	0.581	30	0.541	42
Actual site conditions are differing from the design condition	0.507	45	0.610	16	0.559	33
Lack of communication and team work	0.467	53	0.467	57	0.467	58
Delay in approval of variation orders and interim payments	0.573	26	0.685	8	0.629	15
Owners cash flow problem	0.667	10	0.771	3	0.719	3
Lack of ability of decision making	0.533	39	0.600	19	0.567	29
Suspension of work	0.467	54	0.476	54	0.472	56
Less experience in construction work	0.573	27	0.543	40	0.558	35
Delay in issuing instructions and	0.547	34	0.590	26	0.569	28
Lack of communication with contractors technical and other staff	0.500	48	0.524	49	0.512	50
Delay in evaluation of interim payment and variation orders	0.473	52	0.629	14	0.551	39

Appendix Table B6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
By issuing of wrong instructions increase of rework	0.420	61	0.524	50	0.472	55
Delay in inspection and testing	0.487	50	0.533	48	0.510	51
Late approval of shop drawings	0.460	56	0.590	27	0.525	48
Delay to inform scope growth to the owner	0.460	57	0.476	55	0.468	57
Conflicts between site engineer and contractor	0.507	44	0.476	56	0.492	53
Lack of maintaining and follow up contract documentations	0.527	40	0.533	45	0.530	44
Delay in site mobilization	0.600	24	0.543	42	0.572	27
Lack of professional engineers and other technical staff	0.746	3	0.562	35	0.654	9
Contractors cash flow problem	0.747	2	0.686	7	0.717	4
Lack of resources. (Man, Money, Material and Machines.)	0.727	4	0.667	9	0.697	7
Poor planning and scheduling	0.720	5	0.581	31	0.651	10
Poor communication, coordination and team work with other parties	0.573	28	0.543	43	0.558	34
Poor management. (Money, Time and Resources)	0.640	16	0.552	36	0.596	24
Actual site condition differing with specification and drawings	0.520	41	0.600	20	0.560	32
Difference of actual and BOQ's quantities	0.613	22	0.648	11	0.631	14

Appendix Table B6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
Increase amount of rework	0.533	38	0.600	21	0.567	30
Method of construction is differing with specification	0.513	43	0.543	41	0.528	46
Inadequate construction experience	0.573	29	0.486	53	0.530	45
Conflicts between the contactor and other parties	0.533	37	0.419	59	0.476	54
Approval of required quality of material	0.573	30	0.571	32	0.572	26
Actual transported material deferring with approved quality	0.533	36	0.571	33	0.552	38
Scarcity of material	0.640	15	0.781	2	0.711	5
Less transportation facility to transport material	0.520	42	0.552	39	0.536	43
Increase of the price of material	0.787	1	0.724	5	0.756	2
Lack of additional stocks of material	0.653	12	0.600	22	0.627	17
Protection of material from weather until it uses for the construction	0.540	35	0.514	52	0.527	47
Procurement delay in special kind of material	0.620	20	0.610	18	0.615	18
Environmental restriction for manufacturing and mining of material	0.647	13	0.762	4	0.705	6
Contractor unable to mobilize required equipments on time	0.687	6	0.590	23	0.639	11
Hiring of main equipment	0.647	14	0.581	29	0.614	19
Break down of equipment	0.613	21	0.648	10	0.631	13

Appendix Table B6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	FOI	Rank	FOI	Rank	FOI	Rank
Deploying less efficiency and old equipment	0.667	11	0.590	24	0.629	16
Due to lack of Skill operators will increase rework	0.607	23	0.619	15	0.613	20
Lack of substitution of essential equipment	0.640	18	0.552	37	0.596	23
Idling of equipment	0.686	7	0.533	46	0.610	21
Scarcity of skilled labour	0.673	8	0.848	1	0.761	1
Lack of supervision and assign specific work to each labour	0.627	19	0.581	28	0.604	22
Mismanagement of labour	0.560	32	0.524	51	0.542	41
Labour laws and regulations	0.567	31	0.543	44	0.555	36
Idling of labour	0.600	25	0.533	47	0.567	31
Conflicts among labours	0.500	49	0.419	60	0.460	59
Strikes	0.380	64	0.467	58	0.424	62
High traffic jams	0.553	33	0.610	17	0.582	25
Riots and terrorists attacks	0.460	58	0.400	63	0.430	60
Violations of acts, rules and regulations of other organizations	0.453	59	0.400	62	0.427	61
Curfew situation	0.387	63	0.371	65	0.379	64
Judicial actions	0.360	65	0.381	64	0.371	65
Violent weather condition	0.640	17	0.629	13	0.635	12
Land slides	0.400	62	0.419	61	0.410	63
Flood condition	0.487	51	0.552	38	0.520	49

Appendix Table B7 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner category in pre-construction phase

Delay factors in owner category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Incomplete bid document	0.480	59	0.505	62
Incomplete design	0.520	44	0.610	21
Funding delays	0.627	20	0.619	18
Delay in review and approval of bid documents and designs	0.500	53	0.533	53
Delay in evaluation of bid documents.	0.467	64	0.476	66
Delays in awarding of contract and issuing letter of acceptance	0.473	60	0.505	61
Delay in acquisition of construction site	0.633	19	0.571	37

RAF = 7.0 PA = 77% PD =23%

Appendix Table B8 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner's design engineer category in pre-construction phase

Delay factors in owner's design engineer category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Design not matched with actual site condition	0.500	52	0.648	13
Lack of review of all designs and drawings before issue to the contractor	0.520	45	0.581	35
Frequently changes of design	0.607	25	0.733	5
Relocation of people due to construction not minimized during design stage	0.433	72	0.505	63
Inexperience design engineer	0.453	70	0.552	43

RAF = 21.0 PA = 25% PD = 75%

Appendix Table B9 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner category in construction phase

Delay factors in owner category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Delay in handing over the Site to the contractor	0.440	71	0.562	40
Delay in release of mobilization advance	0.500	54	0.590	29
Lack of issuing of necessary instructions and approvals	0.467	63	0.638	14
Extra work apart from the Scope	0.673	9	0.705	7
Delay in testing of materials and approvals	0.500	51	0.581	34
Actual site conditions are differing from the design condition	0.507	50	0.610	19
Lack of communication and team work	0.467	62	0.467	69
Delay in approval of variation orders and interim payments	0.573	29	0.686	9
Owners cash flow problem	0.667	10	0.771	3
Lack of ability of decision making	0.533	42	0.600	23
Suspension of work	0.467	65	0.476	65

RAF = 19.0 PA =13% PD = 87%

Appendix Table B10 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner's site engineer category in construction phase

