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"ANALYSIS OF FACTORS INFLUENCING DELAY AND QUALITY OF ROADS CONSTRUCTION PROJECTS IN RWANDA "

A THESIS

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CERTIFICATE

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DECLARATION

I hereby declare that the thesis entitled**" Analysis Of Factors Influencing Delay and Quality of Roads Construction Projects in Rwanda"** submitted for the Degree of Master of Science is my original work and the thesis has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship of similar other titles. It has not been submitted to any other University or Institution for the award of any Degree or Diploma.

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BONAFIDE CERTIFICATE

Certified that this thesis titled**" Analysis of Factors Influencing Delay and Quality of Roads Construction Projects in Rwanda"** is the bonafide work of **Pacifique MPORANANAYO (Reg.No: PG20134040)** who carried out the research under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion for this or any other candidate.

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ABSTRACT

Road construction industry provide sustainable economic development, transport enhances productivity and output, facilitates movement of people and goods, and improves access to social services like recreation, education, health services. Generally road network is platform of economic development.

Since year 2010, RTDA has more than 50 projects concerning the construction of roads and bridges. The project management requires the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Roads Construction projects in Rwanda suffer from many problems and complex issues in performance such as time and quality. It is also very important to know the significant factors which can cause any change on the quality, time as well as the cost on initial project planning and also be able to manage any change, when it occurs. The aim of this research is to identify and analyze the factors affecting the performance of road construction in Rwanda, specifically emphasize on factors affecting delay and quality.

To achieve the objectives of the research, different variables affecting delay and quality of road projects were identified 73 and 71 respectively through literature review and discussions with professionals working in the field of road construction.

The research was carried out into three stages; first The questionnaire survey targeted to 64 sampled professionals working in different institution in Rwanda (contractors, consultants as well as people working in public sectors/owners) was carried out for preliminary survey to reduce the variables (factors), whereby data collected by using questionnaires and analyzed with statistical analysis (Weighted mean). Furthermore, a second detailed survey with 10 Experts was carried out by applying a MCDM (pairwise comparison) with Fuzzy AHP Approach to get the final weight of each variable.

The third one, results from the second stage have been compared to the actual situation of 14 selected projects managed by RTDA.

The study showed that most of the key significant factors are related to the design, Consultants, owners/Clients and contractors. The reach provides recommendations for improving the performance of roads construction projects to contractors, consultants and owners.

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LIST OF ABBREVIATIONS

EDPRS Economic Development and Poverty Reduction Strategy

EAC East Africa Community

MTEF Medium Term Expenditure Framework

NIS National Investment Strategy

RSTMP Rwanda Strategic Transport Master Plan

RTSP Rwanda Transport Sector Policy

SSATP Sub Saharan Africa Transport Policy

ToR Terms of Reference

RNP Rwanda National Police

MININFRA Ministry of Infrastructure

MINECOFIN Ministry of Finance and Economic Planning

RTRN Regional Trunk Road Network

CCTFA Central Corridor Transport Facilitation Agency

NCTTC Northern Corridor Transit, Transport Coordination Agency

IRR Internal Rate of Return

NPV Net Present Value

B/C Ratio Benefit/Cost Ratio

RTDA Rwanda Transport Development Agency

TFN Triangular Fuzzy Number

Chapter 1: INTRODUCTION

1.1: Back Ground

Rwanda is a landlocked country and far from the maritime ports having the nearest port of Dar-Es-Salaam approximately 1 400 km away [1].
Transport infrastructure in Rwanda is comprised of the following: (i) Road transport, which until now is the main form of passenger and goods transportation, with a network of about 14,000 km corresponding to a road density of 0.53 km/km², (ii) Air transport with, one international airport and six aerodromes spread across the country, and (iii) lake transport, which is limited mainly to Lake Kivu. Rwanda does not have a rail transportation system [1].

RTDA has currently 52 maintenance and improvements road projects whereby 31 have been completed, 60% of the project have got an extension time to the initial contract period equivalent to 40% [2]. And also in now days, RTDA and other institutions such as Kigali City Council have the road construction in their responsibilities are facing the problem concerning the roads which get damaged quickly after the construction and roads construction projects delay.

The long-term development of Rwanda, as it is elaborated in the Vision 2020, assigns fundamental importance to the development of the economic infrastructure of the country, and in particular transportation infrastructure [3].

Quality is an attitude of mind and to be most effective, every level of an organization should be involved and be committed to achieving the required performance standards by setting and operating procedures and systems which ensure this [4]. Where quality is synonymous with safety, as with aircraft or nuclear design, there is no question which point of the project management triangle is the most important. However, even if the choice is not so obvious, a failure in quality can be expensive, dangerous and can destroy an organization’s reputation far quicker than it took to build up [4].

Delay is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects. Because of the overriding importance of time for both the Owner (in terms of performance) and the Contractor (in terms of money), it is the source of frequent disputes and claims leading to lawsuits. To control this situation, a contract is formulated to identify potential delay situations in advance and to define and fix obligations to preclude such controversies. A substantial number of General Condition's clauses address this subject in one way or another. [5]. Inefficiency of equipment and poor quality of the raw material are factors which cause low productivity.

The iron triangle (cost, time, and quality) is used to measure the project performance and success. Generally, the success measure for a project is defined by completing it within specified cost, time and quality. [6] To overcome the above mentioned issues, there should be the basic information to help in decision making way of enforcing QA usually requires continuing evaluation of factors that affect the design or specification for intended application as well as verification of installation and inspection operations.

Many projects Management and specifically a Management Framework is very important and enable management decisions to be made in a structured manner that is logical and consistent. It provides guidance on the type of decisions that must to be made, the purpose of those decisions, who needs to make them, when must they be made, the information needed to make the decisions, etc.

A Management Framework, when looking at roads, can therefore assist in improving the quality of decision-making, and can result in greater effectiveness and efficiency for both customers of the road network and the road administration [3].

1.2: Statement of the Problem

It is always possible that during the life of the project, problems arise which demand that certain changes have to be made which may involve compromises and trade-offs to keep the project either on programme or within the cost boundaries [4]. For example if one of the project success criteria is that the project finishes by or before a certain date, then there can be no compromise of the date, but the cost may increase or quality may be sacrificed [4].

Sixty percent of the projects carried out or being carried out in the last budget budget year has got a delay [7] For example: ***Periodic Maintenance of Rwamagana-Zaza Unpaved Road (28 km)*** the execution of works has started on 09/08/2012 to be ended at 09/06/2013, but for the moment they have done an extension of 5 months out 10 months of the initial contract accompanied with 19% of addendum of initial cost/contract amount of the project (1,849,378,800 frw) for the contractor.

Accordingly, number of road improvements projects has been planned and some of them are in progress. However, it is learned that the majority of these road projects do not perform as expected especially within time, cost and quality standards due to various factors [8].

Contractors are prone to see most of the delays in the responsibility of the owner, while owners usually want to put the blame on the contractor or third parties. Consequently, it was found necessary to analyze the causes of delays and research the most significant factors of delay in construction projects in order to avoid or minimize their adverse impacts on the project and project participants.

The same as in terms of quality of the roads, many project found with some defects during the provision hand over, mean that after just the completion of execution of works. For example: the rehabilitation of Kigali-Ruhengeri Paved road, some fissures have appeared on the wearing courses for some sections while the project was at the end.

1.3: Significance of the Study

Roads Construction Industry has complexity in its nature because it contains large number of parties such as stakeholders, clients, consultants, contractors, shareholders, regulators and others. Roads Construction projects in the Rwanda suffer from many problems and complex issues in performance because of various reasons and factors. This thesis is very important to identify and to evaluate the main factors affecting the performance of roads construction projects in Rwanda in terms of delay and quality.

These significant factors involve studying the factors that influence delays and quality in roads construction industry and provide the statistical result. The results of the study will be a key component of any organization move towards achieving best practice in order to overcome

performance problem in roads construction, as construction project is considered to be success, when it applies the iron triangle's constrains: time, cost, and quality. And also can be used to measure performance in construction projects as well as for benchmarking purposes.

Changes may be requested by any stakeholder involved with the project [9]. That's why it is necessary to know all parameters which can influence delay and quality for achieving the project goal.

The study is not only important for private or public organizations whose working in roads construction industry but also for academic interest, since there is no previous topic done on this study especially in Rwanda; it is an opportunity for further academic research to develop the parts which need further research, depending on the findings of the researcher.

1.4: Objectives of the Study

The main objective of this research is to analyse the internal and external factors influence delay and quality of roads construction projects in Rwanda in order to improve the performance of project management.

1. To determine owners, consultants, contractors overall perceptions towards the relative importance of the factors influencing delay and quality of roads construction projects in Rwanda.
2. To identify the most significant factors influencing delay of the roads construction projects.
3. To identify the most significant factors influencing quality of the roads construction projects in Rwanda.
4. To formulate recommendations to improve performance of roads construction projects in Rwanda.

1.5: Research questions

To meet the goal of Road construction project, the project is considered to be success when it applies the iron triangle's constrains: time, cost, and quality. The failure of project is due to the lack of one of those main performance indicators which is caused by the problems related to

owners (lack of strategic management, changes in requirements, inadequate project feasibility studies, etc…), consultants (design errors, delay in work approval, etc…), and the contractors (inadequate labor skills, inaccurate estimation, poor contract management, etc…).

The following are the research questions posed for these research problems:

- What are the different perceptions towards the relative importance of the factors influencing delay and quality of roads construction projects in Rwanda between owners, contractors and consultants in government construction projects?
- What are the most important factors do influence the delay and quality of roads construction projects in Rwanda?
- How do we rank the factors influencing delay and qualities on basis of weight?

1.6: Aim, objectives and scope of the research

This dissertation seeks to investigate mainly whether there are weaknesses of different stakeholders (contractors, consultants and clients) in projects life cycle. And find out significant factors that influencing the roads projects performance.

1.7: Limitations of the Study

The research could not cover all the players in the construction industry operating or have been operating in Rwanda, but a limited purposive sample of Sixty four respondents from all categories clients, consultants, and contractors. Whilst this is enough to give an exploratory insight into the status quo to date, covering larger number including donors could have shared more insight into the subject.

1.8: The Scope of the Study

The scope of the study covers the government construction project in Rwanda. This study is met to evaluate the level of understanding and applying these delay concepts in planning, design and field operations. A questionnaire was developed in order to evaluate the importance and weight of the identified causes. Consultants', Contractors' and Clients information was collected from

Rwanda Private Sector Federation and Public Institutions. The study focused on the government projects implemented from the year 2010 up to 2013. The reason behind of choosing that period was that after 2010, it is the time RTDA have started as an Institution with Autonomy in charge of Management and Development of Rwanda Roads Network.

1.9: Thesis Structure

This research consists of five main chapters as followings:

- Chapter one: Introduction: this chapter shows the main objectives of research, statement of the problem, justification of research and the scope of the study.
- Chapter two: Literature review: this chapter shows a historical review from previous studied to identify the main factors influencing the performance of the roads construction projects in terms of quality and delay.
- Chapter three: Methodology: this chapter describe the main methodologies used in previous studies and the methodology used in this research in order to achieve the required objectives
- Chapter four: Results analysis: this chapter shows presentation and analysis of the findings, description and discussion of research results.
- Chapter five: Conclusions and recommendations
- Appendix

Chapter 2: RESEARCH IN DELAYS AND QUALITY SHORTFALLS

2.1 Introduction

2.2 Overview of Road Network in Rwanda

As Rwanda Transport Development Agency (RTDA) is a public institution with legal personality, administrative and financial autonomy. It is under the Ministry of Infrastructure (MININFRA) responsible for managing all day-to-day aspects of the transport sector in Rwanda.

But they manage especially the national roads, urban and districts roads are managed by Kigali City and Districts.

It was put in place by Organic Law No 02⁄2010 of 20⁄01⁄2010 establishing its mission, structure and functioning. [9]

Table2: 1 summarizes the results of the road condition survey

Roads	Total Length (km)	Length surveyed (km)	Length surveyed %	Good condition %
National paved roads	1172	1172	100	97.5
National unpaved roads	1688	1612	95.5	32
District classified roads	1836	1750	95.2	15.1
Overall National roads (paved + unpaved)	2860	2784	97.3	59

RTDA**,** 2011 "*Road Condition Survey Report*

As the development of infrastructure is the one of the aims of EDPRS2 the road network in Rwanda is greatly improving from gravel to bitumen, but the gravel roads still occupy the high percentage the whole road network. As Road Condition Survey Report, 2011 states that only 59% of the roads of the whole network were in good condition [10].

Effort is needed to be made to keep them in good condition. The following are examples of the road projects, which RTDA had to carry out in the year 2012-2013 [2].

Paved Roads

a) Unpaved road to be upgraded to paved road - Lot4,5,6,7 and Tumba College (146.4 km)
b) Rehabilitation of paved -197Km
c) Urban roads (17.6 Km)
d) Kigali urban roads (86.92 Km)
e) Maintenance for paved road-704 Km

Unpaved Road

a) Rehabilitation of unpaved roads-193.6 km
b) Maintenance of unpaved roads-331.5 Km

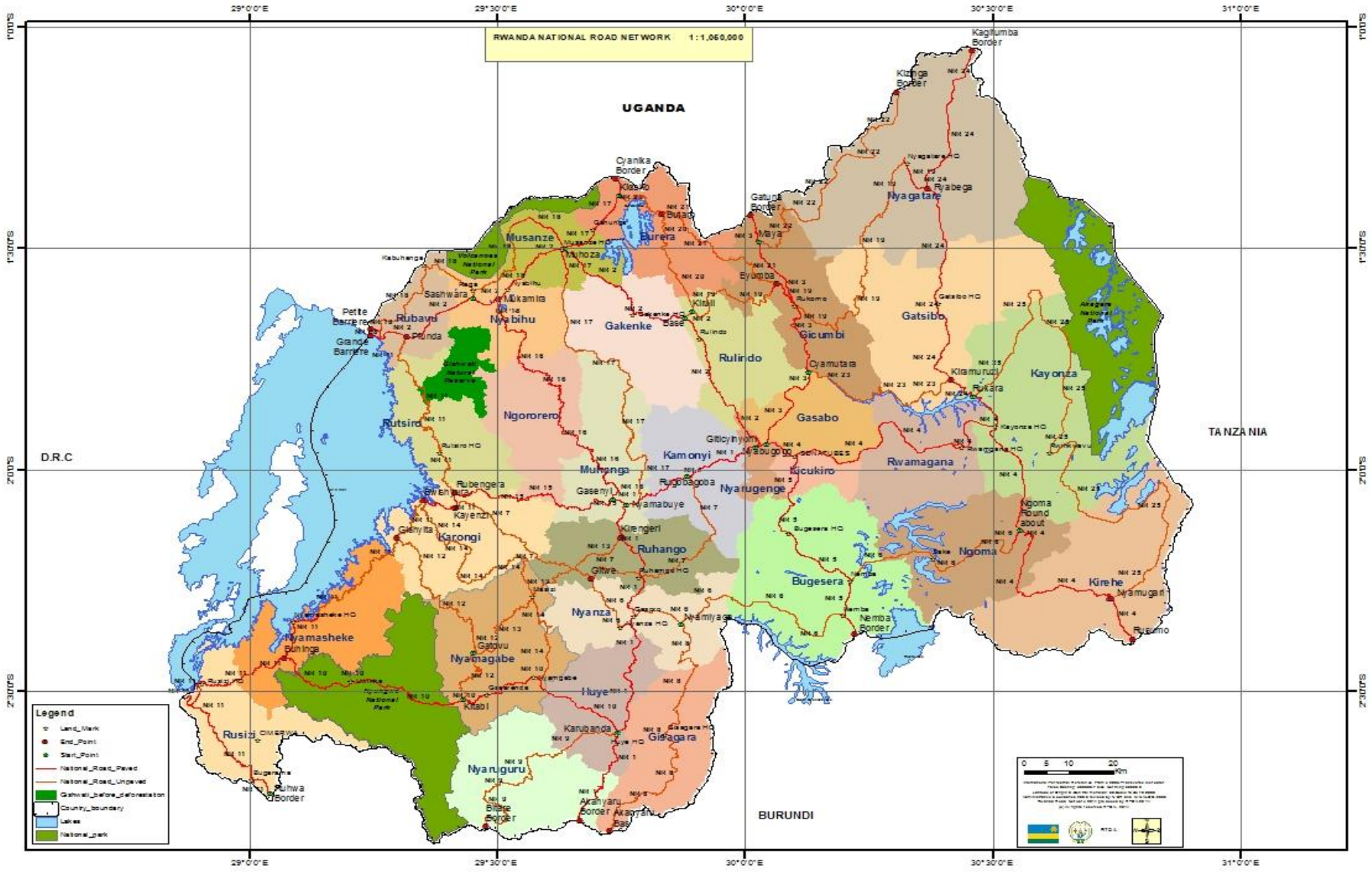


Figure 2: 1 Rwanda Road Network: 2014, Source RTDA

2.3 Over view Project and Project management

Project management as a discipline is recognized as one of the fastest growing professions in today's industries. In the roads construction's industry, it is one of the most important aspects of the entire construction process. Without effective project management, projects are often running into troubles and risking failures. Not understanding the basic concept behind managing construction projects leads to missed deadlines, cost overruns, expensive changes, lost opportunities and frustrated project managers, team members and other stakeholders.

[11] Defines a project as "a temporary endeavor undertaken to produce a unique product, service, or result." According to [12], Projects are temporary in nature; have definite start and end dates; produce a unique product, service, or result; and are completed when their goals and objectives have been met and signed off by the stakeholders.

A project is a temporary endeavor undertaken to create a unique product, service, or result [11]. According to [4] states that, a project is a unique set of co-ordinated activities, with definite starting and finishing points, undertaken by an individual or organization to meet specific objectives within defined schedule, cost and performance parameters.

[13] Defines Project management as application of knowledge, skills, tools and techniques to project activities to achieve project requirements. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing.

[14] Has summarized different definitions of Project management from different literatures of different as:
The application and integration of modern management and project management knowledge, skills, tools and techniques to the overall planning, directing, coordinating, monitoring and control of all dimensions of a project from its inception to completion, and the motivation of all those involved to produce the product, service or result of the project on time, within authorized cost, and to the required quality and requirement, and to the satisfaction of participants.

According to [4], Project management is a process that includes initiating a new project, planning, putting the project plan into action, and measuring progress and performance. It involves identifying the project requirements, establishing project objectives, balancing constraints, and taking the needs and expectations of the key stakeholders into consideration.

2.3.1 Project Management Processes for a Project

A process is a set of interrelated actions and activities performed to achieve a pre-specified product, result, or service. Each process is characterized by its inputs, the tools and techniques that can be applied, and the resulting outputs [11].
(Initiating Process Group, Planning Process Group, Executing Process Group, Monitoring and Controlling Process Group, Closing Process Group)
Those processes performed to finalize all activities across all Process Groups to formally close the project or phase.

Money is always of special importance to those involved in construction project. Hence, completion of any project within the estimated cost of project is the basic criteria for success of any project. The success of any project is highly depends on adequate availability and efficient management of various resources. Hence, prior and adequate arrangement for provision of resource involved in construction such as type and quantity of material, manpower, machines and finance are required at each stage of construction.

2.3.2 Project Time Management

Project Time Management includes the processes required to manage timely completion of the project.
Chapter 6 of the last edition of [11] describes six processes under Project Time Management. The Construction Extension of [11] adds three additional processes for construction PM. The inputs, outputs, tools and techniques involved in these nine processes are summarized as following:

Define Activities The process of identifying the specific actions to be performed to produce the project deliverables.

Sequence Activities The process of identifying and documenting relationships among the project activities.

Estimate Activity Resources The process of estimating the type and quantities of material, people, equipment, or supplies required to perform each activity.

Estimate Activity Durations The process of approximating the number of work periods needed to complete individual activities with estimated resources.

Develop Schedule The process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.

Control Schedule The process of monitoring the status of the project to update project progress and managing changes to the schedule baseline.

Activity Weights definition: Determining the relative and absolute weights for each project activity.

Progress curves development: Analyzing activity weights and project schedule to create progress curve.

Progress monitoring: Monitoring project progress.

2.4. Measurement of Project Performance

According to [15] effective and efficient management of contractors' organizational performance requires commitment to effective performance measurement in order to evaluate, control, and improve performance today and in the future. Performance measurement systems have been one of the primary tools used by the manufacturing sector for business process re-engineering in order to monitor the outcomes and effectiveness of implementation [16].

[17] Obtained an evaluation framework to measure the efficiency of building project management (BPM) by using conventional economic analysis tools such as time, cost and quality. [18] Stated that performance measurement systems are imminent in the construction firms.

2.5 Review of Construction Delays across the World

In the context of the construction industry, delay can be defined as the extra time require to a construction project beyond its original (planned) duration, whether compensated for or not. [19]. generally to finish a project on time, under the planned cost, with the highest quality and also in the safe manner are common goals for all parties including the owner, contractor as well as consultant?

According to International journal of project management the contractor and the client pay for the extra charge for the completion of the project due to delay in large construction projects. When the completion time of the construction project exceeds the agreed completion time, it is known as construction project delay. In construction, delay could be also defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project [20].

Concerns time management, i.e. road works are not completed within the agreed time and benefits of the works to the public are delayed. Another problem concerns cost overruns, i.e. additional but avoidable costs to the decided budgets for varying reasons [21]:

States that delay is actually a postponement of time from the original estimated completion time which might be caused by contractor, owner or consultant as well as by external factors [22].

Therefore, delays in construction projects cause dissatisfaction to all parties involved and the main role of the project manager is to make sure that projects are completed within the budgeted time and cost. Several studies have been undertaken on factors causing delays and cost overruns, and affecting quality, safety and productivity, etc. and specific problems in special types of projects. These studies usually focus on specific aspects of project performance. Practitioners need to develop the capacity to foresee potential problems likely to confront their current and future projects.

2.5.1 Types of delays:

When a construction projects begins, the original plan often changes due to some types of delays. Many type of delays can be avoidable by planning properly. Other types are often predictable due

to conditions beyond the contractor's power. The type of delay can also have an impact on non-critical activities which need a more detailed analysis to determine whether additional time extension can be given, or if the reduction of the time float can be justified (…….).

Generally, delays may be caused by: the client (compensable delays); the contractors (Non-excusable delays); or acts of God or a third party (excusable delays) [23]
According to [24] delay types can be classified into compensatory delays (CD), non-excusable delays (NED), and excusable delays (ED). CD refers to any 3 delays caused by clients (or their representatives), while NED represents delays caused by contractors (or their representatives). Any other delays are referred as ED.

Delays can be grouped in the following four broad categories according to how they operate contractually:

- ✓ Non-excusable delays
- ✓ Excusable non-compensable delays
- ✓ Excusable compensable delays
- ✓ Concurrent delays

2.5.1.1 Non-excusable Delays

Non-excusable delays are delays, which the Contractor either causes or assumes the risk for. These delays might be the results of underestimates of productivity, inadequate scheduling or mismanagement, construction mistakes, weather, equipment breakdowns, staffing problems, or mere bad luck. Such delays are inherently the Contractor's responsibility and no relief is allowed. These delays are within the control of the Contractor or are foreseeable; however, it is not necessary that they be both.

2.5.1.2 Non-compensable Excusable Delays

When a delay is caused by factors that are not foreseeable, beyond the Contractor's reasonable control and not attributable to the Contractor's fault or negligence, it may be "excusable". This term has the implied meaning that neither party is at fault under the terms of the contract and has

agreed to share the risk and consequences when excusable events occur. The Contractor will not receive compensation for the cost of delay, but he will be entitled for an additional time to complete his work and is relieved from any contractually imposed liquidated damages for the period of delay.

2.5.1.3 Compensable Excusable Delays

In addition to the compensable delays that result from contract changes by Change
Notice, there are compensable delays that can arise in other ways. Such compensable delays are excusable delays, suspensions, or interruptions to all or part of the work caused by an act or failure to act by the Owner resulting from Owner's breach of an obligation, stated or implied, in the contract. If the delay is compensable, then the Contractor is entitled not only to an extension of time but also to an adjustment for any increase in costs caused by the delay.
Owner-issued contracts specifically address some potential compensable delays and provide equitable adjustments. The usual equitable adjustment clauses in Owner issued contracts that apply to delay are:
_ Changes
_ Differing Site Conditions
_ Suspension
The changes clause in Owner-issued contracts provides that equitable adjustments may be considered as follows:

2.5.1.3.1 Changes

With the help of a written Change Notice, the Owner may, without any notice to the sureties (if any), unilaterally make any change, at any time in the Work within the general scope of the Contract, including but not limited to changes:

- In the drawings, designs or specifications
- In the method, manner or sequence of Contractor's work
- In Customer or Owner furnished facilities, equipments, materials, services or site(s)
- Directing acceleration or deceleration in the performance of the work
- Modifying the Contract Schedule or the Contract milestones

If at any time Contractor believes that acts or omissions of Customer or Owner constitute a change to the Work not covered by a Change Notice, Contractor shall within ten (10) calendar days of discovery of such act or omission, submit a written Change Notice
Request, explaining in detail the basis for the request. Owner may either issue a Change
Notice or deny the request in writing.

