ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

Risk Assessment and Contingency Allocation on Ethiopian Federal Road Projects

By: Kidist Girma

Addis Ababa, Ethiopia

June 2016

A Thesis submitted to School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements of the Degree of Master of Science in Industrial Engineering

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"Risk Assessment and Contingency Allocation on Ethiopian Federal Road Projects"

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Kidist Girma

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitle "Risk Assessment and Contingency Allocation on Ethiopian Federal Road Projects" is original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been duly acknowledged.

____________________________ ______________________

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List of Abbreviations

COA	Center of Area Method
DSS	Decision support system
ERA	Ethiopian Road Authority
FLS	Fuzzy Logic System
GDP	Gross Domestic Product
MF	Membership Function
RL	Risk Likelihood
RM	Risk Magnitude
RS	Risk Severity

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ABSTRACT

Road construction projects are subjected to substantial risks. This study highlights the risks associated with road construction projects from Client represented by Ethiopian Road Authority (ERA) and local contractors' perspective. One hundred nineteen risks are identified through detail literature review. A questionnaire is then developed to solicit the opinion of construction professionals (ERA experts and local contractors) as to the probability and impact of those risks, in addition to their proper allocation. Eighteen surveys were completed and used in the analysis. The analysis is carried out using fuzzy interval arithmetic and α-cut method to address both objective and subjective opinions considered in the ranking of risks, using linguistic terms, horizontal membership function estimation and triangular best fit approximation. The priority of each risk is calculated by multiplying the probability with the impact for each risk.

The results indicate that the top five significant risks from local contractors' perspective are currency exchange risks/Lack of currency, corruption and lack of respect for law, change in scope of work, shortage of equipment at site, equipment frequently out of order or damaged, whereas, shortage of equipment at site, theft on site, accident and injuries, lack of personal training and management support, equipment frequently out of order or damaged are the top most significance risk among client. Furthermore, local contractors and the client are not in the same level of agreement on the risk ranking.

The top risks discussed clearly indicate where the stakeholders should put much effort in and allocate proper contingencies. Nevertheless, risk management plan is an ongoing effort that cannot stop after a risk assessment or the setting of contingency, it must comprise a decision support system for proper risk mitigation strategy and management plan that should be incorporated in the project execution plan.

Clients should incorporate appropriate risk contingencies in the feasibility stage of a project while the contractors during the biding stage. In addition, the risk response strategies of any risk should be developed in detail and executed by contractors and owners and the risks should be allocated to the parties best able to manage it.

Key word: Risk, Decision support system (DSS), Road Construction projects, Risk assessment, Expert systems, Fuzzy set, Fuzzy arithmetic, Membership function, Alpha cut

CHAPTER ONE

PROBLEM AND ITS APPROACH

1.1 Introduction

One of the most critical decisions that have to be made by construction firms is what are the proper risk contingencies for a project, since construction projects are subject to many risks due to the unique features of construction activities, such as long period, complicated processes, abominable environment, financial intensity and dynamic organization structures (Flanagan, 1993). The diverse interests of project stakeholders on a construction project further exacerbate the changeability and complexity of the risks. While risks cannot be eliminated, successful projects are those where risks are effectively managed, of which early and effective identification and assessment of risks is essential (Patrick X.W. Zou, 2007).

Risk is perceived as ‘the chance of something happening that will have an impact on objectives; which may have a positive or negative impact’ or a ‘combination of the probability or frequency of occurrence of a defined threat or opportunity and the magnitude of the consequences of the occurrence’ (Australian/New Zealand standard on risk management, 2004). Construction projects are perceived to have more inherent risks due to involvement of many contracting parties, such as owners, designers, contractors, subcontractors, suppliers, etc. (PMI, 2004). Thus, risk analysis and management are an important part of the decision-making process in construction industry.

Risk analysis or management in the construction industry involves identifying risk events that could potentially affect a project and its delivery, quantifying those risks, and developing mitigation strategies to enhance project success.

Risk identification is the first step of risk management process, in which potential risks associated with a construction project are identified. As an intermediate process between risk identification and risk response, risk analysis incorporates uncertainty in a qualitative and quantitative manner to evaluate the potential impact of risks. Once the risks of a project have been identified and analyzed, appropriate risk response strategies must be adopted to cope with the risks in the project implementation. The treatment measures on each risk are based on the nature and impact of the risk (Patrick X.W. Zou, 2007).

Traditionally, during the pre-contract stage of project, most of these risks are not properly identified, assess the likelihood of its occurrence, asses it impact on project performance. Rather a 10% contingency is added to the total project cost in order to accommodate the effect of unforeseen circumstances (Luka Goji Tipili, 2014). In most cases the 10% contingency is based on intuitive guesswork and this explains the attendant high cost overrun thus, a need to assess the risk impact on construction project is still desirable. Proper risk analysis and cost control will ensure certainty of project price i.e. project will achieve its cost and will be within budgets, timely delivery of project, project will also receive the best quality and the expenditure must give value for the money spent.

Several models are prevalent in risk quantification and assessment, such as fuzzy logic, hidden Markov and decision tree models, and artificial neural and Bayesian networks, explicitly consider the underlying cause-and-effect relationships and recognize the unknown complexity. With appropriate risk identification and risk control in place, operational risk can be significantly mitigated, despite the lack of consensus concerning which quantitative models should be used (Kailan Shang, November 2013). Therefore, it may be beneficial to build and implement more appropriate operational risk models using a logical approach like fuzzy logic. Fuzzy logic models are more convenient for incorporating different expert opinions and more adapted to cases with insufficient and imprecise data. They provide a framework in which experts' input and experience data can jointly assess the uncertainty and identify major issues. Using approximation and making inferences from ambiguous knowledge and data, fuzzy logic models may be used for modeling risks that are not fully understood (Kailan Shang, November 2013).

Thus, this study focuses on developing a decision support system for road construction project risk assessment and contingency allocation.

1.2 Problem Statement

Large construction projects have been known for their cost overrun and late completion time (Ali Touran, AUGUST 2006). Such projects with uncertain environment can be managed using the risk management concept in the project life cycle (A. Sotoodeh Gohar, November 2012). While risk management is a recognized practice that helps clients deliver projects on schedule and within budget the risk management performed in the construction industry has traditionally been that of gut feel or series of rules-of thumb. Consequently, project risks are often not adequately dealt with (Luka Goji Tipili, 2014).

Currently, construction is one of the sectors leading the way towards modernization and industrialization in Ethiopia (Tecle Hagos, 2012). As a developing country, Ethiopia recently launched extensive and visible construction activities in roads and expansion of airports ((EEA), 2006/07). Construction projects in Ethiopia are largely different from construction projects in developed countries. Due to large differences in both development and business and work culture, problems that are experienced in other countries projects are likely to be of a different nature than the problems experienced in Ethiopian construction projects (Karlsson, 2011). Thus, analyzing critical causes of negative consequences in construction projects with respect to the country's context is essential, rather completely adopting risk factors of other countries experience.

Thought the construction sector is leading the way, the risk management practices in the Ethiopian road construction industry are still in the infant phase, since they are mostly in terms of individual intuition, judgment, and based on experiences gained from previous projects rather than using a systematic approach. It is hardly possible to manage risk just by intuition and/or experience gained from other projects. To comprehensively understand risk factors and propose strategies for their management, it is imperative to understand their nature, source and degree of impact. Therefore, it is crucial to categorize and prioritize risks based on their association with the stakeholders, significance on the various objectives of the project and degree of impact.

In addition, according to the data obtained from Ethiopian Road Authority, from the year 2006 to 2012 G.C around 56 projects were carried out and among this 8 projects faced cost overrun, 11 has faced time overrun and 37 projects faced both time and cost overrun. In addition the average cost overrun of these projects is around 25% (Tafere, October 2015). Thus, this study mainly focuses on improving road construction project risks management practices.

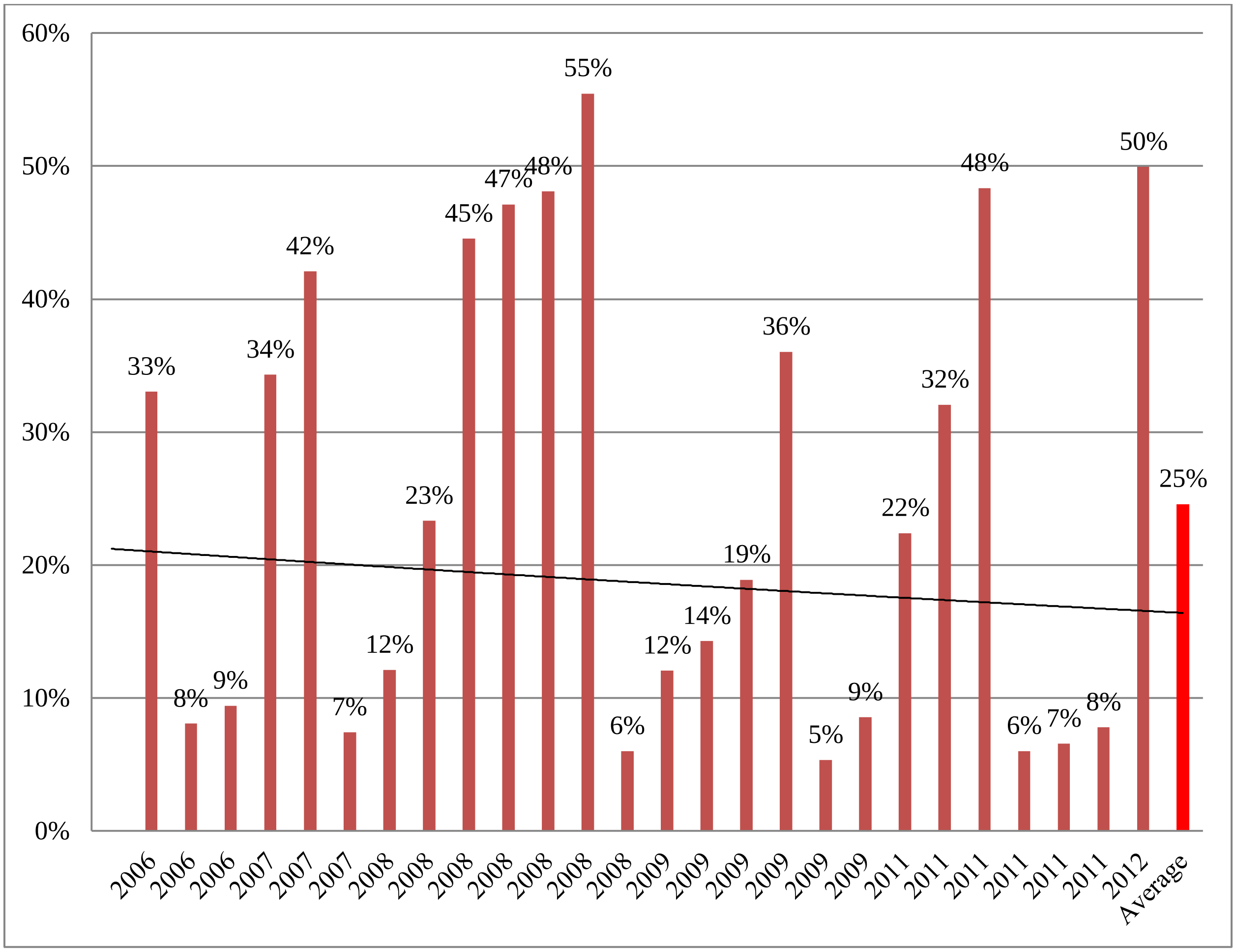


Figure 1: Cost Overrun of Road Projects Completed From 2006-2012

Thus, the above mentioned pitfalls raise several important questions. In order to address these issues, the following research questions have been formulated to support the investigation:

1. What are the major risk factors contributing to cost overrun in federal road construction projects?
2. What are the magnitudes of these risk factors?
3. What is the optimum allocation of contingency for the respective risks in the road construction projects?

4. What is the proper risk allocation among stakeholders?

1.3 Objective

1.3.1 General Objective

The general objective of the study is to propose a decision support system that properly allocate risk contingency among clients and contractors that has high frequency of occurrence and degree of impact in the road construction projects.

1.3.2 Specific Objective

The specific objectives of the study are:

1. Determine the major causes of cost overruns in federal road projects.
2. Determine the magnitudes of these risk factors?
3. Allocate an optimum contingency for each respective risk that can be used for future road construction projects.
4. Identify the proper risk allocation of each risk among stakeholders.
5. Providing practical suggestions and recommendations pointing toward upgrading the risk management process in construction and improve the performance of contracting companies and owners in this field.

1.4 Research Methodology

The objectives set in the study were addressed through literature review, data collection, and data analysis supported by logical discussion.

1. **Literature Survey**: The theoretical background is based on literature survey to assess other countries experience concerning the study areas on risk identification and analysis tools and techniques used. Also to identify major risk factors on construction projects to design a questionnaire based on the information gathered. The literatures are available from electronic media, journals and books.
2. **Data collection:** The data for this research are collected via primary and secondary sources. The primary sources are from informal/unstructured interviews and

questionnaire survey among different construction stakeholders. The secondary data's are from electronic media, journals, books and ERA research document.

In this research, the respondents are road construction experts in Ethiopian Roads Authority (ERA) and Local contractors working with ERA. The respondents were selected based on their experience in the construction sectors mainly based on the number of projects they have been participated which is a minimum of 5 projects and with a working experience of 7 years and educational qualification of B.Sc. and above.

The questionnaire was designed to rank the identified risk factors occurrence and level of impact from the perspective of both client and local contractors. The questionnaire consists of three sections. Section I and II addresses the general information about the organization and respondents. Section III Ranking of risks associated with construction road projects to measure the Risk Magnitude (RM) by considering the likelihood of occurrence (RL) indicated as Rare, Unlikely, Possible, Likely, Almost certain and impact (risk severity) (RS) on the project objectives (cost) indicated as Insignificant, Minor, Moderate, Major, and Catastrophic. And also allocation of these risks by considering the four categories owner, contractor, shared and insurance.

3. **Data Analysis:** After collecting the required information that is needed for the research, the data analysis and synthesis is carried out. To check the collected data's reliability or internal consistency, statistical analysis is carried out using IBM SPSS 20. Cronbach's alpha is used as a measuring variable to check the internal consistency or the extent to which all of the items of a test measure the same latent variable. Then based on the collected data fuzzy set is constructed, membership function is estimated and the risk magnitudes of each factors is measured using one of the fuzzy algebraic operation, interval arithmetic and α-cut method. Sequentially, each risk factor is quantified and ranked in accordance.