Delay factors in owner's site engineer category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Less experience in construction work	0.573	30	0.543	47
Delay in issuing instructions and approvals	0.547	37	0.590	30
Lack of communication with contractors technical and other staff	0.500	55	0.524	57
Delay in evaluation of interim payment and variation orders	0.473	61	0.629	16
By issuing of wrong instructions increase of rework	0.420	73	0.524	58
Delay in inspection and testing	0.487	57	0.533	56
Late approval of shop drawings	0.460	66	0.590	31
Delay to inform scope growth to the owner	0.460	67	0.476	67
Conflicts between site engineer and contractor	0.507	49	0.476	68
Lack of maintaining and follow up contract documentations	0.527	43	0.533	52

RAF = 15.0 PA = 23% PD = 77%

Appendix Table B11 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of contractor category in construction phase

Delay factors in contractor category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Delay in site mobilization	0.600	27	0.543	49
Lack of professional engineers and other technical staff	0.747	3	0.562	41
Contractors cash flow problem	0.747	2	0.686	8
Lack of resources. (Man, Money, Material and Machines.)	0.727	4	0.667	10
Poor planning and scheduling	0.720	5	0.581	36
Poor communication, coordination and team work with other parties	0.573	31	0.543	50
Poor management. (Money, Time and Resources)	0.640	16	0.552	42
Actual site condition differing with specification and drawings	0.520	46	0.600	24
Difference of actual and BOQ's quantities	0.613	24	0.648	12
Increase amount of rework	0.533	41	0.600	25
Method of construction is differing with specification	0.513	48	0.543	48
Inadequate construction experience	0.573	32	0.486	64
Conflicts between the contactor and other parties	0.533	40	0.419	71

RAF = 20.0 PA =18% PD = 82%

Appendix Table B12 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of material category in construction phase

Delay factors in material category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Approval of required quality of material	0.573	33	0.571	38
Actual transported material deferring with approved quality	0.533	39	0.571	39
Scarcity of material	0.640	15	0.781	2
Less transportation facility to transport material	0.520	47	0.552	46
Increase of the price of material	0.787	1	0.724	6
Lack of additional stocks of material	0.653	12	0.600	26
Protection of material from weather until it uses for the construction	0.540	38	0.514	60
Procurement delay in special kind of material	0.620	22	0.610	22
Environmental restriction for manufacturing and mining of material	0.647	13	0.762	4

RAF = 8.0 PA = 70% PD = 30%

Appendix Table B13 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of equipment category in construction phase

Delay factors in equipment category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Contractor unable to mobilize required equipments on time	0.687	6	0.590	27
Hiring of main equipment	0.647	14	0.581	33
Break down of equipment	0.613	23	0.648	11
Deploying less efficiency and old equipment	0.667	11	0.590	28
Due to lack of Skill operators will increase rework	0.607	26	0.619	17
Lack of substitution of essential equipment	0.640	18	0.552	44
Idling of equipment	0.687	7	0.533	54

RAF = 22.0 PA =0% PD = 100%

Appendix Table B14 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of labour category in construction phase

Delay factors in labour category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Scarcity of skilled labour	0.673	8	0.848	1
Lack of supervision and not assign specific work to each labour	0.627	21	0.581	32
Mismanagement of labour	0.560	35	0.524	59
Labour laws and regulations	0.567	34	0.543	51
Idling of labour	0.600	28	0.533	55
Conflicts among labours	0.500	56	0.419	72

RAF = 17.0 PA = 48% PD = 52%

Appendix Table B15 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of act of man category in construction phase

Delay factors in act of man category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Strikes	0.380	76	0.467	70
High traffic jams	0.553	36	0.610	20
Riots and terrorists attacks	0.460	68	0.400	75
Violations of acts, rules and regulations of other organizations	0.453	69	0.400	74
Curfew situation	0.387	75	0.371	77
Judicial actions	0.360	77	0.381	76

RAF = 6.0 PA = 68% PD = 32%

Appendix Table B16 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of act of god category in construction phase

Delay factors in act of god category	Owner's view		Contractor's view	
	FOI	Rank	FOI	Rank
Violent weather condition	0.640	17	0.629	15
Land slides	0.400	74	0.419	73
Flood condition	0.487	58	0.552	45

RAF = 5.0 PA = 78% PD = 22%

Appendix C

Ranking of all delay factors in severity

Appendix Table C1 Delay factors by severity in pre-construction phase

Delay factors	Mean	SD	RII	Rank
Incomplete bid document	3.275	1.281	0.655	5
Incomplete design	3.392	1.133	0.678	4
Funding delays	3.510	1.332	0.702	3
Delay in review and approval of bid documents and designs	2.804	1.077	0.561	9
Delay in evaluation of bid documents	2.647	1.074	0.529	12
Delays in awarding of contract and issuing letter of acceptance	2.863	1.000	0.573	8
Delay in acquisition of construction site	3.745	1.111	0.749	1
Design not matched with actual site condition	3.255	1.036	0.651	6
Lack of review of all designs and drawings before issue to the contractor	3.000	0.849	0.600	7
Frequently changes of design	3.549	1.026	0.710	2
Relocation of people due to construction not minimized during design stage	2.686	1.241	0.537	11
Inexperience design engineer	2.725	1.060	0.545	10

Appendix Table C2 Delay factors by severity in construction phase

Delay factors	Mean	SD	RII	Rank
Delay in handing over the Site to the contractor	3.333	1.260	0.667	17
Delay in release of mobilization advance	3.098	1.188	0.620	27
Lack of issuing of necessary instructions and approvals	2.922	0.714	0.584	38
Extra work apart from the Scope	3.608	1.002	0.722	9
Delay in testing of materials and approvals	2.784	0.856	0.557	49
Actual site conditions are differing from the design condition	3.118	0.952	0.624	25
Lack of communication and team work	2.549	0.808	0.510	58
Delay in approval of variation orders and interim payments	3.353	1.110	0.671	16
Owners cash flow problem	3.902	1.171	0.780	3
Lack of ability of decision making	2.980	0.905	0.596	33
Suspension of work	3.294	1.346	0.659	19
Less experience in construction work	2.863	0.895	0.573	45
Delay in issuing instructions and approvals	3.000	0.849	0.600	31
Lack of communication with contractors technical and other staff	2.608	0.850	0.522	56

Appendix Table C2 (continued)