If any change under this clause causes directly or indirectly an increase or decrease in the cost, or the time required for the performance of any part of the Work, whether or not changed by any order, an equitable adjustment shall be made and the contract will be modified accordingly.

The clause recognizes that changes in the work or changes in the method or manner of performance may require changes in the schedule and schedule milestones and this could further necessitate revisions in activity durations, sequence of work items, or interrelationships of various tasks. These changes may have a direct impact on the schedule, as where a change in method requires a greater or lesser period of performance or its effects may be subtler, as where the change merely rearranges priorities.
In addition to a time extension, the contract's clause provides compensation for any delay resulting from a contract change by allowing an equitable adjustment for the increased cost of the performance of the work caused by the change.

2.5.1.3.2 Differing Site Conditions

The portion of the clause addressing cost or time adjustments for 'differing site conditions' provides:
If such conditions do differ in material and thus cause an increase/decrease in the
Contractor's cost or time required for performance of the Work, an equitable adjustment will be made pursuant to the General Condition titled "Changes". No claim of the
Contractor under this clause will be allowed unless the Contractor has given the required notice. The main intention is to leave the Contractor neither damaged nor enriched because of the resultant delay.

The differing site conditions clause must not be confused with the Site Conditions clause in Owner issued contracts - the so-called “Exculpatory” clause. Its intent is to disallow any claims for delays relating to conditions at the site, which the Contractor should have anticipated. The exceptions are limited to those conditions defined in the Differing Site Conditions clause.

2.5.1.3.3 Concurrent Delays

Concurrent delays occur when both Owner and the Contractor are responsible for the delay. Generally, if the delays are inextricably intertwined, neither the Contractor can be held responsible for the delay (forced to accelerate, or be liable for liquidated damages) nor can he recover the delay damages from the Owner.

Until the development of CPM schedule analysis, there was no reliable method to differentiate the impact of Contractor caused delays from Owner-caused delays. With the sophisticated computerized techniques now available, however, it has become possible to segregate the impacts of apparently concurrent Owner and Contractor delays.

In analyzing a delay claim, an analysis based on a comparison of the Contractor’s approved CPM schedule with the as-built CPM schedule should be performed to apportion proper responsibility for delay. Because the critical path may shift as the job progresses, it is updated based upon contractually required input from the Contractor.

2.6 Effect of construction Delays

Construction delays occur either as a liability on part of the client and his team, liability on part of the contractor and his team, nature i.e. causes of force majeure and social political issues through the changes bye-laws, statues etc. The effects of these delays is always debilitating on construction project performance. Studies conducted on the effect of delay on project delivery have revealed that delays are associated with time and cost overruns as well as litigation and project abandonment [25].

Delays influence negatively on the contractors performance and contribute to adverse impacts in construction comes like contract disputes increase and low productivity in construction prices which will additionally influence on the pre determined of construction project objectives [26].

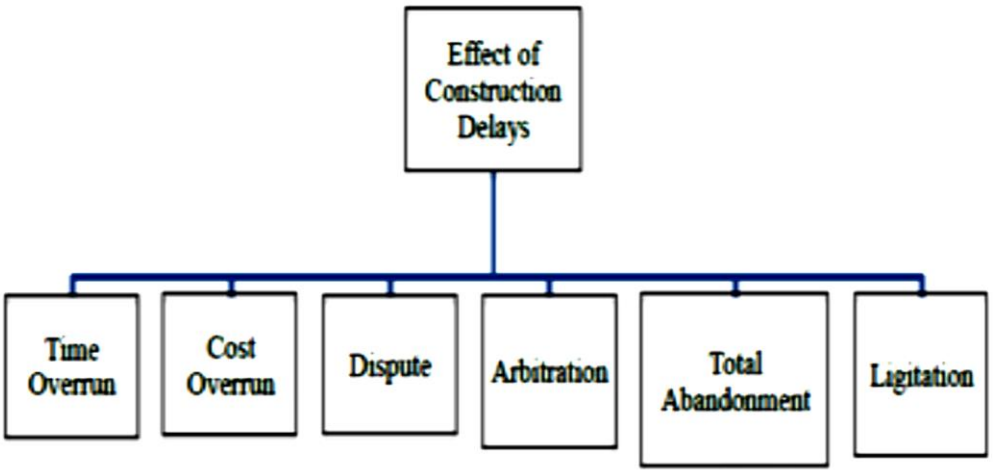


Figure 2: 2 Effects of Construction Delays [26]

Across the world many articles and studies conducted on the causes of construction project delays have been examined.

[27] concluded in his surveys on the problems of projects and effects of delays in the construction industry of pakistan that The survey results indicated that the majority of delay factors are relevant to client factor. It is concluded from survey for dipping in delay client must have strong economical ability and financial arrangement for project, correctly time decision.

2.7 Causes of delays

The causes of project delays fluctuate according to and due to the faults and weaknesses of the owner and the contractor. The causes for the delays of construction projects in developing countries are multifarious in nature and change from region to region and county to country [28] Construction delays occur either as a liability on part of the client and his team, liability on part of the contractor and his team, nature i.e. causes of force majeure and social political issues through the changes bye-laws, statues etc.

Survey conducted by Kaminget al. In studied influencing factors on 31 high-rise projects in Indonesia and found out that cost overruns occur more frequently and are more severe problem than time overruns. They pointed out that the major factors influencing cost overrun are material cost increase due to inflation, inaccurate material estimation and degree of complexities [29].

2.8 Project Delays across the world and in the region

The road construction sector in Tanzania is evidenced from many studies to experience mainly three kinds of extended problems [21]:

One problem concerns time management, i.e. road works are not completed within the agreed time and benefits of the works to the public are delayed. The overall assessment of implementation performance has a score of 1.8 which is unsatisfactory. The delay in implementation exceeds 9 months [30].

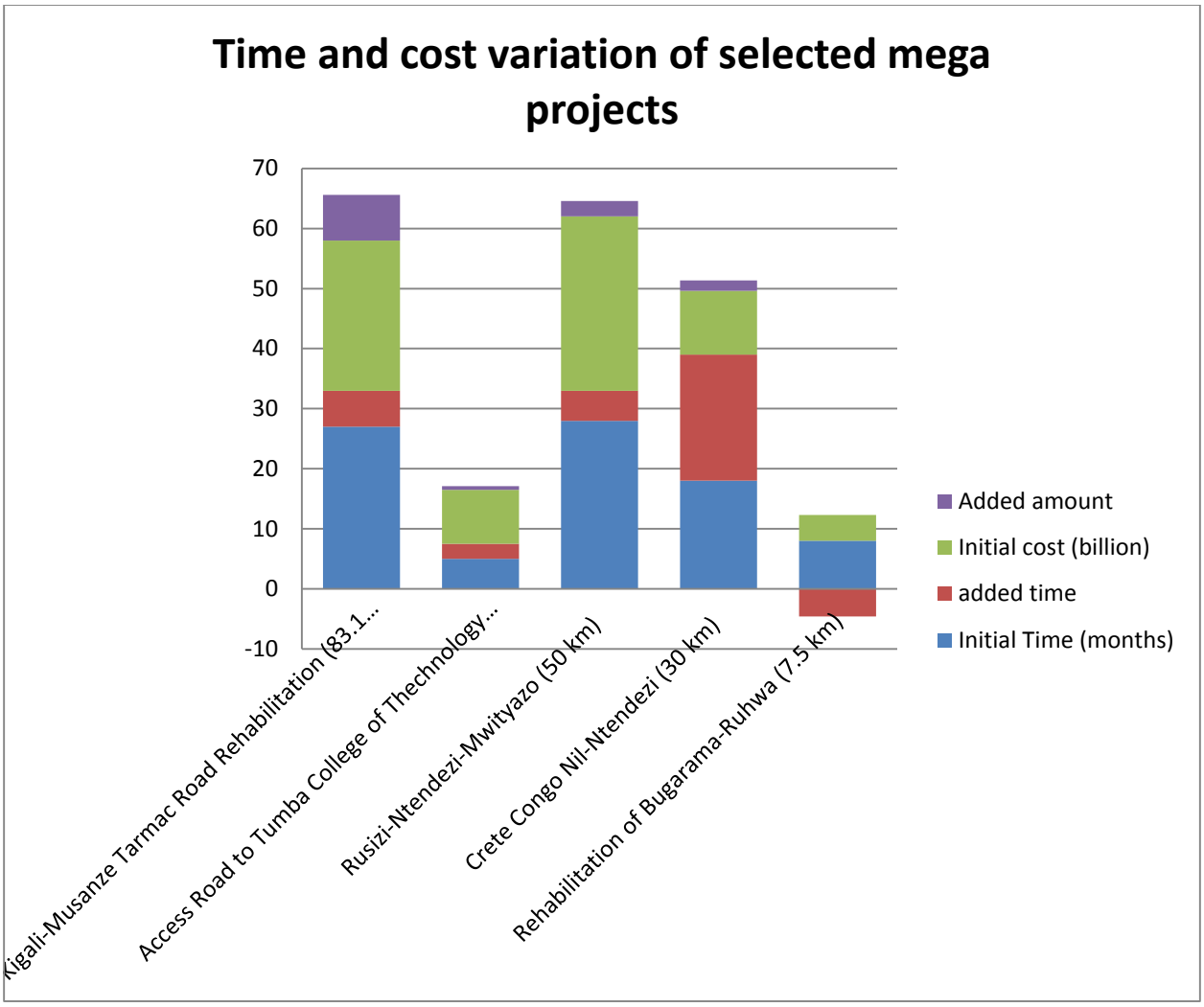


Figure 2: 3 Delay and cost variation of five mega projects selected (Source; RTDA)

According to addendums and modifications made on the contracts for above mentioned projects and reviewed correspondences, the following are the main and common reasons for changes: Scarcity of materials in the region, external factors such as rainfall, late in equipments and materials exemption, slowness in decision making by the owner, unexpected site condition (due to the poor study) and financing project by the contractor.

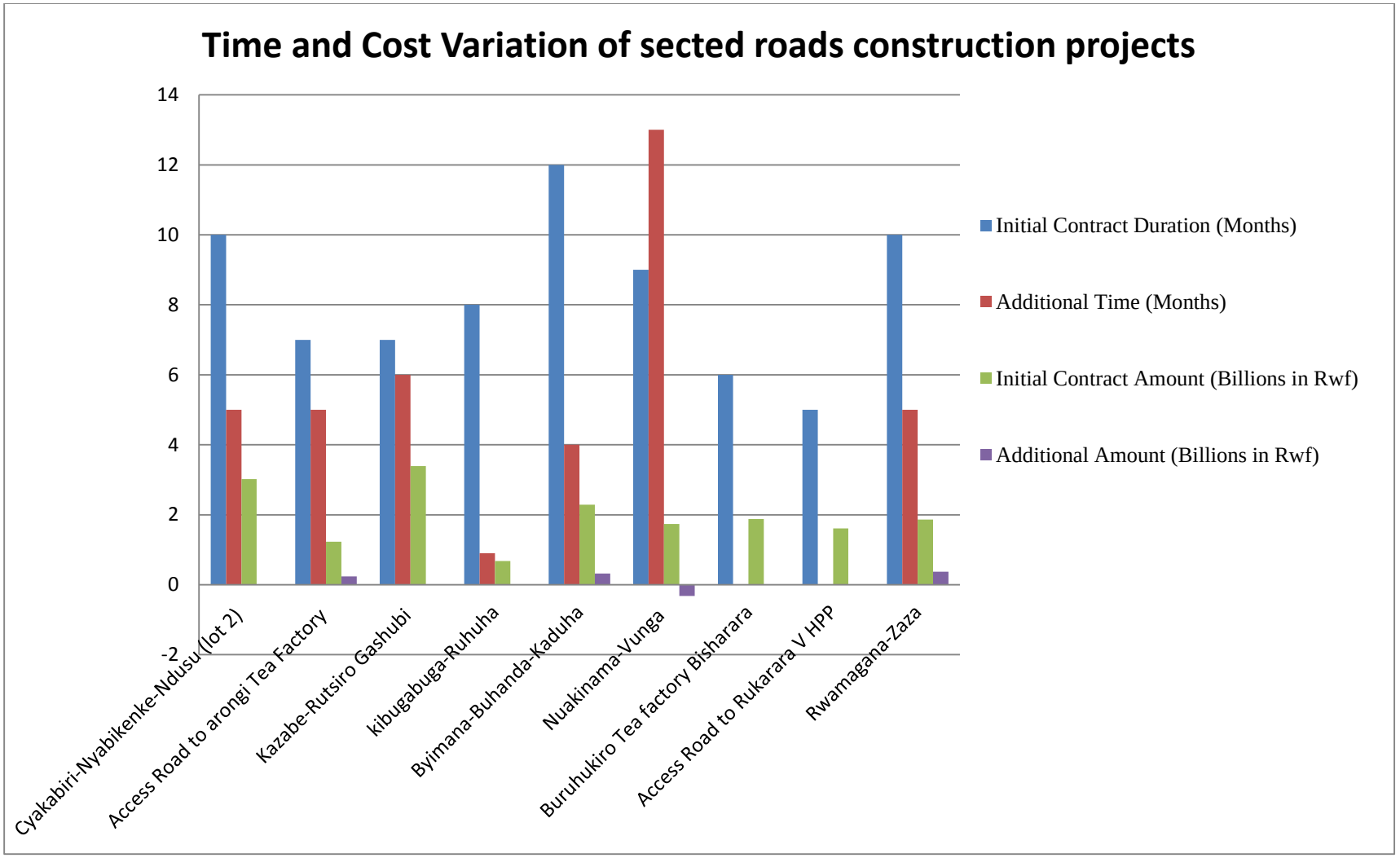


Figure 2: 4 Delay and cost variation of five mega projects selected (Source; RTDA)

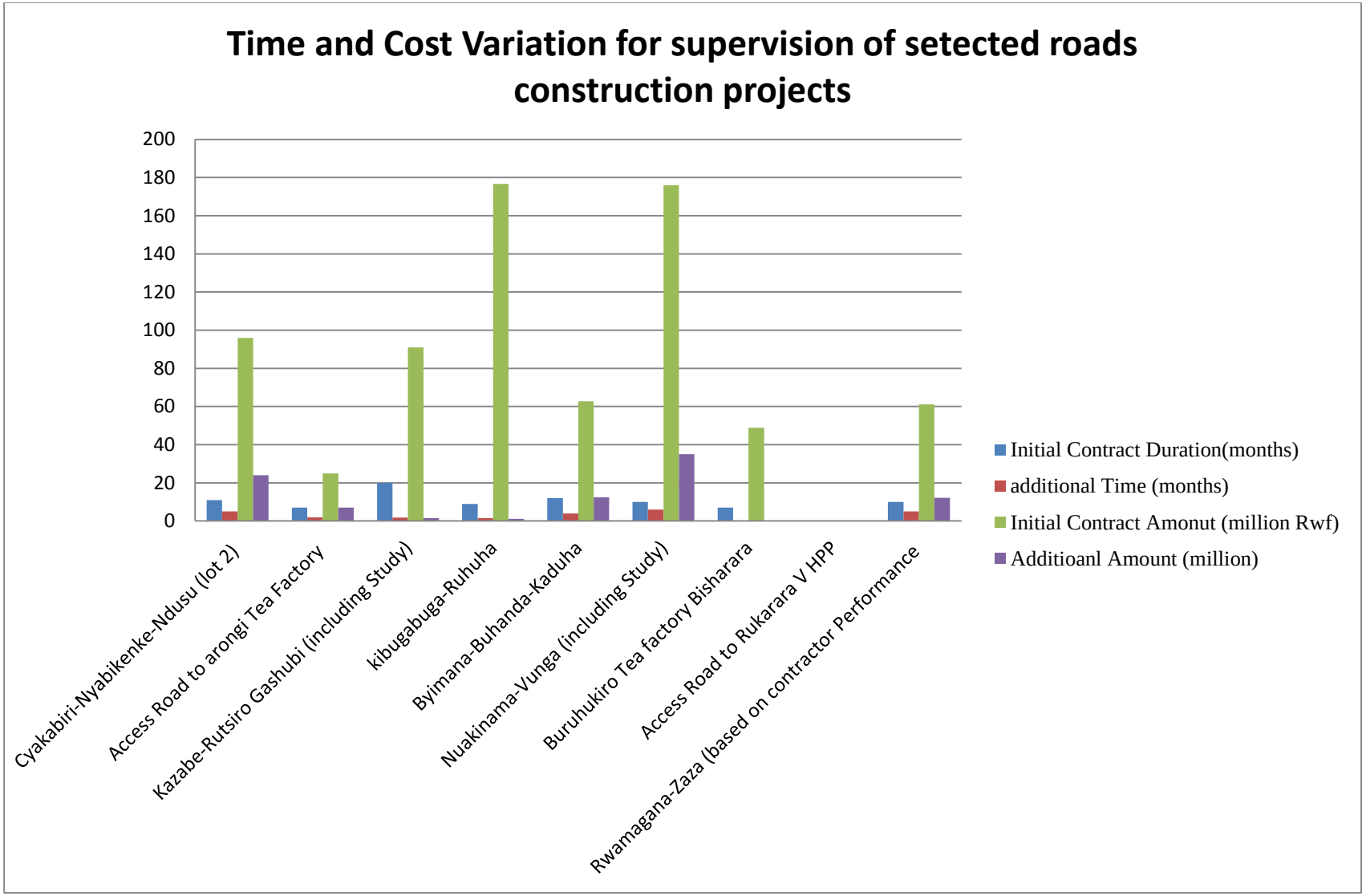


Figure 2: 5 Delay and cost variation of five mega projects selected (Source; RTDA)

According to addendums and modifications made on the contracts for above mentioned projects and reviewed correspondences, the following are the main and common reasons for changes: equipments breakdown, Scarcity of materials in the region, external factors such as rainfall, late in equipments and materials exemption, poor site management, slowness in decision making by the owner, unexpected site condition (due to the poor study) and financing project by the contractor.

2.9 Cost Overrun in Construction Projects

There is a wide range of views for causes of quality shortfall, schedule delays and cost escalations in engineering and construction projects. Some are attributable to a single party, others can be ascribed to several quarters, and many relate more to systemic faults or deficiencies rather than to a group or groups of people [31].

A cost overrun, also known as cost increase of budget overrun, involves unexpected costs incurred in execs of budgeted amounts due to an underestimation of the actual cost during budgeting. Cost overrun should be distinguished from cost escalation, which is used to express an anticipated growth in a budgeted cost due to factors such as inflation [32].

Cost is among the major considerations throughout the project life cycle. The gap between the cost at completion and that originally estimated known as cost overrun can be regarded as one of the most important parameters reflecting the success of projects [33].

According to [34] for tenders planned to be executed within a period which exceeds nine (9) months, the bidding document shall determine the modalities for revising the price. Such modalities shall be defined in the procurement regulations.

However, prices shall not be revised for completed works or works that have delayed to be completed when the successful bidder is responsible for such delays except where the revision is meant for reducing the price.

2.9.1 Review of cost deviation across the world

A study for cost deviation in road construction based on 74projects awarded in the West Bank in Palestine over the years 2007–2010, reveals that the average of cost deviation in road construction projects is 16.73%, ranging from _20.33% to 56.01%.

The statistical analyses of cost deviation of 74 road construction projects indicate the following [35]:

1. 100% of the project suffers from cost deviation.
2. The cost under estimation is more predominant in road construction projects.
3. Weak linear relation between cost deviation in road construction and project's physical characteristics such as terrain conditions, soil and rock suitability, and soil and rock drill ability.
4. Good correlation between project size and cost deviation inroad construction project.
5. Moderate correlation between cost deviation in road construction and a combination of road size (m2) and its physical characteristics (i.e. terrain conditions, soil and rock suitability, and soil and rock drill ability).

Inaccuracy of traffic forecasts and cost estimates on large transport projects. On seven large Danish bridge and tunnel projects since 1960, construction costs had been underestimated (average cost overrun was 14%) and traffic had been overestimated in the initial phases of planning. Cost overrun and benefit shortfall pattern is also found in studies from other countries of large transport projects. The result of this over optimism in the initial phases of planning was that decisions were based on misleading forecasts that might lead to a misallocation of funds and underperforming projects [36].

Based on cost estimations and outcomes of 167 road and rail projects in Sweden during the period 1997-2009, the average cost overruns are 11% (SD = 24.6%) and 21% (SD = 50.5%) for road and rail projects, respectively. In Sweden, the average cost overrun in road projects is similar to other countries, while the average cost overrun in rail projects is lower than in other countries. However, the standard deviation of cost overruns in Swedish rail projects is very high.

One of the first empirical studies with a narrow focus on cost overruns in large projects. He argues that delays in project implementation and cost overruns have become a regular feature of public sector projects. The average cost overrun found in this study is 82%. As far as possible causes are

concerned, concludes that about 20 - 25% can be attributed to price increases, and the remaining 70-75% has to be explained in terms of real factors, such as delays in implementation [37].

2.9.2 Causes of cost escalation

According to [38], the following are the factors causing the cost escalation of the construction project.

Cost Escalation Factors by Cause and Development Phase

Source	Cost escalation factor
Internal	Bias
	Delivery/procurement approach
	Project schedule changes
	Engineering and construction complexities
	Scope changes
	Scope creep
	Poor estimating
	Inconsistent application of contingencies
	Faulty execution
	Ambiguous contract provisions
	Contract document conflicts
External	Local concerns and requirements
	Effects of inflation
	Scope changes
	Scope creep
	Market conditions
	Unforeseen events
	Unforeseen conditions

The five most important causes of delays and cost overrun are changes in scope, delayed payment to contractor, poor monitoring and control and high inflation and interest rates.

According to [39], the main controllable causes of the projects‟ cost overruns include but are not limited to the following:

a) Inadequate project formulation: Poor field investigation, inadequate project information, bad cost estimates, lack of experience, inadequate project formulation and feasibility analysis, poor project appraisal leading to incorrect investment decisions.

b) Poor planning for implementation: Inadequate time plan, inadequate resource plan, inadequate equipment supply plan, inter-linking not anticipated, poor organization poor cost planning.
c) Lack of proper contract planning and management: Improper pre-contract actions, poor post-award contract management.
d) Lack of project management during execution: Insufficient and ineffective working, delays, changes in scope of work and location, law and order.

2.10 Review of Roads construction Quality shortfall

The term quality, particularly when applied to constructed facilities, has no single generally accepted meaning. [4] defined the quality as the totality of features and characteristics of a product, service or facility that bear on its ability to satisfy a given need. According to the American Society for Quality, "quality" can be defined in the following ways:

Based on customer's perceptions of a product/service's design and how well the design matches the original specifications. The ability of a product/service to satisfy stated or implied needs. Quality is a value-laden term that depends on one's point of view [40].

In engineering and manufacturing, quality control and quality engineering are involved in developing systems to ensure products or services which are designed and produced to meet or exceed customer requirements and expectations [41].
Achieved by conforming to established requirements within an organization.

There are five aspects of quality in a business context:

- ✓ Producing - providing something.
- ✓ Checking - confirming that something has been done correctly.
- ✓ Quality Control - controlling a process to ensure that the outcomes are predictable.
- ✓ Quality Management – directing an organization so that it optimizes its performance through analysis and improvement. According to [42] A QMS can be defined as the managing structure, responsibilities, procedures, processes, and management resources to implement the principles and action lines needed to achieve the quality objectives of an

organization. A quality management system is a management technique used to communicate to employees what is

- ✓
- ✓ Quality Assurance – obtaining confidence that a product or service will be satisfactory. (Normally performed by a purchaser)

Within the limited context of the design and construction stage of a facility, quality can be more readily defined as conformance to adequately developed requirements. This definition indicates that a quality constructed facility will result provided that the following conditions are met [40].