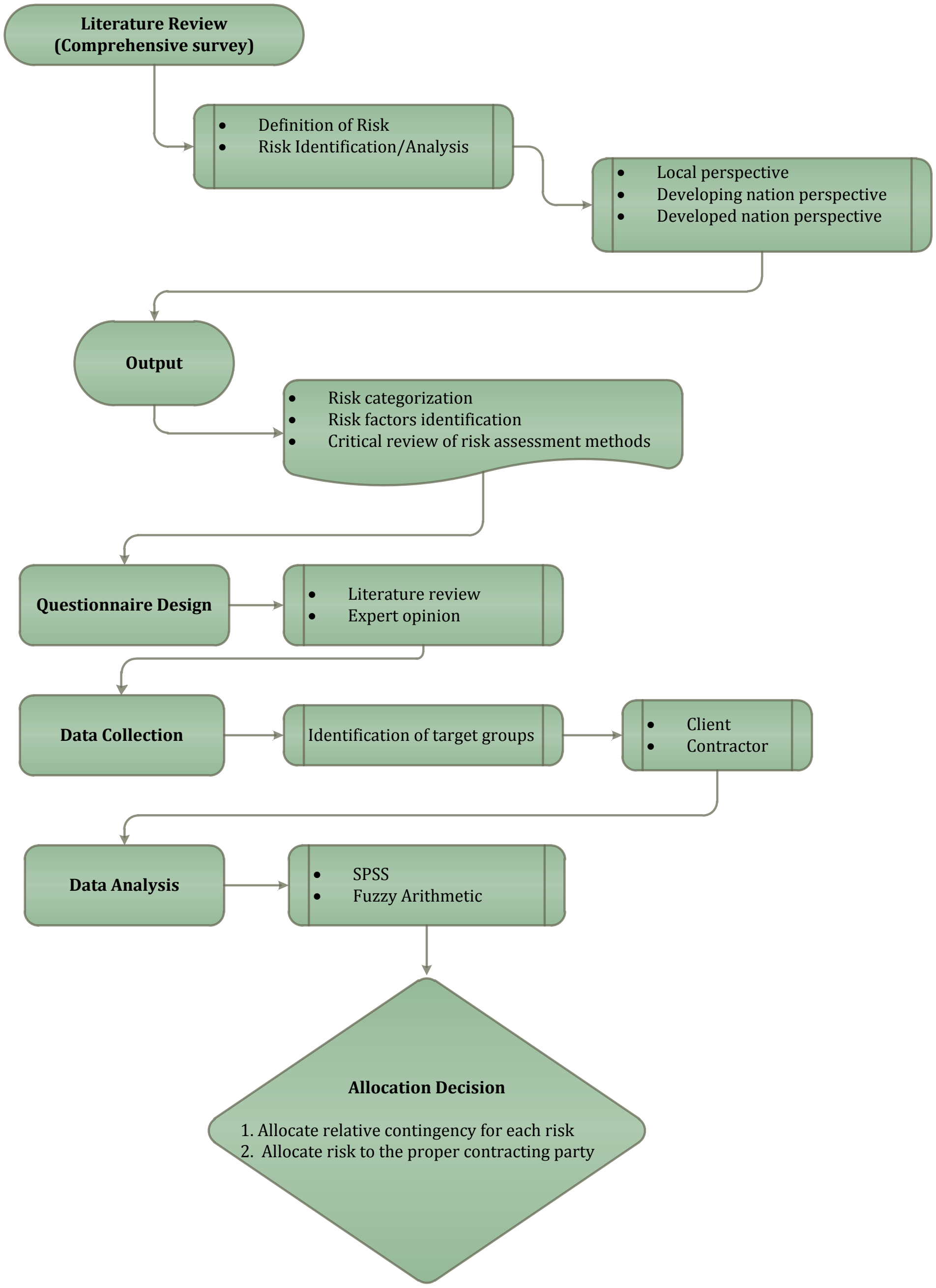


Figure 2: Research Design

1.5 Scope of the Study

The study focuses on identifying risks associated with road construction projects mainly through literatures and analyzing this using interval arithmetic and α-cut approach and prioritizing them accordingly for proper contingency allocation. This research was done on projects of Ethiopian Road Authority (ERA) from client and local contractors through survey questionnaire.

- This research is only from the perspective of the federal road projects and did not take into account that other categories of construction industry.
- This research is limited to the Local contractors who have a valid registration and working with ERA who meets the selection criteria.
- This study is limited to the construction industry practitioners in ERA (Ethiopian Road Authority) and local contractor worked/working on ERA projects.

1.6 Significance of the Study

The main significance of the study is to demonstrate a fuzzy decision support system for proper risk contingency allocation to be used by stakeholders, mainly by clients and contractor during feasibility and biding stage respectively.

1.7 Organization of the Study

The study is organized in six major chapters. The first chapter included the problem and its approaches. The second chapter is the theoretical framework of the study which discuss about the concept of risk and risk assessment methods and the previous study approaches. The research design and methodology are discussed in chapter three. Empirical data presentation and analysis is included in the fourth chapter. The fifth chapter includes the result and discussions of the empirical data, based on the previously presented theory. The last part included conclusions, recommendations, references used and appendixes.

CHAPTER TWO

THEORETICAL FRAMEWORK

2.1 Overview

This chapter presents the theoretical framework used in this thesis. It explores the definitions of risk and risk management practices from the perspective of both developed and developing nation as well as from Ethiopian context respectively. And also the risk assessment tools, techniques and theories.

2.2 Introduction

The construction industry is one of the most dynamic, risky and challenging businesses. However, the industry has a very poor reputation for managing risks, with many major projects failing to meet deadlines and cost targets. All too often, risks are either ignored, or dealt with in a completely arbitrary way: simply adding 10 per cent contingency onto the estimated cost of a project is typical. In a business as complex as construction, such an approach is often inadequate, resulting in expensive delays, litigation, and even bankruptcy (Mils, 2001).

The Construction Industry in developing countries are more fundamental, more serious, more complex, and, generally much more pressing than those confronting their counterparts that is, developed countries. Therefore, one can imagine the extent of risks involved in developing countries as compared to the developed ones (Mengesha, December 2008). Hence, the Construction industry and its stakeholders are widely associated with a high degree of risk due to the nature of the construction business, its activities, processes, environment and organizations (Mengesha, December 2008).

As the construction industry is a key activity in any economy, it influences and is influenced by the gross domestic product of any country (Enshassi, 2006). In Ethiopia the construction industry is the third largest economic sector after agriculture and service about 10% of GDP in the last fifteen years (Institute, September 2008). Surprisingly, it is not the large & medium scale industries that have had the highest share in GDP but the construction sub-sector ((EEA), 2006/07).

In order to understand the level of the existing risk management practices in road construction projects from both developing and developed nation experience and adopt the best practice to Ethiopian road construction industries an extensive literature is carried out on multiple references that addressed issues related to this area of research.

Given the large volume of published work, there was a need to limit the scope of the review. The study focuses on risk quantification and analysis in construction projects such as highway, road and building constructions specifically using fuzzy logic. The target literature sources are limited to refereed academic journals, published in English. Papers published on construction risk assessment for the past two decades have been reviewed. Relevant research papers are identified and gathered first, using keyword searching on several online databases, including Emerald Database, Science Direct, Taylor and Francis, Springer Link, Google Scholar and ProQuest. For this purpose keywords used include "Risks in construction projects", Risk quantification in construction projects" Risk analysis in construction projects" and "Risk quantification and analysis in construction projects using fuzzy logic".

As a result of the search, 98 open access journal articles have been found. From this only 83 papers that have direct relation with the thesis are presented for review. The papers were reviewed and essential information was captured. This information include authors' name, year of publication, paper title, journal title, country of origin, research method, data analysis method, sector, purpose and research goals etc. The review of the literature revealed a wide range of risk types and sources in construction projects, and that various risk management methods and techniques can be employed in the management of construction projects in order to control potential risks. The detail of the review is briefly explained in Section 2.4 and 2.5.

Table 1: Number of Reviewed Publications per Continent

No.	Continent		Number of Publication
1	Africa		16
2	Asia		44
3	Australia		3
4	Europe		17
5	North America		3
		Total	**83**

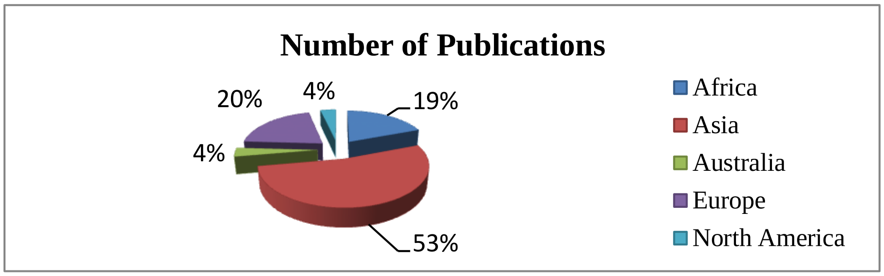


Figure 3: Number of Publications from Different Continents

2.3 Risks in Construction Projects

As this research deals with risk management in the construction project, it is reasonable to start with a discussion on the overview of risk.

Risk in the construction industry is perceived to be a combination of activities, which adversely affect the project objectives of time, cost, scope and quality. Some risks in construction processes can be easily predicted or readily identified; still some can be totally unforeseen.

In literatures, the word ‘Risk’ has been used in many different meanings with many different words such as hazard or uncertainty (Hertz, 1983). English dictionary, Cambridge dictionary online and Merriam-Webster dictionary respectively define risk as the possibility of incurring misfortune or loss; hazard, the possibility of something bad happening, the possibility that something bad or unpleasant (such as an injury or a loss) will happen. The AACE International Risk Management Committee in their Professional Practice Guide to Risk (Guide, April 2000) defines "risk as the same as uncertainty" (risk = threats + opportunities), or "risk is the net impact of uncertainty" (risk = threats + opportunities)."

According to (Ward, 2003) the term risk is generally defined as an uncertain event which may or may not happen, but which if it occurs has a significant impact on the project outcome. Also (Akintoye, 1997) has described risk in relation to construction as “a variable in the process of a construction project whose variation results in uncertainty as to the final cost, duration and quality of the project”.

Risk is therefore generally seen as an abstract concept, but even though the concept of risk varies according to viewpoint, attitudes and experience of each sector, the most suitable definition of risk for this research is “a variable in the process of a construction project whose variation results in uncertainty as to the final cost, duration and quality of the project”.

2.4 Risk Factors

2.4.1 Developed World Trends

Once country economic status and its exposure to risk has direct relation to one other because the level of a country’s economic are the main causes of changes in any business environment. Thus, it is important to understand different countries perspective towards existing risks on construction projects and its management practices.

Hence, a detailed literature review was carried out to gather various risks factors considered by construction practitioners in developed and developing countries. These risk factors are tabulated in Table 2 & 3. As it can be seen from below:

Table 2: Classifications of Risk Factors from Developed Countries Perspective

No.	Authors	Country	Classification of Risk Factors
1	(N.N. Hlaing, 2008)	Singapore	1. Client-generated risks 2. Contractor-generated risks 3. Project specific risks 4. Procurement specific risks 5. Subcontractor/supplier generated risks 6. External risks
2	(Mills, 2001)	Australia	1. Planning risks 2. Design and construction risks 3. Site-related risks

			4. Market risks
3	(Katrin Fischer, 2010)	Germany	1. Sites risks 2. Demand risks 3. Subsoil risks 4. Building structure risks 5. Tendering and awarding risks 6. Complaint and protest risks 7. Design risks 8. Contractual risks 9. Approval risks 10. Input risks 11. Interference risks 12. Management risks 13. Technical implementation risks 14. Technology risks 15. Operation risks 16. Risk arising for change in service standard 17. Maintenance risks 18. Vandalism risks 19. Financial risks 20. Inflation risks 21. Tax risks 22. Income risks 23. Risk of the principal and contractors insolvency 24. Risks of changes in laws/standards 25. Force majeure 26. Exploitation risks
4	(SYED M. AHMED, 1999)	Hong Kong	1. Contractor 2. Owner 3. Both owner and contractor 4. other
5	(Irem Dikmen M. T., 2007)	Turkey	1. Technical risk 2. Managerial risk 3. Productivity risk 4. Design risk 5. Payment risk 6. Client risk 7. Subcontractor risk 8. Construction risk 9. Project risk

6	(Doloi, 2012)	Australia	1. Planning and design 2. Communication site conditions 3. Market dynamics 4. Construction risk 5. Policy, legislation and regulation
7	(Mehdizadeh Rasool, June 2012)	France	1. Political 2. Design change 3. Financial (internal and external resources) 4. Unexpected weather 5. Natural constraints of site 6. Time management 7. Economic 8. Natural hazards 9. Defective design 10. Quality management 11. Poor communication
8	(J. H. M. Tah, 2000)	London	1. Internal risks 2. External risks
9	(Yelin Xu, 2012)	China	1. Macroeconomic risk 2. Construction and operation risk 3. Government maturity risk 4. Market environment risk 5. Economic viability risk
10	(Patrick. X.W. Zou, 2009)	Australia	1. Cost related risks 2. Time related risks 3. Quality related risks 4. Environment related risks 5. Safety related risks

2.4.2 Developing World Trends

Table 3: Classifications of Risk Factors from Developing Countries Perspective

No.	Author	Developing Countries Risks	Classification of Risk Factors
1	(Wa'el Alaghbari Mohd., 2007)	Malaysia	1. Contractor's Factor 2. Owner's Factor 3. Consultant's Factor
2	(Ibrahim	West Bank	1. Risk factor under logic and environment

	Mahamid, 2011)		group 2. Risk factor under managerial group 3. Risk factor under consultant group
3	(Joshua O Dada, 2007)	Nigeria	Factors related to procurement method
4	(Adnan Enshassi, 2009)	Gaza Strip	1. External Factors 2. Factors related to Material 3. Contractor's responsibilities 4. Labor and equipment 5. Owner's responsibilities 6. Consultant's responsibilities 7. Professional management 8. Factors related to Execution 9. Government relations 10. Contractual relationship 11. Design and documentation 12. Project
5	(O.A. Adedokun, 2013)	Nigeria	1. Internal (controllable) 2. External (uncontrollable)
6	(I. Mañelele, 2008)	Zambia	1. Project initiation risks 2. Community contribution and participation risks 3. Budget and Financial risks 4. Skilled labor risks 5. Materials procurement risks 6. Technical supervision and quality control risks
7	(Charles Teye Amoatey, 2015)	Ghana	1. Financial 2. Resource 3. Technical 4. Economic 5. Environmental 6. Operational 7. Government and political 8. Relationship 9. Security/safety 10. Legal
8	(Abdulaziz M. Jarkas, 2015)	Qatar	1. Client 2. Contractor 3. Consultant 4. Exogenous
9	(Wa'el Alaghbari Mohd., 2007)	Malaysia	1. Contractor's responsibility 2. Consultant's responsibilities 3. Owner's responsibilities 4. External factors
10	(A D Ibrahim,	Nigeria	1. Exogenous risk factors

	2006)		2. Endogenous risk factors
11	(Yao-Chen Kuo, 2013)	Taipei	1. Engineering design 2. Construction management 3. Construction safety-related 4. Natural hazard 5. Social and economic
12	(Laila Mohamed Khodeir, 2015)	Egypt	1. External 2. Internal 3. External/internal
13	(Fethi HamzaoFranck Taillandier, 2015)	Algeria	1. Project stakeholders 2. Management 3. External risks
14	(Shahid IQBAL, 2015)	Pakistan	1. Client's responsibility 2. Contractor's responsibility 3. Shared responsibility 4. Undecided responsibility
15	(KAMALESH PANTHI, 2009)	Taiwan	1. Construction related 2. Financial and economic 3. Performance related 4. Contractual and legal 5. Physical 6. Political and social
16	(HEMANTA DOLOI, 2012)	India	1. Contractor's inefficiency 2. Lack of commitment 3. Improper planning 4. Client's influence
17	(Sid Ghosh, 2004)	Thailand	1. Financial and economic risk 2. Contractual and legal risk 3. Subcontractors related risk 4. Operational risk 5. Safety and social risk 6. Design risk 7. Force majeure risk 8. Physical risk 9. Delay risk
18	(Tarek Zayed, 2008)	China	1. Political 2. Financial 3. Cultural 4. Market 5. Technology 6. Contract and legal issues 7. Resources 8. Design 9. Quality 10. Construction 11. others

19	(S.M. Mousavi, 2011)	Iran	1. Engineering 2. Procurement 3. Construction 4. Management
20	(Yao-Chen Kuo, 2013)	Sri Lanka	1. Technical and contractual risks 2. Economic, financial and political risks 3. Managerial risks 4. External and site condition risks
21	(Adnan Enshassi S. M., 2009)	Gaza Strip	1. Cost factors 2. Time factors 3. Quality factors 4. Productivity factors 5. Client satisfaction factors 6. Regular and community satisfaction factors 7. People factor 8. Health and safety factors 9. Innovation and learning factors 10. Environment factors
22	(Abdullah Alhomidan, June 2013)	Saudi Arabia	1. Under managerial group 2. Under consultant group 3. Under financial group 4. External group

Table 4 : Summary of Risk Factor Classification Trend from both Developing and Developed World Trend

No.	Risk Factor (Developing country)	Risk Factor (Developed country)
1	Project stakeholders (client, contractor and owners generated)	Project stakeholders (client, contractor and owners generated)
2	Procurement method	Financial, Political and Economic risks
3	Technical factor	Security and safety risks
4	Managerial factor	Environmental and Physical risks
5	Operational factor	Personnel risks
6	External factor (environmental, Force majeure…)	Contractual, legal and Technical risks
7	Budget and financial risks	Management risks
8	Contractual and legal risks	Procurement risks
9	Political and social risks	Operational risk
10	Physical risks	

11	Safety risks
13	Resource risks
14	Government and political risks
15	Personnel risks

As shown in Table 4 the classification of the risk factors in developed and developing world are similar, this might be due to the adoption of the risk factors from previously published journals.