Delay factors	Mean	SD	RII	Rank
Delay in evaluation of interim payment and variation orders	3.059	1.103	0.612	30
By issuing of wrong instructions increase of rework	2.902	1.153	0.580	41
Delay in inspection and testing	2.745	0.868	0.549	50
Late approval of shop drawings	2.824	0.842	0.565	47
Delay to inform scope growth to the owner	2.627	0.894	0.525	55
Conflicts between site engineer and contractor	2.529	0.987	0.506	59
Lack of maintaining and follow up contract documentations	2.686	0.812	0.537	52
Delay in site mobilization	3.627	1.280	0.725	8
Lack of professional engineers and other technical staff	3.510	0.880	0.702	12
Contractors cash flow problem	4.059	1.085	0.812	1
Lack of resources. (Man, Money, Material and Machines.)	3.961	0.958	0.792	2
Poor planning and scheduling	3.569	0.900	0.714	11
Poor communication, coordination and team work with other parties	2.784	0.832	0.557	48
Poor management. (Money, Time and Resources)	3.392	1.060	0.678	15

Appendix Table C2 (continued)

Delay factors	Mean	SD	RII	Rank
Actual site condition differing with specification and drawings	2.961	0.848	0.592	36
Difference of actual and BOQ's quantities	3.059	0.925	0.612	29
Increase amount of rework	3.078	1.036	0.616	28
Method of construction is differing with specification	2.627	0.692	0.525	54
Inadequate construction experience	2.922	0.845	0.584	39
Conflicts between the contactor and other parties	2.569	0.922	0.514	57
Approval of required quality of material	2.941	0.904	0.588	37
Actual transported material deferring with approved quality	2.961	0.824	0.592	34
Scarcity of material	3.843	1.155	0.769	5
Less transportation facility to transport material	2.882	0.840	0.576	43
Increase of the price of material	3.784	0.808	0.757	6
Lack of additional stocks of material	3.196	0.749	0.639	21
Protection of material from weather until it uses for the construction	2.667	0.739	0.533	53
Procurement delay in special kind of material	3.451	1.154	0.690	14
Environmental restriction for manufacturing and mining of material	3.588	1.214	0.718	10
Contractor unable to mobilize required equipments on time	3.667	1.077	0.733	7
Hiring of main equipment	3.216	1.045	0.643	20
Break down of equipment	3.294	0.986	0.659	18

Appendix Table C2 (continued)

Delay factors	Mean	SD	RII	Rank
Deploying less efficiency and old equipment	3.196	0.960	0.639	22
Due to lack of Skill operators will increase rework	3.176	0.974	0.635	23
Lack of substitution of essential equipment	3.098	0.922	0.620	26
Idling of equipment	3.000	0.959	0.600	32
Scarcity of skilled labour	3.863	1.114	0.773	4
Lack of supervision and assign specific work to each labour	2.961	0.827	0.592	35
Mismanagement of labour	2.902	0.944	0.580	40
Labour laws and regulations	2.745	0.935	0.549	51
Idling of labour	2.843	0.903	0.569	46
Conflicts among labours	2.333	0.841	0.467	62
Strikes	2.882	1.409	0.576	44
High traffic jams	3.176	1.090	0.635	24
Riots and terrorists attacks	2.529	1.224	0.506	60
Violations of acts, rules and regulations of other organizations	2.333	0.997	0.467	63
Curfew situation	2.118	1.125	0.424	65
Judicial actions	2.196	1.132	0.439	64
Violent weather condition	3.510	1.102	0.702	13
Land slides	2.353	1.197	0.471	61
Flood condition	2.902	1.188	0.580	42

Appendix Table C3 Different perceptions of project participants of delay category in pre-construction phase

Delay categories	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
Owner	0.573	1	0.725	1	0.649	1
Owner's design engineer	0.544	2	0.701	2	0.623	2

Appendix Table C4 Different perceptions of project participants of delay category in construction phase

Delay categories	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
Owner	0.573	4	0.724	2	0.649	4
Owner's site engineer	0.529	5	0.596	5	0.563	5
Contractor	0.628	1	0.677	3	0.652	2
Material	0.598	3	0.732	1	0.665	1
Equipment	0.626	2	0.676	4	0.651	3
Labour	0.471	7	0.557	7	0.514	7
External	0.494	6	0.590	6	0.542	6

Appendix Table C5 Different perceptions of project participants in pre-construction phase

Delay factors	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
Incomplete bid document	0.547	8	0.810	4	0.679	5
Incomplete designs	0.580	4	0.800	5	0.690	4
Funding delays	0.633	2	0.820	2	0.727	3
Delay in review and approval of bid documents and designs	0.520	10	0.619	9	0.570	9
Delay in evaluation of bid documents	0.480	11	0.600	11	0.540	11
Delays in awarding of contract and issuing letter of acceptance	0.552	7	0.610	10	0.581	8
Delay in acquisition of construction site	0.700	1	0.819	3	0.760	1
Designs not matched with actual site condition	0.567	5	0.771	6	0.669	6
Lack of review of all designs and drawings before issue to the contractor	0.553	6	0.667	7	0.610	7
Frequently changes of design	0.600	3	0.867	1	0.734	2
Relocation of people due to construction not minimized during design stage	0.473	12	0.629	8	0.551	10
Inexperience design engineer	0.527	9	0.571	12	0.549	12

Appendix Table C 6 Different perceptions of project participants in construction phase

Delay factors	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
Delay in handing over the Site to the contractor	0.567	29	0.810	11	0.689	16
Delay in release of mobilization advance	0.547	37	0.724	21	0.636	25
Lack of issuing of necessary instructions and approvals	0.533	46	0.657	34	0.595	38
Extra work apart from the scope	0.640	13	0.837	8	0.739	9
Delay in testing of materials and approvals	0.520	52	0.610	44	0.565	48
Actual site conditions are differing from the design condition	0.573	26	0.695	24	0.634	26
Lack of communication and team work	0.533	47	0.476	59	0.505	58
Delay in approval of variation orders and interim payments	0.567	28	0.819	10	0.693	15
Owners cash flow problem	0.680	7	0.924	2	0.802	2
Lack of ability of decision making	0.567	30	0.638	38	0.603	35
Suspension of work	0.580	24	0.771	15	0.676	18
Less experience in construction work	0.547	38	0.610	45	0.579	44
Delay in issuing instructions and approvals	0.573	27	0.638	39	0.606	32
Lack of communication with contractors technical and other staff	0.533	48	0.505	58	0.519	56
Delay in evaluation of interim payment and variation orders	0.527	50	0.733	18	0.630	28