• contract documents comprise a clear, complete, and accurate description of the facility to be constructed, correctly conveying the intent of the owner regarding the characteristics of a facility needed to serve his or her purposes;
• contract documents define a constructed facility considered acceptable under applicable regulatory codes and standards of professional practice, in terms of its reliability, the ease with which maintenance and repairs can be performed, the durability of its materials and operating systems, and the life safety afforded its users; and
• The facility is constructed in accordance with those documents.

2.10.1 Poor Quality of Roads Construction Projects

The process of road deterioration can be slowed significantly by effective asset management. This can extend the pavement life and ensure a safe and smooth travelling surface [43].

The road construction sector in Tanzania is evidenced from many studies to experience mainly three kinds of extended problems [21].
One problem concerns time management, i.e. road works are not completed within the agreed time and benefits of the works to the public are delayed.
Second problem concerns cost overrun, i.e. additional but avoidable costs to the decided budgets for varying reasons, and
A third problem concerns the weaknesses in quality control system of the road works which results into early wear and tear necessitating repair and maintenance.

Rates of deterioration are higher than anticipated which implies early repair and maintenance [21].

According to the project documents; inadequately prepared designs is the main cause of problems in the construction phase [21].
Despite the fact that TANROADS' officials state that its quality control system is working well, this audit has found that there is still need for improvement. The quality control in the design phase is obviously not effective [21].

2.10.2 Factors causing cost escalation, schedule overruns and quality shortfalls

Factors that cause cost escalation, schedule overruns and quality shortfalls were identified. The study further established that: insufficient initial analysis of costs; change orders or scope changes; and inflation; were the three most significant causal factors for cost escalation. Financial difficulties on the part of contractors; change orders or scope changes; and poor sub-contractor performance were the three most significant causal factors for schedule overruns while those for quality shortfalls included: inadequate and/or inconsistent release of project funds by clients; poor financial management by contractors; and long time lapse between feasibility study and implementation of projects [44].
[13] Considers this a bad choice of terms, as time management implies personal efforts to manage one's time. For projects, it refers to developing a schedule that can be met, then controlling work to ensure that this happens! It's that simple. One cause of project failure is that quality is overlooked or sacrificed so that a tight deadline can be met. It is not very helpful to complete a project on time, only to discover that the thing delivered won't work properly! [13]

2.10.3 Road Assets Condition and Deterioration

The performance of a highway facility is determined primarily by the degree of deterioration of its individual components, known as road assets. Each type of road asset will deteriorate differently from the other. Below figure shows the variation over time of the performance corresponding to a generic road asset. The physical deterioration of the asset causes its performance to decline. This variation in performance is represented by a curve line. According to [45], the deterioration curve can be obtained by measuring the physical condition of the road asset at different points in time.

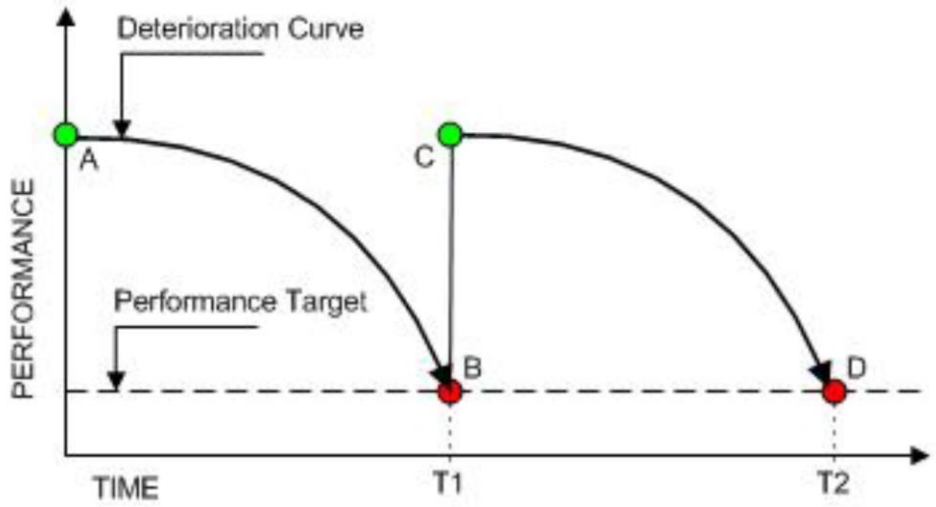


Figure 2: 6 Road construction deterioration [45]

Point A in **Figure indicates** the initial level of asset performance after the construction of the facility. The horizontal dashed line is the lowest performance level at which the asset is allowed to perform. This lower limit is called the performance target and it is usually defined during the development phase. Right after construction, the road asset starts deteriorating and its 14 performance declines. The decline continues until it reaches point B at time T1. At this point, the asset is restored to its original conditions, point C, and the deterioration cycle restarts.

Road deterioration is broadly a function of the original design, material types, construction quality, traffic volume, axle load characteristics, road geometry, environmental conditions, age of pavement, and the maintenance policy pursued [46].

The condition of the drains will deteriorate unless they are maintained adequately through, for example, routine maintenance. The deterioration of side-drains has the effect of reducing pavement strength and accelerating its deterioration. Drain life is expressed as a function of terrain, drain type, climate type and the maintenance policy pursued. A number of drain types are considered in RD modelling [47].

The modelling of road shoulder deterioration is required in order to assess the effect on the rate of pavement deterioration; and the impact on non-motorised transport and traffic flow in terms of Road User Costs. It is proposed to include this feature in a future release of HDM-4.

2.10.4 Defects Liability Period Challenges in Rwanda

Despite the roads construction contracts state that the provisional handover is done within 20 days after the notification of work completion by the contractor. The final handover is done after 365 days starting from the date of declaration of provisional handover the sane as Rwanda Public Procurement Law No.05/2013 of 13/02/2013 law modifying and completing the Law No. 12/2007 of 27/03/2007 on Public Procurement up to date. Many projects are now facing the issue of getting a final notification just after one year of provision notification due to the rapid deterioration.

Km 54+000: wicked crack. .(this happened after construction this section in time less than 1 year)

Km 37+700 RHS, there was slope sliding and settlement Half of pavement is broken.(this happened after construction this section in time less than 1 year)

Figure 2: 7 Defects on Kagali-Musanse paved Road (Source: Project Engineer Final Report of Rehabilitation of Kigali - Ruhengeri).

According to consultant who carried out technical audit states that landslide caused by lack of soil cohesion [48]. Said that the failure caused by deforestation.

PK 28 on Rusizi-Bugarama Paved Road After the failure, caused by poor site investigation during the study.

Beginning of the Failure

Figure 2: 8 Defects on Rusizi-Bugarama paved Road (Source: Project Engineer).

From 2010 the following projects have not been handed over after one year as it was specified in the contracts due to the deterioration of some sections and some of them required a technical audit to identity and determine the responsibilities of each stakeholder in the failure this resulted from misunderstanding and the issues are still pending.

- Final Report of Rehabilitation of Kigali - Ruhengeri paved road (83 Km)
- Final Report of Rehabilitation of Ngororero-Mukamira Paved road

Others got handover acceptance after 2 years and above;

- Maintenance works Kibeho-Muse unpaved Road (Km)
- Maintenance works Buringa Remera unpaved Road

The contract modifications are normal part and bridge construction process and are required to authorize payment for additional project costs not in the original contract agreement. Contract modifications are also necessary to address changes in contract specifications that alter the quantity of materials used in the project, changes that require additional work or materials not specified in the original, contract, monetary adjustments to an individual contract pay item or to the entire contract, changes to the contract completion dates, and miscellaneous changes to the contract. [21]

According to [49] the main common causes of quality shortfalls in construction projects were identified to include: corruption; lack of qualified personnel on site; lack of motivation amongst site personnel; lack of reliable sources of materials; poor quality control; and lack of adequate supervision. The ranking of these causes were based on the frequency of interviewees who mentioned them as critical casual factors for quality shortfalls on construction projects.

Table2: 2 Project Procurement in Ghana Using the Traditional System [50].

Authors	Problem	Causes
Westring (1997)	Delays and cost overruns	Extensive post-award negotiations, delays in the preparation of technical specifications and drawings, delays in evaluation, an extensive system of controls, reviews and approvals, and land ownership disputes,
Westring, 1997; World Bank, 1996;2003	poor quality	Service providers cutting corners to limit losses or abandoning the work altogether.
Eyiah and Cook, 2003; Westring, 1997	Delays	Long process of payment to contractors and suppliers – "over thirty steps from invoice to receipt of payment cheque", over-centralised.
World Bank, 1996; 2003	Insecurity of funding for projects	Fiscal constraints and poor procurement practices resulting in delayed payments and arrears to contractors and consultants; accumulated interest on late payments and the frequent price changes due to extensive renegotiation; difficulties by contractors and consultants in processing claims
Dansoh, 2005; Westring, 1997.	Contractual and procurement issues	Lack of respect for contract with neither party expects contracts to be fully binding; ad hoc approaches to economic-sizes project; difficulties in long-term strategic planning by contractors; poor monitoring and control of procurement.

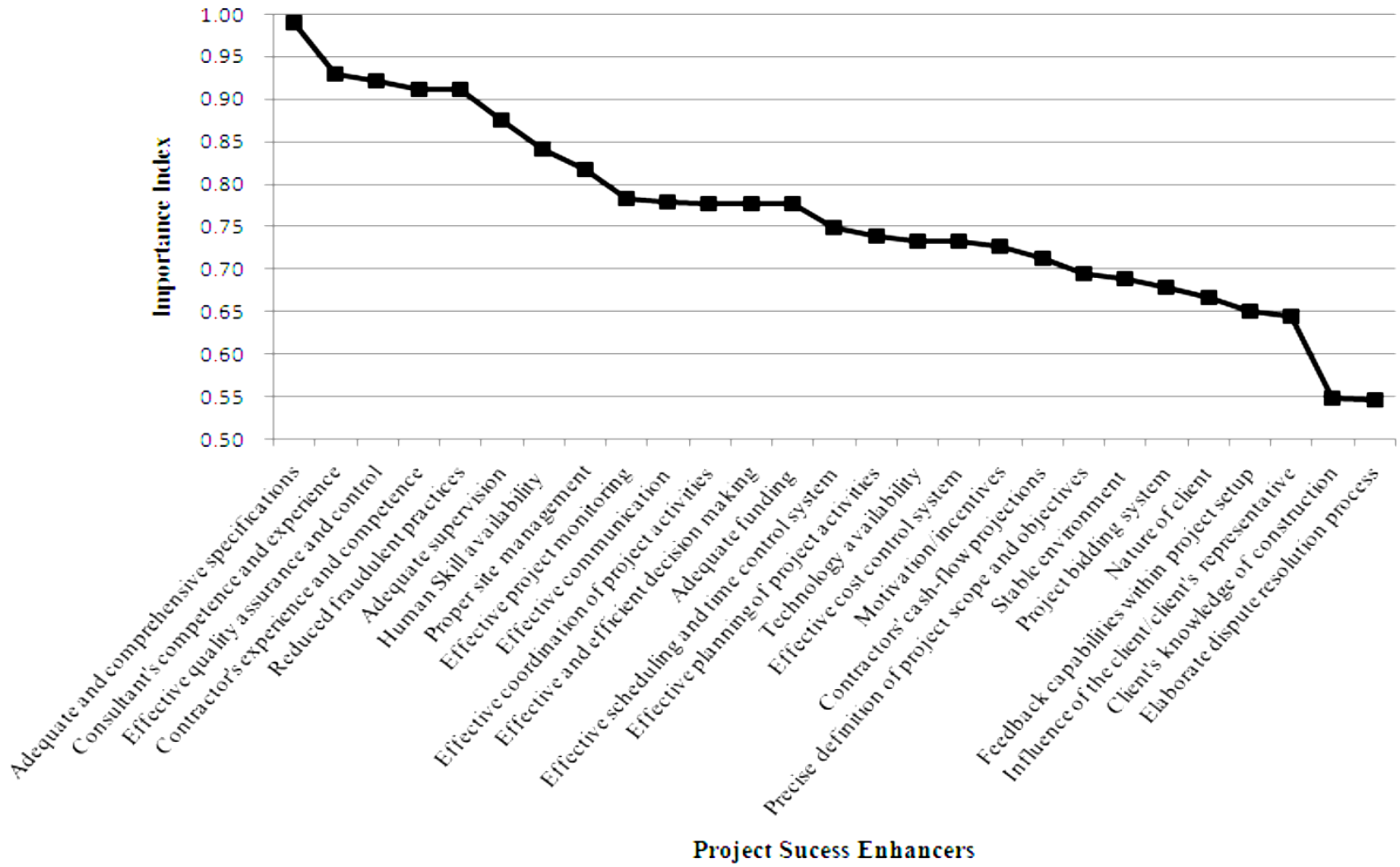


Figure 2: 9 Rating of project success factors with respect to quality [49]

Chapter 3: METHODOLOGY AND DATA COLLECTION

3.1 Introduction

According to [51] a research design must Cleary describe the general plan of how the research questions will be answered together with providing justification of the methods selected and employed for a particular research design.

There is a variation within and between methodologies in how research design is defined, for example; in one study research design may reflect the entire research process, from conceptualizing a problem to literature review, research questions, methods, and conclusion, whereas in another study, research design refers only to the methodology of a study (e.g., data collection and analysis).

According to [52] to determine the methodology of the research, the fundamental question must be defined in order to plan logical steps from which conclusions could be drawn. The major question the research seeks to explore is: What are the factors that affluence delay and quality of road construction projects in Rwanda?

This chapter investigates current research approaches with a view to selecting the most appropriate methodology for the current research project, including study design, target population, sample design, data collection procedure, and the data analysis methods.
The research design should:

- Make explicit the questions the research should answer
- Provide hypotheses or propositions about these questions
- Develop a data collection methodology, and
- Discuss the data in relation to the initial research questions and hypotheses or propositions.

The research was carried out in four phases as follows:

1. A literature search from journal, web sites and books was undertaken to ascertain the general knowledge of the project topic.
2. 1st Questionnaire was designed and sent to Civil Works Consultants, Road Contractors and Public Institutions, such as Ministry of Infrastructure, City of Kigali, Rwanda Transport Development Agency (RTDA) and Districts. This was to seek their opinion on the factors that affect delays and quality of Roads construction Projects in Rwanda. After the classification of variables according to their importance rating, the unimportant variables were removed from the lists.
3. 2nd Fuzzy-AHP Questionnaire was designed and sent to the experts in Road Construction field. This was to seek their opinion on pair wise comparison between Alternatives and subcriterias by using triangular fuzzy number and linguistic terms.
4. The results of the questionnaire was analyzed using the Fuzzy AHP Calculations to determine the weight for ranking of the Criterias and subcriterias (factors) according to their weight influencing delay and quality in road construction field.

3.2 Data collection

According to [53] a data collection plan is essential to ensure the collected data supports the overall objectives of the performance monitoring program.

Surveys are fixed sets of questions that can be administered by paper and pencil, as a Web form, or by an interviewer who follows a strict script [54].

Many considerations go into deciding the appropriate method of data collection to use, or even if data collection is appropriate, for answering the research questions.

The first questions that you should ask are: Has this been done before? Do these data already exist? If so, is there value-added in doing this again? [54]

The main objective of the data collection plan is to identify the information needed as well as the sources that can provide that information [55]. For instance, in the case of road construction project management, one must first define the main stakeholders of the project (e.g., Client, Donors, Contractors, etc…) in charge of project initiation; planning and implementation. Once the

stakeholders are defined, the next step is to identify the data sources that will aid in conducting performance evaluations. Close attention must be paid to collecting
only what is needed, and not all that is available [55].

3.3 Questionnaires Development

The structured questionnaires are attached as appendix C. The questionnaires were developed with brevity as an intended goal. The questionnaire was tested within a small section of professionals in the RTDA for clarity, ease of use, and value of the information that could be gathered.

3.3.1 First round of the survey

The questionnaire was developed in accordance with the objectives of the research which was to identify the significant factors that cause the delays and influence the quality of roads construction projects in Rwanda.
For the 1st round of the survey, the questionnaire was organized in three parts. The first part contained questions that seek to identify the establishment and level of experience of the respondents. The option of evaluation was based upon Likert scale ranging from extremely important (1st level) to unimportant (5th level). A Likert scale is composed of a series of four or more Likert-type items that are combined into a single composite score/variable during the data analysis process [56].

Mehrdad Madhoushi did a research on "analysis of the factors of projects success or failure and offering a prediction model" to obtain a Ph.D. in management. In this research, a project which is completed in the framework of the determined time and budget and the function in question and meets the expectations of the manager, user or client, is defined as a successful project. 68 variables, which influence the project success/failure were defined and classified in 9 variable groups. In this research developed and updated Likert scale was used as the measurement tool. Evaluation of this tool confirmed its reliability and validity. Success prediction model was developed based on the critical and key factors and its validity was examined [57].

The variables were rated on the five point Likert scales which have importance rating values from 1 to 5. Please, respondents were asked to give their details by ticking one of the boxes provided.

3.3.2 Second round of the survey

For the 2nd round of the survey, the questionnaire was organized in two parts. The first part contained questions related to delay of road construction projects whereby to make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared [58] Assign scale: 1 = 'Not Important' to 9 = 'Extremely Important' [59]. By using Fuzzy AHP model, it has been used the linguistic terms whereby decision maker fell more comfortable using terms. For example, some may consider that payment i is "absolutely important" compared with the slowness in decision making j under delay criteria, decision maker may set *aij*=(8, 9, 9). Element j is thought to be "absolute less important" than element i the pair wise comparison between *i* and *j* could be presented by using fuzzy number *aij*= (1/u_1, 1/m_1, 1/l_1) = (1/9, 1/9, 1/8).

3.4 Sampling in Evaluation Research Design

3.4.1 Key Sampling Terms and Concepts

Why do we use sample surveys? We have no choice when the population is continuous (that is, effectively infinite), but we can define a sample from either a finite or an infinite population.

Surveys are done for several reasons. A sample survey costs less than a census of the equivalent population, assuming that relatively little time is required to establish the sample size [60].
According to [61], In addition to the purpose of the study and population size, three criteria usually will need to be specified to determine the appropriate sample size: the level of precision, the level of confidence or risk, and the degree of variability in the attributes being measured.

3.4.2 Definitions

Before examining sampling methods in detail, you need to be aware of some more formal definitions of some terms used so far, and some that will be used in subsequent sections.

Table3: 1: Definition of key sampling Terms

Terms	Definitions
Population	A finite (or infinite) set of 'objects' whose properties are to be studied in a survey
Target **Population**	The population whose properties are estimated via a sample; usually the same as the 'total' population.
Sample	A subset of the target population chosen so as to be representative of that population
Sampling Unity	A member of the sample frame A member of the sample
Probability **Sampling**	Any method of selecting a sample such that each sampling unit has a specific probability of being chosen. These probabilities are usually (but not always) equal. Most probability sampling employs some form of random sample to generate equal probabilities for each unit of being selected.
Non-probability	A method in which sample units are collected with no sample specific probability structure.

3.4.3 Sampling Technique

The questionnaires were sent to select Public Institutions, and randomly selected Consultants Companies, and Road Contractors.

The Public Institutions were bodies that implement road projects in the country. These were made up of Rwanda Transport Development Agency, Districts and City of Kigali. The Road Contractors and Consultants Companies were selected from Rwanda Private Sector Federation (PSF).

Statistical method was used in establishing the sample size for Public Institutions, Consultants Companies, and Road Contractors for the study.

According to [62] statistical formula for determining the sample size are stated below:

$$n = \frac{n^1}{\left(1 + \frac{n^1}{N}\right)}$$

Where:

$n = Sample\ Size$

$n^1 = \frac{S^2}{V^2}$

$N = Population\ Size$

$S = Maximum\ standard\ deviation\ in\ the\ population\ element$
$(Total\ error = 0.1\ a\ confidence\ level\ of\ 95\%)$

$V = Standard\ error\ of\ sampling\ distribution = 0.05$

$P = the\ propotion\ of\ the\ population\ elements\ that\ belong\ to\ the\ defined\ class$

$S^2 = P(1-P) = 0.5(1-0.5) = 0.25$

Sample size for Public Institutions/owners

$$n = \frac{n^1}{\left(1 + \frac{n^1}{N}\right)}$$

$N = 52\ (District, Kigali\ City\ and\ RTDA, 2014)$

$$n^1 = \frac{0.25}{0.05^2} = 100$$

$$n = \frac{100}{\left(1 + \frac{100}{52}\right)} = 34.21 = 34$$

Sample size for Local Consultant Companies

$$n = \frac{n^1}{\left(1 + \frac{n^1}{N}\right)}$$

$N = 15$ $(District, Kigali\ City\ and\ RTDA, 2014)$

$$n = \frac{100}{\left(1 + \frac{100}{15}\right)} = 13.04 = 13$$

Sample size for Contractors

$$n = \frac{n^1}{\left(1 + \frac{n^1}{N}\right)}$$

$N = 20$ $(District, Kigali\ City\ and\ RTDA, 2014)$

$$n = \frac{100}{\left(1 + \frac{100}{20}\right)} = 16.66 = 17$$

The following personnel/organization chart in above Public Institutions the questionnaires were given to the following:

- Directors/Roads Construction and Rehabilitation Units
- Project Engineers/Projects Managers

This gives a total of Thirty Four (34) questionnaires sent to the above Public Institutions.

The following personnel/organization chart in above Private Companies (Consultants & Contractors) the questionnaires were given to the following:

- Project managers
- Head of missions

This gives a total of Thirty (30) questionnaires sent to the above Public Institutions.

Table3: 2 Sample size for each of the selected Group (1st round)

Institutions/Companies	Minimum Sample Size	Number of Questionnaires Allotted
Public Institutions	34	68
Consultants	13	26
Companies Contractors	17	34
Total	**64**	**128**

3.4.5 Sampling Technique for survey (2nd round)

When there is insufficient data about the project and high level of uncertainty resulting from ambiguity, it is unreliable to use statistical data of the past projects for dealing with the risk of the projects. In such cases, according to it is better to use expert opinion and prediction to make a proper estimation (Page 2000) [63]. In the complex world system, the problems dealt with are often greater than the resources available to handle them.

To deal with such complex and unstructured problems, there is need to prioritize, agree that one objective outweighs another, and make trade-offs to serve the greatest common interest or overall objective. It is advised to use Experts or experienced people in the field when you are using Fuzzy AHP model. The second questionnaire, which was distributed among the field experts after the first one, was in the form of Fuzzy-AHP questionnaire and was designed for weighting the criteria and sub criteria with respect to the Alternative. Ten Experts have been given the questionnaires in this study.

3.5 Data Analysis

All data collected during the first survey from the questionnaires was recorded into the Excel sheet. [31] Used mean and Fuzzy-Ahp approach for developing financial decision support for highway infrastructure sustainability. This research also used the same approach to support criticality index to dealy and quality components related to project performance.

3.5.1 Mean Importance Rating

The level of importance was based on their professional judgment on a given five Likert-scale from 1 to 5 (where 1 is most important at all and 5 is less important). Lower mean scores reflect responses that indicate the lower importance of the respective quality or delay components/factors. The first five critical criteria or sub-criteria have been retained and analyzed in the second stage with mathematical model Fuzzy-AHP.

The mean scores ratings of all proposed criteria and sub-criteria were calculated using (Eq….)

$$a = \frac{1(n1) + 2(n2) + 3(n3) + 4(n4) + 5(n5)}{(n1 + n2 + n3 + n4 + n5)}$$

Where "a" is the mean importance rating of an attribute and n1, n2, n3, n4, and n5, represent the number of subjects who rated the cost components as 1, 2, 3, 4 and 5, respectively.
The data from the survey was analysed using mean and standard deviation to rate the cost components.

3.6 Decision making with the analytic hierarchy process

The construction industry is a very competitive high-risk business. Increasing uncertainties in technology, budgets and development processes create a dynamic construction industry.
Construction projects are now much more complex and difficult and the construction project team faces unprecedented changes. The study of project success and critical success factors is means of understanding and thereby improving the effectiveness of construction projects. However the concept of project success remains ambiguously defined in the mind of construction professionals. There is no an industry-accepted or standardized definition of project success because the fact is that individual project teams find themselves in unique situations, implying that their definition of success will differ from that of another project team. Project success is a topic that is frequently discussed and yet rarely agreed upon.

We are all fundamentally decision makers. Everything we do consciously or unconsciously is the result of some decision [57] the information we gather is to help us understand occurrences, in order to develop good judgments to make decisions about these occurrences.

According to [57] the Analytic Hierarchy Process (AHP) is a theory of measurement through pair wise comparisons and relies on the judgments of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments that represents how much more; one element dominates another with respect to a given attribute.