2.4.3 Ethiopian Context

Construction industries have great influence on the state of the nation's socio-economic health. In fact, this industry is the keystone in the growth of the national economy of most countries. Though the construction sector has a major impact on the country's development, less attention has been given on the risk management process, which is an important part of decision-making process in all construction companies. To the best of the author's knowledge from the online databases used for this research, international publications related to construction risk management on Ethiopian context have not been found. However, there are academic papers published in university level to address some of the issues faced by the construction sectors. These papers are summarized in Table 5.

Review of the academic papers reveals the risk assessment method is solely based on descriptive statistics. While this technique provides general information on the risk assessment, it does not address the subjective nature of the expert's opinion and the uncertainty of the construction activities.

Table 5: Summary of the Selected Studies on Risk Management in Ethiopian Context

No.	Author	Title	Sector/Institute	Method of identification and analysis	Remark
1	(Abrham Talargie H/Gebriel, 2004)	Model Development for Improving the Performance of Projects	Ethiopian Roads Authority (ERA)	• Questionnaire survey and interview • Cause and Effect analysis	Analyze the major project management related problems that frequently occur in road construction projects administered under the Ethiopian Roads Authority

2	(Addis Mesfin, 2014)	A Study on Construction Contract Risk Management Practices in Ethiopian Building Construction Projects	Building	• Questionnaire survey
				• Descriptive statistics method
				  ○ Frequencies
				  ○ Percentages
				  ○ Mean scores
					The research deals with construction contract risk management practices in Ethiopian building construction projects.
					• Identifies the level of use and awareness of contract risk management technique
					• Areas and causes of risk in meeting project

					objectives
3	(FETENE NEGA, 2008)	Causes and Effects of Cost Overrun on Public Building Construction Projects in Ethiopia	Public building construction	• Questionnaire survey • Weighted average and Spearman rank order correlation analysis	The study assess factors that cause cost overrun during construction and their effects on public building construction projects in Ethiopia
4	(Getachew Tsegay e, 2009)	Design Risk Manage ment in Ethiopian Federal Road Projects	Ethiopian Roads Authority (ERA)	• Case study and interview • Descriptive Statistic analysis	Examine the contribution of design risks on cost and time overruns, and poor quality of works

2.5 Review of Project Risk Management Methods

Introduction to a systematic management method like road projects will initiate organizations to rethink their approach in their projects. The major steps involved in risk management of a project are identification of risks, the measurement/assessment of risks, and the process of prioritizing and responding to these risks. Among the three, risk assessment is perhaps the most difficult task. It involves evaluation of the probability of occurrence of risk events and their impact on project objectives such as time, cost, quality and safety.

This paper reviews only the two stages of project risk management steps, which are risk identification and analysis which supports the scope of the thesis.

(Toakley, 1991) stated that risk identification is a necessary first step before risks can be analyzed and an appropriate treatment strategy can be determined as the processes of risk analysis and risk treatment management may only be performed on identified potential risks. There are a number of risk identification procedures used by construction practitioners to identify potential risks. Based on the reviewed papers, they can be broadly grouped into 11 distinct categories. These are:

1. Identification conducted through literature review and questionnaire survey
2. Identification by the analyst by interviewing a member of project team
3. Identification from database
4. Identification through Delphi approach among experts
5. Identification by project analyst
6. Identification by brainstorming session
7. Identification by nominal group technique
8. Identification through tender document review
9. Identification conducted through group of experts
10. Identification by Risk Breakdown Structure (RBS)
11. Identification conducted through checklist

For this thesis, the risk identification is going to be conducted through literature review to investigate the existing risk variables from the international and within the African context, which is going to be used as a base line to design a questionnaire, while pilot survey and interview among project owners to obtain actual data on the potential risk factors on road construction projects.

Apart from identifying the constructs that make up risk management processes, the literature shows a variety of tools that are employed for measuring risks based on both qualitative and quantitative approaches with varying degrees of complexity. The variation and the degree of complexity of these tools could be based on to the nature of risks, the sector specific environment in which they are being implemented and at the same time the availability of dates and knowledge of the risk analyst.

Table 6: Summary of Reviewed Studies on Risk Assessment in Developing and Developed Economies

No.	Analysis Method	No. of publication
1	Descriptive and Inferential Analysis	31
2	AHP Pair wise comparison	2
3	Different probabilistic models	1
4	Fuzzy-TOPSIS	3
5	Non parametric Jackknife technique	1
6	Fuzzy fault tree	2
7	Fuzzy rating with influence diagram	1
8	Fuzzy set theory	5
9	Modified AHP with fuzzy approach	1
10	Fuzzy analytical network	1
11	Bayesian network	3
12	Relative importance index (RII)	1
13	Fuzzy system dynamics approach	1
14	AHP-ELECTRE method	2
15	Structural equation modeling (SEM)	1
16	Descriptive and Inferential Analysis with RII	6
17	AHP Pair wise comparison with RII	1

18	AHP Pair wise comparison with Fuzzy-TOPSIS and RII	1
19	Descriptive and Inferential Analysis with Fuzzy Set Theory	1
20	Significance index score	1
21	AHP Pair wise comparison with Monte carol simulation	1
22	Descriptive and Inferential Analysis with Structural equation modeling (SEM)	1
23	Descriptive and Inferential Analysis with Fuzzy Set Theory and RII	1
24	RBS Model	2
25	RBS with fuzzy model	1
26	QSR software application	1
27	TOPSIS Grey	1
28	Interpretive structural modeling (ISM) technique and Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC)	1
29	Unknown (not clearly stated)	8
	TOTAL	**83**

As shown in Figure 4, out of the 29 risk assessment methods identified, about 37.35 percent of the papers adopted descriptive and inferential analysis, 7.23 percent descriptive and inferential analysis with RII, 6.02 percent Fuzzy set theory, 2.41 percent shared by AHP Pair wise comparison, Fuzzy fault tree, AHP-ELECTRE method, RBS Model respectively, Fuzzy TOPSIS and Bayesian network share 3.61 percent respectively, 9.64 percent of the papers doesn’t clearly state the methods implemented, the remaining 22.89 percent are equality distributed among 19 methods. Even though the most commonly used method among researchers is the descriptive and inferential analysis it doesn’t necessarily indicate its strength. This is because it lacks to address the uncertainty and biasness associated with the involvement of experts and project analyst. This large usage could possibly be due its simplistic nature for implementation.

Comparatively the fuzzy approach gives the experts the freedom to express the risk factors in numerical values, a range of numerical values, a linguistic term or a fuzzy number. In addition, the awareness and the use of systematic risk management tools in Ethiopian construction companies industry is very low. Thus, the opinion of the experts is expected to have high uncertainty. Therefore, in this study the fuzzy approach is found to be more consistent with the nature of the problem at hand as a risk assessment tool.

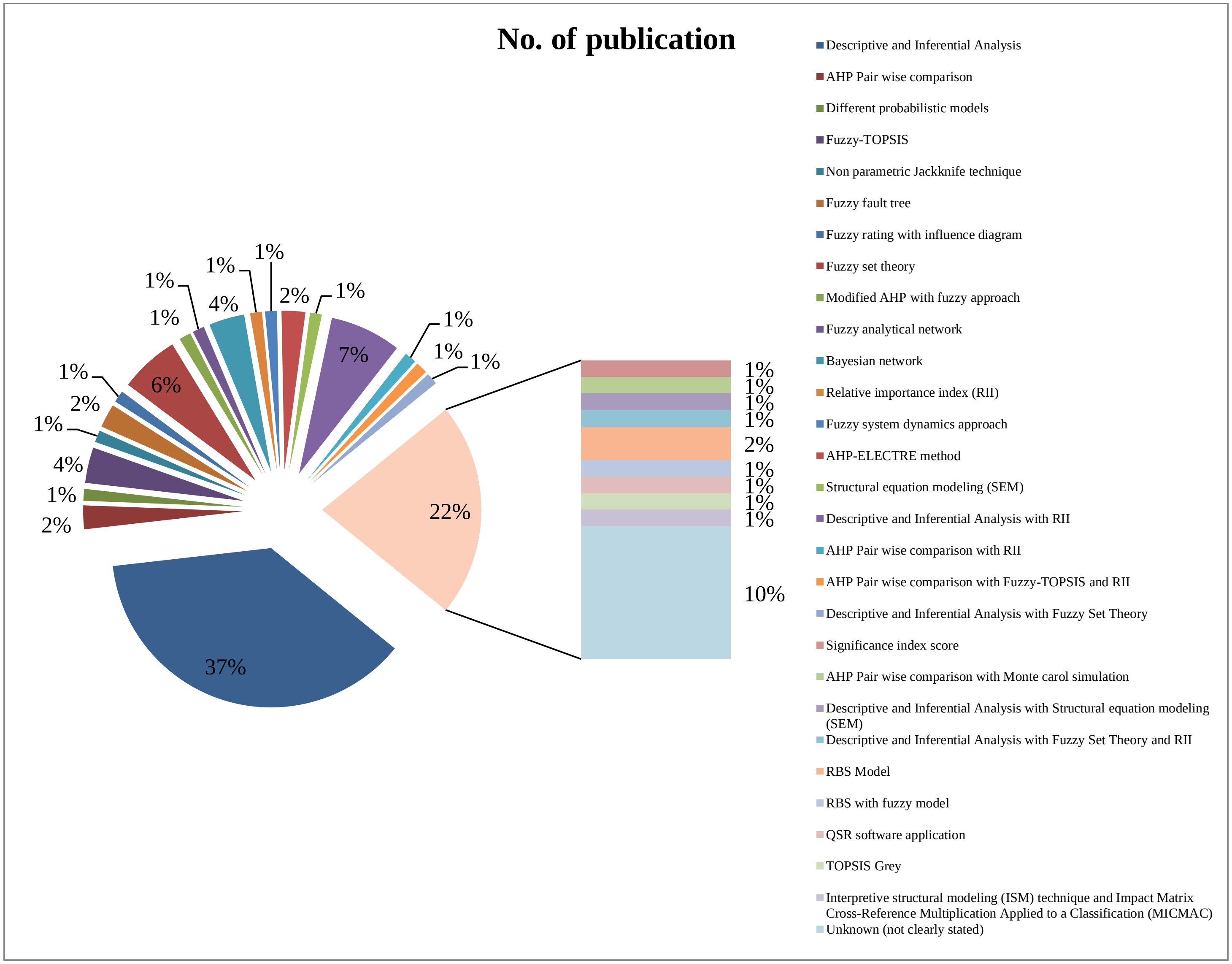


Figure 4: Risk Assessment Methods

2.6 Findings of the Literatures Reviewed

Some of the reviewed findings are:

- Construction risks are time dependent; the risks that exist today may not have the same magnitude after a while. Even though, the construction industries and practitioners, are working on adjusting the most suitable risk assessment methods for managing risks, it still lacks to address the time dependent issues that comes together with construction.
- Risk occurrence is different from one state to another. Once country economic status and its exposure to risk has direct relation to one other because the level of a country's economic are the main causes of changes in any environment.
- Thought, the road sectors are the keystone in the growth of the national economy of most countries especially the developing nation like Ethiopia, the numbers of published works regarding this area are very few.
- In most cases, the reviewed papers indicate there are no new findings but contextualize the existing knowledge and method of analysis (Descriptive and Inferential) to the countries construction industries.
- These methods of analysis lack to address the uncertainty and vagueness associated with construction projects and the experts involved.
- Fuzzy expert system is found to be the most suitable tool to address the expert opinions and imprecise data involved in the risk assessment methods.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter covers an overview of the methodology used in the study. The discussion in this chapter is structured around the research design, population sampling, data collection and data analysis.

3.2 Definition of Methodology

The research method is a technique for collecting data which can involve specific instruments such as questionnaires or structured interview etc.. In this study the methodology includes the sampling, the data collection and data processing and analysis techniques.

The main focus of this study is to identify the key risk factors that have high frequency of occurrence and impact in the Ethiopian road construction projects, to calculate their magnitude and prioritizing them in accordance. Therefore the research approach is both quantitative and qualitative.

Hence, research methodology selected comprises a comprehensive literature review, a closed-ended questionnaire with unstructured interview to project managers in Ethiopian Road Authority (ERA) and local contractors participated in ERA projects, a statistical and fuzzy arithmetic analysis of the survey data, and prioritization of the identified risk factors.

3.3 Population

A population consists of the totality of the observation with which we are concerned (Wal pole & Myers, 1998). In this research, the population is experts form Ethiopian Road Authority (six regional directors) and local contractors participated in ERA projects.

3.4 Sampling Approach

(Wood, 1998) defined the sampling as the process of selecting representative units of a population for the study in a research investigation.

A non-probability purposive sampling design is used for the study. The participants met the eligibility a criterion as described in Table 7, was contacted, the purpose of the study explained and agreement to participate obtained. Since only Ethiopian Road Authority (ERA) represents the owner perspective, the researcher chose Top Management Personnel as participants because of a need for experts.

Table 7: Respondents Criteria

Criteria	**Project Participation**		**Work Experience**	**Academic Qualification**
	Client	**Contractor**	**Client**	**Client and Contractor**
Range	Min 5	≥ 3	7 years and above	B.Sc. and above

Hence, a total of 18 (eighteen) respondents have participated, six Regional Directors (East, West, North, South and also from Design Build department) from client and 12 (twelve) local contractors. Regarding, the local contractors, since the sample size is small all local contractors worked on three and above projects on ERA project are selected to represent the population.

3.5 Data Collection

Data gathering is the precise, systematic gathering of information relevant to the research problems, using methods such as interviews, participant observation, survey, focus group discussion, narratives and case histories (Burns N., 1987). In this study data is gathered through a comprehensive literature review to identify the major risk factors, a closed-ended questionnaire to rank each risk occurrence and consequence to obtain the risk magnitude and unstructured interview to provide an explanation regarding the questionnaire and a situation where the participants' can express their intake and comment regarding the questionnaire.

3.5.1 Questionnaire Design

The questionnaire survey is conducted to rank the major risk factors in road construction projects and by assessing the consequences and impact of this factor on the project objective respectively form owners and local contractors' perspective. Furthermore to allocate the top risks to the proper contracting party.

The identified risk factors were grouped into nine risk categories. This includes Financial and Economic Risks, Physical/Environmental Risks, Resource Risks, Technical Risks, Personnel and Managerial Risks, Government and Political Risks, Safety and Security Risks, Environmental Regulation Risks and Contractual and Legal Risks. The details of each risk categories are shown in ANNEX 2.

A close-ended questionnaire was used for its advantages as it is easy to ask and quick to answer, they require no writing by either respondents or interviewer. The questionnaire was composed of three sections to accomplish the aim of this research, as follows:

1. General information about the organization and respondents profile (Owner and contractor)
    - Academic qualification
    - Working experience in road construction sector
    - Current job status
    - Professional background
    - Respondents project participation
    - Number of projects executed by the company
    - Type of contract or engineering procurement method used
    - Experience of the organization in road construction
    - Work volume or investment made in the last 5 years
    - Method of cost estimation and risk assessment
2. Measurement of Risk Magnitude (RM): Five linguistic variables are used in describing parameters.

Risk Magnitudes (RM) are measured considering the likelihood of occurrence (RL) indicated as Rare, Unlikely, Possible, Likely, Almost certain and impact (risk severity) (RS) on the project objectives (time, cost, quality) indicated as Insignificant, Minor, Moderate, Major, and Catastrophic. These were source from a journal paper (Jiahao Zeng, 2007) .

3. Allocation of Risk: Moreover to establish the responsibility of these factors among stakeholders the respondents were also asked to choose suitable risk allocation. The allocation of the construction risks are based on project stakeholders, Owner, Contractor, Shared risk and Insurance.

To ensure obtaining complete and meaningful response to the questionnaire an unstructured interview was conducted with each respondent to explain the objective of the study and to get input towards the questionnaire design, especially towards identifying risk factors.

3.6 Data Processing and Analysis

Data analysis is a mechanism for reducing and organizing data to produce findings that require interpretation by the researcher (Burns N., 1987).

3.6.1 Measurement of Reliability

The first step in analyzing survey data is to check the reliability of the instrument (Likert scale). The reliability of an instrument is the degree of consistency with which it measures the attribute it is supposed to be measuring (Polit D., 1985). The less variation an instrument produces in repeated measurements of an attribute, the higher its reliability.