Appendix Table C6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
By issuing of wrong instructions increase of rework	0.520	53	0.667	33	0.594	39
Delay in inspection and testing	0.513	54	0.600	47	0.557	50
Late approval of shop drawings	0.507	55	0.648	35	0.578	45
Delay to inform scope growth to the owner	0.500	57	0.562	49	0.531	55
Conflicts between site engineer and contractor	0.540	42	0.457	62	0.499	60
Lack of maintaining and follow up contract documentations	0.533	49	0.543	52	0.538	52
Delay in site mobilization	0.647	12	0.838	7	0.743	8
Lack of professional engineers and other technical staff	0.720	3	0.676	29	0.698	14
Contractors cash flow problem	0.760	1	0.886	5	0.823	1
Lack of resources. (Man, Money, Material and Machines.)	0.747	2	0.857	6	0.802	3
Poor planning and scheduling	0.707	4	0.724	20	0.716	11
Poor communication, coordination and team work with other parties	0.560	33	0.552	51	0.556	51
Poor management. (Money, Time and Resources)	0.673	8	0.686	27	0.680	17
Actual site condition differing with specification and drawings	0.540	43	0.667	32	0.604	33
Difference of actual and BOQ's quantities	0.560	34	0.686	28	0.623	29

Appendix Table C 6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
Increase amount of rework	0.547	39	0.714	22	0.631	27
Method of construction is differing with specification	0.500	58	0.562	50	0.531	54
Inadequate construction experience	0.620	16	0.533	55	0.577	46
Conflicts between the contactor and other parties	0.580	25	0.419	65	0.500	59
Approval of required quality of material	0.547	40	0.648	36	0.598	37
Actual transported material deferring with approved quality	0.560	35	0.638	40	0.599	36
Scarcity of material	0.660	9	0.923	3	0.792	5
Less transportation facility to transport material	0.547	41	0.619	42	0.583	43
Increase of the price of material	0.706	5	0.829	9	0.768	6
Lack of additional stocks of material	0.607	22	0.686	26	0.647	22
Protection of material from weather until it uses for the construction	0.527	51	0.543	53	0.535	53
Procurement delay in special kind of material	0.613	17	0.800	12	0.707	13
Environmental restriction for manufacturing and mining of material	0.613	18	0.905	4	0.759	7
Contractor unable to mobilize required equipments on time	0.705	6	0.771	14	0.738	10
Hiring of main equipment	0.613	19	0.686	25	0.650	20
Break down of equipment	0.607	21	0.733	17	0.670	19

Appendix Table C 6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	RII	Rank	RII	Rank	RII	Rank
Deploying less efficiency and old equipment	0.613	20	0.676	30	0.645	24
Due to lack of Skill operators will increase rework	0.587	23	0.705	23	0.646	23
Lack of substitution of essential equipment	0.620	15	0.619	43	0.620	30
Idling of equipment	0.640	14	0.543	54	0.592	41
Scarcity of skilled labour	0.653	10	0.943	1	0.798	4
Lack of supervision and assign specific work to each labour	0.567	31	0.667	31	0.617	31
Mismanagement of labour	0.540	44	0.638	41	0.589	42
Labour laws and regulations	0.507	56	0.610	46	0.559	49
Idling of labour	0.560	36	0.581	48	0.571	47
Conflicts among labours	0.473	60	0.457	61	0.465	63
Strikes	0.453	62	0.752	16	0.603	34
High traffic jams	0.567	32	0.733	19	0.650	21
Riots and terrorists attacks	0.500	59	0.514	57	0.507	57
Violations of acts, rules and regulations of other organizations	0.460	61	0.476	60	0.468	62
Curfew situation	0.413	65	0.438	64	0.426	65
Judicial actions	0.427	64	0.457	63	0.442	64
Violent weather condition	0.653	11	0.771	13	0.712	12
Land slides	0.433	63	0.524	56	0.479	61
Flood condition	0.540	45	0.648	37	0.594	40

Appendix Table C 7 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner category in pre-construction phase

Delay factors in owner category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Incomplete bid document	0.547	44	0.810	14
Incomplete design	0.580	27	0.800	16
Funding delays	0.633	16	0.820	11
Delay in review and approval of bid documents and designs	0.520	61	0.619	52
Delay in evaluation of bid documents.	0.480	70	0.600	57
Delays in awarding of contract and issuing letter of acceptance	0.553	42	0.610	53
Delay in acquisition of construction site	0.700	7	0.819	12

RAF = 12.0 PA = 58% PD = 42%

Appendix Table C 8 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner's design engineer category in pre-construction phase

Delay factors in owner's design engineer category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Design not matched with actual site condition	0.567	34	0.771	20
Lack of review of all designs and drawings before issue to the contractor	0.553	43	0.667	40
Frequently changes of design	0.600	25	0.867	6
Relocation of people due to construction not minimized during design stage	0.473	71	0.629	49
Inexperience design engineer	0.527	58	0.571	60

RAF = 12.0 PA = 50% PD = 50%

Appendix Table C 9 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner category in construction phase

Delay factors in owner category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Delay in handing over the Site to the contractor	0.567	33	0.810	15
Delay in release of mobilization advance	0.547	45	0.724	27
Lack of issuing of necessary instructions and approvals	0.533	54	0.657	41
Extra work apart from the Scope	0.640	14	0.838	9
Delay in testing of materials and approvals	0.520	62	0.610	54
Actual site conditions are differing from the design condition	0.573	30	0.695	30
Lack of communication and team work	0.533	55	0.476	71
Delay in approval of variation orders and interim payments	0.567	32	0.819	13
Owners cash flow problem	0.680	8	0.924	2
Lack of ability of decision making	0.567	35	0.638	45
Suspension of work	0.580	28	0.771	21

RAF = 11.0 PA = 21% PD = 79%

Appendix Table C 10 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner's site engineer category in construction phase

Delay factors in owner's site engineer category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Less experience in construction work	0.547	46	0.610	55
Delay in issuing instructions and approvals	0.573	31	0.638	46
Lack of communication with contractors technical and other staff	0.533	56	0.505	70
Delay in evaluation of interim payment and variation orders	0.527	59	0.733	24
By issuing of wrong instructions increase of rework	0.520	63	0.667	39
Delay in inspection and testing	0.513	64	0.600	58
Late approval of shop drawings	0.507	65	0.648	42
Delay to inform scope growth to the owner	0.500	67	0.562	61
Conflicts between site engineer and contractor	0.540	50	0.457	74
Lack of maintaining and follow up contract documentations	0.533	57	0.543	64

RAF = 16.0 PA = 0% PD = 100%

Appendix Table C11 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of contractor category in construction phase