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method that helps the decision-maker facing a complex problem with multiple conflicting and subjective criteria (e.g. location or investment selection, projects ranking, and so forth) [64]. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process.

Having been developed on the basis of the fact that when human beings make decisions their brains utilize the analytic process in a gradual or hierarchical way, this theory is the method to arrive at a final decision making by decomposing the whole process of analysis into several sub-processes and then analyzing them independently step by step [65].

The AHP is a very flexible and powerful tool because the scores, and therefore the final ranking, are obtained on the basis of the pairwise relative evaluations of both the criteria and the options provided by the user. The computations made by the AHP are always guided by the decision maker's experience, and the AHP can thus be considered as a tool that is able to translate the evaluations (both qualitative and quantitative) made by the decision maker into a multicriteria ranking. In addition, the AHP is simple because there is no need of building a complex expert system with the decision maker's knowledge embedded in it.

3.6.1 The analytic hierarchy process

To make a decision in an organised way to generate priorities we need to decompose the decision into the following steps [58]

1) Define the problem and determine the kind of knowledge sought.
2) Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).
3) Construct a set of pair wise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
4) Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared.

3.6.2 Fuzzy Comparison judgment

According to [31] to deal with an MCDM problem Fuzzy AHP methodology is used as a decision support tool in this study. The Fuzzy AHP methodology is intended for alternative selection by integrating the concept of fuzzy set theory and hierarchical structure analysis. The application of fuzzy methodology enables the decision makers evaluate the decisions based on both qualitative and quantitative data.

The first and the last steps of the AHP are relatively simple and rather straightforward Procedures, while the assessment of local priorities, based on pair wise comparisons needs some prioritization method to be applied.

The FAHP method is an advanced analytical method which is developed from the AHP. In spite of the popularity of AHP, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-makers perception to exact numbers. In FAHP method, the fuzzy comparison ratios are used to be able to tolerate vagueness. Decision maker wants to use the uncertainty while performing the comparisons of the alternatives.

However, the standard AHP eigenvalue prioritization approach cannot be used, when the decision-maker faces a complex and uncertain problem and expresses his/her comparison judgments as uncertain ratios, such as 'about two times more important', 'between two and four times less important', etc.

A natural way to cope with such uncertain judgments is to express the comparison ratios as fuzzy sets or fuzzy numbers, which incorporate the vagueness of the human thinking. When comparing any two elements *i E* and *j E* at the same level of the decision hierarchy, the uncertain comparison judgment can be represented by the fuzzy number *ij a*~.

According to [66] to handle the uncertainty and vagueness of the subjective perception of the evaluation procedures, extended AHP and proposed the fuzzy analytical hierarchy process (FAHP) method by employing fuzzy ratios in place of exact ratios and deriving the fuzzy weights of criteria by a geometric mean method. The practical applications reported in the literature have suggested the advantages in handling unquantifiable/qualitative criteria and obtaining reliable results [31].

3.6.3 Construction of fuzzy judgment matrixes for the AHP

3.6.3.1 Triangular fuzzy numbers

A fuzzy number is a special fuzzy set $F = \{(x, u_F(x)), x \in R\}$, where x takes its values on the real line R_1: $-\infty < X < +\infty$ and $u_F(x)$ is a continuous mapping from R_1 to the close interval [0, 1]. In general, for a triangular fuzzy number $M = (l, m, u)$, the membership function $u_M(x)$: $R \rightarrow [0, 1]$ can be defined as follows [67]:

$$\mu_M(x) = \begin{cases} 1 & x = m \\ \dfrac{x-l}{m-l} & l \le x \le m \\ \dfrac{n-x}{n-m} & n \le x \le n \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Figure3: 1 Triangular Fuzzy Number

Where $l \le m \le u, l$ and u stand for the lower and upper value of support of M, respectively and m *is* the mid-value of M. Where $l=m=u$, it is a non-fuzzy number by convention.

For two triangular fuzzy numbers $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, the main operational laws are expressed below.

$$M_1 \oplus M_2 = (l_1 + l_{2,}, m_1 + m_2, u_{1+}u_2)$$

$$M_1 \otimes M_2 = l_1 l_2\,, m_1 m_2, u_1)$$

$$\lambda \otimes M_1 = (\lambda l_1, \lambda m_1, \lambda u_1), \lambda > 0, \lambda \in R \qquad \text{Eq. 1}$$

$$M_1^{-1} \approx (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1})$$

Let $X = \{x1, x2,..., xn\}$ be an object set and $U = \{u1, u2,..., um\}$ be a goal set. According to the method of extent analysis [68] each object is taken and the extent analysis for each goal, gi, is implemented respectively. Therefore, the M extent analysis values for each object can be obtained, with the following signs:

Table3: 3 the meaning of relative importance for fuzzy ratio scales

Relative importance	Linguistic Scale for Importance	Abbreviation	Triangular Fuzzy Number
$\tilde{1}$	Equal Importance	EI	(1, 1, 2)
$\tilde{2}$	Weak Importance	WI	(1, 2, 3)
$\tilde{3}$	Moderate importance	MI	(2, 3, 4)
$\tilde{4}$	Moderate plus Importance	MPI	(3, 4, 5)
$\tilde{5}$	Strong importance	SI	(4, 5, 6)
$\tilde{6}$	Strong plus Importance	SPI	(5, 6, 7)
$\tilde{7}$	Very Strong Importance	VSI	(6, 7, 8)
$\tilde{8}$	Very Very Strong Importance	VVSI	(7, 8, 9)
$\tilde{9}$	Absolute importance	AI	(8, 9, 9)

$M_{gi}^{1}, M_{gi}^{2}, M_{gi}^{m}, \qquad i = 1,2, \dots \dots, n$

Where all the $M_g^j (j = 1,2, \dots, n)$ are triangular fuzzy number.

In this research, all elements in the judgement matrix and weight vectors are represented by a triangular fuzzy number $\tilde{1}$, $\tilde{3}$, $\tilde{5}$, $\tilde{7}$, $\tilde{9}$ from equal to absolute importance, and $\tilde{2}$, $\tilde{4}$, $\tilde{6}$, $\tilde{8}$ are the middle values. The fuzzy numbers in the weight vector reflect the perceived importance of each criterion. The definition of a fuzzy number is given in Table3:3 and shown in Eq. 1. Also in Eq. 1, According to [69] the relative importance between elements is gradual and not as abrupt as in the ratio scale defined, leads to more reasonable decision results. In addition, for the triangular fuzzy number $\tilde{N} = (l, m, n)$, the membership function $\mu(x)$ can be depicted as in Eq.2.

Once the fuzzy judgement matrix is constructed, the fuzzy geometric mean and procedure for determining the criteria weights can be calculated by [66] as follows:

$$\tilde{r}i = \left(\tilde{a}\,(i1) \otimes \tilde{a}\,(i2) \otimes \tilde{a}\,(i3) \right)^{1}/n \qquad \text{Eq. 2}$$

$$\tilde{w}i = (\tilde{w}\,(i1) \otimes \tilde{w}\,(i2) \otimes w\,(i3))\text{^} - 1$$

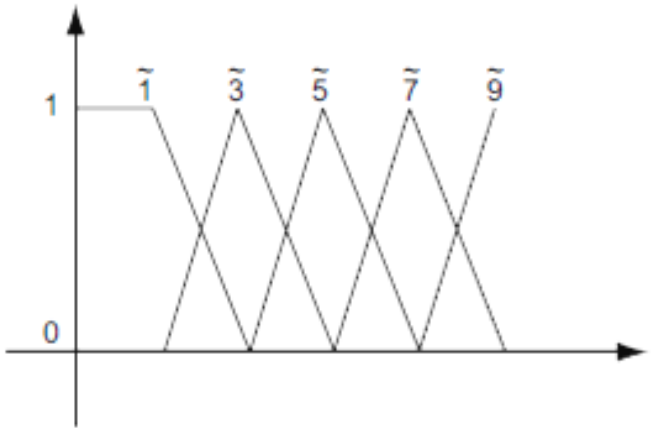


Figure3: 2 Fuzzy Ration Scale

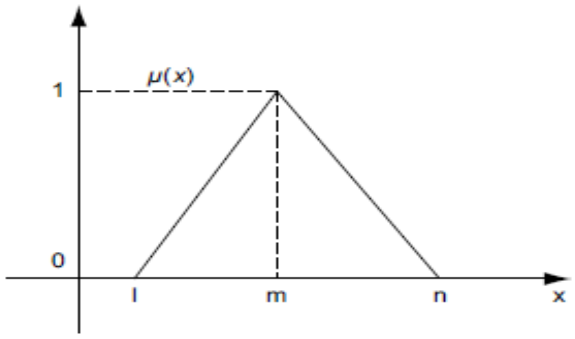


Figure3: 3 Membership function for triangular fuzzy numbers

Where ã (*in*)the fuzzy comparison is value of criterion *i* to criterion *n*. thus, ñi is the geometric mean of a fuzzy comparison value of criterion I to each criterion. ~*wi* is the fuzzy weight of the *i*th criterion, which can be indicated by a triangular fuzzy number, *wi* = (*Lwi*, *Mwi*, *Uwi*). Here, *Lwi*, *Mwi* and *Uwi* represent the lower, middle and upper values of the fuzzy weight of the *i*th criterion. In this research, the de-fuzzification method of triangular fuzzy numbers was employed to convert the fuzzy comparison matrices into crisp matrices to investigate the consistency. A triangular fuzzy number, $M = (l, m, u)$, can be de-fuzzified to a crisp number as follows [67]:

$$M\_crisp = (l + m + u)/3$$

But after constructing fuzzy judgment matrixes for the AHP, a consistency test have been carried out.

3.6.3.2 Analysise consistency

The priority of the decision elements can be compared the computation of eigenvalues and eigenvectors (the weight vector) as below:

$A.w = \boldsymbol{\lambda_{max}.w}$

Where *w* is the eigenvector of matrix *A*, and λ_{max} is the largest eigenvalue of *A*.

The consistency property of the matrix A is then checked to ensure the consistency of judgments in the pairwise comparison [69]

The consistence index (CI) and Consistence ration (CR) are defined as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

Where *n* is the number of Items being compared in the matrix.

The Average CI of randomly generated pairwise comparison of similar size [70].

Size	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Chapter 4: RESULTS AND ANALYSIS

This chapter presents findings from the field work and interpretation of the results (outputs) obtained using statistical method for preliminary survey to reduce the criterias and sub criterias and multi criteria decision making (**MCDM)** with mathematical model Fuzzy Ahp. It describes also the demographic or personal information data of respondents.

4.1 Personal Information of respondents

4.1.1 Age

This figure presents the age distribution of respondents from public institutions, contractors and consultants, and it shows the 24% are below thirty, 53% are between thirty and thirty nine which means that the remaining 23% are forty and above.

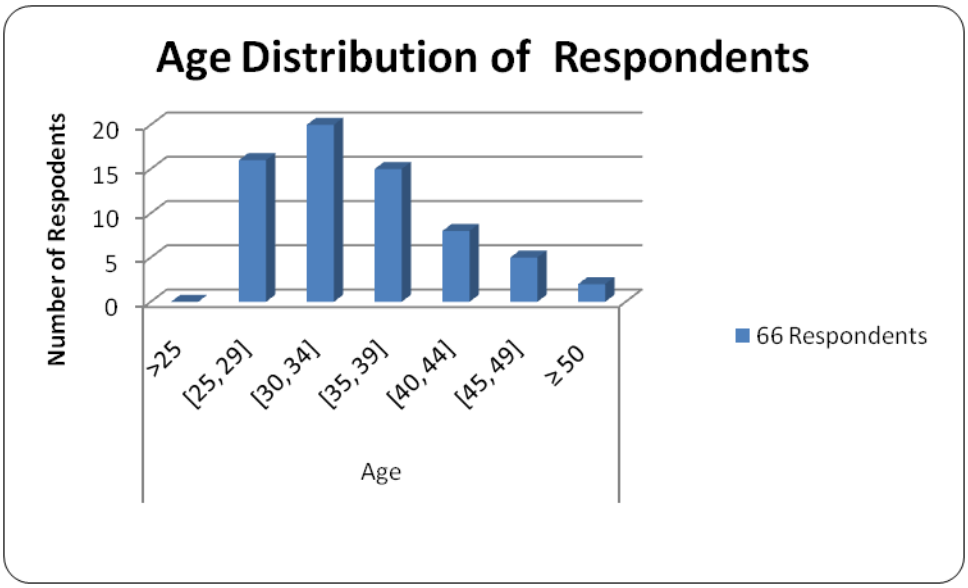


Figure 4. 1: Age distribution of respondents

4.1.2 Gender

This figure presents the gender distribution of respondents from public institutions, contractors and consultants, and it shows that only 23% are women and remaining 77% are men. It shows the dominance of men in the roads construction industry.

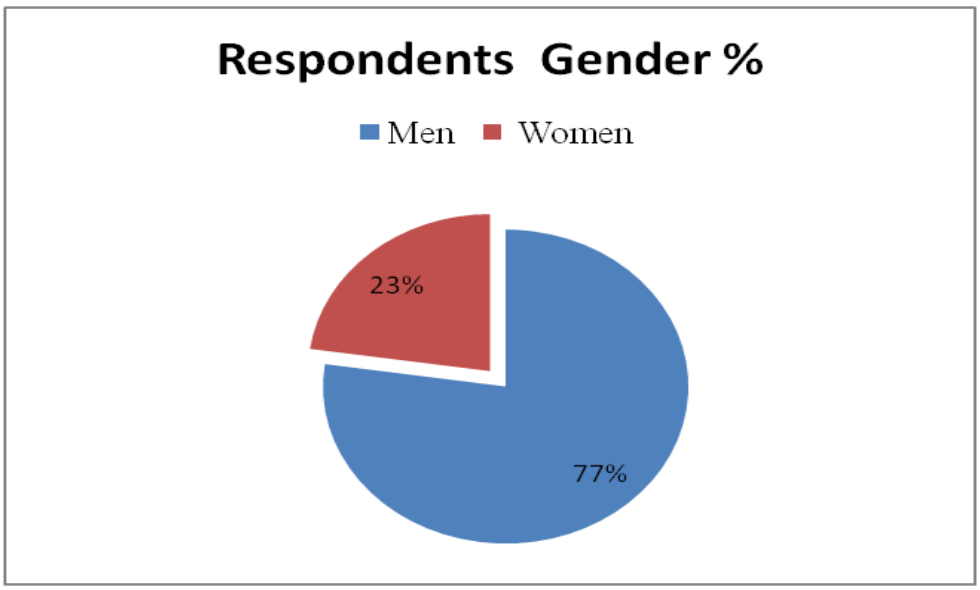


Figure 4. 2: Gender distribution of respondents

4.1.3 Educational levels

Figure indicates the highest academic qualification of the respondents. 91% of the respondents have bachelors' degrees which predominate in the sample size, only 9% percent of respondents have master degree. It shows that that well qualified personnel are employed in the roads industry therefore performance is expected to be optimal. It also indicates that their views are useful.

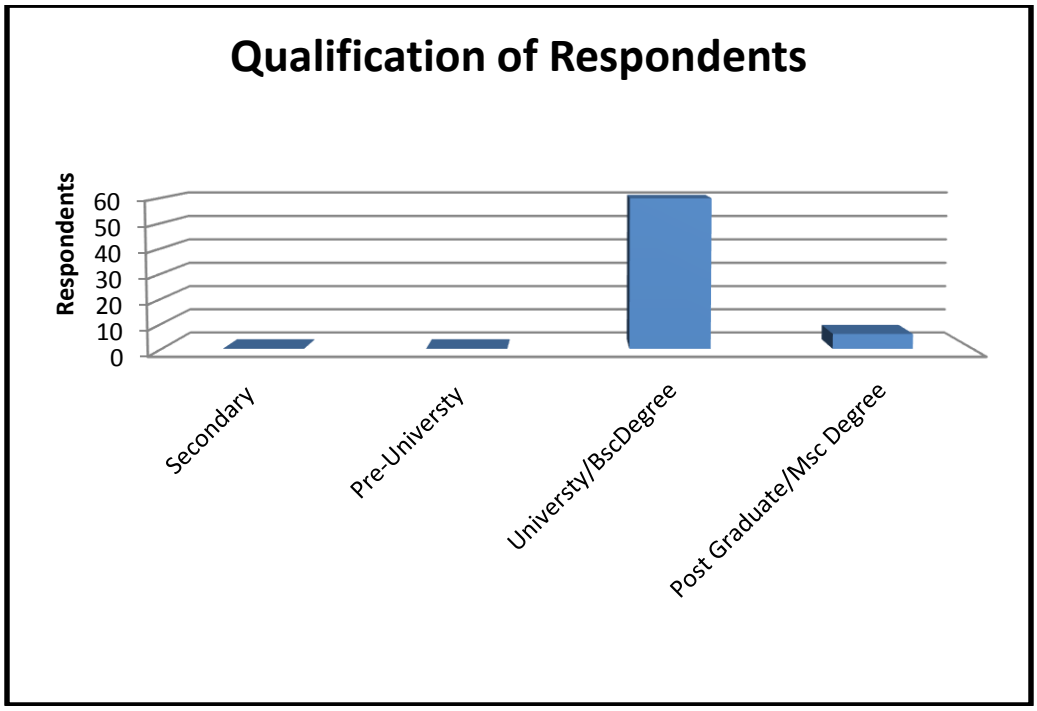


Figure 4. 3: Qualification level of respondents

Figure indicates the organization types of the respondents. Actually roads construction industry has four stakeholders, Owner, Donor, Consultants and contractors. In this research only Owner, Consultants and contractors have been questioned as institutions which daily for up implementation of the projects. 53% are from Public institutions which dominate in the sample, 27% from Contractors and 20 from consultants firm.

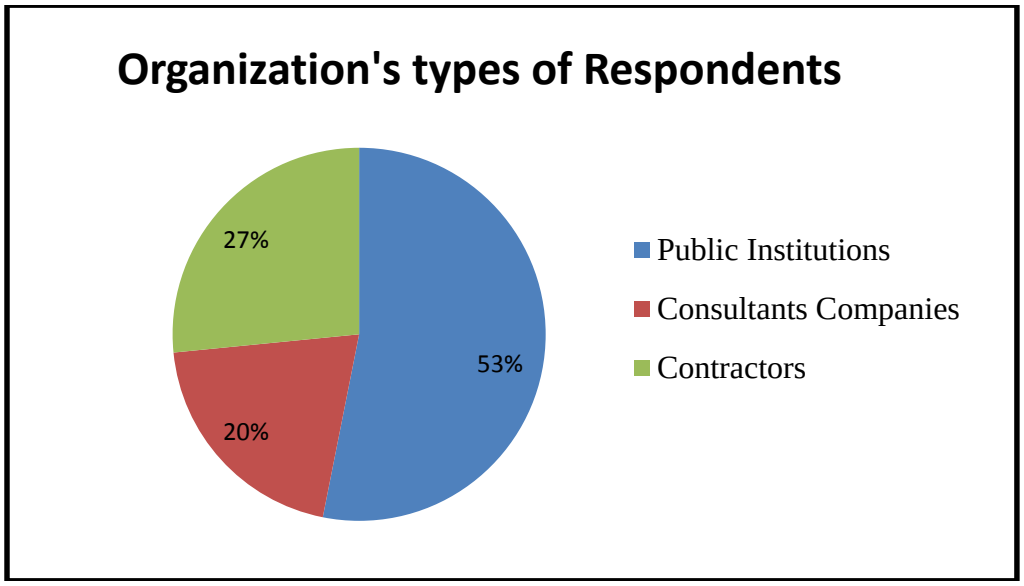


Figure **Organization Types of respondents**

4.1.4 Organization Working Experience

Figure indicates the organization working experience in roads construction industry of the respondents. During the survey, experienced institutions and companies have been looked at whereby the roads construction experience is distributed as follows:

< 4	6%
[4-8]	17%
]8-12]	21%
> 12	56%

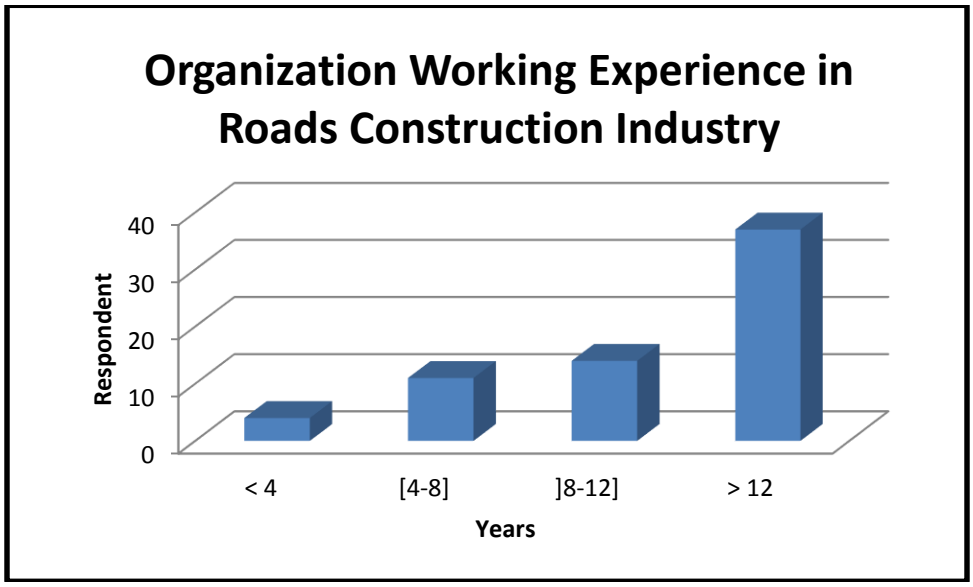


Figure: Organization working experience in Roads construction Field

4.1.5 Respondents Occupation Level in organizations

Figure indicates the respondents' positions or occupation levels in their organizations 64% are staff in charge of projects management in their daily activities whereby the executive and managerial levels have 21% and 15% respectively.

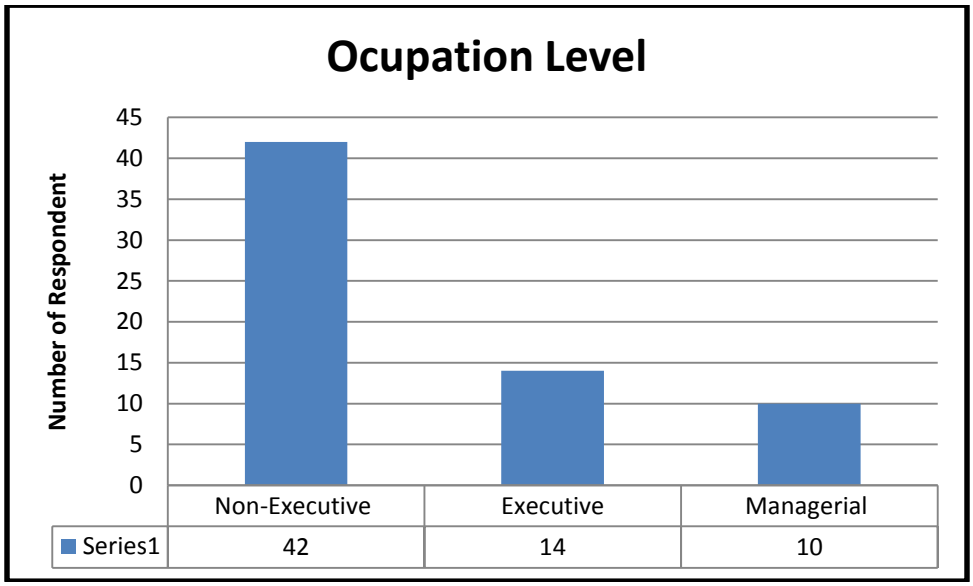


Figure: Respondents occupation level

4.1.6 Experience of Respondents

Figure indicates the working experience of respondents, this is very important due to the fact that more the people be involved in the project management more he knows all components that may lead to the failure of the project in terms of cost, time and quality. Distribution of experience in the sample was as follows;

<4 years	20%
4-8 years	47%
8 -12 years	18%
>12 years	15%

It appears that almost 50% of respondents have between 4 and 8 years of experience and 33 above eight.