The measures of internal reliability of a given scale, i.e. the extent to which the items included in the scale are correlated were evaluated using Cronbach’s Alpha. High values of Cronbach’s Alpha indicate that all the items included in the scale are measuring the same thing and their correlations between each other and with the latent variable measured though the items are very strong. In this study, a cut-off value of 0.7 was used to indicate an acceptable level of internal consistency (Xiao-Hua Jin, 2012).

3.6.2 Development of Fuzzy Set

There are two approaches to construct fuzzy sets, data driven or expert driven. Since this research is based on expert opinion, expert driven fuzzy set construction approach is selected.

Hence, the first step in the development of a fuzzy set is the creation of a comprehensive list of evaluation criteria. In this case the evaluation criteria's are linguistic variables used in describing parameters (Risk Occurrence) as shown in Table 8.

Table 8: Risk Likelihood Descriptors

Rating	Description	Likelihood of Occurrence
1	Rare	Highly unlikely, but it may occur in exceptional circumstances. It could happen, but probably never will.
2	Unlikely	Not expected, but there's a slight possibility it may occur at some time
3	Possible	The event might occur at some time as there is a history of casual occurrence in similar institutions.
4	Likely	There is a strong possibility the event will occur as there is a history of frequent occurrence in similar institutions.
5	Almost Certain	Very likely. The event is expected to occur in most circumstances as there is a history of regular occurrence in similar institutions.

The next step in the development of fuzzy set is creating a membership functions for the variables. The detail procedure of the estimation of the membership function is shown in the preceding section.

3.6.3 Estimation of Membership Function

Membership functions are used to represent linguistic states of a variable. Each element on the relevant scale of a variable is assigned a membership value ranging from 0 (no membership) to 1 (full membership) in each membership function, indicating its degree of belonging in the membership function used to represent the linguistic term.

There are two standard expert driven approaches for the estimation of membership function. These are horizontal and vertical modes of membership estimation. They reflect distinct ways of looking at fuzzy sets whose membership functions at some finite number of points are quantified by experts (Witold Pedrycz, 2007). The horizontal method combined with visual curve fitting was used to generate the membership functions for the variables.

A horizontal scheme of membership estimation is selected due to its simplicity as the technique relies on explicitly upon a direct counting of responses.

The answers are expected to come in a binary (yes–no) format. The concept A defined in X could be any linguistic notion. Given n experts whose answers for a given point of X form a mix of yes–no replies, we count the number of ‘‘yes’’ answers and compute the ratio of the positive answers (p) versus the total number of replies (n), that is, p/n. This ratio (likelihood) is treated as a membership degree of the concept at the given point of the universe of discourse. When all experts accept that the element belongs to the concept, then its membership degree is equal to 1. Higher disagreement between the experts (quite divided opinions) results in lower membership degrees (Witold Pedrycz, 2007).

$$A(x_i) = \frac{P_{X_i}}{N}$$

Where $A(x_i) =$ Membership value (normalized if required)

$P_{X_i} =$ Number of positive responses

N = Total number of responses

Then transform the membership functions to fit triangular or trapezoidal shapes, with parameters a, b, c, d (b=c for triangular).

A triangular fuzzy number A can be defined as a triplet [a, b, c]. Its membership function is defined as:

$$\mu_A(x) = \begin{cases} \dfrac{x-a}{b-a}, a \le x \le b \\ \dfrac{c-x}{c-b}, b \le x \le c \end{cases}$$

If the parameters cannot be determined visually, total error calculation can be done for that membership function to determine the best-fit parameter that produces smallest error.

$$Error = \sum_{i=1}^{n} \frac{A(x_i)_{actual} - A(x_i)_{estimated}}{A(x)_{\max} - A(x)_{\min}}$$

3.6.4 Fuzzy Set Computation

Since risk magnitude is a multiplication of two factors (occurrence and consequence), a basic multiplication operation is employed.

Multiplication: [a, b] * [c, d] = [min (ac, ad, bc, bd), max (ac, ad, bc, bd)]

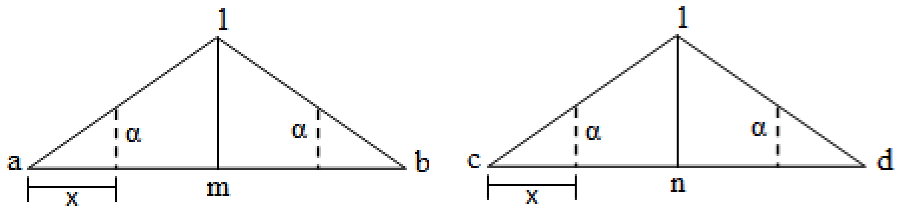
Basically, there exist two fundamental methods to carry out algebraic operations on fuzzy numbers. The first method is based on interval arithmetic and α-cuts, while the second one employs the extension principle (Witold Pedrycz, 2007). In this research interval arithmetic α-cut method to perform fuzzy arithmetic is employed because they are important to develop parametric representation of fuzzy numbers to control their shapes and associated approximation error.

Now, let A and B be two fuzzy numbers and let * be any of the four basic arithmetic operations. Thus, for any $\alpha \in (0, 1]$ the fuzzy set A*B is computed using the α-cuts A_α and B_α of A and B, respectively,

$$(A * B)_\alpha = A_\alpha * B_\alpha$$

Recall that, by definition, the α-cuts A_α and B_α are closed intervals, and therefore the formulas of interval operations can be applied for each value of α.

If A and B are two triangular fuzzy numbers, denoted as $A\ (x, a, m, b)$ and $B\ (x, c, n, d)$ then their α-cuts are determined as:



$$A_{\alpha} = [(m-a)\alpha + a, (m-b)\alpha + b]$$

$$B_{\alpha} = [(n-c)\alpha + c, (n-d)\alpha + d]$$

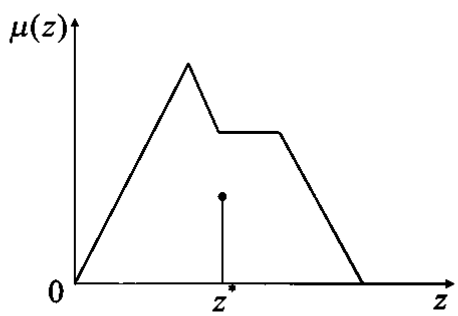
3.6.5 Risk Magnitude Interpretation

Once computed the fuzzy set, there are two options of obtaining and interpreting the risk magnitude:

1. **Using centroid analysis**

This is the most widely used method. This method is known as center of gravity of center of area method. The method focuses on finding a single value that will represent the risk magnitude. it can be defined by the algebraic expression as.

$$z^{*} = \int \frac{\mu_c(z)z\,dz}{\mu_c(z)dz}, for\ all\ z \in z$$



2. Using α - cut method

In this case it focuses on an interval of the Risk Magnitude, based on a given α value. The α value is equivalent to level of confidence in statistical risk analysis. For Risk analysis, 85% confidence interval is commonly used in Monte-Carlo simulation based Risk models (AbouRizk, 1997-2008). After obtaining the two risk magnitude intervals z_1 and z_2, take the central value of the intervals as the risk magnitude value.

$$Z = \frac{z_1 + z_2}{2}$$

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Data Presentation

The major risk factors that affect project objectives (cost) of road construction projects were identified through literature review and questionnaire survey. The questionnaires were targeted at experienced respondents from Ethiopian Road Authority (owner) and local contractors working with the road authority. The questions for the survey were structured based on the information gathered through literature review. The main purpose was to identify and rank the major risk factors affecting road projects and prioritize them in accordance for proper cost contingency plan.

4.1.1 Contents of the Questionnaire

For the purpose of the survey, the major risk factors that affect project objectives (cost) of road construction projects were identified through literature review. An extensive literature review was made to understand the context of risk from the practices of developed and developing world. From the Ethiopian context, the scant information available in academic documents was assessed. Based on the review, 119 risk factors were identified as tabulated ANNEX 2 PART III.

4.1.2 Target Population

The ranking and prioritization of the major risk factors was carried out from the perspective of a client by taking the opinions of experts and local contractors who met the minimum criteria as shown in Table 7.

The survey was initially made from client by involving 6 experts. Subsequently, a preliminary analysis was done to incorporate feedbacks provided by the experts. Accordingly, some enhancements were included in the questionnaires distributed to the local contractors. The main modifications were paraphrasing the risk factors into their technical terms and addition of two risk factors based on the suggestions made by experts. A total of 14 local contractors have participated, of which 12 have properly respond to the survey. For this specific survey the profile of respondents is indicated in Table 9.

Table 9: Respondents and Company Profile of Contractors and Owner

No.	Category	Ranges	Respondent (Contractor)		Ranges	Respondent (Contractor)	
			Number	Percent (%)		Number	Percent (%)
1	Role	Contractor	12	85.7	Owner	6	100
2	Educational background	MSc	7	58.3	MSc	4	66.7
		BSc	3	25	BSc		
		other	2	16.7	-	2	33.3
3	Professional background	R&T Engineer	1	8.3	Cotm. Engineer	3	50
		Civil Engineer	11	91.7	Civil Engineer	3	50
4	Work experience in the road sector	> 13 years	6	50	> 13 years	1	16.7
		10-13 years	5	41.7	10-13 years	1	16.7
		8-10 years	1	8.3	8-10 years	4	66.7

5	Work experience in current position	> 6 years	4	33.3	2-4 years	1	16.7
		4-6 years	5	41.7	1-2 years	4	66.7
		< 4 year	3	25	< 1 year	1	16.7
6	Number of road projects the respondent participated in	More than 10 projects	8	66.7	More than 10 projects	6	100
		3 - 5 projects	1	8.3	-	-	-
		5 - 7 projects	2	16.7	-	-	-
		7 - 9 projects	1	8.3	-	-	-
7	Number of executed projects in the last 5 years by the company	More than 10 projects	2	16.7	More than 10 projects	6	100
		3 - 5 projects	5	41.7	-	-	-
		5 - 7 projects	3	25	-	-	-
		7 - 9 projects	2	16.7	-	-	-
8	Number of years of work experience of the company in road project	More than 10 years	8	66.7	More than 10 years	6	100
		3-5 years	1	8.3	-	-	-
		5-10 years	3	25	-	-	-
9	Work position of the respondent	Director, Project Manager, Department Manager Eng. & Con. Dept, Deputy Director, Contract Admin. Dept. Head, Planning & Contract Manager, Engineering Operations Manager,			Regional Director	6	100

Before the questionnaires were distributed to each respondent, a quick briefing was made to elaborate the context of the questionnaire regarding, the object of the thesis and some reference attached to the questionnaire to explain some technical terms and also the linguistic definition of each Likert scale.

Table 10: Questionnaire Return Rate

Party	Number of questionnaires sent	Number of responses received	Response rate (percent)	Number of questions sent	Number of responses received	Response rate (percent)
Owner	6	6	100	117	73	62.4
Contractor	14	12	85.7	119	72	60.5

4.2 Data Analysis and Discussion

In this section, first measurement of internal consistency ("reliability") of each Likert scale was checked with the help of SPSS (Version 20) statistical tool. Then a fuzzy set is constructed by converting the crisp set of input data gathered to a fuzzy set using fuzzy linguistic variables and estimating the membership functions of each risk factor to graphically represent a fuzzy set. Last, the fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step using the Center of Area and the α-cut method.

4.2.1 Measures of Reliability

Each question was a 5-point Likert item from "Rare" to "Almost Certain" to risk occurrence and “Insignificant” to “Catastrophic” to risk consequence. Then all responses both from owner and contractor were feed into a separate data editor by defining the necessary variables. Finally, in order to understand whether the questions in this questionnaire all reliably measure the same latent variable, a Cronbach's alpha was run on both owner and contractor data. Two measures of alpha are reported in the Table (22-24): "Cronbach's Alpha" and "Cronbach's Alpha Based on Standardized Items". The first Cronbach's alpha employs the covariances among the items, whereas the alpha based on standardized items employs the correlations among items.

On Table 11, we can see that Cronbach's alpha is 0.741, 0.673, 0.807**,** and 0.688 which indicates an acceptable cut-off value (Refer section 3.6.1) of internal consistency for our scale.

Table 11: Reliability Analysis of Risk Occurrence and Impact from Owner's and Contractors Perspective

Description	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No of Items
Risk Occurrence from Owner's Perspective	**.741**	.743	6
Risk Impact from Owner's Perspective	**.673**	.681	6
Risk Occurrence from Contractor's Perspective	**.807**	.825	12
Risk Impact from Contractor's Perspective	**.688**	.705	12

4.2.2 Development of Fuzzy Set

As indicated Section 3.6.2 the fuzzy set can be constructed first by:

- Converting a crisp set of input data gathered into a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions.
- Then mapping the fuzzy output to a crisp output using the membership functions

I. Estimation of Membership Function

A Membership Function (MF) is a function that specifies the degree to which a given input belongs to a set, and its value is always limited between 0 and 1. And are used in the fuzzification and defuzzification steps of a FLS (fuzzy logic system), to map the non-fuzzy input values to fuzzy linguistic terms and vice versa.

Since horizontal scheme of membership estimation is selected, the first step is to obtain the membership value of each risk factor. For example, if we consider the first risk factor;

(R_1) = Fluctuation of inflation rate (buying power of money)

Then the membership value is given by:

$$A(R_1) = \frac{P_{R1}}{N}$$

Where, $A(x_i)$ = Membership value of $R_1 - R_{73}$

$\frac{P_{X_i}}{N}$ = Number of positive responses of $R_1 - R_{73}$

N = Total number of responses (6 respondents to the owner perspective and 12 respondents to contractors perspective)

For the case of risk assessment from the contractor's perspective 12 respondents gave their responses. As shown in Table 12 none of the respondents believe that the occurrence of R_1 (Fluctuation of inflation rate (buying power of money)) is "Rare". That means, R_1, has "zero" positive or "yes" replies for rare occurrence. Thus, the corresponding Membership value is zero. On the other hand, four respondents believe that the probability of R_1 occurring is "Almost certain". That means, R_1, for "Almost certain" occurrence has "four" positive or "yes". Thus, the corresponding Membership value is $\frac{4}{12} = 0.33$.

For the other remaining events, the computed membership values are indicated in Table 12. Similarly, for the consequence of risk (R_1), the corresponding membership values are summarized in the right side of Table 12.

Table 12: Membership Value of Risk Factor (R1) Occurrence and Consequence

Scale	**1**	**2**	**3**	**4**	**5**	**Scale**	**1**	**2**	**3**	**4**	**5**
No "yes" replies (P_{R1})	0	1	4	3	4	**No "yes" replies (P_{R1})**	0	1	2	8	1
$A(R_1)$	0.00	0.08	0.33	0.25	0.33	**$A(R_1)$**	0.00	0.08	0.17	0.67	0.08

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. Hence, in order to express the membership values in fuzzy set between 0 and 1 each values in Table 13 are normalized using Max-Min principle.

$$A(R_1N) = \frac{A(R_1)}{MAX.VALUE}$$

Table 13: Normalized Membership Value of Risk Factor (R1) Occurrence and Consequence

A(R_1)	**0.00**	**0.08**	**0.33**	**0.25**	**0.33**	**A(R_1)**	**0.00**	**0.08**	**0.17**	**0.67**	**0.08**
A(R_1N)	0	0.25	1	0.75	1	A(R_1)	0.00	0.13	0.25	1.00	0.13

The next step is to transform the membership functions to approximately fit triangular shapes, with parameters a, b, c, d (b=c for triangular fit).

Shapes and parameters can be selected using visual analysis of initial membership functions. If a parameters cannot be determined visually, total error calculation done for that membership function to determine the best-fit parameter that produces smallest error (Krista Marsh, 2008).

$$Error = \sum_{i=1}^{n} \frac{A(x_i)_{actual} - A(x_i)_{estimated}}{A(x)_{\max} - A(x)_{\min}}$$

Where: $A(x)_{\max} = 1$ $\quad\quad$ $A(x)_{\min} = 0$

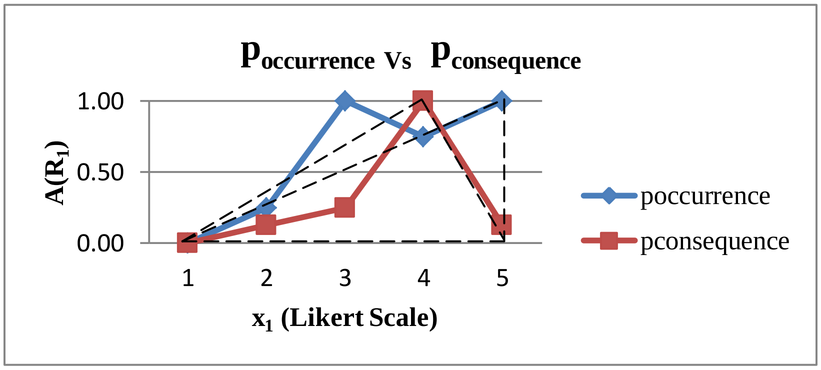
$A(x_i)_{actual}$ = final MBF (based on chosen parameters)

$A(x_i)_{estimated}$ = MBF based on horizontal method expert response

Most parameters can be determined visually. For high MBF, b parameters determined using best fit analysis.