Delay factors in contractor category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Delay in site mobilization	0.647	13	0.838	8
Lack of professional engineers and other technical staff	0.720	3	0.676	35
Contractors cash flow problem	0.760	1	0.886	5
Lack of resources. (Man, Money, Material and Machines.)	0.747	2	0.857	7
Poor planning and scheduling	0.707	4	0.724	26
Poor communication, coordination and team work with other parties	0.560	38	0.552	63
Poor management. (Money, Time and Resources)	0.673	9	0.686	33
Actual site condition differing with specification and drawings	0.540	51	0.667	38
Difference of actual and BOQ's quantities	0.560	39	0.686	34
Increase amount of rework	0.547	47	0.714	28
Method of construction is differing with specification	0.500	68	0.562	62
Inadequate construction experience	0.620	18	0.533	67
Conflicts between the contactor and other parties	0.580	29	0.419	77

RAF = 20.0 PA = 41% PD = 59%

Appendix Table C12 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of material category in construction phase

Delay factors in material category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Approval of required quality of material	0.547	48	0.648	43
Actual transported material deferring with approved quality	0.560	40	0.638	47
Scarcity of material	0.660	10	0.924	3
Less transportation facility to transport material	0.547	49	0.619	50
Increase of the price of material	0.707	5	0.829	10
Lack of additional stocks of material	0.607	24	0.686	32
Protection of material from weather until it uses for the construction	0.527	60	0.543	65
Procurement delay in special kind of material	0.613	19	0.800	17
Environmental restriction for manufacturing and mining of material	0.613	20	0.905	4

RAF = 6.0 PA = 80% PD = 20%

Appendix Table C 13 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of equipment category in construction phase

Delay factors in equipment category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Contractor unable to mobilize required equipments on time	0.707	6	0.771	19
Hiring of main equipment	0.613	21	0.686	31
Break down of equipment	0.607	23	0.733	23
Deploying less efficiency and old equipment	0.613	22	0.676	36
Due to lack of Skill operators will increase rework	0.587	26	0.705	29
Lack of substitution of essential equipment	0.620	17	0.619	51
Idling of equipment	0.640	15	0.543	66

RAF = 18.0 PA = 5% PD = 95%

Appendix Table C 14 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of labour category in construction phase

Delay factors in labour category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Scarcity of skilled labour	0.653	11	0.943	1
Lack of supervision and assign specific work to each labour	0.567	36	0.667	37
Mismanagement of labour	0.540	52	0.638	48
Labour laws and regulations	0.507	66	0.610	56
Idling of labour	0.560	41	0.581	59
Conflicts among labours	0.473	72	0.457	73

RAF = 7.0 PA = 76% PD = 24%

Appendix Table C15 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of act of man category in construction phase

Delay factors in act of man category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Strikes	0.453	74	0.752	22
High traffic jams	0.567	37	0.733	25
Riots and terrorists attacks	0.500	69	0.514	69
Violations of acts, rules and regulations of other organizations	0.460	73	0.476	72
Curfew situation	0.413	77	0.438	76
Judicial actions	0.427	76	0.457	75

RAF = 11.0 PA = 56% PD = 44%

Appendix Table C16 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of act of god category in construction phase

Delay factors in act of god category	Owner's view		Contractor's view	
	RII	Rank	RII	Rank
Violent weather condition	0.653	12	0.771	18
Land slides	0.433	75	0.524	68
Flood condition	0.540	53	0.648	44

RAF = 7.0 PA = 70% PD = 30%

Appendix D

Ranking of all delay factors in severity and frequency

Appendix Table D1 Delay factors by severity and frequency in pre-construction phase

Delay factors	Mean	SD	SFI	Rank
Incomplete bid document	2.760	8.169	0.552	7
Incomplete design	3.020	8.912	0.604	4
Funding delays	3.270	11.695	0.654	3
Delay in review and approval of bid documents and designs	2.645	7.025	0.529	8
Delay in evaluation of bid documents.	2.465	6.525	0.493	11
Delays in awarding of contract and issuing letter of acceptance	2.625	7.019	0.525	9
Delay in acquisition of construction site	3.330	11.088	0.666	2
Design not matched with actual site condition	2.980	8.611	0.596	5
Lack of review of all designs and drawings before issue to the contractor	2.830	7.566	0.566	6
Frequently changes of design	3.380	10.759	0.676	1
Relocation of people due to construction not minimized during design stage	2.445	6.599	0.489	12
Inexperience design engineer	2.550	6.022	0.510	10

Appendix Table D 2 Delay factors by severity and frequency in construction phase

Delay factors	Mean	SD	SFI	Rank
Delay in handing over the Site to the contractor	2.820	7.747	0.564	38
Delay in release of mobilization advance	2.850	8.808	0.570	32
Lack of issuing of necessary instructions and approvals	2.645	7.285	0.529	49
Extra work apart from the Scope	3.485	10.795	0.697	8
Delay in testing of materials and approvals	2.695	6.786	0.539	45
Actual site conditions are differing from the design condition	2.895	7.252	0.579	28
Lack of communication and team work	2.515	5.066	0.503	55
Delay in approval of variation orders and interim payments	3.195	9.761	0.639	14
Owners cash flow problem	3.690	13.118	0.738	5
Lack of ability of decision making	2.875	7.537	0.575	30
Suspension of work	2.720	7.033	0.544	44
Less experience in construction work	2.820	7.354	0.564	37
Delay in issuing instructions and approvals	2.895	7.254	0.579	29
Lack of communication with contractors technical and other staff	2.550	5.871	0.511	53

Appendix Table D2 (continued)

Delay factors	Mean	SD	SFI	Rank
Delay in evaluation of interim payment and variation orders	2.840	7.749	0.568	34
By issuing of wrong instructions increase of rework	2.535	6.500	0.507	54
Delay in inspection and testing	2.615	6.248	0.523	52
Late approval of shop drawings	2.675	6.305	0.535	47
Delay to inform scope growth to the owner	2.460	5.979	0.492	57
Conflicts between site engineer and contractor	2.475	6.648	0.495	56
Lack of maintaining and follow up contract documentations	2.655	6.483	0.531	48
Delay in site mobilization	3.165	9.217	0.633	17
Lack of professional engineers and other technical staff	3.390	10.240	0.678	10
Contractors cash flow problem	3.785	13.139	0.757	1
Lack of resources. (Man, Money, Material and Machines.)	3.695	12.231	0.739	4
Poor planning and scheduling	3.400	10.570	0.680	9
Poor communication, coordination and team work with other parties	2.775	7.165	0.555	41
Poor management. (Money, Time and Resources)	3.170	9.571	0.634	16

Appendix Table D2 (continued)