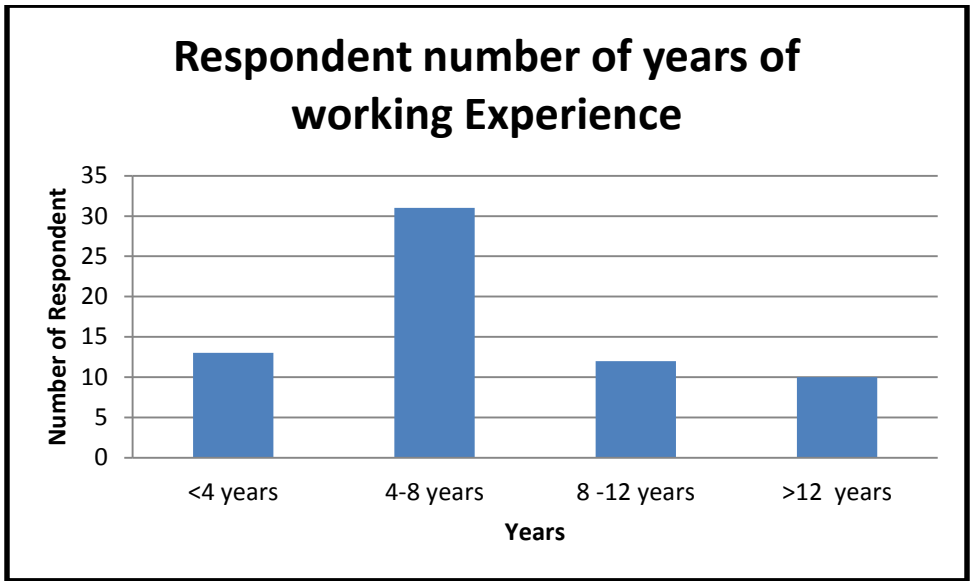


Figure: Respondents number of working experience

Table 4: 1 Reduced Factors Influencing Delay (1)

	Factors Influencing Delay							
		Likert Scale/Frequencies					**MIR**	**Ranking**
No	**Design Related Factors**	**1**	**2**	**3**	**4**	**5**		
1	Design mistakes	27	24	9	3	3	1.95	1
2	Insufficient data collection and survey before design	18	24	0	21	3	2.50	2
3	Delays in producing design documents	12	18	24	12	0	2.55	3
4	Inadequate design-team experience	12	18	12	18	6	2.82	4
5	Unclear and inadequate details in drawings	12	12	21	18	3	2.82	5
	Owner/Client Related Factors							
6	Delay in progress payments by owner	18	24	15	9	0	2.23	1
7	Slowness in decision making process by owner	27	9	12	18	0	2.32	2
8	Late in revising and approving design documents by owner	9	27	18	3	9	2.64	3
9	Delay in approving shop drawings and sample materials	12	18	15	18	3	2.73	4
10	Poor communication and coordination by owner and other parties	15	18	6	24	3	2.73	4
	Consultants Related Factors							

11	Delay in approving major changes in the scope of work by consultant	12	30	21	3	0	2.23	1
12	Late in reviewing and approving design documents by consultant	15	27	15	6	3	2.32	2
13	Poor communication/coordination between consultant and other parties	15	21	21	6	6	2.52	3
14	Inadequate experience of consultant	18	9	18	18	3	2.68	4
15	Delay in performing inspection and testing by consultant	0	27	30	6	3	2.77	5

Table 4: 2 Reduced Factors Influencing Delay (2)

	Factors Influencing Delay							
		Likert Scale/Frequencies					**MIR**	**Ranking**
No	**Design Related Factors**	**1**	**2**	**3**	**4**	**5**		
16	Shortage of equipment	33	18	6	3	6	1.95	1
17	Equipment breakdowns	21	24	12	6	3	2.18	2
18	Lack of high-technology mechanical equipment	18	27	6	12	3	2.32	3
19	Low productivity and efficiency of equipment	18	15	24	6	3	2.41	4
20	Low level of equipment-operator's skill	12	9	27	15	3	2.82	5
	Contractors Related Factors							
21	Ineffective planning and scheduling of project by contractor	42	15	3	6	0	1.59	1
22	Difficulties in financing project by contractor	42	12	6	6	0	1.64	2
23	Poor site management and supervision by contractor	45	6	6	3	6	1.77	3
24	Poor qualification of the contractor's technical staff	24	27	9	0	6	2.05	4
25	Improper construction methods implemented by contractor	21	24	6	15	0	2.23	5
26	Delay in site mobilization	30	15	9	0	12	2.23	6

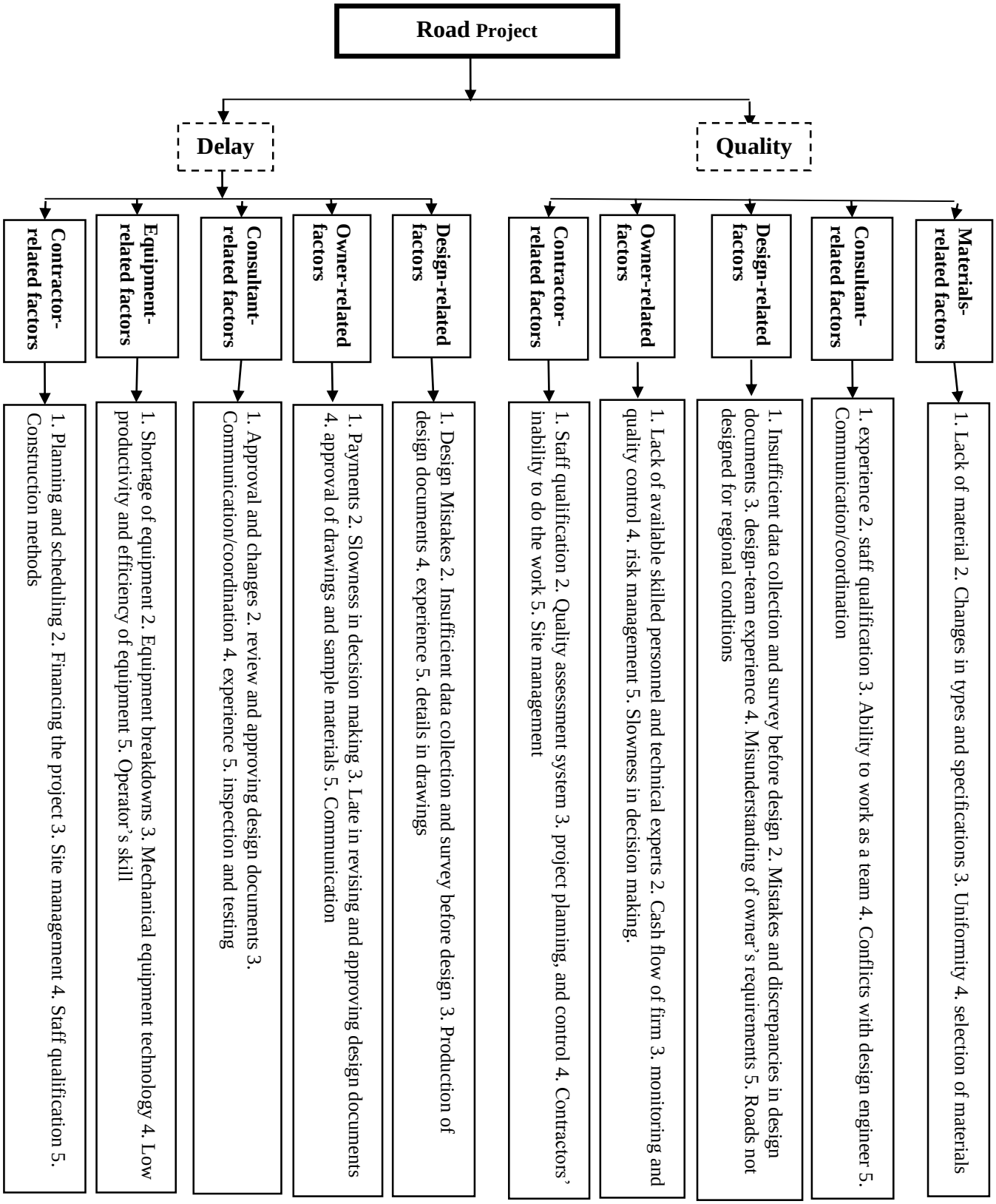
Table 4: 3 Factors Influencing Quality (1)

	Factors Influencing Quality							
		Likert Scale/Frequencies					**MIR**	**Ranking**
No	**Owner-related factors**	**1**	**2**	**3**	**4**	**5**		
1	Lack of available skilled personnel and technical experts	27	27	6	3	0	1.76	1
2	Cash flow of firm	21	33	3	9	0	2.00	2
3	Poor monitoring and quality control by regulatory agencies	30	15	9	12	3	2.17	3
4	Poor risk management	21	27	6	9	3	2.18	4
5	Slowness in decision making process by owner	18	21	15	12	0	2.32	5
	Consultant-related factors							
6	Inadequate experience of consultant	18	21	21	3	0	2.14	1
7	Availability of qualified staff	15	33	15	3	3	2.22	2
8	Ability to work as a team and coordinate	15	24	21	3	3	2.32	3
9	Conflicts between consultant and design engineer	15	18	18	12	3	2.55	4
10	Poor communication/coordination between consultant and other parties	6	30	15	15	0	2.68	5
	Contractor-related factors							
11	Poor qualification of the contractor's technical staff	30	30	6	0	0	1.64	1
12	Poor and lack of Quality assessment system in organization	33	21	9	3	0	1.73	2
13	Ineffective project planning, and control including underestimation of time and cost	42	12	6	0	6	1.73	3
14	contractors inability to do the work	33	15	15	3	0	1.82	4
15	Poor site management and supervision by contractor	30	24	6	6	0	1.82	5

Table 4: 4 Factors Influencing Quality (2)

	Factors Influencing Quality							
		Likert Scale/Frequencies					MIR	Ranking
		1	2	3	4	5		
No	**Design-related factors**							
16	Insufficient data collection and survey before design	51	9	6	0	0	1.32	1
17	Mistakes and discrepancies in design documents	21	30	6	3	6	2.14	2
18	Inadequate design-team experience	18	21	24	3	0	2.18	3
19	Misunderstanding of owner's requirements by design engineer	15	21	21	6	3	2.41	4
20	Roads not designed for regional conditions	15	30	9	3	9	2.41	5
	Materials-related factors							
21	Scarcity and lack of original materials requirement	36	18	3	3	6	1.86	1
22	Changes in material types and specifications during construction	3	21	24	15	3	2.91	2
23	Uniformity of materials	12	30	12	12	0	2.36	3

Decision making hierarchical structure of selection the critical success factors in the roads construction projects



Project Success factors with respect to the quality

Seventy one Sub criteria under seven criteria with two alternatives (Quality & Delay) in identified literature were carefully analyzed and incorporated in the question for preliminary survey. Twenty five sub criteria and five criterias influencing the quality performance of roads construction projects qualified for the second survey with fuzzy Ahp approach. The respondents were asked to rate their relative importance with respect to the delay and quality performance on a roads construction projects. The use of weighted averages was adopted for developing indices [67]. The survey established that the factors identified in literature were almost important in enhancing roads construction projects delivery as many of them had Importance Indices below 3.5.

Table 4: 5 Final Results with respect to the consultants and Quality

Table Final Results with respect to the materials and Quality

No	Sub criteria	Weight	Normalized weight	Rank
1	lack of materials	0.671	0.642	1
2	Changes in types and specifications	0.171	0.164	3
3	Uniformity	0.203	0.194	2

Therefore, the overall respondents' weights for Experts of Sub Criterias with respect to the quality such as lack of materials, Changes in Types and specifications and uniformity were 0.671; 0.171; 0.203 respectively. Following the above analysis procedure, the relative weights of all sub criterias from 10 Experts were obtained with respect to the material und quality performance and then after combined to get aggregated weight using the mean. It has been realized that lack of material is very important with 64% whereby Changes in Types and specifications and uniformity have 19.4% and 16.4 respectively, these problems can be considered as an obstacle for quality performance of projects. Recycling and stabilization technology is one the solution.

Table 4: 6 Final Results with respect to the consultants and Quality

Table Final Results with respect to the consultants and Quality				
No	**Subcriterias**	**Weight**	**Normalized Weight**	**Rank**
1	experience	0.40	0.365	1
2	staff qualification	0.20	0.180	2
3	Ability to work as a team	0.17	0.153	3
4	Conflicts with design engineer	0.17	0.153	4
5	communication/coordination	0.17	0.150	5

According to all responses, experience was the most important sub criteria under the consultants as it has the first rank among all sub criterias weight = **0.365** equivalent to 36.5 %.

Therefore, the overall respondents' weights for Experts of Sub Criteria such as experience, staff qualification, Ability to work as a team, Conflicts with design engineer, communication and coordination were 0.40; 0.20; 0.17; 0.17; 0.17 respectively. Experience has been also lacked in the preliminary survey by Engineers/officers as the most challenge component.

Table 4: 7 Aggregated Results with respect to Design and Quality

No	Sub criteria	Weight	Normalized Weight	Rank
1	Insufficient data collection and survey before design	0.382	0.343	1
2	Mistakes and discrepancies in design documents	0.131	0.118	5
3	design-team experience	0.256	0.230	2
4	Misunderstanding of owner's requirements	0.165	0.148	4
5	Roads not designed for regional conditions	0.176	0.158	3

From the perceptions of all Experts through the questionnaire's responses insufficient data collection and survey before design has been ranked as the more influential sub criteria in design under quality performance of road construction projects.

The following are the percentage equivalent to the ranking scores Insufficient data collection and survey before design, Mistakes and discrepancies in design documents, design-team experience, Misunderstanding of owner's requirements, Roads not designed for regional conditions were 34.3%, 11.8%, 23%, 14.8%, and 15.8% respectively. Enhancement of teams in charge of design review and approval as well as capacity of consultants/Supervisor in terms of capacity building and apparatus.

Table 4: 8 Aggregated Results with respect to Owner and Quality

No	Sub criterias	Weight	Normalized Weight	Rank
1	Availability of skilled personnel and technical experts	0.339	0.316	1
2	Cash flow of the firm	0.153	0.143	5
3	monitoring and quality control	0.219	0.204	2
4	Risk management	0.159	0.148	4
5	Slowness in decision making	0.202	0.189	3

According to all responses, Availability of skilled personnel and technical experts was the most important sub criteria with respect to the consultants under the quality as it has been ranked the first (more influential) among all sub criterias weight = **0.316** equivalent to 31.6 %. Therefore, the overall respondents' weights for Experts of Sub Criteria such as Availability of skilled personnel and technical experts, Cash flow of the firm, monitoring and quality control, Risk management, Slowness in decision making were 31.6%, 14.3%, 20.4, 14.8%, 18.9% respectively. Monitoring and quality control was also ranked on the second place, which shows that monitoring manuals as well construction guidance specifically for Rwanda are needed.

Table 4: 9 Aggregated Results with respect to Contractor and Quality

No	Sub criterias	Weight	Normalized Weight	Rank
1	Staff qualification	0.295	0.273	1
2	Quality Assessment System	0.169	0.157	4
3	Project Planning and Control	0.259	0.240	2
4	Inability to do the work	0.143	0.132	5
5	Site Management	0.212	0.197	3

Therefore, the overall respondents' weights for contractor of Sub Criteria such as Staff qualification, Quality Assessment System, Project Planning and Control, Inability to do the work and Site Management were 0.295; 0.169; 0.259, 0.143, 0.212 respectively. Following the above analysis procedure, the relative weights of all sub criterias from 10 Experts were obtained with respect to the contractor under the quality performance and then after combined to get aggregated weight using the mean. It has been realized that lack of Staff qualification is very important with 27.3% whereby Project Planning and Control, Site Management, Quality Assessment System, Inability to do the work have 24%, 19.7%, 15.7%, and 13.2%.

Table 4: 10 Aggregated Results with respect to Design and Delay

No	Sub criteria	Weight	Normalized Weight	Rank
1	Design Mistakes	0.316	0.297	1
2	Data collection and survey before Design	0.285	0.268	2
3	Production of design documents	0.113	0.106	5
4	Experience	0.230	0.216	3
5	Details in drawing	0.121	0.113	4

Following the preliminary survey, pair wise comparison (Fuzzy Ahp) has been applied to test importance of the criterias as well as sub criterias. Through all above motioned analysis process were ranked to establish more important factors (critical) to influence the roads construction project delays. It has been realized that lack of design mistakes is very important with 29.7% whereby Data collection and survey before Design, Experience, details in drawing and Production of design documents have 26.8%, 21.6%, 11.3%, and 10.6%. According to [71], certain practices

and / or the downstream of a lack of designers‟ commitment may result in the schedule deadlines not being met. This may have relationship with the mistakes in the designs.

Table 4: 11 Aggregated Results with respect to Owner and Delay

No	Sub criterias	Weight	Normalized Weight	Rank
1	Payment	0.177	0.164	4
2	Slowness in decision making	0.362	0.334	1
3	Revision and approval of design documents	0.227	0.210	2
4	Approval of drawings and sample materials	0.181	0.166	3
5	Communication	0.137	0.126	5

According to all responses, Slowness in decision making was the most important sub criteria with respect to the client/owner as it has been ranked the first (more influential) among all sub criterias with the weight = **0.362** equivalent to 33.4 %. Therefore, the overall respondents' weights for Experts of Sub Criteria such as Revision and approval of design documents, Approval of drawings and sample materials, Payment, Communication were 21.%, 16.6%, 16.4, 12.6% respectively.

Table 4: 12 Aggregated Results with respect to Consultant and Delay

No	Sub criterias	Weight	Normalized Weight	Rank
1	Approval of changes	0.281	0.259	1
2	Review and approval of design documents	0.191	0.176	4
3	Communication	0.141	0.130	5
4	Experience	0.246	0.227	2
5	Inspection and Testing	0.227	0.209	3

From the perceptions of all Experts through the questionnaire's responses Approval of changes has been ranked as the more influential sub criteria for Consultants under delay of road

construction projects weight equal to 0.281 and equivalent to 25.9% (global weight for consultants related factors).

The following are the percentage equivalent to the ranking scores of Experience, Inspection and Testing, Review and approval of design documents, Communication, were 22.7%, 20.9%, 17.6%, 13% respectively. It is needed to set the time period for approving or rejecting any change raised design documents as well as other administrative documents.

Table 4: 13 Aggregated Results with respect to Equipment and Delay

No	Sub criterias	Weight	Normalized Weight	Rank
1	Shortage of equipment	0.299	0.281	1
2	Equipment breakdowns	0.294	0.276	2
3	Mechanical equipment technology	0.153	0.144	4
4	Productivity and efficiency of equipment	0.168	0.157	3
5	Operator's Skills	0.152	0.142	5

The combined results that are presented in above table show that shortage of equipments is mostly important sub criteria/component with respect to the Equipment under delay of roads construction projects and followed by Equipment breakdowns, Productivity and efficiency of equipment, Mechanical equipment technology and Operator’s Skills with scores of 0299, 0.294, 0.168, 0.153 and 0.152.

Enhancement of public sector (contractors) should be done by facilitating them to easy import those machines.

Table 4: 14 Aggregated Results with respect to Contractor and Delay

No	Sub criterias	Weight	Normalized Weight	Rank
1	Planning and Scheduling	0.291	0.274	2
2	Financing Project	0.295	0.278	1
3	Site Management	0.164	0.154	4
4	Staff qualification	0.204	0.192	3
5	Construction Method	0.108	0.102	5

According to all responses from aggregated results, financing project was the most important sub criteria with respect to the contractor as it has been ranked the first (more influential) among all sub criterias with the weight = **0.295 and** followed by Planning and Scheduling, Staff qualification, Site Management, Construction Method with 0.291, 0.204, 0.164, 0.108 respectively. There should be a political system for promoting contractors using financial institution to support their financial capacity. According to [71], it was found that the twelve parameters in question 27 could lead to a delay of 35.3% on project delivery according to the perceptions of respondents. The parameter that has the highest percentage influence on project delivery time is the quality of management during construction which covers all above mentioned components.

Table 4: 15 Aggregated Results with respect to Quality

No	criterias	Weight	Normalized Weight	Rank
1	Material Related	0.172	0.155	4
2	Consultant Related Factors	0.237	0.213	3
3	Design Related Factors	0.252	0.227	2
4	Owner Related Factors	0.123	0.110	5
5	Contractors Related Factors	0.327	0.295	1

From the perceptions of all Experts through the questionnaire's responses Contractors Related Factors has been ranked as the more influential criteria for the quality of roads construction with the weight equal to 0.327 and equivalent to 32.7% (global weight for criterias with respect to the quality) and followed by Design Related Factors, Consultant Related Factors, Material Related, Owner Related Factors with 0.252, 0.237, 0.172, 0.123 weight respectively.

Table 4: 16 Aggregated Results with respect to Delay

No	criterias	Weight	Normalized Weight	Rank
1	Design Related Factors	0.153	0.137	4
2	Owner Related Factors	0.126	0.113	5
3	Consultant Related Factors	0.162	0.146	3
4	Equipment Related Factors	0.335	0.302	1
5	Contractors Related Factors	0.334	0.301	2

The aggregated results that presented in above table, show that the Equipment Related Factors is mostly important criteria/component with weight equal to 0.335, with respect to the delay of roads construction projects and followed by Contractors Related Factors, Consultant Related Factors, Design Related Factors and Owner Related Factors with 0.334, 0.162, 0.153, and 0.126.

Enhancement of public sector (contractors) should be done by facilitating them to easy import those machines.

Table 4: 17 Aggregated Results with respect to Goal

Table Aggregated Results with respect to Goal				
No	**criterias**	**Weight**	**Normalized Weight**	**Rank**
1	Delay	0.665	0.644	1
2	Quality	0.367	0.356	2

According to all responses, Delay was the most important sub criteria with respect to the project performance (goal) as it has been ranked the first (more influential) compared to the quality with 0.665 and 0.367 respectively.

4.2. Comparison of obtained results and actual performance of selected projects

The obtained results have been compared with the performance situation of recent roads construction projects whereby 9 unpaved roads projects and 5 paved (upgrading) roads projects have been considered. Review of the projects documents including contracts, correspondences, minutes addendums and monthly reports and also discussion with project managers the questionnaires have been filled on five Likert-scale from 1 to 5 (where 1 is less important at all

and 5 is most important) in order to find out the degree of influence of high ranked factors versus actual performance situation of selected projects by calculating the mean importance rating.

4.2.1 General situation for unpaved roads projects

According to addendums, minutes, correspondences and modifications made on the contracts for selected projects the causes of poor performance in terms of quality and time reflect to the results obtained through the questionnaires. The main and common factors affecting the initial working schedule are the following; Site Management, Planning and Scheduling, Financing Project, Productivity and efficiency of equipment, Equipment breakdowns, Shortage of equipment, Payment, Approval of changes, Slowness in decision making, Design mistakes, Data collection and survey before Design, Experience.
Whereby the main and common factors affecting the quality are Site Management; Project Planning and Control; Slowness in decision making; Availability of skilled personnel and technical experts; design-team experience; Insufficient data collection and survey before design; lack of materials refer to the Appendices F, G, J and C.

According to the staff experience of consultants and contractors, most of them they provide wrong information regarding their background and frequently they change during the execution or service compared to their bids. 88 companies are now blacklisted whereby 68 companies are blacklisted due to the forgery documents and provisional of wrong information in public procurement. [72]

4.2.2 General situation for paved roads projects

According to technical auditing reports; failures happened; conversations with projects managers; addendums, minutes, correspondences and modifications made on the contracts for selected projects the causes of poor performance in terms of quality and time reflect to the results obtained through the questionnaires. The main and common factors affecting the initial working schedule are the following; Design mistakes; Data collection and survey before Design; Slowness in decision making; Payment; Equipment breakdowns and Financing Project,

Whereby the main and common factors affecting the quality are lack of material; conflicts with design engineer; insufficient data collection and survey before design; staff qualification; Project planning and control and quality assessment system refer to the Appendices H, I, K and M.

Chapter 5: CONLUSION AND RECOMMENDATION

5.1 Introduction

Construction industry is considered as an important sector in the world as it develops and achieves the goals of society. Award of contract to competent Consultants and Contractors with qualified personnel will go a long way to ensure that the feasibility studies, designs and supervision of the projects are well done [52] Time, cost and quality have their proven importance as the prime measures for project success [73] The main aim of this thesis is to identify the factors influencing the performance of roads construction projects in the Rwanda. It was found that too much effort are needed for all stakeholders especially for contractors, all recommendations and conclusions have been established following the above obtained results as following:

5.2 Conclusion and Recommendation on Delay and Quality shortfalls of Roads Construction Projects

Construction clients/owners demand the timely completion of projects without delay or any additional cost with expected quality, the key conclusion are as follows.

i. Rwandan roads construction industry is suffering with projects delays and quality shortfalls caused by deferent factors related to different stakeholders as well as materials and equipments.
ii. Schedule overrun and quality shortfalls in roads construction projects are always potential obstacles to project success.
iii. The study reported in this dissertation established that there are a significant number of factors/variables which need to be adequately dealt with if projects delay and quality shortfalls are to be minimized on roads construction projects in Rwanda.
iv. Factors that cause roads construction projects delay and quality shortfalls were identified.