Considering the same example (R_1) = Fluctuation of inflation rate (buying power of money), the $A(x_i)_{estimated}$ MBF based on horizontal method expert response and $A(x_i)_{actual}$ is shown in Figure 5.

$$Total.Error_{occrence} = \frac{0+0+(1.0-0.5)+0+0}{(1-0)} = 0.5$$



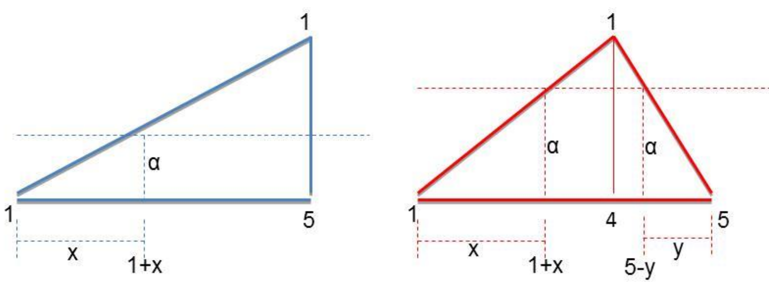


Figure 5: Best Fit Triangular Membership Function for R_1

The remaining risk factors membership functions are estimated following the above procedure and the summary of each risk factor is stated in ANNEX 1.

II. Fuzzy Set Computation

Basically, there exist two fundamental methods to carry out algebraic operations on fuzzy numbers. The first method is based on interval arithmetic and α-cuts, while the second one employs the extension principle. Since α-cuts are becoming important to develop parametric presentation of fuzzy numbers to control their shapes and associated approximation (Witold Pedrycz, 2007) this method of fuzzy computation is used to construct the resulting fuzzy number.

Since risk magnitude is a multiplication of its likelihood of occurrence and its unwanted consequence, a basic multiplication was developed to perform the arithmetic operation.

Multiplication: $[a, b].[c, d] = [\min(ac, ad, bc, bd), \max(ac, ad, bc, bd]$,

Recalling Section 3.6.3 the method of α-cuts for two fuzzy set A_α and B_α, in this case fuzzy set A is represented by occurrence and fuzzy set B by Consequence. For example, if we consider the second risk factor; (R_2) Currency exchange risks/Lack of currency,

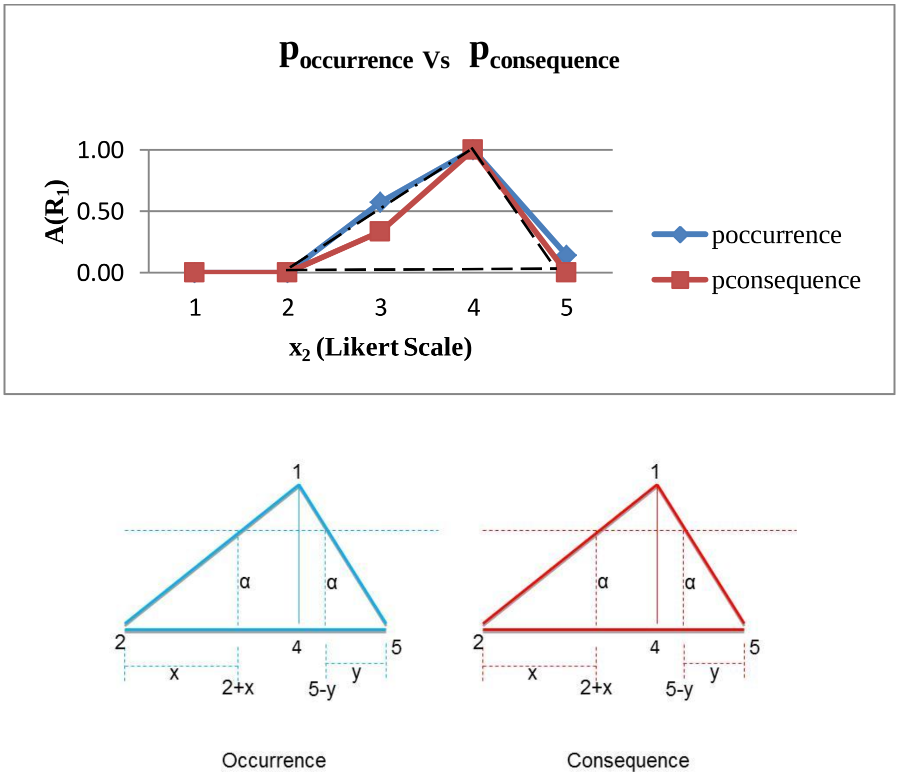


Figure 6: Best Fit Triangular Membership Function for R2

Let Occurrence is formulated by a fuzzy set $O(\,x,\ a,\ m,\ b)$ and Impact is formulated by a fuzzy set $I\ (y,\ c,\ n,\ d)$. In Figure 6 , $O(\,x,\ a = 2,\ m = 4,\ b = 5)$ and $I\ (y,\ b = 2,\ n = 4,\ d = 5)$.

As both the Occurrence and Impact are computed on the positive x-axis, you can take the increasing and decreasing parts separately to compute the Risk Magnitude $M(z) = O * I$.

A. Left Side of Risk Magnitude

$$M \text{ for } ac \le z \le mn \rightarrow 4 \le z \le 16$$

Taking the increasing part of the Risk Magnitude fuzzy set will become, after taking the left sides of the Occurrence and Impact fuzzy sets:

Equation for x and y

$x = (m - a)\alpha + a$

$y = (n - c)\alpha + c$

Equation for z_1

$$z = (m - a)(n - c)\alpha^2 + (m - a)\alpha c + a(n - c)\alpha + ac = (2\alpha + 2) * (2\alpha + 2) = 4\alpha^2 + 8\alpha + 4$$

$$4\alpha^2 + 8\alpha + 4 = 0$$

Solving for α:

$\alpha = -1 + \frac{\sqrt{z}}{2}$

$M(z) = -1 + \frac{\sqrt{z}}{2}, for\ 4 \le z \le 16$

B. Right Side of Risk Magnitude

$$M \text{ for } mn \le z \le bd \rightarrow 16 \le z \le 25$$

Taking the decreasing part of the Risk Magnitude fuzzy set will become, after taking the right sides of the Occurrence and Impact fuzzy sets:

Equation for x and y

$x = (m - b)\alpha + b$

$y = (n - d)\alpha + d$

Equation for z_2

$$z = (m-b)(n-d)\alpha^2 + (m-b)\alpha d + b(n-d)\alpha + bd = (-\alpha+5)*(-\alpha+5) = \alpha^2 - 10\alpha + 25$$

$$\alpha^2 - 10\alpha + 25 - z = 0$$

Solving for α:

$\alpha = 5 - \sqrt{z}$

$M(z) = 5 - \sqrt{z},\ for\ 16 < z \le 25$

Therefore, the Risk Magnitude $M(z)$ becomes:

$$M(z) = \begin{cases} -1 + \dfrac{\sqrt{z}}{2}, for\ 4 \le z \le 16 \\ 5 - \sqrt{z}, for\ 16 < z \le 25 \\ 0, otherwise \end{cases}$$

III. Defuzzification (Risk Magnitude Computation)

Fuzzy set computation or defuzzification is the process of transforming a fuzzy output of a fuzzy inference system into a crisp output. Mostly used algorithms for defuzzification are:

- The Center of Area Method
- The right most maximum
- The left most minimum
- α- cut method

Out of the above algorithms, Center of Area and α-cut methods are used to obtain a final crisp output. The details of each method computation is shown in the following sections.

1. Using Center of Area Method

In this method a single value that will represent the risk magnitude can be obtained. To simplify the computation needed, fit a linear line as shown in Figure 7 below. Thus, the Risk Magnitude fuzzy set will be triangular and the centroid value will be computed using the two triangular areas.

$$C = \frac{A_1 * \left(x_1 + \frac{2}{3} b \right) + A_2 * \left(x_2 + \frac{1}{3} b \right)}{A_1 + A_2}$$

Where, C is the centroid of a triangle

x_1, x_2 are the x-coordinates of the vertices of the triangle

b bases of a triangle

A_1 & A_2 areas of the two triangles

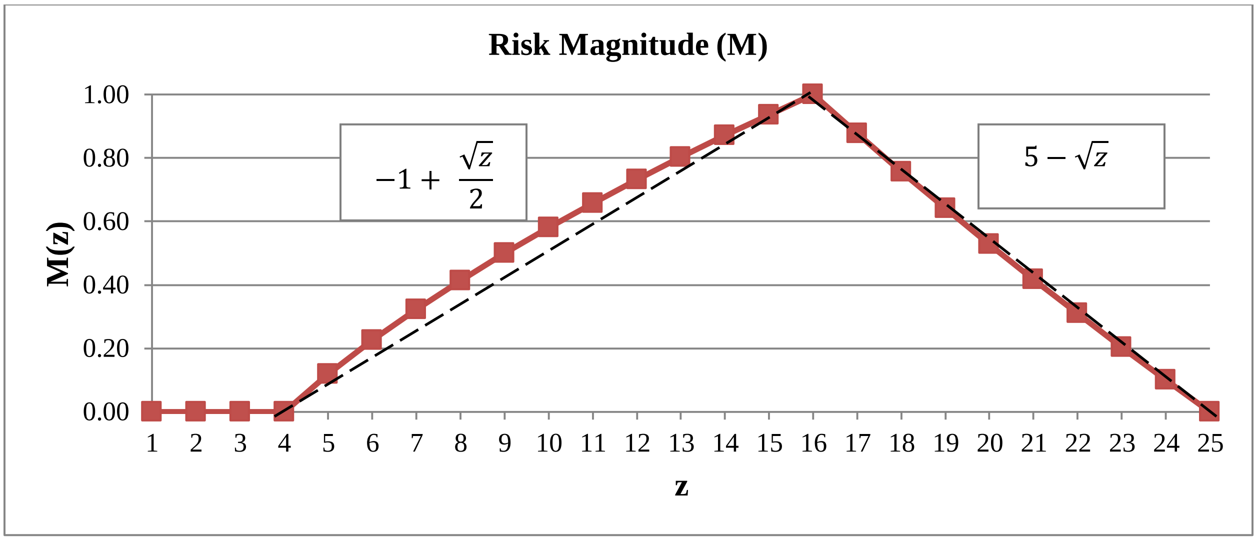
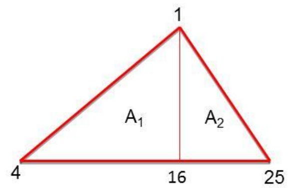


Figure 7: Linear Approximation of the Best Fit Membership Function

Hence, the centroid value of this risk becomes,

$$C = \frac{\frac{12*1}{2}*\left(4+\frac{2}{3}*12\right)+\frac{9*1}{2}*(16+\frac{1}{3}9)}{6+4.5} = 15$$



As the maximum value is 25, the relative value will be $=\frac{15}{25}=0.6\ \mathit{or}\ 60\%$

2. Using α - cut method

In this method an interval of the Risk Magnitude, based on a given α value can be obtained. The α value is equivalent to level of confidence in statistical analysis. For Risk analysis, 85% confidence interval is commonly used in Monte-Carlo simulation based Risk models. So, assuming, $\alpha = 85\% = 0.85$, the Risk Magnitude interval will become as shown below by substituting the α value into the equation that gives the Min-Max value.

Risk Magnitude $M = [z_{1,} z_2] = [4\alpha^2 + 8\alpha + 4, \alpha^2 - 10\alpha + 25] = [13.69, 17.22]$

Once calculated the risk, take the central value of the interval as the risk magnitude value.

i.e. $= \frac{13.69 + 17.22}{2} = 15.46$

The relative value will be $\frac{15.46}{2} = 61.83\%\ \mathit{or}\ 0.618$

Then do the same for each risk and then take the average of the values to get the overall measure. In this case you can also take the lowest value (i.e., 13.69) for optimistic view or the highest value (i.e., 17.22) for pessimistic view.

The other option in calculating the overall or aggregated risk will be involve taking the interval values of each risk and then add them together and divide them by the number of risks. This will involve additional computation and the results might not be that different.

Based on this analytical scheme the responses from the experts and local contractors were analyzed and the results are discussed in the preceding section.

CHAPTER FIVE

RESULT AND DISCUSSIONS

5.1 Introduction

This chapter discuss about the ranking of the risk factors from the owner and contractors perspective respectively. And also the recommend risk allocation of the top factor.

5.1.1 Owner Perspective

Table 14, shows the computed risk magnitudes of the 73 risk factors both by α-cut and Center of Area method. Out of all, a risk factor with a maximum weight from the owners perspective is W_{COA} = 0.68 and W_{alpha} = 0.763 which indicates Price escalation (material, labor, equipment). Similarly a risk factor with a minimum weight is, W_{COA} = 0.42 and W_{alpha} = 0.168 indicating (Custom and import restrictions and Epidemic/deadly diseases) and Currency exchange risks for α-cut and Center of Area method respectively.

Table 14 A: Financial and Economic Risks

No.	Financial and Economic Risks		
	Risk Factors	W_{COA}	W_{alpha}
1	Currency exchange risks	0.6	0.168
2	Fluctuation of interest rate	0.47	0.364
3	Increase of tax rate	0.47	0.364
4	Price escalation (material, labor, equipment)	0.68	0.763
5	Delay in payment to contractor	0.48	0.372
6	Rise in fuel price	0.52	0.476
7	Delay of bank in project fund allocation	0.48	0.372
8	Bankruptcy	0.47	0.230
	Total	**0.52**	**0.388**

In any construction industry fluctuations in the economic conditions, inflation and foreign exchange risks will strongly affect the overall performance of the company. Similarly, as indicated in Table 14 A, the top significant risks in the ERA related to the financial and economic risks are mainly due to fluctuating price of goods, currency exchange risks, and fluctuation of interest rate and increase of tax rate. Thus, this is an indication that some risks, which include interest rate fluctuation, inflation, foreign currency exchange rate fluctuation, tax rate increase, funding /payment shortage are allocated to the local employer, local owner.

Table 14 B: Physical/Environmental Risks

No.	Physical/Environmental Risks Risk Factors	W_{COA}	W_{alpha}
9	Poor site condition (location, ground, etc.)	0.56	0.597
10	Geotechnical fault (contaminated soil)	0.43	0.262
	Total	**0.5**	**0.429**

Physical or environmental risks are the responsibilities of the host organization. These risks are commonly allocated to the owner because the ground investigation and the construction design are conducted by the owner prior to construction.