Delay factors	Mean	SD	SFI	Rank
Actual site condition differing with specification and drawings	2.845	7.265	0.569	33
Difference of actual and BOQ's quantities	3.080	8.747	0.616	22
Increase amount of rework	2.905	7.944	0.581	27
Method of construction is differing with specification	2.630	5.716	0.526	51
Inadequate construction experience	2.775	6.906	0.555	40
Conflicts between the contactor and other parties	2.460	5.331	0.492	58
Approval of required quality of material	2.866	7.542	0.573	31
Actual transported material deferring with approved quality	2.822	7.179	0.564	35
Scarcity of material	3.631	12.644	0.726	6
Less transportation facility to transport material	2.744	6.666	0.549	42
Increase of the price of material	3.770	12.244	0.754	2
Lack of additional stocks of material	3.149	8.497	0.630	19
Protection of material from weather until it uses for the construction	2.640	6.152	0.528	50
Procurement delay in special kind of material	3.220	10.159	0.644	13
Environmental restriction for manufacturing and mining of material	3.539	12.339	0.708	7
Contractor unable to mobilize required equipments on time	3.386	10.796	0.677	11
Hiring of main equipment	3.119	9.555	0.624	20
Break down of equipment	3.183	9.325	0.637	15

Appendix Table D2 (continued)

Delay factors	Mean	SD	SFI	Rank
Deploying less efficiency and old equipment	3.153	9.638	0.631	18
Due to lack of Skill operators will increase rework	3.084	8.676	0.617	21
Lack of substitution of essential equipment	3.024	9.061	0.605	24
Idling of equipment	3.039	9.158	0.608	23
Scarcity of skilled labour	3.759	13.203	0.752	3
Lack of supervision and assign specific work to each labour	3.003	7.329	0.601	25
Mismanagement of labour	2.777	6.616	0.555	39
Labour laws and regulations	2.721	6.787	0.544	43
Idling of labour	2.819	7.039	0.564	36
Conflicts among labours	0.461	4.819	2.306	60
Strikes	0.478	6.123	2.389	59
High traffic jams	0.598	8.677	2.992	26
Riots and terrorists attacks	0.460	6.348	2.301	61
Violations of acts, rules and regulations of other organizations	0.441	4.563	2.205	62
Curfew situation	0.394	4.673	1.970	64
Judicial actions	0.395	3.918	1.977	63
Violent weather condition	0.658	10.343	3.290	12
Land slides	0.427	5.546	2.135	65
Flood condition	0.537	7.044	2.687	46

Appendix Table D3 Different perceptions of project participants of delay category in pre-construction phase

Delay categories	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
Owner	0.542	1	0.621	2	0.582	1
Owner's design engineer	0.513	2	0.644	1	0.579	2

Appendix Table D4 Different perceptions of project participants of delay category in construction phase

Delay categories	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
Owner	0.541	4	0.608	2	0.567	4
Owner's site engineer	0.506	6	0.542	6	0.519	6
Contractor	0.616	2	0.572	4	0.595	3
Material	0.599	3	0.632	1	0.622	1
Equipment	0.630	1	0.588	3	0.619	2
Labour	0.560	5	0.493	5	0.498	5
External	0.466	7	0.470	7	0.464	7

Appendix Table D5 Different perceptions of project participants in pre-construction Phase

Delay factors	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
Incomplete bid document	0.499	9	0.626	6	0.563	7
Incomplete designs	0.538	4	0.698	4	0.618	4
Funding delays	0.623	2	0.699	3	0.661	3
Delay in review and approval of bid documents and designs	0.501	8	0.569	8	0.535	8
Delay in evaluation of bid documents	0.467	11	0.530	12	0.498	12
Delays in awarding of contract and issuing letter of acceptance	0.507	7	0.552	10	0.530	9
Delay in acquisition of construction site	0.659	1	0.676	5	0.668	2
Designs not matched with actual site condition	0.521	6	0.703	2	0.612	5
Lack of review of all designs and drawings before issue to the contractor	0.529	5	0.618	7	0.574	6
Frequently changes of design	0.594	3	0.793	1	0.694	1
Relocation of people due to construction not minimized during design stage	0.443	12	0.554	9	0.499	11
Inexperience design engineer	0.480	10	0.551	11	0.516	10

Appendix Table D 6 Different perceptions of project participants in construction phase

Delay factors	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
Delay in handing over the Site to the contractor	0.491	55	0.668	144	0.580	33
Delay in release of mobilization advance	0.513	45	0.651	20	0.582	32
Lack of issuing of necessary instructions and approvals	0.493	53	0.646	23	0.570	36
Extra work apart from the scope	0.650	11	0.764	7	0.707	8
Delay in testing of materials and approvals	0.500	50	0.592	38	0.546	47
Actual site conditions are differing from the design condition	0.531	38	0.648	22	0.590	28
Lack of communication and team work	0.492	54	0.470	57	0.481	59
Delay in approval of variation orders and interim payments	0.564	27	0.746	9	0.655	13
Owners cash flow problem	0.667	7	0.838	3	0.753	4
Lack of ability of decision making	0.542	35	0.621	29	0.582	31
Suspension of work	0.506	47	0.598	37	0.552	43
Less experience in construction work	0.557	29	0.570	46	0.564	38
Delay in issuing instructions and approvals	0.556	30	0.611	33	0.584	29
Lack of communication with contractors technical and other staff	0.510	46	0.512	55	0.511	54
Delay in evaluation of interim payment and variation orders	0.494	52	0.674	13	0.584	30

Appendix Table D 6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
By issuing of wrong instructions increase of rework	0.453	60	0.584	40	0.519	53
Delay in inspection and testing	0.496	51	0.561	47	0.529	50
Late approval of shop drawings	0.479	57	0.651	31	0.565	46
Delay to inform scope growth to the owner	0.475	58	0.515	54	0.495	55
Conflicts between site engineer and contractor	0.516	44	0.464	58	0.490	57
Lack of maintaining and follow up contract documentations	0.526	41	0.537	51	0.532	49
Delay in site mobilization	0.610	20	0.665	17	0.638	16
Lack of professional engineers and other technical staff	0.727	4	0.612	32	0.670	11
Contractors cash flow problem	0.746	1	0.773	5	0.506	2
Lack of resources. (Man, Money, Material and Machines.)	0.730	3	0.751	8	0.741	6
Poor planning and scheduling	0.708	5	0.639	24	0.674	10
Poor communication, coordination and team work with other parties	0.562	28	0.545	50	0.554	41
Poor management. (Money, Time and Resources)	0.651	10	0.609	34	0.630	19
Actual site condition differing with specification and drawings	0.527	40	0.629	26	0.578	35
Difference of actual and BOQ's quantities	0.583	25	0.664	18	0.624	20