Design related factors

The findings from the perception of roads construction stakeholders is that Design Mistakes, Data collection and survey before Design with respect to the design factor are the top significant factors causes of delay in road construction project delivery whereby data collection and survey before design has been ranked as most important for quality shortfall.

Owner related factors

The overall result shows that Slowness in decision making, Revision and approval of design with respect to the owner are the more influential in delay of road construction projects, sometimes this result from the miss of confidence as well as ownership whereby Availability of skilled personnel, technical experts, and Cash flow of the firm, monitoring and quality control are most the important.

Consultants related factors

Approval of changes and Experience are the key most significant factors contribute to the delay of roads constructions projects. And also according to the quality shortfalls it has been realized that experience, staff qualifications, Ability to work as a team and Conflicts with design engineer are more contributors' factors.

Equipments related factors

The overall result indicates that Shortage of equipment and Equipment breakdowns with respect to the equipments are the most significant factors that contribute in roads construction projects delay in Rwanda. Many of contractors do not own equipments the required for the roads construction work. They rent the equipments when required. During the season when there are many construction projects, the equipments are in short supply and are poorly maintained. This leads of the equipments causing the progress to be hampered.

Contractors related factors

It appears that the survey results indicated that the Financing Project and Planning and Scheduling majority with respect to the contractors are the top significant factors influencing delay quality

shortfalls of roads construction projects. Especially Local contractors often fail to come out with a practical and workable ‘‘work program’’ at the initial planning stage.

5.3 Recommendation on Delay and quality shortfalls of Roads Construction

To avoid further delays and quality shortfalls of the roads construction projects in Rwanda Consultants should minimize the time taken to approve the changes and look for experienced and qualified staff in the field. In addition, consultants are recommended to facilitate and quicken orders delivered to contractors to obtain better time performance and to minimize disputes and claims and also spending enough time for the studies known as phase zero and ensuring the precise studies which leads to save the time, cost and quality of doing the projects.

Contractors should not engage in huge number of projects implementation that cannot be performed successfully in terms of projects financing. In addition, planning and scheduling should be done carefully in accordance with the works to be executed. And also Improvement of the process of auditing the quality requirements and the results from quality control measurements to ensure appropriate quality standards and operational activities are recommended.

Owners are recommended to establish a framework to facilitate a quick payment to contractors in order to overcome delays. There should be a significant participation of all stakeholders in decision making for any change to avoid any misunderstanding on the project as well as slowness in decision making.

A strong communication, coordination and relationship between project stakeholders are required through project life cycle in order to solve problems and develop project performance. Public Institutions (RTDA, Cok and Districts) need to have a budget covering the whole of the project and strongly affects budgetary control throughout the project. Professional trainings are also recommended.

Further researchers are recommended to establish a strategic frame work to reinforce capacity of institutions working in roads construction industry in terms of financial and capacity building.

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APPENDICES

APPENDIX-A

QUESTIONNAIRE

INTRODUCTION

This questionnaire consists of three parts, the first one is for respondent information, and the second part is for factors influencing delay while the third one is for quality. It has been designed based on the factors influencing delay and quality of road project identified during literature review.

The option of evaluation is based upon Likert scale ranging from extremely important (1st level) to unimportant (5th level).

BN: this research is for academic purpose

INSTRUCTIONS

- The variables were rated on the five point Likert scales which have importance rating values from 1 to 5. Please, give your details by ticking one of the boxes provided.
- Ticking in more than one box on the same low of variable is not allowed.
- You can use any symbol you want for ticking (i.e: X,…..).
- For any clarification do not hesitate to contact us through e-mail address: mpascie@yahoo.fr or on the phone number: (+250)788541710

PART ONE

PARICIPANTS DETAIL		Frequency
Age	<25	
	25-29	
	30-34	
	35-39	
	40-44	
	45-49	
	≥50	
Sex	Male	
	Female	
Education	Secondary	
	Pre-University	
	University/Bsc Degree	
	Post Graduate/Msc Degree	
Types Of Organization	Owners (Gourvement)	
	Stakeholders/Donors	
	Consultant	
	Contractors	
Organization working experience	< 4 years	
	4-8 years	
	8 -12 years	
	>12 years	
Occupational level	No-Executive	
	Executive	
	Managerial	
Respondent number of working experience	<4 years	
	4-8 years	
	8 -12 years	
	>12 years	
Largest project involve based on contract sum	<$2 million	
	$2 million-$10 million	
	>$10 million	

PART TWO

Factors influencing delay		**1**	**2**	**3**	**4**	**5**
Project-related factors	Original contract duration is too short					
	Legal disputes between various parts					
	Inadequate definition of substantial completion					
	Ineffective delay penalties					
	Type of construction contract (Turnkey, construction only,.)					
	Type of project bidding and award (negotiation, lowest bidder,.)					
Owner/client-related factors	Delay in progress payments by owner					
	Delay to furnish and deliver the site to the contractor by the owner					
	Change orders by owner during construction					
	Late in revising and approving design documents by owner					
	Delay in approving shop drawings and sample materials					
	Poor communication and coordination by owner and other parties					
	Slowness in decision making process by owner					
	Conflicts between joint-ownership of the project					
	Unavailability of incentives for contractor for finishing ahead of schedule					
	Suspension of work by owner					

Factors influencing delay		**1**	**2**	**3**	**4**	**5**
Contractors-related factors	Difficulties in financing project by contractor					
	Conflicts in sub-contractors schedule in execution of project					
	Rework due to errors during construction					
	Conflicts b/w contractor and other parties (consultant and owner)					
	Poor site management and supervision by contractor					
	Poor communication and coordination by contractor with other parties					
	Ineffective planning and scheduling of project by contractor					
	Improper construction methods implemented by contractor					
	Delays in sub-contractors work					
	Inadequate contractor's work					
	Frequent change of sub-contractors because of their inefficient work					
	Poor qualification of the contractor's technical staff					
	Delay in site mobilization					
Consultant-related factors	Delay in performing inspection and testing by consultant					
	Delay in approving major changes in the scope of work by consultant					
	Inflexibility (rigidity) of consultant					
	Poor communication/coordination between consultant and other parties					
	Late in reviewing and approving design documents by consultant					
	Conflicts between consultant and design engineer					
	Inadequate experience of consultant					

Factors influencing delay		1	2	3	4	5
Design-related factors	Mistakes and discrepancies in design documents					
	Delays in producing design documents					
	Unclear and inadequate details in drawings					
	Complexity of project design					
	Insufficient data collection and survey before design					
	Misunderstanding of owner's requirements by design engineer					
	Inadequate design-team experience					
	Un-use of advanced engineering design software					
Materials-related factors	Shortage of construction materials in market					
	Changes in material types and specifications during construction					
	Delay in material delivery					
	Damage of sorted material while they are needed urgently					
	Delay in manufacturing special building materials					
	Late procurement of materials					
	Late in selection of finishing materials due to availability of many types in market					
Equipments-related factors	Equipment breakdowns					
	Shortage of equipment					
	Low level of equipment-operator's skill					
	Low productivity and efficiency of equipment					
	Lack of high-technology mechanical equipment					

Factors influencing delay		**1**	**2**	**3**	**4**	**5**
Labor-related factors	Shortage of labors					
	Unqualified workforce					
	Nationality of labors					
	Low productivity level of labors					
	Personal conflicts among labors					
External factors	Effects of subsurface conditions (e.g., soil, high water table, etc.)					
	Delay in obtaining permits from municipality					
	Hot weather effect on construction activities					
	Rain effect on construction activities					
	Unavailability of utilities in site (such as, water, electricity, telephone, etc.)					
	Effect of social and cultural factors					
	Traffic control and restriction at job site					
	Accident during construction					
	Differing site (ground) conditions					
	Changes in government regulations and laws					
	Delay in providing services from utilities (such as water, electricity)					
	Delay in performing final inspection and certification by a third party					

PART THREE

No	FACTORS INFLUENCING QUALITY IN ROAD COANSTRUCTION PROJECT						
	Owner-related factors	**Importance rating**					
		1	**2**	**3**	**4**	**5**
1	Poor monitoring and quality control by regulatory agencies					
2	Poor risk management					
3	Government policies,					
4	Level of economic development					
5	Client satisfaction					
6	Cash flow of firm					
7	Lack of available skilled personnel and technical experts					
8	Mode of financing and payment for completed work					
9	Frequent changes and inconsistence in government policy and priority					
10	Prequalification procedure and corrupt government officials.					
11	Project scope creep with massive amount of change or variation orders					
12	Late in revising and approving design documents by owner					
13	Delay in approving shop drawings and sample materials					
14	Poor communication and coordination by owner and other parties					
15	Slowness in decision making process by owner					
16	Conflicts between joint-ownership of the project					
17	Suspension of work by owner					
	Consultant-related factors					
18	Inadequate experience of consultant					
19	Availability of qualified staff					
20	Availability of technology					
21	Professionals engaged					
22	Corruption and communication gap among project personnel					

23	Poor communication/coordination between consultant and other parties					
24	Late in reviewing and approving design documents					
25	Ability to work as a team and coordinate					
26	Conflicts between consultant and design engineer					

No	FACTORS INFLUENCING QUALITY IN ROAD COANSTRUCTION PROJECT					
	Contractor-related factors	**Importance rating**				
		1	**2**	**3**	**4**	**5**
27	contractors inability to do the work					
28	Misunderstanding of the work requirement and non compliance with condition of the contract					
29	Ineffective project planning, and control including underestimation of time and cost					
30	Poor and lack of Quality assessment system in organization					
31	Poor qualification of the contractor's technical staff					
32	Improper construction methods implemented by contractor					
33	Amount of work subcontracted					
34	Availability of technology					
35	Execution of other projects					
36	lack of Commitment					
37	Ability to work as a team and coordinate					
38	Interest rate					
39	Poor site management and supervision by contractor					
40	Poor communication and coordination by contractor with other parties					
41	Ineffective planning and scheduling of project by contractor					
42	unexperinced and unqualified sub-contractors					
43	Frequent change of sub-contractors because of their inefficient work					
44	Failure on the part of contractors to obtain vital inputs such as materials, manpower and machines.					
45	Quality training/meeting					
	Design-related factors					
46	Mistakes and discrepancies in design documents					
47	Unclear and inadequate details in drawings					
48	Complexity of project design					

49	Insufficient data collection and survey before design					
50	Misunderstanding of owner's requirements by design engineer					
51	Inadequate design-team experience					
52	Un-use of advanced engineering design software					
53	Roads not designed for regional conditions					

No	FACTORS INFLUENCING QUALITY IN ROAD COANSTRUCTION PROJECT					
	Equipment-related factors	**Importance rating**				
		1	**2**	**3**	**4**	**5**
54	Capacity constraints in terms of construction equipments					
55	Equipment breakdowns					
56	Low level of equipment-operator's skill					
57	Low productivity and efficiency of equipment					
58	Lack of high-technology mechanical equipment					
	Materials-related factors					
59	Scarcity and lack of original materials requirement					
60	Changes in material types and specifications during construction					
61	Late in selection of finishing materials due to availability of many types in market					
62	Uniformity of materials					
	External factors					
63	Location of project					
64	Rain effect					
65	Effects of subsurface conditions (e.g., soil, high water table, etc.)					
66	Hot weather effect on construction activities					
67	Inappropriety of Traffic control and restriction at job site					
68	Changes in government regulations and laws					
69	Delay in performing final inspection and certification by a third party					
70	Social and cultural factors					
71	Differing site (ground) conditions					

APENDIX-B

No	Factors Influencing Delay	Frequency					(MIR)	STD	Rank	Average of MIR
		1	2	3	4	5				
	Projects Related Factors									
1	Original contract duration is too short	9	9	24	18	6	3.05	2.51	2	3.13
2	Legal disputes between various parts	9	9	12	21	15	3.36	1.67	3	
3	Inadequate definition of substantial completion	9	9	12	15	21	3.45	1.67	4	
4	Ineffective delay penalties	9	9	18	9	21	3.36	1.95	3	
5	Type of construction contract (Turnkey, construction only,.)	3	9	18	21	15	3.55	2.41	5	
6	Type of project bidding and award (negotiation, lowest bidder,.)	33	9	18	3	3	2.00	4.22	1	
	Owner/Client Related Factors									
7	Delay in progress payments by owner	18	24	15	9	0	2.23	3.05	1	2.84
8	Delay to furnish and deliver the site to the contractor by the owner	18	21	3	6	18	2.77	2.70	5	
9	Change orders by owner during construction	9	30	6	15	9	2.78	3.21	6	
10	Late in revising and approving design documents by owner	9	27	18	3	9	2.64	3.13	3	
11	Delay in approving shop drawings and sample materials	12	18	15	18	3	2.73	2.07	4	
12	Poor communication and coordination by owner and other parties	15	18	6	24	3	2.73	2.88	4	
13	Slowness in decision making process by owner	27	9	12	18	0	2.32	3.36	2	
14	Conflicts between joint-ownership of the project	3	9	27	24	3	3.23	3.85	8	

15	Unavailability of incentives for contractor for finishing ahead of schedule	6	18	21	15	6	2.95	2.30	7	
16	Suspension of work by owner	3	6	6	27	27	4.00	4.04	10	

No	**Factors Influencing Delay**	**Frequency**					**(MIR)**	**STD**	**Rank**	**Average of MIR**
		1	**2**	**3**	**4**	**5**				
	Contractors Related Factors									
17	Difficulties in financing project by contractor	42	12	6	6	0	1.64	5.55	2	2.45
18	Conflicts in sub-contractors schedule in execution of project	9	15	21	15	9	3.00	1.67	9	
19	Rework due to errors during construction	3	27	12	18	6	2.95	3.21	8	
20	Conflicts b/w contractor and other parties (consultant and owner)	3	30	18	12	3	2.73	3.78	6	
21	Poor site management and supervision by contractor	45	6	6	3	6	1.77	5.94	3	
22	Poor communication and coordination by contractor with other parties	21	24	9	9	3	2.23	2.97	5	
23	Ineffective planning and scheduling of project by contractor	42	15	3	6	0	1.59	5.68	1	
24	Improper construction methods implemented by contractor	21	24	6	15	0	2.23	3.36	5	
25	Delays in sub-contractors work	9	3	33	18	3	3.05	4.22	10	
26	Inadequate contractor’s work	0	30	18	12	6	2.91	3.85	7	
27	Frequent change of sub-contractors because of their inefficient work	0	6	24	33	3	3.50	4.83	11	
28	Poor qualification of the contractor’s technical staff	24	27	9	0	6	2.05	3.91	4	
29	Delay in site mobilization	30	15	9	0	12	2.23	3.65	5	

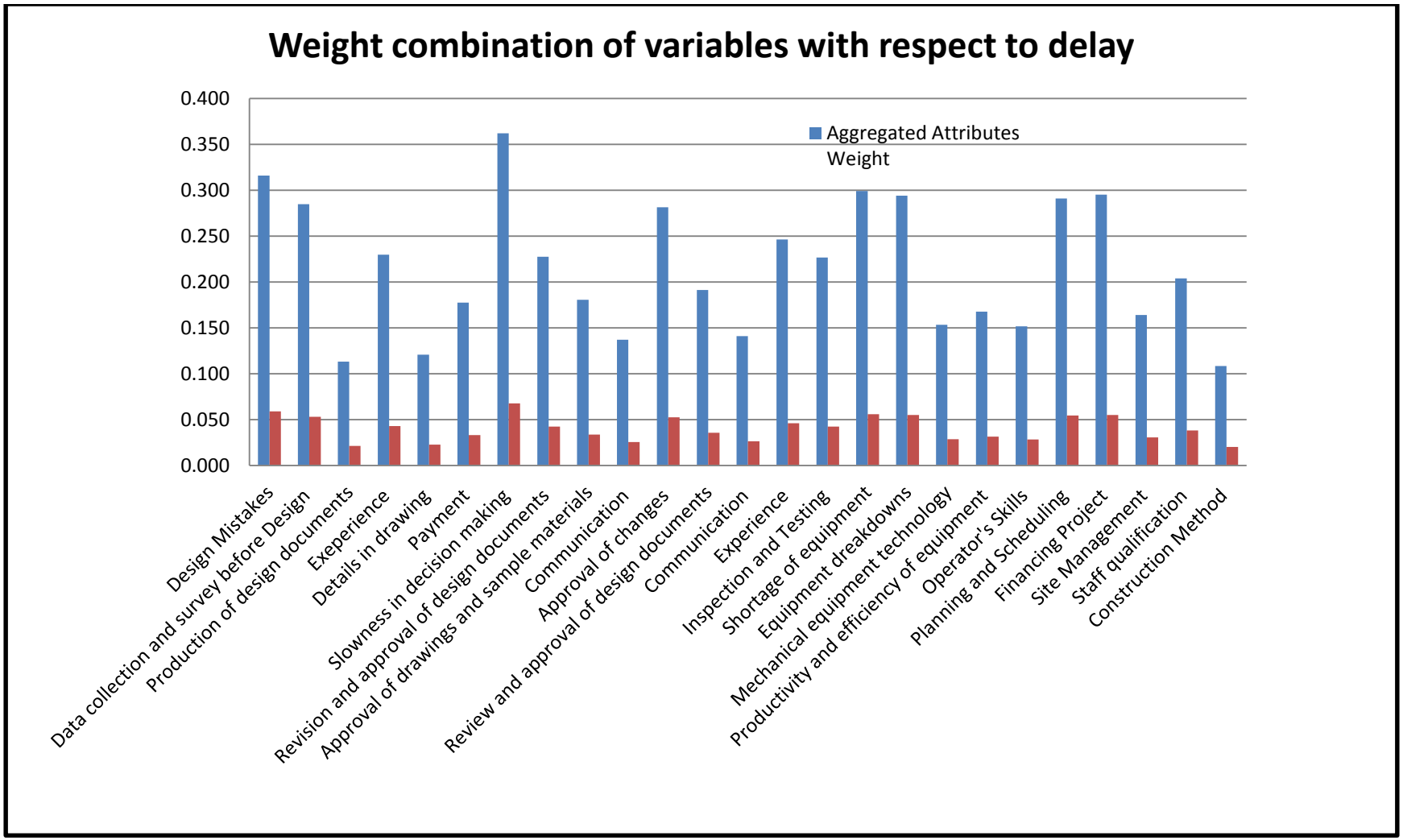
No	Factors Influencing Delay	Frequency					(MIR)	STD	Rank	Average of MIR
		1	2	3	4	5				
	Consultants Related Factors									
30	Delay in performing inspection and testing by consultant	0	27	30	6	3	2.77	4.72	5	2.63
31	Delay in approving major changes in the scope of work by consultant	12	30	21	3	0	2.23	4.16	1	
32	Inflexibility (rigidity) of consultant	9	15	21	30	0	2.96	3.81	7	
33	Poor communication/coordination between consultant and other parties	15	21	21	6	6	2.52	2.51	3	
34	Late in reviewing and approving design documents by consultant	15	27	15	6	3	2.32	3.13	2	
35	Conflicts between consultant and design engineer	6	21	18	12	9	2.95	2.07	6	
36	Inadequate experience of consultant	18	9	18	18	3	2.68	2.30	4	
	Design Related Factors									
37	Mistakes and discrepancies in design documents	27	24	9	3	3	1.95	3.85	1	2.81
38	Delays in producing design documents	12	18	24	12	0	2.55	2.97	3	
39	Unclear and inadequate details in drawings	12	12	21	18	3	2.82	2.30	5	
40	Complexity of project design	0	9	21	24	12	3.59	3.21	7	
41	Insufficient data collection and survey before design	18	24	0	21	3	2.50	3.65	2	
42	Misunderstanding of owner’s requirements by design engineer	0	9	36	18	3	3.23	4.83	6	

43	Inadequate design-team experience	12	18	12	18	6	2.82	1.67	4	
44	Un-use of advanced engineering design software	6	27	6	12	15	3.05	2.88	6	

No	**Factors Influencing Delay**	**Frequency**					**(MIR)**	**STD**	**Rank**	**Average of MIR**
		1	**2**	**3**	**4**	**5**				
	Materials Related Factors									
45	Shortage of construction materials in market	18	6	15	9	18	3.05	1.82	5	2.76
46	Changes in material types and specifications during construction	12	9	15	18	15	3.22	1.14	6	
47	Delay in material delivery	24	27	6	0	9	2.14	3.91	2	
48	Damage of sorted material while they are needed urgently	0	9	27	24	6	3.41	3.91	7	
49	Delay in manufacturing special building materials	18	12	15	15	6	2.68	1.52	3	
50	Late procurement of materials	24	27	6	9	0	2.00	3.91	1	
51	Late in selection of finishing materials due to availability of many types in market	18	9	12	21	6	2.82	2.07	4	
	Equipments Related Factors									
52	Equipment breakdowns	21	24	12	6	3	2.18	3.05	2	2.34
53	Shortage of equipment	33	18	6	3	6	1.95	4.16	1	
54	Low level of equipment-operator’s skill	12	9	27	15	3	2.82	2.97	5	
55	Low productivity and efficiency of equipment	18	15	24	6	3	2.41	2.88	4	
56	Lack of high-technology mechanical equipment	18	27	6	12	3	2.32	3.21	3	

No	Factors Influencing Delay	Frequency					(MIR)	STD	Rank	Average of MIR
		1	2	3	4	5				
	Materials Related Factors									
	Labor Related Factors									
57	Shortage of labors	0	33	15	12	6	2.86	4.16	3	3.32
58	Unqualified workforce	15	12	33	6	0	2.45	4.16	1	
59	Nationality of labors	0	3	18	18	30	4.09	4.10	4	
60	Low productivity level of labors	12	12	30	6	6	2.73	3.29	2	
61	Personal conflicts among labors	0	3	6	15	42	4.45	5.68	5	
	External Related Factors									
62	Effects of subsurface conditions (e.g., soil, high water table, etc.)	9	15	24	9	9	2.91	2.19	3	3.49
63	Delay in obtaining permits from municipality	15	9	21	12	9	2.86	1.67	2	
64	Hot weather effect on construction activities	9	6	6	3	42	3.95	5.41	10	
65	Rain effect on construction activities	21	12	18	12	3	2.45	2.30	1	
66	Unavailability of utilities in site (such as, water, electricity, telephone, etc.)	0	12	21	15	18	3.59	2.70	7	
67	Effect of social and cultural factors	3	0	21	12	30	4.00	4.16	11	
68	Traffic control and restriction at job site	3	0	12	33	18	3.95	4.39	9	
69	Accident during construction	3	3	9	27	24	4.00	3.85	11	
70	Differing site (ground) conditions	3	12	21	15	15	3.41	2.19	4	
71	Changes in government regulations and laws	6	6	15	15	27	3.74	2.88	8	
72	Delay in providing services from utilities (such as water, electricity)	6	6	21	21	12	3.41	2.51	5	
73	Delay in performing final inspection and certification by a third party	3	15	12	15	21	3.55	2.19	6	