Table 14 C: Resource Risks

No.	Resource Risks Risk Factors	W_{COA}	W_{alpha}
11	Availability/shortage of labor	0.48	0.372
12	Availability/shortage of construction material at site	0.52	0.452
13	Availability/shortage of material in the market	0.5	0.442
14	Shortage of equipment at site	0.56	0.581
15	Low quality of material (below standard)	0.55	0.463
16	Lack of maintenance for equipment	0.56	0.581
17	High material waste	0.48	0.372
	Total	**0.52**	**0.466**

Table 14 D: Technical Risks

Technical Risks			
No.	**Risk Factors**	W_{COA}	W_{alpha}
18	Poor judgment in estimating time and resource (underestimation of quantities)	0.57	0.607
19	Poor material handling on site	0.52	0.474
20	Inappropriate construction method	0.52	0.476
21	Mistakes during construction	0.52	0.452

22	Equipment frequently out of order or damaged	0.55	0.485
23	Bad preparing and approval of shop drawings	0.5	0.422
24	Inaccurate prediction of equipment production	0.48	0.372
25	Lack of designer experience	0.51	0.466
26	Unclear specifications	0.55	0.463
27	Poor design (lack of design information)	0.55	0.485
28	Delay in design work	0.52	0.474
29	Slow drawing revision and distribution	0.48	0.372
30	Frequent design changes (error and omissions in design drawings)	0.48	0.372
31	Shortage of new technology	0.47	0.325
32	Defective workmanship and rework	0.48	0.372
33	Change in scope of work	0.55	0.463
34	Inadequate site information (soil test and survey report)	0.55	0.485
35	Poor documentations	0.52	0.474
36	Design team unfamiliar with new technology	0.45	0.315
	Total	**0.51**	**0.439**

Table 14 E: Personal and Managerial Risks

No.	Personal and Managerial Risks		
	Risk Factors	**W_{COA}**	**W_{alpha}**
37	Unethical behavior used by contractors to achieve the highest possible level of profit	0.55	0.485
38	Low speed of decision making within each project team	0.480	0.372
39	Unrealistic project duration imposed by owners	0.47	0.364
40	Owner interference	0.5	0.391
41	Lack of personal training and management	0.55	0.485
42	Lack of technical and managerial skill of staff	0.55	0.485
43	Inadequate contractor experience	0.51	0.38
44	Contractor uncommitment to consultants instructions	0.51	0.38
45	Low harmony between technical team of contractor and consultants which may lead to controversy	0.55	0.566
46	Poor communications and misunderstanding	0.48	0.403
47	Absence of consultant’s site staff	0.52	0.474
48	Owner has no priority/urgency to complete the project	0.44	0.272
49	Problems arising due to clients’/owner lack of experience	0.48	0.383
50	Labor problem and dispute (workers strike)	0.45	0.315
51	Incompetence and lack of responsibility of site engineer	0.51	0.38
52	Slow site handover	0.47	0.364

53	Poor material management and planning	0.55	0.485
54	Poor equipment management and planning	0.51	0.38
55	Poor labor planning	0.51	0.38
56	Corruption and lack of respect for law	0.52	0.452
57	Protest and interference nearby residence	0.48	0.372
	Total	**0.50**	**0.408**

Table 14 F: Governmental and Political Risks

Governmental and Political Risks			
No.	**Risk Factors**	**W_{COA}**	**W_{alpha}**
58	Slow permit approval by government agencies (excessive procedure)	0.43	0.262
59	Changes in laws and regulations	0.48	0.372
60	Change of government	0.56	0.526
61	Custom and import restrictions	0.42	0.226
	Total	**0.47**	**0.346**

Table 14 G: Safety and Security Risks

No.	**Safety and Security Risks**		
	Risk Factors	**W_{COA}**	**W_{alpha}**
62	Accident and injuries	0.56	0.576
63	Theft on site	0.57	0.577
64	Epidemic/deadly diseases	0.42	0.226
65	Inadequate safety and security	0.57	0.577
66	Inadequate safety measure and operations	0.6	0.691
	Total	**0.54**	**0.529**

Table 14 H: Environmental Regulation Risks

Environmental Regulation Risks			
No.	**Risk Factors**	**W_{COA}**	**W_{alpha}**
67	Environmental protection pressure of other groups	0.44	0.267
68	Serious noise pollution caused by construction	0.47	0.322
69	Water pollution caused by construction	0.47	0.322
70	Prosecution due to unlawful disposal of construction waste	0.44	0.267
	Total	**0.45**	**0.295**

Table 14 I: Contractual and Legal Risks

Contractual and Legal Risks			
No.	**Risk Factors**	**W_{COA}**	**W_{alpha}**
71	Contract modifications (addition of new work to the project and change in specification)	0.48	0.372
72	Ambiguous conditions of contract (Insufficient details in contract documents)	0.48	0.372
73	Lack of clear understanding of contract document by all stakeholders	0.51	0.38
	Total	**0.49**	**0.375**

The variation between the maximum and the minimum risk magnitude for the α-cut method is ΔW_{alpha} = 0.595 while for the Center of Area method is ΔW_{COA} = 0.26. The different range values between the two methods indicate that, the relative importance of the risk factors is better reflected using the α-cut method. This characteristic is illustrated in Figure 8 in a more comprehensive manner for all risk factors.

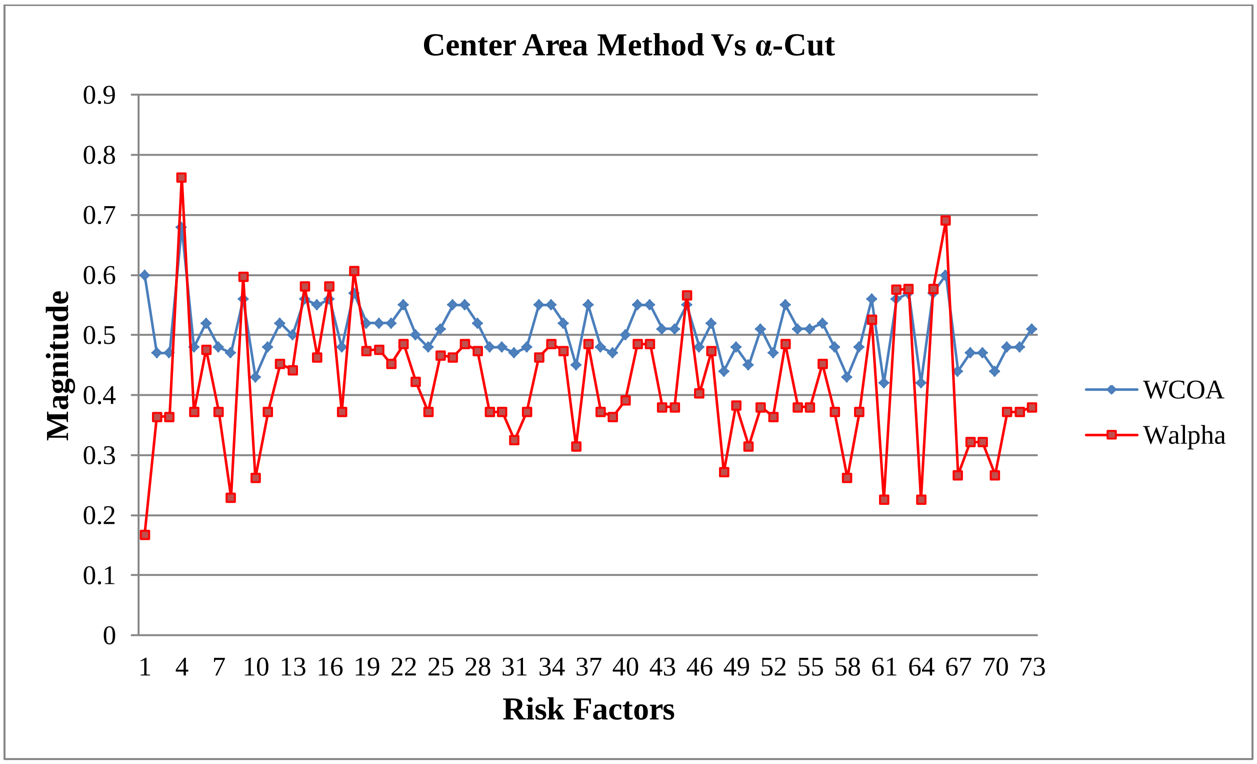


Figure 8: Risk Magnitude by Center Area Method and α-cut Method from Owners Perspective

Table (14 J) and (K) shows the results of the assessment and prioritization made to establish a most-to-least-critical importance ranking. Ranking risks in terms of their criticality or importance provides insights to the project's management on where resources may be needed to manage or mitigate the realization of high probability/high consequence risk events.

Hence looking at the top and least ten risks in Table (5.1.1 J) and (K) from the perceptions of client (ERA experts), only considering the α-cut method, "Price escalation (material, labor, equipment)" takes the top of the rank with a 0.763 risk magnitude. Similarly, the least critical risk being "Currency Exchange Risks" with a rank of 0.168. Hence, these indicate which risk factors are least critical and which needs to be given more attention.

Table 14 J: Top Ten Risk Factors per W_{alpha} Method

Top Ten Risk Factors per W_{alpha} Method			
No.	**Risk Factors**	**W_{alpha}**	**Rank**
1	Price escalation (material, labor, equipment)	0.763	1
2	Inadequate safety measure and operations	0.691	2
3	Poor judgment in estimating time and resource (underestimation of quantities)	0.607	3
4	Poor site condition (location, ground, etc.)	0.597	4
5	Shortage of equipment at site	0.581	5
6	Lack of maintenance for equipment	0.581	6
7	Theft on site	0.577	7
8	Inadequate safety and security	0.577	7
9	Accident and injuries	0.576	8
10	Low harmony between technical team of contractor and consultants which may lead to controversy	0.566	9

Table 14 K: Bottom Ten Risk Factors per W_{alpha} Method

Bottom Ten Risk Factors per W_{alpha} Method			
No.	**Risk Factors**	**W_{alpha}**	**Rank**
1	Currency exchange risks	0.168	73
2	Custom and import restrictions	0.226	72
3	Epidemic/deadly diseases	0.226	71
4	Bankruptcy	0.230	70
5	Geotechnical fault (contaminated soil)	0.262	69
6	Slow permit approval by government agencies (excessive procedure)	0.262	68

7	Environmental protection pressure of other groups	0.267	67
8	Prosecution due to unlawful disposal of construction waste	0.267	66
9	Owner has no priority/urgency to complete the project	0.272	65
10	Design team unfamiliar with new technology	0.315	64
11	Labor problem and dispute (workers strike)	0.315	63

5.1.2 Contractor perspective

Similarly Table 15, shows a contractors perspective of a maximum and minimum risk magnitude both by α-cut and Center of Area Method.

Table 15 A: Financial and Economic Risks

No.	**Financial and Economic Risks**		
	Risk Factors	**W_{COA}**	**W_{alpha}**
1	Fluctuation of inflation rate (buying power of money)	0.61	0.727
2	Currency exchange risks/Lack of currency	0.6	0.618
3	Fluctuation of interest rate	0.5	0.442
4	Liquidity risk/cash flow problems	0.57	0.600
5	Absence of price index	0.56	0.596
	Total	**0.57**	**0.596**

Table 15 B: Physical/Environmental Risks

No.	**Physical/Environmental Risks**		
	Risk Factors	**W_{COA}**	**W_{alpha}**
6	Exceptionally adverse climatic condition	0.57	0.600
7	Act of God (flood, earthquake…)	0.44	0.254
8	Geotechnical fault (contaminated soil)	0.51	0.466
9	Landslide	0.52	0.474
	Total	**0.51**	**0.448**

Table 15 C: Resource Risks

No.	**Resource Risks**		
	Risk Factors	**W_{COA}**	**W_{alpha}**
10	Availability/shortage of skilled labor (managerial)	0.51	0.380
11	Unavailability of specialized sub-contractors	0.51	0.466
12	Availability/shortage of construction material at site (site produced)	0.55	0.485
13	Availability/shortage of material in the market (imported/processed	0.52	0.476

	material)		
14	Shortage of equipment at site	0.55	0.485
15	Machinery downtime due (spare parts, fuel, machine interdependence, maintenance system)	0.6	0.618
16	Low productivity of machineries	0.51	0.466
17	Wastage of material	0.47	0.364
	Total	**0.53**	**0.467**

Table 15 D: Technical Risks

Technical Risks			
No.	**Risk Factors**	W_{COA}	W_{alpha}
18	Poor judgment in estimating time and resource	0.52	0.474
19	Underestimation of quantities	0.56	0.596
20	Poor material handling on site	0.47	0.364
21	Inappropriate construction method	0.52	0.474
22	Equipment frequently out of order or damaged	0.53	0.482
23	Bad preparing and approval of shop drawings	0.47	0.364
24	Inaccurate prediction of equipment production rate	0.47	0.364
25	Unclear specifications	0.51	0.466
26	Poor design (lack of design information/designer experience)	0.52	0.474
27	Delay in design work	0.51	0.466
28	Slow drawing revision and distribution	0.51	0.466
29	Frequent design changes (error and omissions in design drawings)	0.55	0.485
30	Defective workmanship and rework	0.51	0.466
31	Change in scope of work	0.55	0.566
32	Inadequate/Poor construction site survey (sub surface characterization, material identification and location, surveying	0.52	0.474
33	Poor documentations	0.48	0.372
34	Poor work schedule not tailored to scope of work and resource deployed	0.55	0.485
35	Insufficient supervision	0.47	0.364
36	Late internal approval process from owner	0.58	0.587
	Total	**0.52**	**0.462**

Table 15 E: Personal and Managerial Risks

Personal and Managerial Risks			
No.	**Risk Factors**	W_{COA}	W_{alpha}
37	Poor provision of information to project participants	0.6	0.590

38	Unethical behavior/practice used by contractors and owners	0.6	0.590
39	Suspension of work by contractor	0.52	0.417
40	Low speed of decision making within each project team	0.52	0.476
41	Unrealistic project duration imposed by owners	0.51	0.466
42	Lack of personal training and management support	0.52	0.476
43	Contractor un-commitment to consultants instructions	0.45	0.335
44	Low harmony between technical team of contractor and consultants which may lead to controversy	0.6	0.59
45	Poor communications and misunderstanding	0.52	0.452
46	Absence of consultant's site staff	0.52	0.474
47	Owner has no priority/urgency to complete the project	0.42	0.226
48	Antagonistic relation between owner, contractor and consultant	0.55	0.567
49	Problems arising due to clients'/owner lack of experience	0.45	0.335
50	Lack of experience on the part of the consultant's site staff; (managerial and supervisory personnel)	0.57	0.577
51	Incompetence and lack of responsibility of site engineer, superintendent, foreman	0.52	0.476
52	Slow site handover	0.52	0.476
53	Poor material management and planning	0.51	0.466
54	Poor equipment management and planning	0.51	0.466
55	Poor labor planning	0.52	0.474
56	Corruption and lack of respect for law	0.55	0.567
57	Protest and interference by local community	0.45	0.335
58	High human resource turnover	0.51	0.466
	Total	**0.52**	**0.468**

Table 15 F: Governmental and Political Risks

Governmental and Political Risks			
No.	**Risk Factors**	**W_{COA}**	**W_{alpha}**
59	Slow permit approval by government agencies (excessive procedure)	0.51	0.466
60	Bureaucracy in government agencies	0.55	0.463
61	Government intervention/political	0.57	0.577
62	Changes in laws and regulations	0.48	0.403
63	Lack of cooperation from government	0.47	0.34
64	Custom and import restrictions	0.51	0.466
65	Change in priority and focus by the state	0.48	0.403
66	Delay in right of way (ROW) obstruction removal	0.68	0.765
	Total	**0.53**	**0.485**

Table 15 G: Safety and Security Risks

Safety and Security Risks			
No.	**Risk Factors**	**W_{COA}**	**W_{alpha}**
67	Accident and injuries	0.48	0.372
68	Theft on site	0.48	0.372
69	Epidemic/deadly diseases	0.48	0.48
	Total	**0.48**	**0.408**

Table 15 H: Contractual and Legal Risks

Contractual and Legal Risks			
No.	**Risk Factors**	**W_{COA}**	**W_{alpha}**
70	Mistakes and discrepancy in contract documents	0.52	0.474
71	Unfair and unreasonable stipulation or inappropriate risk allocation in contract	0.57	0.58
72	Lack of clear understanding of contract document by all stakeholders	0.51	0.466
	Total	**0.53**	**0.506**

As shown in Table 14 the maximum risk magnitude as per W_{COA} = 0.68 and W_{alpha} = 0.765 which represents a risk factor “Delay in right of way (ROW) obstruction removal”. And a risk factor with a minimum weight is W_{COA} = 0.42 and W_{alpha} = 0.226 representing a risk factor “Owner has no priority/urgency to complete the project”. Looking at the ΔW of the risk magnitudes, ΔW_{COA} = 0.26 and ΔW_{alpha} = 0.54 there is a similar range of variation between the two defuzzification methods, indicating that the risk magnitude is better represented using the α-cut method.