Appendix Table D 6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
Increase amount of rework	0.532	37	0.650	21	0.591	27
Method of construction is differing with specification	0.501	49	0.549	49	0.525	52
Inadequate construction experience	0.586	24	0.507	56	0.547	45
Conflicts between the contactor and other parties	0.544	33	0.418	63	0.481	58
Approval of required quality of material	0.552	31	0.603	35	0.578	34
Actual transported material deferring with approved quality	0.540	36	0.600	36	0.570	37
Scarcity of material	0.643	12	0.845	2	0.744	5
Less transportation facility to transport material	0.525	42	0.581	42	0.553	42
Increase of the price of material	0.741	2	0.772	6	0.757	3
Lack of additional stocks of material	0.623	16	0.638	25	0.631	17
Protection of material from weather until it uses for the construction	0.530	39	0.524	53	0.527	51
Procurement delay in special kind of material	0.611	19	0.693	10	0.652	14
Environmental restriction for manufacturing and mining of material	0.624	15	0.827	4	0.726	7
Contractor unable to mobilize required equipments on time	0.684	6	0.667	15	0.676	9
Hiring of main equipment	0.621	18	0.627	28	0.624	21
Break down of equipment	0.603	21	0.685	12	0.644	15

Appendix Table D6 (continued)

Delay factors	Owner's view		Contractor's view		Without biased	
	SFI	Rank	SFI	Rank	SFI	Rank
Deploying less efficiency and old equipment	0.631	14	0.628	27	0.630	18
Due to lack of Skill operators will increase rework	0.588	22	0.657	19	0.623	22
Lack of substitution of essential equipment	0.622	17	0.580	43	0.601	25
Idling of equipment	0.659	8	0.534	52	0.597	26
Scarcity of skilled labour	0.656	9	0.889	1	0.773	1
Lack of supervision and assign specific work to each labour	0.587	23	0.618	30	0.603	24
Mismanagement of labour	0.543	34	0.574	44	0.559	40
Labour laws and regulations	0.524	43	0.571	45	0.548	44
Idling of labour	0.571	26	0.554	48	0.563	39
Conflicts among labours	0.480	56	0.434	61	0.457	61
Strikes	0.404	63	0.582	41	0.493	56
High traffic jams	0.551	32	0.666	16	0.609	23
Riots and terrorists attacks	0.470	59	0.446	60	0.458	60
Violations of acts, rules and regulations of other organizations	0.450	61	0.428	62	0.439	62
Curfew situation	0.392	64	0.397	65	0.395	65
Judicial actions	0.386	65	0.409	64	0.398	64
Violent weather condition	0.637	13	0.688	11	0.663	12
Land slides	0.405	62	0.458	59	0.432	63
Flood condition	0.503	48	0.587	39	0.545	48

Appendix Table D 7 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner category in pre-construction phase

Delay factors in owner category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Incomplete bid document	0.498	59	0.626	34
Incomplete design	0.538	40	0.698	13
Funding delays	0.623	17	0.699	12
Delay in review and approval of bid documents and designs	0.501	56	0.569	54
Delay in evaluation of bid documents	0.467	70	0.530	64
Delays in awarding of contract and issuing letter of acceptance	0.507	53	0.552	58
Delay in acquisition of construction site	0.658	9	0.676	17

RAF = 11.0 PA = 66% PD = 34%

Appendix Table D 8 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner's design engineer category in pre-construction phase

Delay factors in owner's design engineer category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Design not matched with actual site condition	0.521	49	0.703	11
Lack of review of all designs and drawings before issue to the contractor	0.529	44	0.617	37
Frequently changes of design	0.594	24	0.793	5
Relocation of people due to construction not minimized during design stage	0.443	73	0.553	57
Inexperience design engineer	0.479	66	0.551	59

RAF = 17.0 PA = 35% PD = 65%

Appendix Table D9 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner category in construction phase

Delay factors in owner category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Delay in handing over the Site to the contractor	0.491	64	0.668	19
Delay in release of mobilization advance	0.513	51	0.651	25
Lack of issuing of necessary instructions and approvals	0.493	62	0.646	28
Extra work apart from the Scope	0.650	12	0.764	8
Delay in testing of materials and approvals	0.499	58	0.592	45
Actual site conditions are differing from the design condition	0.531	42	0.648	27
Lack of communication and team work	0.492	63	0.470	69
Delay in approval of variation orders and interim payments	0.564	30	0.746	10
Owners cash flow problem	0.667	7	0.838	3
Lack of ability of decision making	0.542	38	0.621	35
Suspension of work	0.506	54	0.598	44

RAF = 17.0 PA = 18% PD = 82%

Appendix Table D 10 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of owner's site engineer category in construction phase

Delay factors in owner's site engineer category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Less experience in construction work	0.557	32	0.570	53
Delay in issuing instructions and approvals	0.556	33	0.611	40
Lack of communication with contractors technical and other staff	0.510	52	0.512	67
Delay in evaluation of interim payment and variation orders	0.494	61	0.674	18
By issuing of wrong instructions increase of rework	0.453	71	0.584	47
Delay in inspection and testing	0.496	60	0.561	55
Late approval of shop drawings	0.478	67	0.615	38
Delay to inform scope growth to the owner	0.475	68	0.515	66
Conflicts between site engineer and contractor	0.516	50	0.464	70
Lack of maintaining and follow up contract documentations	0.526	46	0.537	62

RAF = 18.0 PA = 9% PD = 91%

Appendix Table D11 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of contractor category in construction phase

Delay factors in contractor category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Delay in site mobilization	0.610	22	0.665	22
Lack of professional engineers and other technical staff	0.727	4	0.612	39
Contractors cash flow problem	0.746	1	0.773	6
Lack of resources. (Man, Money, Material and Machines.)	0.730	3	0.751	9
Poor planning and scheduling	0.708	5	0.639	29
Poor communication, coordination and team work with other parties	0.562	31	0.545	61
Poor management. (Money, Time and Resources)	0.651	11	0.609	41
Actual site condition differing with specification and drawings	0.527	45	0.629	31
Difference of actual and BOQ's quantities	0.583	28	0.664	23
Increase amount of rework	0.532	41	0.650	26
Method of construction is differing with specification	0.500	57	0.549	60
Inadequate construction experience	0.586	27	0.507	68
Conflicts between the contactor and other parties	0.544	36	0.418	75

RAF = 19.0 PA = 34% PD = 66%

Appendix Table D 12 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of material category in construction phase

Delay factors in material category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Approval of required quality of material	0.552	34	0.603	42
Actual transported material deferring with approved quality	0.540	39	0.600	43
Scarcity of material	0.643	13	0.845	2
Less transportation facility to transport material	0.525	47	0.581	49
Increase of the price of material	0.741	2	0.772	7
Lack of additional stocks of material	0.622	18	0.638	30
Protection of material from weather until it uses for the construction	0.530	43	0.524	65
Procurement delay in special kind of material	0.611	21	0.693	14
Environmental restriction for manufacturing and mining of material	0.624	16	0.827	4