APPENDIX-C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0.300
0.250
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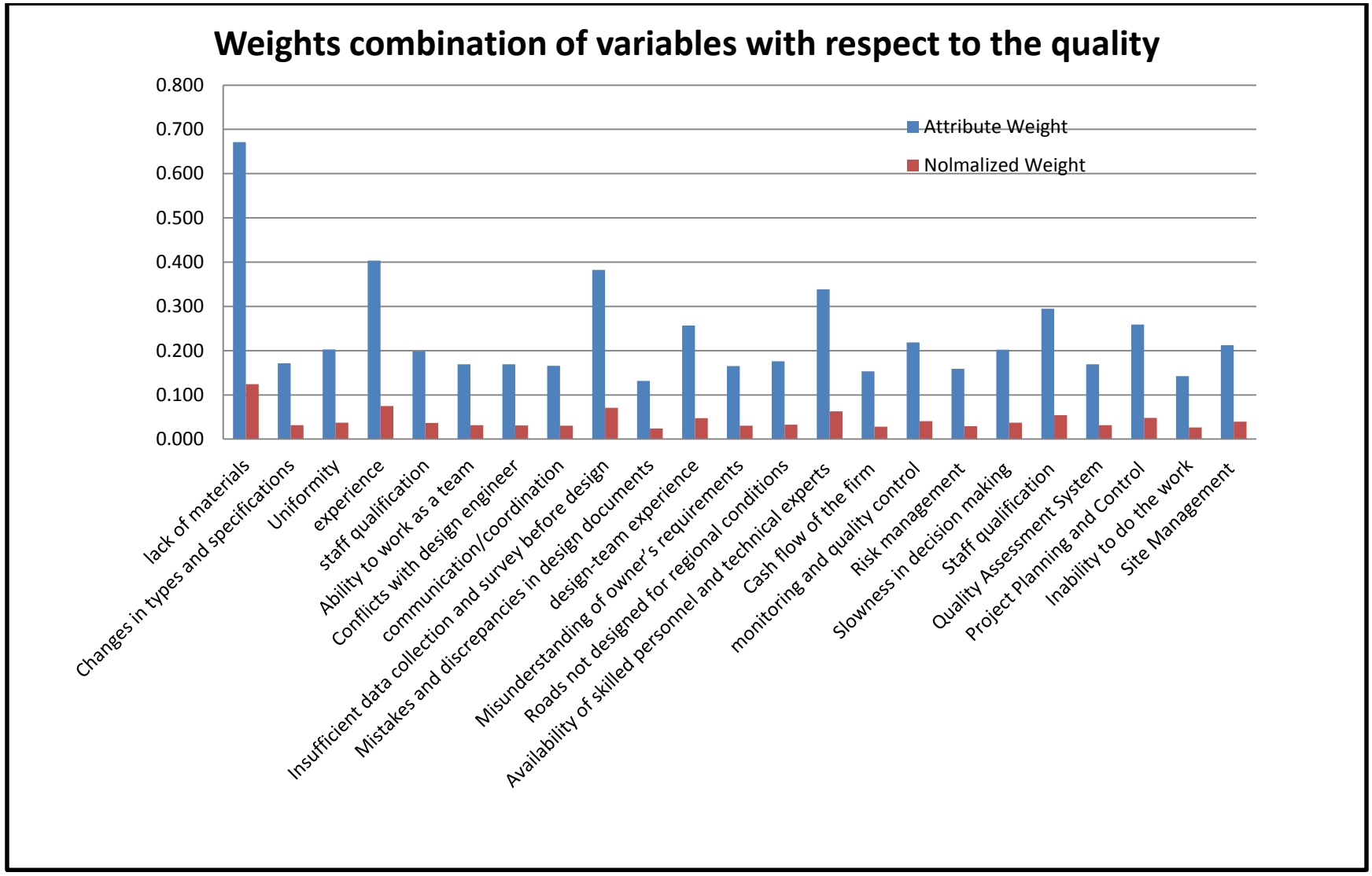
0.150
0.100
0.050
0.000
Aggregated Attributes Weight
Design Mistakes
Data collection and survey before Design
Production of design documents
Exeperience
Details in drawing
Payment
Slowness in decision making
Revision and approval of design documents
Approval of drawings and sample materials
Communication
Approval of changes
Review and approval of design documents
Communication
Experience
Inspection and Testing
Shortage of equipment
Equipment dreakdowns
Mechanical equipment technology
Productivity and efficiency of equipment
Operator's Skills
Planning and Scheduling
Financing Project
Site Management
Staff qualification
Construction Method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0.600
0.500
0.400
0.300
0.200
0.100
0.000
Attribute Weight
Nolmalized Weight
lack of materials
Changes in types and specifications
Uniformity
experience
staff qualification
Ability to work as a team
Conflicts with design engineer
communication/coordination
Insufficient data collection and survey before design
Mistakes and discrepancies in design documents
design-team experience
Misunderstanding of owner's requirements
Roads not designed for regional conditions
Availability of skilled personnel and technical experts
Cash flow of the firm
monitoring and quality control
Risk management
Slowness in decision making
Staff qualification
Quality Assessment System
Project Planning and Control
Inability to do the work
Site Management

APPENDIX-D
APPENDIX: INVITATION LETTER-FUZZY AHP QUESTIONNAIRE
Invitation for Fuzzy AHP Questionnaire Participation

Analysis of factors influencing delay and quality of Highways/Roads construction Projects in Rwanda: Using Fuzzy-AHP Approach

To WHOM IT MAY CONCERN

Dear Sir/Madam
This research study intends to investigate and evaluate the highway infrastructure projects by comparing the factors influencing poor performance of Roads construction projects in terms of Quality and delays. Previous survey (Questionnaire Survey) was designed to reduce factors in order to get those which are critical.
In this survey (Fuzzy AHP Questionnaire) ,this study aims to prioritize these critical factors by pair-wise comparison, and to investigate the interdependent relationship between the alternatives/sub criteria.
Your inputs are greatly valuable and we do hope that you can participate in this final survey.
Your relevant experience and expertise in highway infrastructure is valuable and you are invited to participate in this survey. If you agree, please email me mpascie@yahoo.fr. We can arrange the time that suits to your schedule to conduct this survey. This survey will take about 30 minutes to complete. All the answers will remain confidential and all the information will be analyzed in general, without reference to specific individuals (See below of this letter for more details).
If you have any queries about this project, please contact me or my Principal Supervisor, Dr Bari Mahabubuli on (07)31381028 or QUT Reearch Ethic office on (07)31382340 for further information about the ethical conduct of the project.
Your contribution towards this study is greatly appreciated!
Yours Sincerely,

MPORANANAYO Pacifique
Postgraduate Candidate
University of Rwanda/College of Science and Technology
Faculty of Science/Department of Civil Engineering and Environmental Technology
Tel: (+250)788541710
E-mail: mpascie@yahoo.fr

Additional Information

Participation

Thank you for your time to consider this survey. Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the project without comment or penalty. Your decision to participate will in no way impact upon your current or future relationship with QUT. Please note that it will not be possible to withdraw, once you have submitted the questionnaire.

Risks

There are no risks beyond normal day-to-day living associated with your participation in this project.

Confidentiality

All comments and responses are anonymous and will be treated confidentially. The names of individuals persons are not required in any of the responses.

Consent to Participate

The return of the completed questionnaire is accepted as an indication of your consent to participate in this project.

Questions/further information about the project

Please contact the researcher team members named above to have any questions answered or if you require further information about the project.

Concerns/ complaints regarding the conduct of the project

QUT is committed to researcher integrity and the ethical conduct of the project you may contact the QUT Research Ethics Officer on 3138 2340 or ethicscontact@qut.edu.au. The Research Ethics Officer is not connected with the research project and can facilitate aresolution to your concern in an impartial manner.

APPENDIX: SAMPLE OF FUZZY AHP QUESTIONNAIRE

Instruction

Each section in this survey consists of a number of question sets. Each question within a question set asks you to compare two factors/criteria at a time(i.e. pair-wise comparisons)with respect to a third factor/criterion.

Please read each question carefully before giving your opinions/answers, and answer according to the following ranting scale:

Example

If a sustainability indicator on the left is more important than the one on the right, put cross mark ”x” to the left of the “Equal Importance” column. Under the importance level (column) you prefer. On the other hand, if a on the left is less important than the one on the right, put cross mark ”X” to the right of the equal important “EI” column under the importance level(column)you prefer based on the project preference.

Q1. How important is the Design Error and issues when it is compared to staff qualification?

Q2.How important is the agency Design Error when it is compared to External Factors?

Q3. How important is the environmental staff qualification when it is compared to External Factors?

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Design Error					X													Staff qualification
Design Error				X														External factors/Environmental
Staff qualification									X									External factors/Environmental

Factors Influencing Performance of Road Construction Projects/Time **(Delay)** of roads construction projects

Design Related Factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Design mistakes																		data collection and survey before design
Design mistakes																		production of design documents
Design mistakes																		experience

Design mistakes																	details in drawing
data collection and survey before design																	production of design documents
data collection and survey before design																	experience
data collection and survey before design																	details in drawings
production of design documents																	experience
production of design documents																	details in drawing
experience																	details in drawing

Owner-related factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Payment																		Slowness in decision making
Payment																		revision and approval of design documents
Payment																		approval of drawings and sample materials
Payment																		Communication
Slowness in decision making																		revision and approval of design documents
Slowness in decision making																		approval of drawings and sample materials
Slowness in decision making																		Communication
revision and approval of design documents																		approval of drawings and sample materials
revision and approval of design documents																		Communication

approval of drawings and sample materials																		Communication

Consultant-related factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Approval of changes																		review and approval of design documents
Approval of changes																		Communication
Approval of changes																		Experience
Approval of changes																		Inspection and Testing
review and approval of design documents																		Communication
review and approval of design documents																		Experience
review and approval of design documents																		Inspection and Testing

Communication																		Experience
Communication																		Inspection and Testing
Experience																		Inspection and Testing

Equipment-related factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Shortage of equipment																		Equipment breakdowns
Shortage of equipment																		mechanical equipment technology
Shortage of equipment																		productivity and efficiency of equipment
Shortage of equipment																		operator's skills
Equipment breakdowns																		mechanical equipment technology
Equipment breakdowns																		productivity and efficiency of equipment
Equipment breakdowns																		operator's skills
mechanical equipment technology																		productivity and efficiency of equipment

mechanical equipment technology																		operator's skills
productivity and efficiency of equipment)																		operator's skills

Contractor-related factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
planning and scheduling																		Financing Project
planning and scheduling																		site management
planning and scheduling																		Staff qualification
planning and scheduling																		site mobilization
planning and scheduling																		Construction methods
Financing Project																		site management
Financing Project																		Staff qualification
Financing Project																		site mobilization
Financing Project																		Construction methods

site management																		Staff qualification
site management																		site mobilization
site management																		Construction methods
Staff qualification																		site mobilization
Staff qualification																		Construction methods
site mobilization																		Construction methods

Factors Influencing Performance of Road Construction Projects/**Quality** of roads

Material related

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
lack of materials																		Changes in types and specifications
lack of materials																		Uniformity
Changes in types and specifications																		Uniformity

Consultant Related Factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
experience																		staff qualification
experience																		Ability to work as a team
experience																		Conflicts with design engineer
experience																		communication/coordination
staff qualification																		Ability to work as a team
staff qualification																		Conflicts with design engineer
staff qualification																		communication/coordination
Ability to work as a team																		Conflicts with design engineer
Ability to work as a team																		communication/coordination
Conflicts with design engineer																		communication/coordination

Design Related Factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Insufficient data collection and survey before design																		Mistakes and discrepancies in design documents
Insufficient data collection and survey before design																		design-team experience
Insufficient data collection and survey before design																		Misunderstanding of owner's requirements
Insufficient data collection and survey before design																		Roads not designed for regional conditions
Mistakes and discrepancies in design documents																		design-team experience
Mistakes and discrepancies in design documents																		Misunderstanding of owner's requirements

Mistakes and discrepancies in design documents																		Roads not designed for regional conditions
Inadequate design-team experience																		Misunderstanding of owner's requirements
Inadequate design-team experience																		Roads not designed for regional conditions
Misunderstanding of owner's requirements																		Roads not designed for regional conditions

Contractors related

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
staff qualification																		Quality assessment system
staff qualification																		Project planning and control
staff qualification																		inability to do the work
staff qualification																		site management
Quality assessment system																		Project planning and control
Quality assessment system																		inability to do the work
Quality assessment system																		site management
Project planning and control																		inability to do the work
Project planning and control																		site management

inability to do the work																	site management

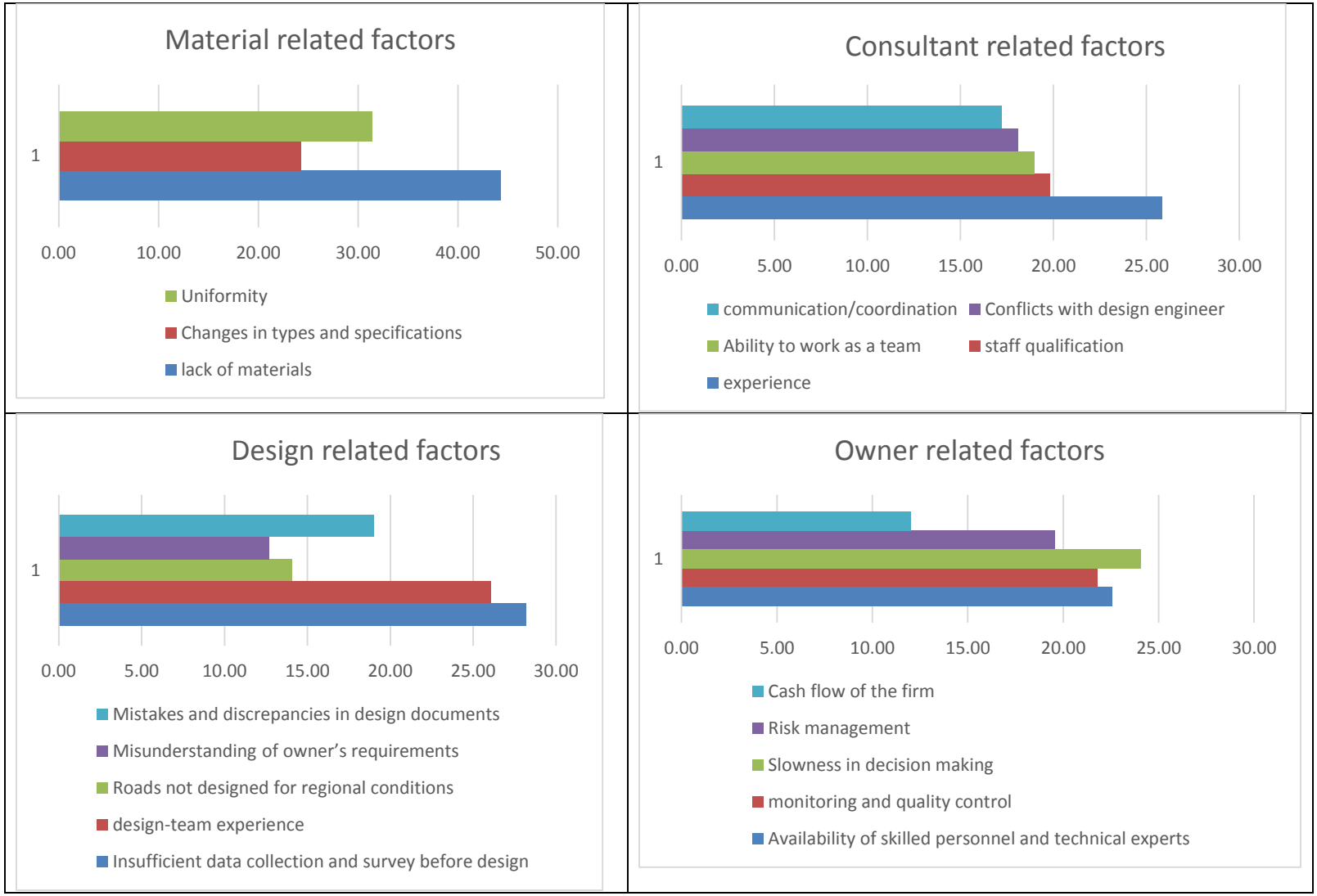
APENDIX-E

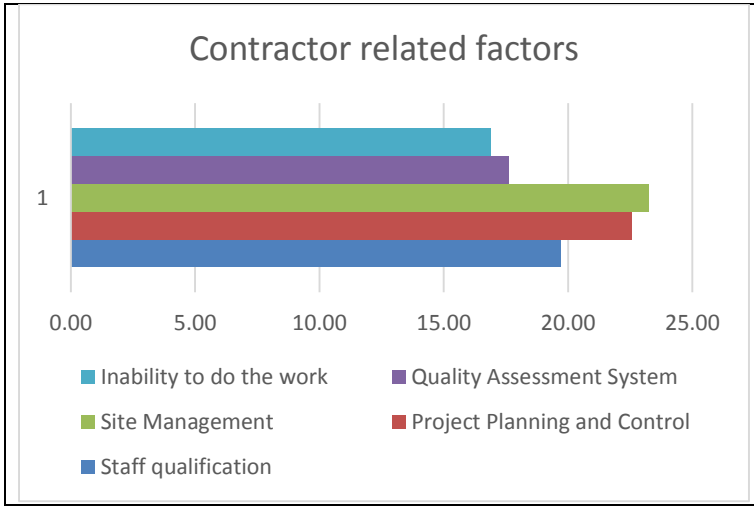
Top 10 ranked risks	Significance Index scores
Cost related risks:	
Tight project schedule	0.67
Design variations	0.49
Variations by the client	0.46
Unsuitable construction program planning	0.42
Occurrence of dispute	0.42
Price inflation of construction materials	0.41
Excessive approval procedures in administrative government departments	0.40
Incomplete approval and other documents	0.39
Incomplete or inaccurate cost estimate	0.38
Inadequate program scheduling	0.38
Time related risks:	
Tight project schedule	0.57
Design variations	0.48
Excessive approval procedures in administrative government departments	0.48
Variations by the client	0.47
Incomplete approval and other documents	0.45
Unsuitable construction program planning	0.45
Inadequate program scheduling	0.42
Bureaucracy of government	0.39
High performance or quality expectations	0.38
Variations of construction program s	0.38
Quality related risks:	
Tight project schedule	0.39
Inadequate program scheduling	0.28
Unsuitable construction program planning	0.27
Incomplete or inaccurate cost estimate	0.27
Low management competency of subcontractors	0.25
High performance or quality expectations	0.25
Variations of construction programs	0.24
Unavailability of sufficient amount of skilled labour	0.24
Design variations	0.23
Lack of coordination between project participants	0.23
Safety related risks:	
	0.45
Tight project schedule	0.37
Low management competency of subcontractors	0.33
Unsuitable construction program planning	0.30
Variations of construction programs	0.30
General safety accident occurrence	0.27
High performance or quality expectations	0.26
Design variations	0.26
Lack of coordination between project participants	0.25
Excessive approval procedures in administrative government departments	0.24

Unavailability of sufficient amount of skilled labour Unavailability of sufficient professionals and managers	0.24

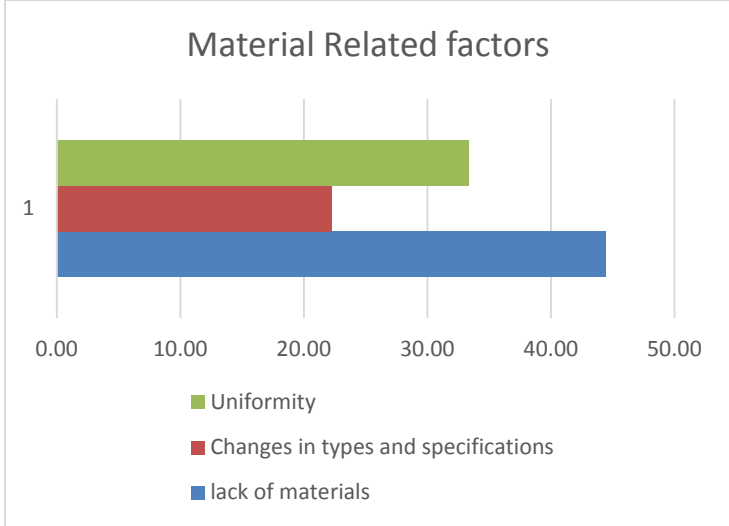
Source: LGU Construction Supervision team

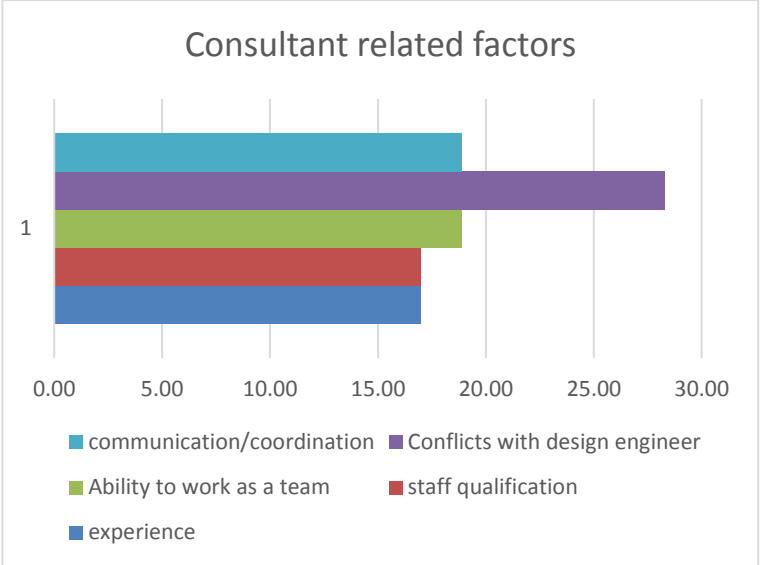
Appendix F: Most Important criterias vs actual situation of selected Unpaved/Murrum Roads Projects in terms of quality

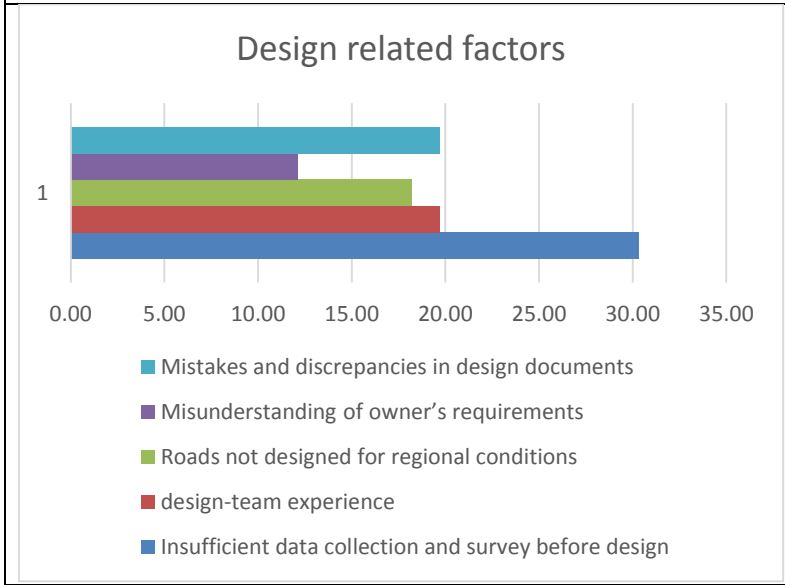


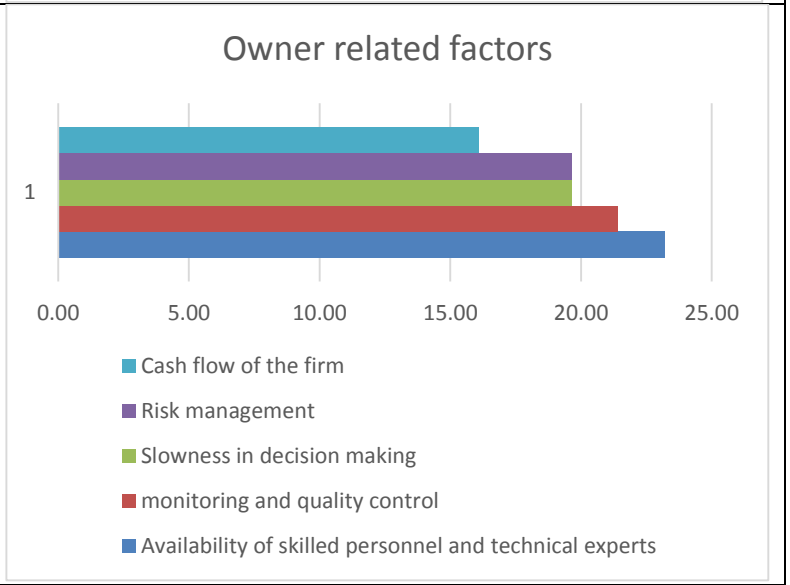

Contractor related factors
1
0.00
5.00
10.00
15.00
20.00
25.00
Inability to do the work
Quality Assessment System
Site Management
Project Planning and Control
Staff qualification