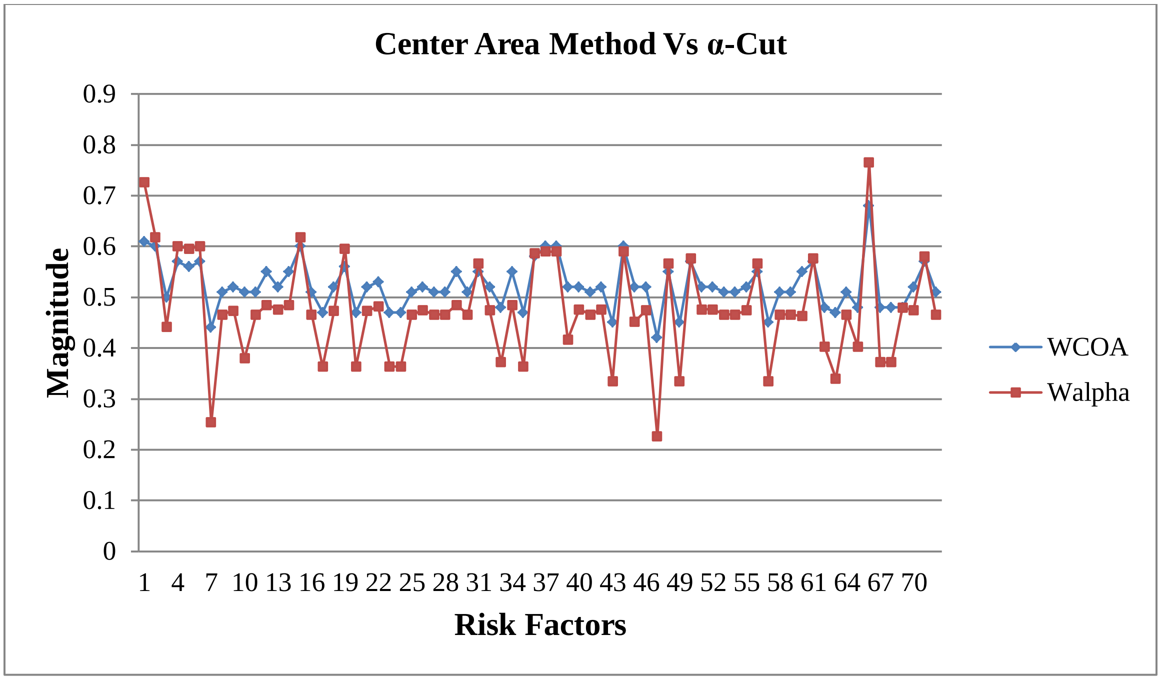


Figure 9: Risk Magnitude by Center Area Method and α-cut Method from Contractors Perspective

Table 15 I and J show the lists of the highest to the lowest priority risks in a descending order. This gives an indication on which risk factors that an attention needed to be given in the final step of the risk planning process.

Hence looking at the top and least ten risks in Table (15 I) and (J) from the perceptions of Local Contractor, only considering the α-cut method, "Delay in right of way (ROW) obstruction removal" takes the top of the rank with a 0.765 risk magnitude, similarly, the least critical risk being "Owner has no priority/urgency to complete the project" with a rank of 0.266. Generally, the right of way acquisition is the responsibility of the client but delay in the obstruction removal will cost the contractor time, resource tide up and value of money.

Table 15 I: Top Ten Risk Factors per W_{alpha} Method

Top Ten Risk Factors per W_{alpha} Method			
No.	**Risk Factors**	**W_{alpha}**	**Rank**
1	Delay in right of way (ROW) obstruction removal	0.765	1
2	Fluctuation of inflation rate (buying power of money)	0.727	2

3	Currency exchange risks/Lack of currency	0.618	3
4	Machinery downtime due (spare parts, fuel, machine interdependence, maintenance	0.618	4
5	Liquidity risk/cash flow problems	0.600	5
6	Exceptionally adverse climatic condition	0.600	5
7	Absence of price index	0.596	6
8	Underestimation of quantities	0.596	6
9	Poor provision of information to project participants	0.590	7
10	Unethical behavior/practice used by contractors and owners	0.590	7
11	Low harmony between technical team of contractor and consultants which may lead to controversy	0.59	8

Table 15 J: Bottom Ten Risk Factors per W_{alpha} Method

Bottom Ten Risk Factors per W_{alpha} Method			
No.	**Risk Factors**	**W_{alpha}**	**Rank**
1	Owner has no priority/urgency to complete the project	0.226	72
2	Act of God (flood, earthquake…)	0.254	71
3	Contractor un-commitment to consultants instructions	0.335	70
4	Problems arising due to clients'/owner lack of experience	0.335	69
5	Protest and interference by local community	0.335	68
6	Lack of cooperation from government	0.340	67
7	Wastage of material	0.364	66
8	Poor material handling on site	0.364	65
9	Inaccurate prediction of equipment production rate	0.364	64
10	Bad preparing and approval of shop drawings	0.364	63
11	Insufficient supervision	0.364	62

In the same manner the total risk magnitude of each risk category listed in Section 4.1.1 are prioritized in accordance to their descending order as shown Table (15 K) and (L) both from owners and contractors perspective.

Table 15 K: Risk Ranking by Category from Owner Perspective

Risk Category	**W_{alpha} per Category**	**Rank**
Safety and Security Risks	0.53	**1**
Resource Risks	0.47	**2**
Technical Risks	0.44	**3**
Physical/Environmental Risks	0.43	**4**

Personal and Managerial Risks	0.41	**5**
Financial and Economic Risks	0.39	**6**
Contractual and Legal Risks	0.37	**7**
Governmental and Political Risks	0.35	**8**
Environmental Regulation Risks	0.29	**9**

Table 15 L: Risk Ranking by Category from Contractors Perspective

Risk Category	W_{alpha} per Category	Rank
Financial and Economic Risks	0.60	**1**
Contractual and Legal Risks	0.51	**2**
Governmental and Political Risks	0.49	**3**
Personal and Managerial Risks	0.47	**4**
Resource Risks	0.47	**4**
Technical Risks	0.46	**5**
Physical/Environmental Risks	0.45	**6**
Safety and Security Risks	0.41	**7**

Bearing in mind the practical trend, the risk rankings from the contractors' perspective seems to be reasonable. This is because in the Ethiopian construction industry the bureaucratic hurdles for payment release are very high. However, the ranking from the owner perspective seems to deviate from the general perception in the construction industry. This may have several reasons such as since the owner being state owned and the respondents response may have been influenced by political implication.

5.1.3 Comparison of Contractors' and Owners View

Table 16 A: Comparison of Contractors' and Owners View

No.	Risk Factors	Contractor	Owner
		W_{alpha}	W_{alpha}
1	Currency exchange risks/Lack of currency	0.618	0.168
2	Fluctuation of interest rate	0.442	0.364
3	Availability/shortage of material in the market (imported/processed material)	0.476	0.442
4	Shortage of equipment at site	0.485	0.581
5	Wastage of material	0.364	0.372
6	Equipment frequently out of order or damaged	0.482	0.485
7	Bad preparing and approval of shop drawings	0.364	0.422

8	Inaccurate prediction of equipment production rate	0.364	0.372
9	Unclear specifications	0.466	0.463
10	Slow drawing revision and distribution	0.466	0.372
11	Defective workmanship and rework	0.466	0.372
12	Change in scope of work	0.566	0.463
13	Low speed of decision making within each project team	0.476	0.372
14	Unrealistic project duration imposed by owners	0.466	0.364
15	Lack of personal training and management support	0.476	0.485
16	Poor communications and misunderstanding	0.452	0.403
17	Owner has no priority/urgency to complete the project	0.226	0.272
18	Problems arising due to clients'/owner lack of experience	0.335	0.383
19	Poor equipment management and planning	0.466	0.38
20	Poor labor planning	0.474	0.38
21	Corruption and lack of respect for law	0.567	0.452
22	Slow permit approval by government agencies (excessive procedure)	0.466	0.262
23	Changes in laws and regulations	0.403	0.372
24	Custom and import restrictions	0.466	0.226
25	Accident and injuries	0.372	0.576
26	Theft on site	0.372	0.577

Contractors and owners view risks differently. Contractors always try to transfer the risk to the owner to gain more time and money on the project. The owners try to save the time and money and transfer the risks to the contractor, forcing the contractor to accept the risks and mitigate the contractor's own cost and minimize the project duration. These are the reasons behind the main problems that occur between owners and contractors. Table (16 A) presents the comparison between the views of contractors and owners as to the overall priority of road construction risks.

A currency exchange risk is ranked 1st and 26th by contractors and owners, respectively. These shows the owner do not consider a currency exchange as a risk that have a high impact on the project, while contractors consider it to be the highest of all. Thought currency exchange risk is ranked 1st by contractors, when we look at this risk in Table 15 A, the risk is allocated to be the responsibility of the owner. These indicate that either the contractors wanted to transfer the risk to the owner or the risk should be shared by both parties.

Also Change in scope of work was ranked 3rd and 6th by contractors and owners, respectively. Shortage of equipment, Corruption and lack of respect for law, Equipment frequently out of order or damaged, Availability/shortage of material in the market (imported/processed material), and Lack of personal training and management support are on the top 10 lists of both contractors and owners.

As it can be seen in Table (16 B) there is a high difference in the ranking of the top risks. Furthermore, some risks should have a better ranking than what is stated, such as Owner has no priority/urgency to complete the project is ranked by the owner as the least concerning risk, but it is known that the longer the project completion time the more cost overrun since the construction industries is more prone to change.

Table 16 B: Contractors versus Owners by Overall Propriety

Risk	Risk Factors	Contractor		Owner	
		W_{alpha}	Rank	W_{alpha}	Rank
1	Currency exchange risks/Lack of currency	0.618	1	0.168	26
21	Corruption and lack of respect for law	0.567	2	0.452	8
12	Change in scope of work	0.566	3	0.463	6
4	Shortage of equipment at site	0.485	4	0.581	1
6	Equipment frequently out of order or damaged	0.482	5	0.485	4
3	Availability/shortage of material in the market (imported/processed material)	0.476	6	0.442	9
13	Low speed of decision making within each project team	0.476	6	0.372	15
15	Lack of personal training and management support	0.476	6	0.485	4
20	Poor labor planning	0.474	9	0.38	13
9	Unclear specifications	0.466	10	0.463	6
10	Slow drawing revision and distribution	0.466	10	0.372	15
11	Defective workmanship and rework	0.466	10	0.372	15
14	Unrealistic project duration imposed by owners	0.466	10	0.364	21
19	Poor equipment management and planning	0.466	10	0.38	13
22	Slow permit approval by government agencies (excessive procedure)	0.466	10	0.262	24
24	Custom and import restrictions	0.466	10	0.226	25
16	Poor communications and misunderstanding	0.452	17	0.403	11
2	Fluctuation of interest rate	0.442	18	0.364	22

23	Changes in laws and regulations	0.403	19	0.372	15
25	Accident and injuries	0.372	20	0.576	3
26	Theft on site	0.372	21	0.577	2
7	Bad preparing and approval of shop drawings	0.364	22	0.422	9
5	Wastage of material	0.364	22	0.372	15
8	Inaccurate prediction of equipment production rate	0.364	22	0.372	15
18	Problems arising due to clients'/owner lack of experience	0.335	25	0.383	12
17	Owner has no priority/urgency to complete the project	0.226	26	0.272	23

To check the strength of correlation between two sets of rankings, the Spearman's rank correlation (R) is calculated using the formula below. When written in mathematical notation the Spearman Rank formula:

$$R = \frac{1 - 6\sum d^2}{n^3 - n}$$

Where, R = Spearman's rank correlation and n = number of data

d = the difference between the ranking of the owner and contractor for each risk

The Spearman's rank correlation is calculated to be 0.178, which indicates a weak correlation or an overall disagreement between the owners and contractors in the ranking of the risks. The P-value is 0.385 using the two-tailed test. This is calculated using SPSS 20 software.

5.2 Risk Allocation

Risk allocation is an important issue in the risk management process. It refers to allocation risks to the proper contracting party, namely, the owner or the contractor.

Table (17 A) shows the suggested allocations based on the respondents' replies and the recommended allocation. Hence, it is noticed that most risks are allocated to the proper party; some risks are stated to be the contractors responsible, such as "Low speed of decision making within each project team" where this risk is a responsibilities of both stakeholders and also "Unrealistic project duration imposed by owners" is a responsibility of the owner. This might be due to a traditional contract forms that place the power in the hands of the owner only.

Table 17 A: Risk Allocation

No.	Risk Factors	Suggested Allocation			Recommended
		Contractor	Owner	Shared	Allocation
1	Fluctuation of inflation rate (buying power of money)	7	10	8	Owner
2	Currency exchange risks/Lack of currency	7	10	7	Owner
3	Availability/shortage of skilled labor (managerial)	23	0	1	Contractor
4	Availability/shortage of construction material at site (site produced)	24	0	0	Contractor
5	Availability/shortage of material in the market (imported/processed material)	17	4	4	Contractor
6	Shortage of equipment at site	23	1	0	Contractor
7	Low quality of material (below standard)	22	1	1	Contractor
8	Lack of maintenance for equipment	24	0	0	Contractor
9	Wastage of material	21	0	3	Contractor
10	Poor judgment in estimating time and resource	13	6	7	Contractor
11	Poor material handling on site	22	2	0	Contractor
12	Inappropriate construction method	24	0	0	Contractor

13	Mistakes during construction	23	0	1	Contractor
14	Equipment frequently out of order or damaged	24	0	0	Contractor
15	Bad preparing and approval of shop drawings	17	2	6	Contractor
16	Unclear specifications	1	19	4	Owner
17	Poor design (lack of design information/designer experience)	3	17	4	Owner
18	Slow drawing revision and distribution	5	18	1	Owner
19	Frequent design changes (error and omissions in design drawings)	1	16	7	Owner
20	Defective workmanship and rework	23	0	1	Contractor
21	Low speed of decision making within each project team	11	6	9	Contractor
22	Unrealistic project duration imposed by owners	13	8	5	Contractor
23	Lack of technical and managerial skill of staff	15	8	6	Contractor
24	Inadequate contractor experience	15	9	3	Contractor
25	Contractor un-commitment to consultants instructions	16	7	4	Contractor
26	Low harmony between technical team of contractor and consultants which may lead to controversy	6	5	16	Shared
27	Absence of consultant's site staff	1	20	4	Owner
28	Problems arising due to clients'/owner lack of experience	1	18	5	Owner
29	Incompetence and lack of responsibility of site engineer, superintendent, foreman	10	9	5	Contractor
30	Slow site handover	1	20	3	Owner
31	Poor material management and planning	24	0	0	Contractor
32	Poor equipment management and planning	24	0	0	Contractor
33	Poor labor planning	24	0	0	Contractor
34	Corruption and lack of respect for law	3	3	18	Shared
35	Protest and interference by local community	2	12	9	Owner
36	Ambiguous conditions of contract (Insufficient details in contract documents)	3	14	7	Owner
37	Lack of clear understanding of contract document by all stakeholders	7	4	15	Shared

5.3 Discussion

Like any construction sector, Ethiopian road construction industry involves a lot of risks in its projects. Before the application of any risk assessment techniques, it is vital that all potential risks are identified and recognized together with their irrespective occurrence and consequence on project objectives. In these study 119 risk factors, critical to the road construction project were identified and grouped into 9 categories. This study adopts fuzzy athematic and α-cut principle to integrate the probability and consequence of each risk. The top ranking by category from the stakeholders perspective are stated in the preceding section.

5.3.1 Owners' View

The top risk factors ranked by client in the category of Financial and Economic Risks, Physical/Environmental Risks, Resource Risks, Technical Risks, Personnel and Managerial Risks, Government and Political Risks, Safety and Security Risks, Environmental Regulation Risks and Contractual and Legal Risks, are Price escalation, poor site condition, lack of maintenance for equipment, poor judgment in estimating time and resource, unethical behavior used by contractors to achieve the highest possible level of profit, change of government, theft on site, water pollution caused by construction.

5.3.2 Contractors View

The contractors ranked, Fluctuation of inflation rate (buying power of money), exceptionally adverse climatic condition, machinery downtime due (spare parts, fuel, machine interdependence, maintenance system, underestimation of quantities, poor revision of information to project participants, government intervention, epidemic and unfair and unreasonable stipulation or inappropriate risk allocation in contract from contractors perspective as a top significant risk.

In addition, the result of this study clearly shows that shortage of equipment at site is the most significant risk in Ethiopian Road Authority (ERA) and Currency exchange risks/Lack of currency is the most significant to Local contractors.