RAF = 9.0 PA =67 % PD = 33%

Appendix Table D 13 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of equipment category in construction phase

Delay factors in equipment category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Contractor unable to mobilize required equipments on time	0.684	6	0.667	20
Hiring of main equipment	0.620	20	0.627	33
Break down of equipment	0.603	23	0.685	16
Deploying less efficiency and old equipment	0.631	15	0.628	32
Due to lack of Skill operators will increase rework	0.588	25	0.657	24
Lack of substitution of essential equipment	0.621	19	0.580	50
Idling of equipment	0.659	8	0.534	63

RAF = 20.0 PA = 2% PD = 98%

Appendix Table D14 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of labour category in construction phase

Delay factors in labour category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Scarcity of skilled labour	0.656	10	0.889	1
Lack of supervision and assign specific work to each labour	0.587	26	0.618	36
Mismanagement of labour	0.543	37	0.574	51
Labour laws and regulations	0.524	48	0.571	52
Idling of labour	0.571	29	0.554	56
Conflicts among labours	0.480	65	0.434	73

RAF = 12.0 PA = 60% PD = 40%

Appendix Table D15 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of act of man category in construction phase

Delay factors in act of man category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Strikes	0.404	75	0.582	48
High traffic jams	0.551	35	0.666	21
Riots and terrorists attacks	0.470	69	0.446	72
Violations of acts, rules and regulations of other organizations	0.450	72	0.428	74
Curfew situation	0.392	76	0.397	77
Judicial actions	0.386	77	0.409	76

RAF = 8.0 PA = 64% PD = 36%

Appendix Table D16 Rank agreement factor (RAF), Percentage agreement (PA) and percentage disagreement (PD) of act of god category in construction phase

Delay factors in act of god category	Owner's view		Contractor's view	
	SFI	Rank	SFI	Rank
Violent weather condition	0.637	14	0.688	15
Land slides	0.405	74	0.458	71
Flood condition	0.503	55	0.587	46

RAF = 4.0 PA = 82% PD = 18%

Appendix E

Delay and Remedy matrix

Appendix Table E1 Remedies for delays in pre-construction phase

Responsible party	Delay factor	Remedy
Project owner	Funding delay	Timely submission of all required documents to the donor agencies according to their expected standards, the timely funding for the projects can be enhanced.
Project owner	Delay in acquisition of construction site	By giving Attractive compensation package equal to present market value of the land those who are lost their land due to construction. In addition to that ex-gratia payment for the affected people those who early vacate their lands for starting construction. Try to avoid densely populated areas and use bare lands as much as possible for the designing of the highway trace.
Project owner's design engineer	Frequent changes of design	Designer must be convinced of actual site conditions and owner's objectives and intended needs of the project before starting project designs. Both parties should have proper channel of communication and the same objective setting.
Project owner's design engineer	Incomplete design	By using modern computer design software to perform design work can be minimized errors. By appointing another designer for re-checking the finished designs and making corrections before issuing them to the bidders.
Project owner's design engineer	Designs not matched with actual site conditions	By motivating designers for frequent site visits and checked the designs with actual site conditions and the project owner can introduce attractive subsistence package for designer to increase the habit of frequent site visits.
Project owner's design engineer	Lack of review of all designs and drawings before issuing to the contractor	After finishing some extent of the project design, one or two designers in the same group could be appointed for reviewing of all finished designs and drawings for further corrections as fast as possible without delaying the bidding phase of the project.

Appendix Table E1 (Continued)

Responsible party	Delay factor	Remedy
Project owner	Incomplete bid/ contract document	By giving additional training for the project owner to improve working knowledge of FIDIC and ICTAD conditions of contracts.
Project owner	Delay in review and approval of bid documents and designs	By selecting expert professionals including contract document specialist, senior quantity surveyor and senior design engineer. The owner can delegate the approving authority of documents to these experts on behalf of the owner can increase the working capacity, efficiency and timely starting bidding process.
Project owner	Delay in awarding the contract and issuing of letter of acceptance	By minimizing external problems such as land acquisition, funding delay and political interferences could be vital to avoid this cause of delay.
Project owner's design engineer	Inexperienced design engineer	To avoid selection of inexperience designer by using special criteria based on minimum 10 years similar project experience, overseas project experience and member of professional institution.

Appendix Table E2 Remedies for delay in construction phase

Responsible party	Delay factor	Remedy
Contractor	Contractor's cash flow problem	Timely issue mobilization advance to the contractor at the beginning of the contract and timely issue monthly interim payment to the contractor. Requesting monthly cash flow program from the contractor to make sure that avoid misuse of mobilization advance.
Neither party	Scarcity of skilled labour	Expand vocation training centers up to village level and to provide sufficient training for the young generations and recruit more skilled people for the construction industry. Increase labour wages according to their performance and also increase job security.
Neither party	Increased price of materials	Avoid under-bidding situations and quote material price including present price with markup for the future price fluctuations in the market. Add reasonable percentage to the BOQ amount as for the price escalations of materials.
Project owner	Owner's cash flow problem	Avoid misuse of project budget for another purpose such as settling of urgent payment of other ongoing projects, initiates new projects without having proper budget and settling compensation payment for affected people. The owner has to follow strict financial regulation to avoid misuse of project budget.
Contractor	Lack of resources	Government has to arrange easy payment loan or tax free system for the contractors to purchase special construction machinery and make arrangement to reduce spare part cost of these machinery.

Appendix Table E2 (continued)

Responsible party	Delay factor	Remedy
Neither party	Scarcity of material	Introduce material management plan to the contractor for optimum usage of material per day, minimize wastage of material, required total quantity of material and minimum quantity of material needed per day for performing the work without idle equipment and labour.
Neither party	Environmental restrictions for mining of materials	Reduce excessive mining of river sand by using alternatives of river sand such as manufacturing sand during rock blasting and crushing process and use sea sand by removing salinity from the sand.
Project owner	Extra work apart from the scope	While deciding the project scope project owner has to brain storm the knowledge and experience with other expert professionals in the organization and try to develop best scope to match with allocated budget with minimizing extra works.
Contractor	Contractor failure to mobilize required equipment on time	Project owner must be very strict to the contractor and half of the mobilization advance can be paid to the contractor after mobilizing all required equipment to the site otherwise the owner could stop payment until to mobilize all required equipment.
Contractor	Poor planning and scheduling	By using sophisticated software for the project planning work including MS project and Primavera can be used to enhance proper planning and scheduling.

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