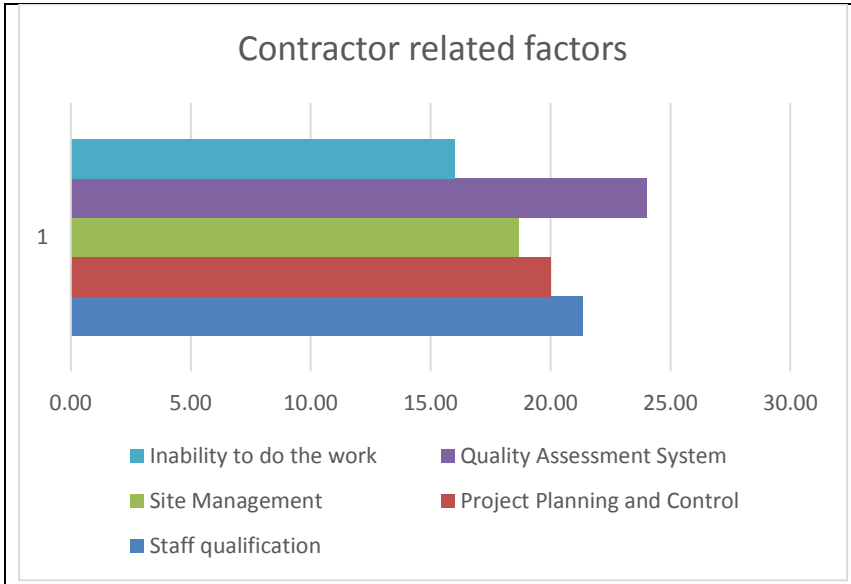
APENDIX-G Most Important criterias vs actual situation of selected Unpaved/Murrum Roads Projects in terms of time



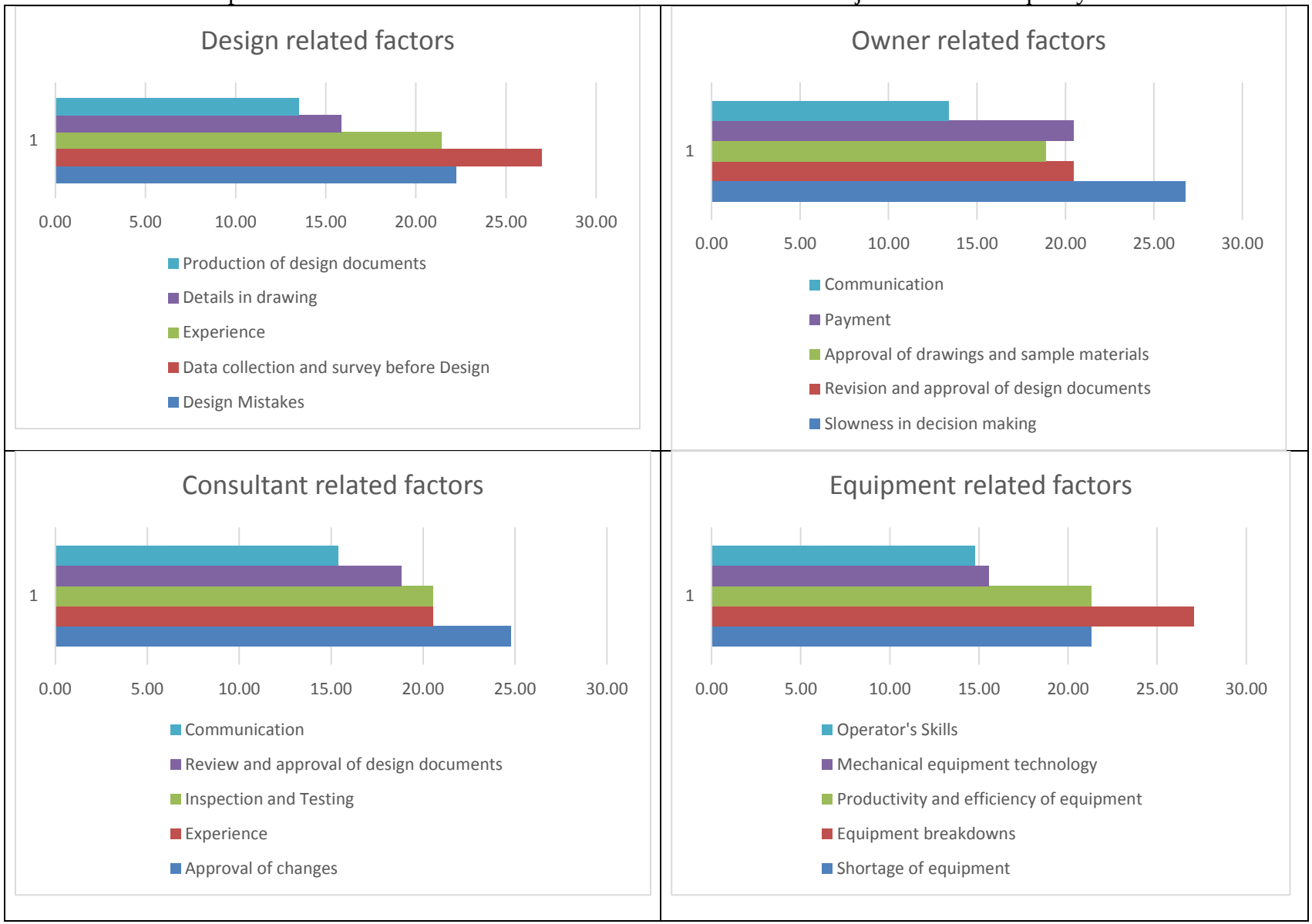


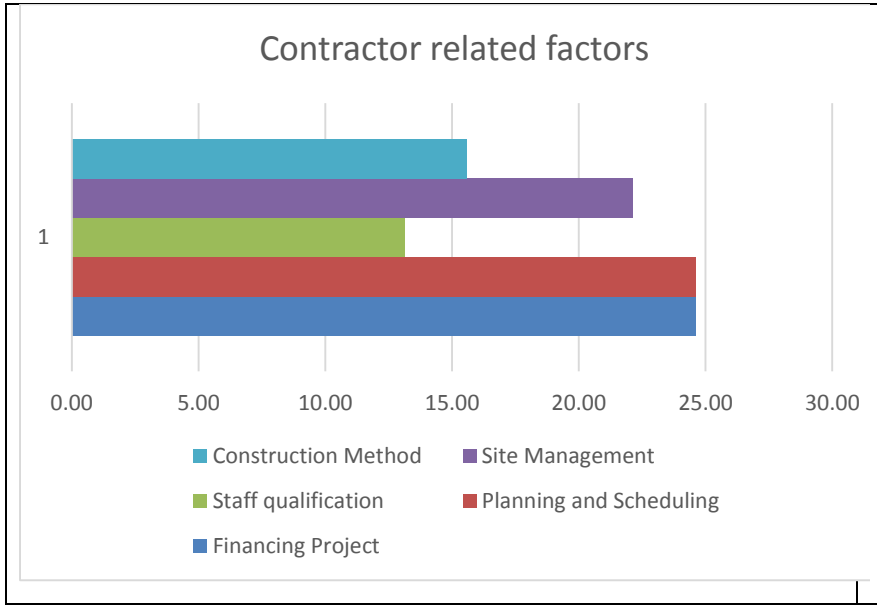




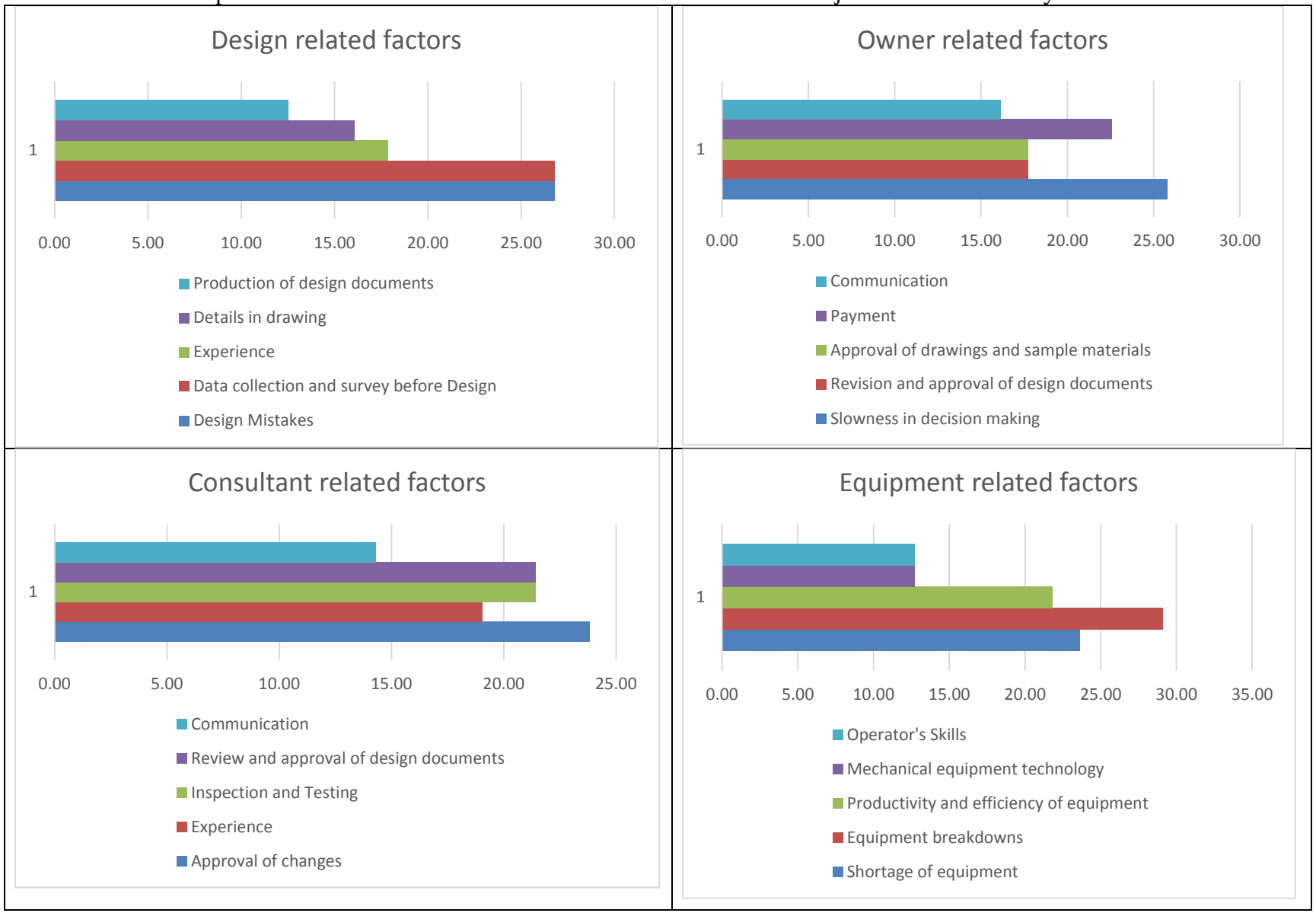

Contractor related factors
1
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Inability to do the work
Quality Assessment System
Site Management
Project Planning and Control
Staff qualification

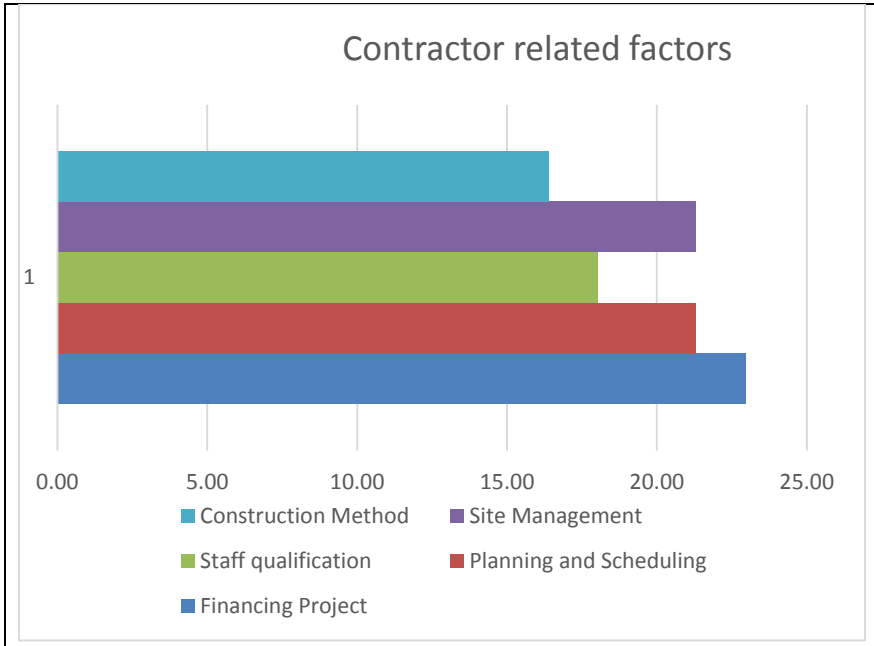
APENDIX-H Most Important criterias vs actual situation of selected Paved Roads Projects in terms of quality




Contractor related factors
1
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Construction Method
Site Management
Staff qualification
Planning and Scheduling
Financing Project

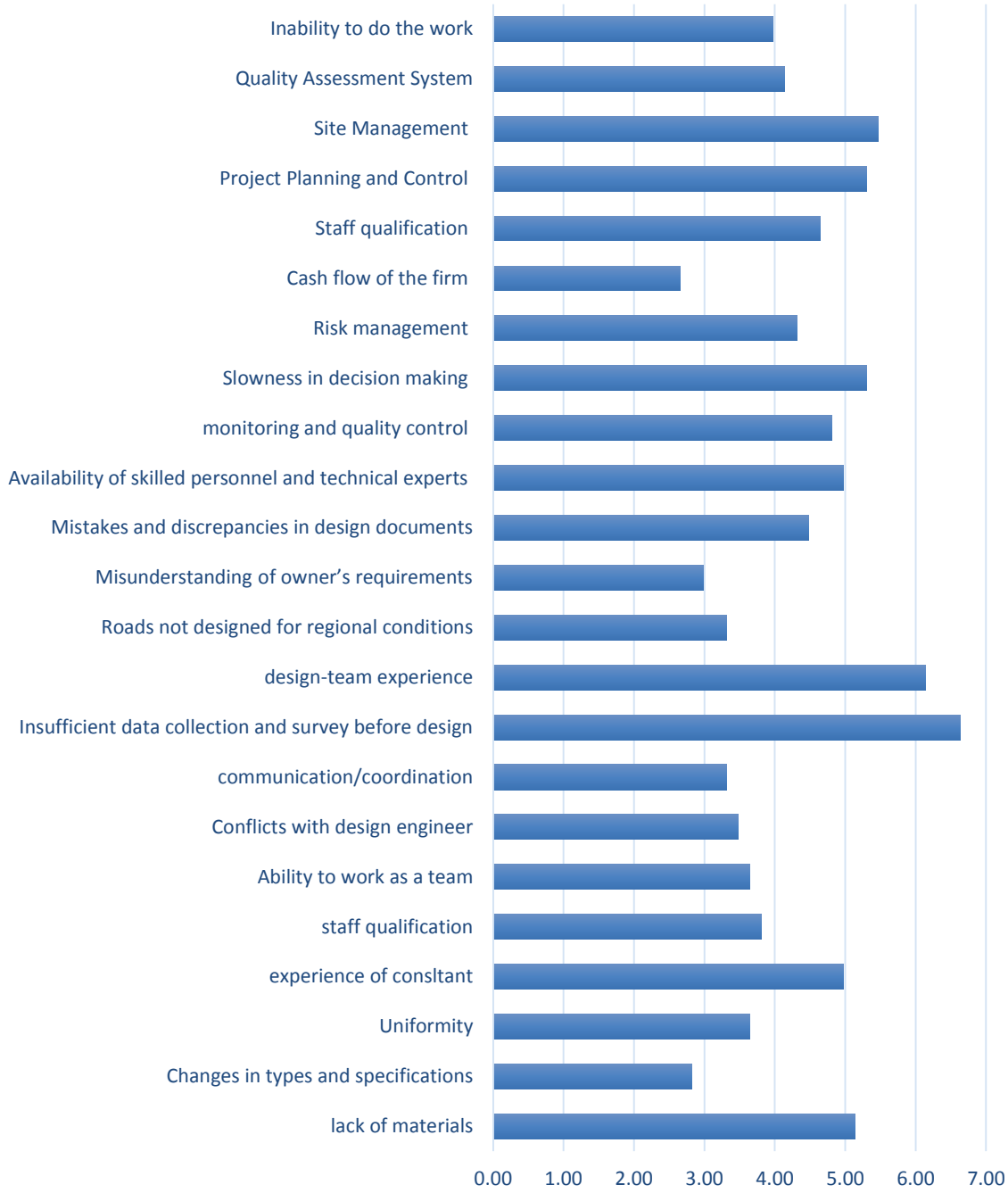
APENDIX-I Most Important criterias vs actual situation of selected Paved Roads Projects in terms of Delay



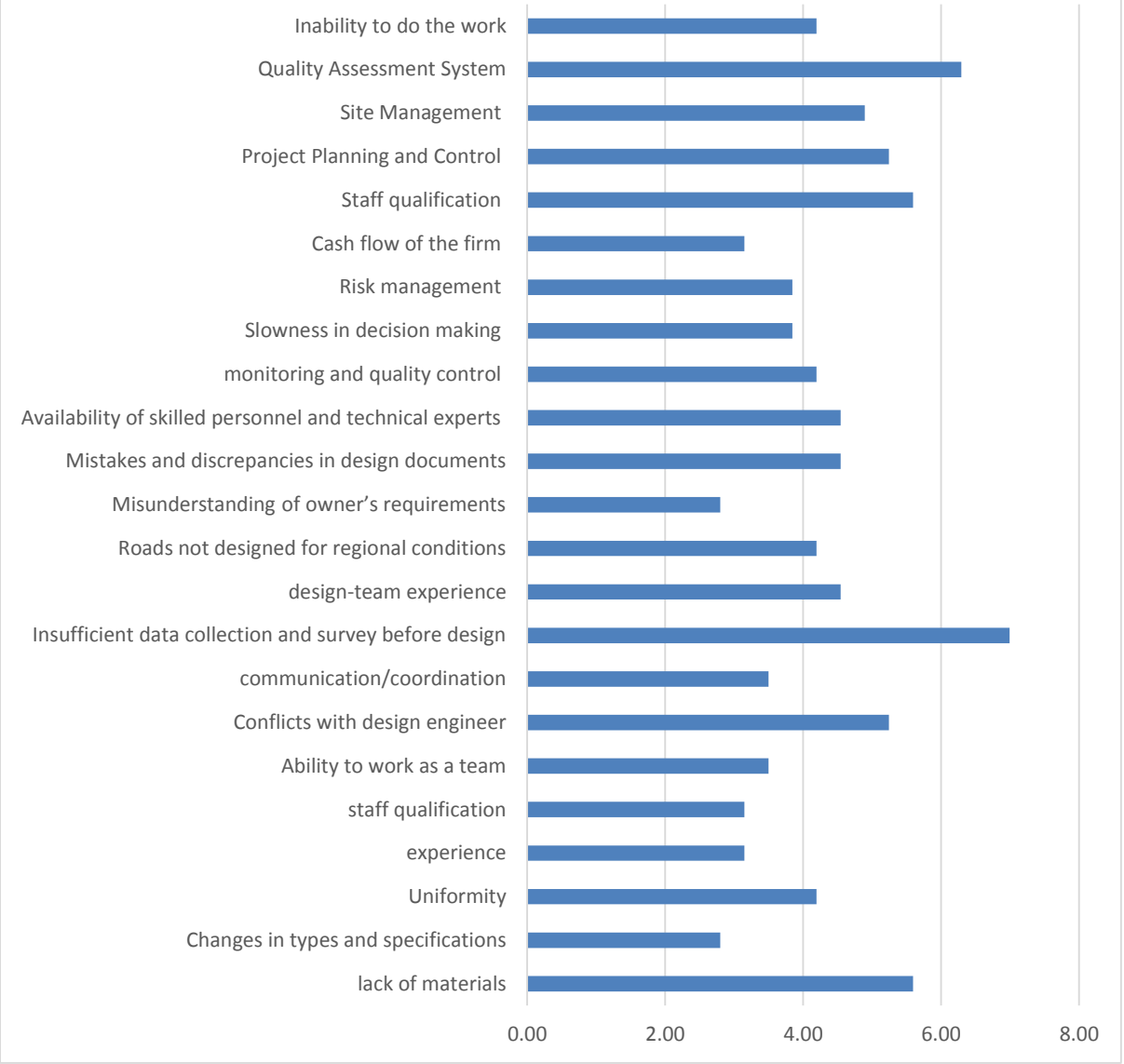

Contractor related factors
1
0.00
5.00
10.00
15.00
20.00
25.00
Construction Method
Site Management
Staff qualification
Planning and Scheduling
Financing Project

APENDIX-J

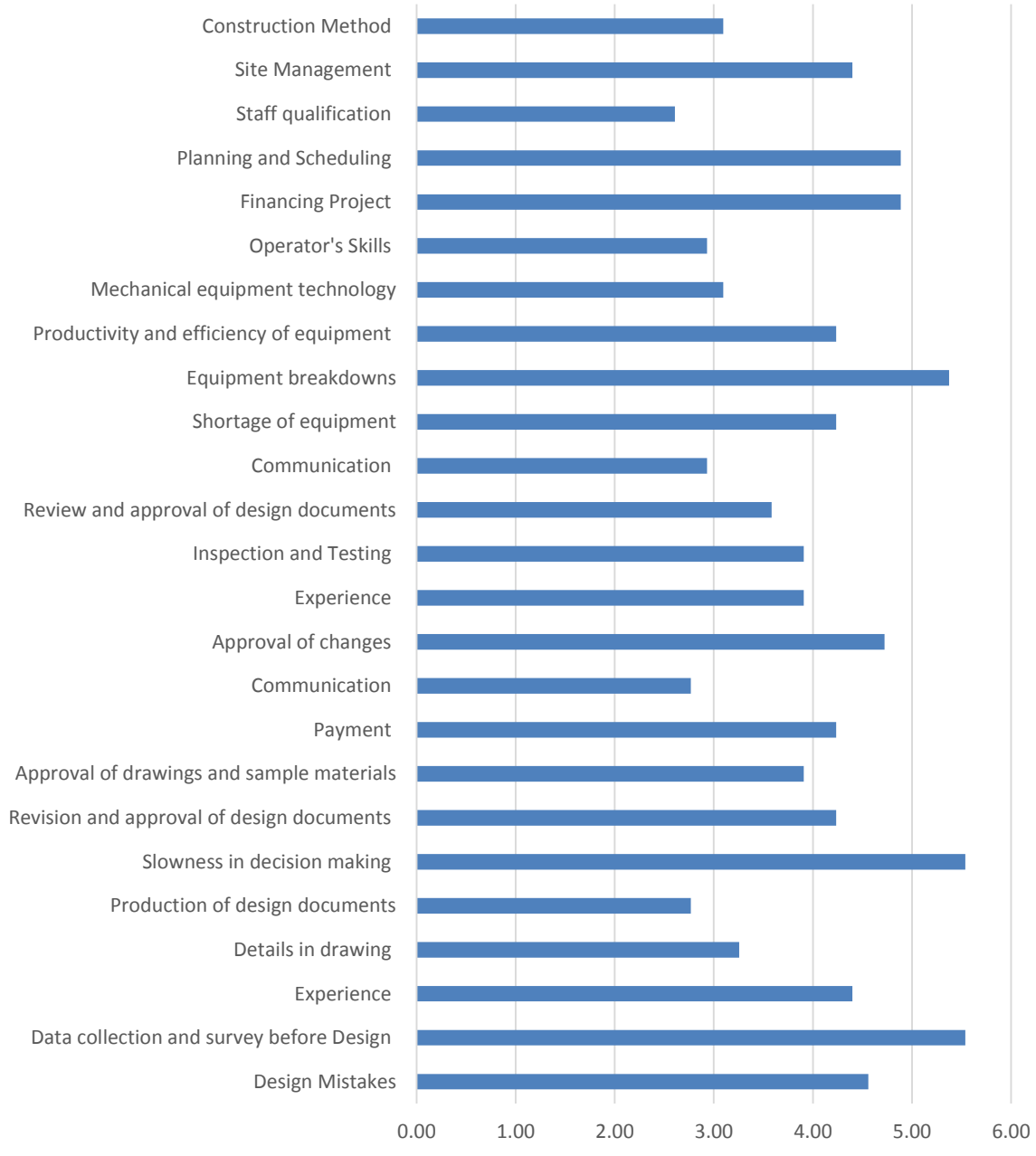
Most Important criterias vs actual situation of selected Murrum Roads Projects/Quality



APENDIX-K
Most Important criterias vs actual situation of selected Asphalt Roads Projects/Quality



APENDIX-L
Most important criterias vs actual situation of selected murrum roads projects/Delay



APENDIX-M

Most Important criterias vs Actual situation of selected Asphalt roads projects/Delay