These critical risks from both client and contractors perspective are clear indication on which parts stakeholders should focuses on and allocate the appropriate contingency to manage this risks. Mostly 10% contingency is added to the total project cost to accommodate this risk. However, as the result of the study indicates, each risk has its own respective weight, hence the percentage share of the contingency allocation among this risks should be based on its magnitudes and ranking.

Moreover, the construction stakeholders need a decision support system on proper risk management tool and contingency allocation. This study demonstrates that the fuzzy expert system is an important tool that can configure the uncertain nature and characteristics of construction risks with the expert's inputs.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In this study the major risk factor that affects road construction projects were identified through literature review and the risk factors were ranked by experts form both client and local contractor's side through questionnaire survey. Moreover, their respective risk magnitude of each risk was calculated considering the ranked risk occurrence and impact using interval arithmetic and α-cut method. In addition, the recommended risk allocation of each factors were obtained. Based on the survey and analysis made in this study the following conclusions are put forward:

1. It has been found that the identified risk factors are more or less the same but their risk magnitude varies, since the magnitude of risk is highly dictated by country's context such as culture, technological evolution, political structure and legal system, as well as its geography and natural resource etc.
2. The risk magnitudes of each factors from both owner and contractors perspective were analyzed, and their respective rankings were made that enables stakeholders to incorporate a calculated risk in their decision making process.
3. The allocation of risks among stakeholders has been carried out and it was found that the characteristics of the Ethiopian road construction industry give more power to the owner.
4. According to the classified risk categories Financial and Economic risk is the top significant risk to the local contractors whereas Safety and Security is the top ranking risk to the owner.

6.2 Recommendation

Based on the result and conclusion discussed above the following recommendations are forwarded to the road construction industries:

1. To address the gaps that exist between the risk management methods and the subjective nature of experts involved in the assessing of risk probability and impact, the construction practitioner can embrace the fuzzy expert system as a promising risk assessment tool.
2. The commonly used 10% cost contingency for cost overrun is more of an average based approach which may over estimate or underestimate the contingency allocation. Hence the project planners should incorporate a calculated risk in their projects for improved reliability.

6.3 Future Research Area

In this study, the participant bodies are limited to Client (ERA) and local contractors, hence, this research can further be broadened including all stakeholders' consultants and foreign contractors to have full spectrum of stakeholders' perspective towards risk and its risk assessment plan.

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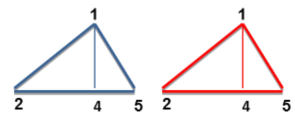
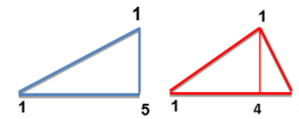
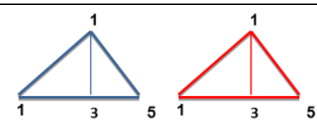
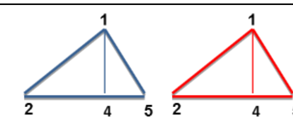
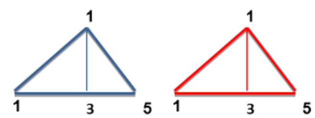
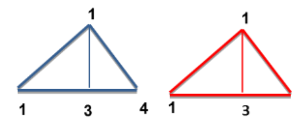
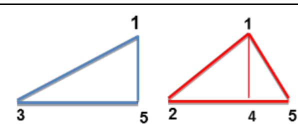
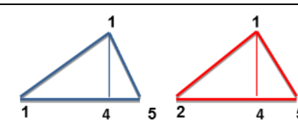
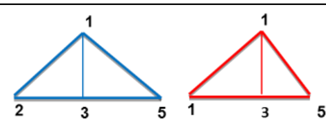
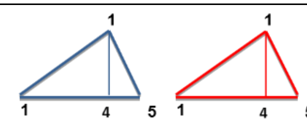
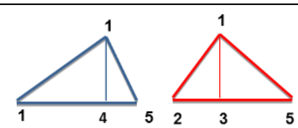
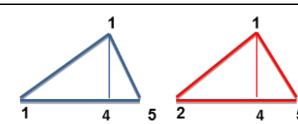
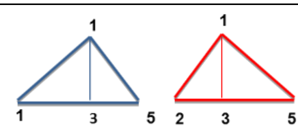
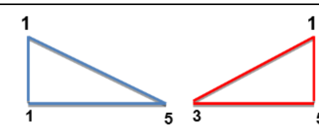
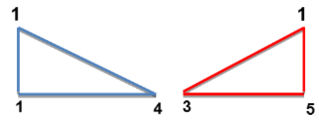
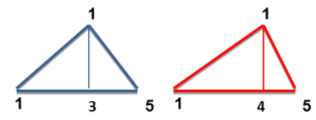
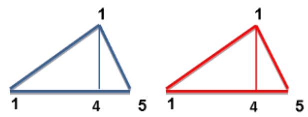
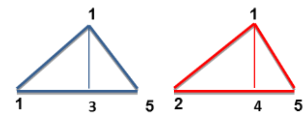
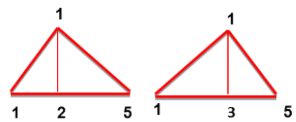
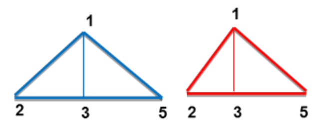
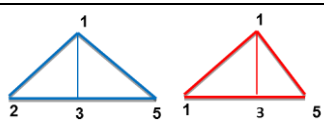
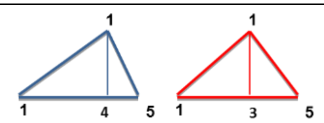
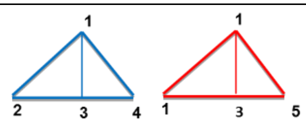
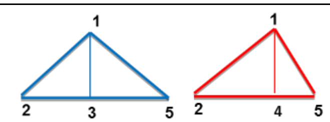
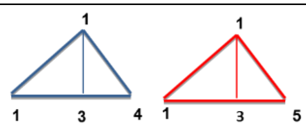
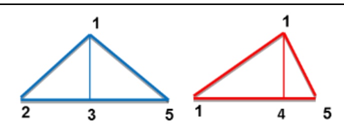
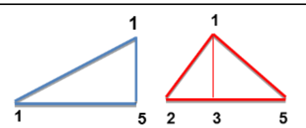
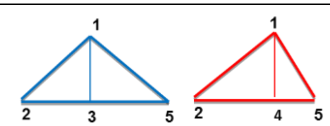
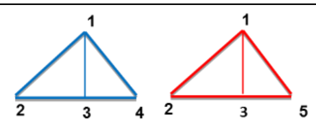
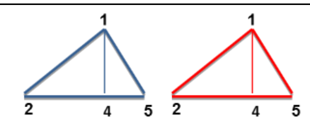
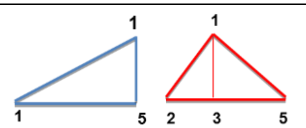
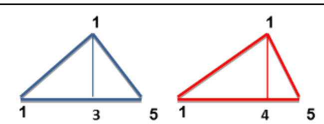
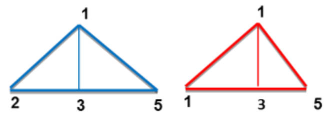
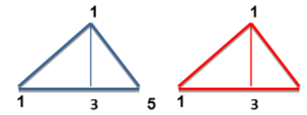
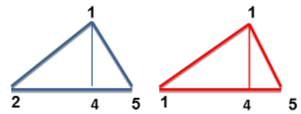
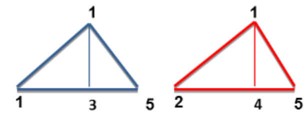
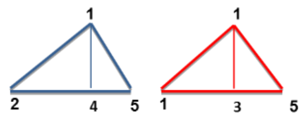
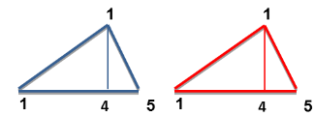
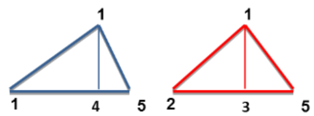
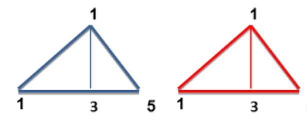
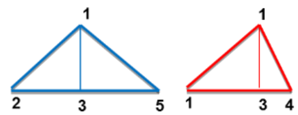
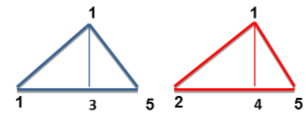
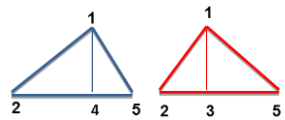
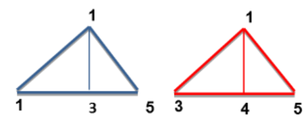
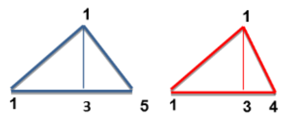
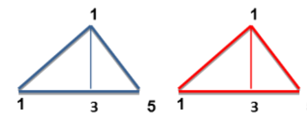
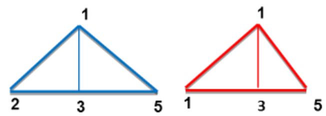
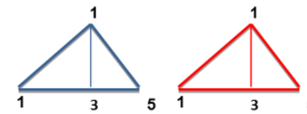
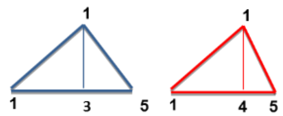
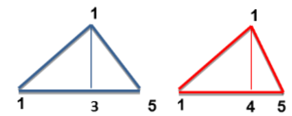
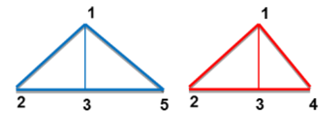
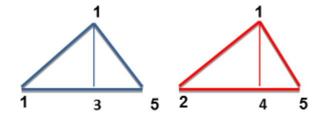
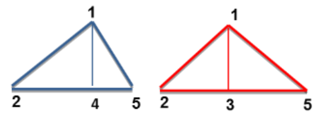
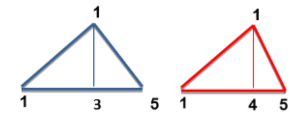
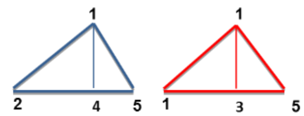
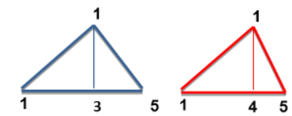
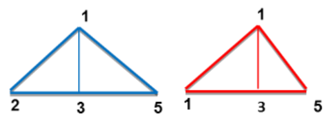
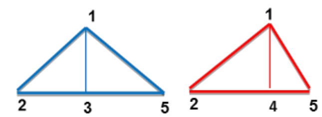
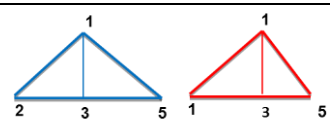
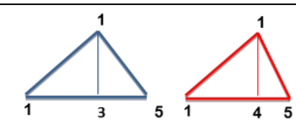
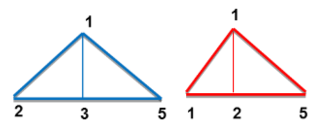
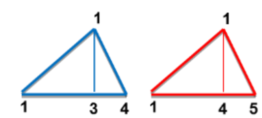
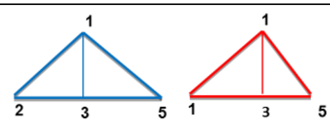
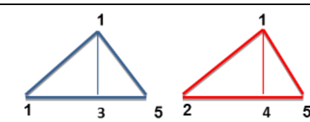
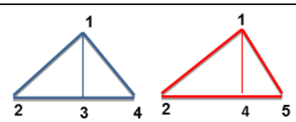
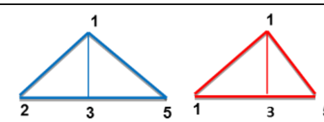
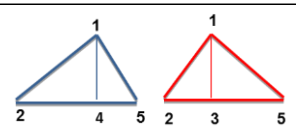
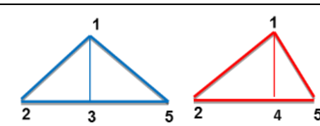
ANNEX

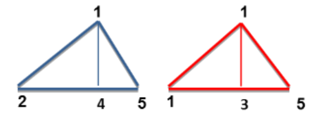
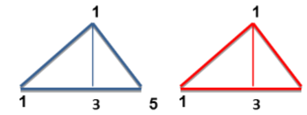
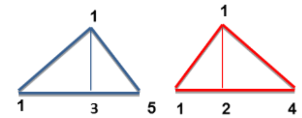
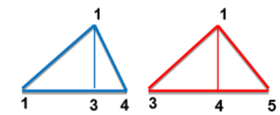
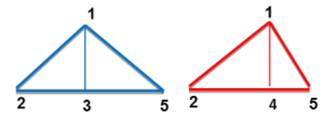
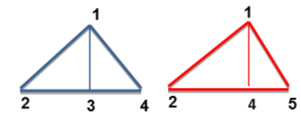
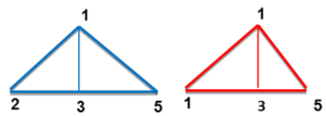
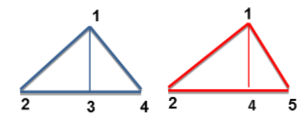
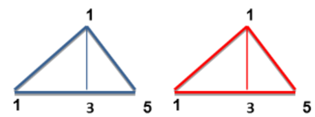
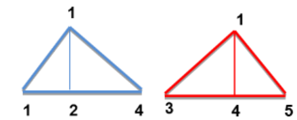
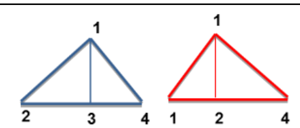
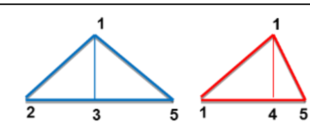
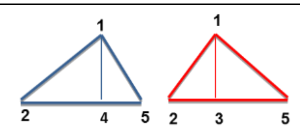
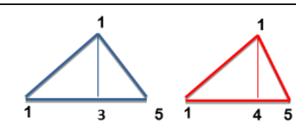
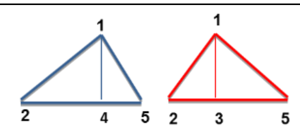
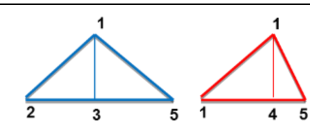
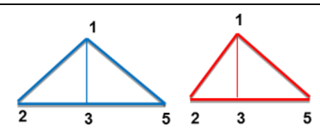
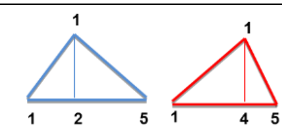
ANNEX 1: Best Fit Triangular Membership Function of Owner and Contractor Response

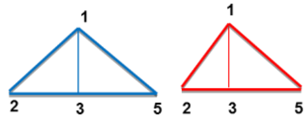
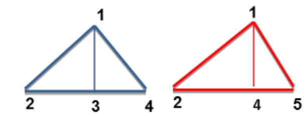
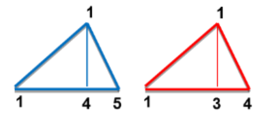
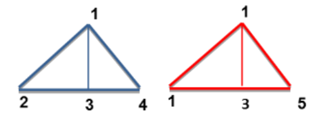
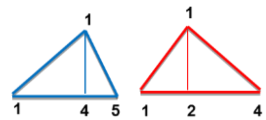
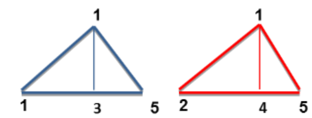
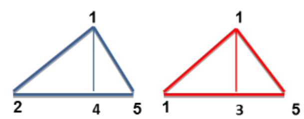
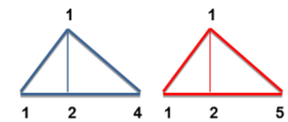
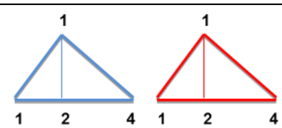
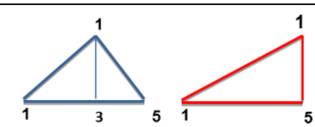
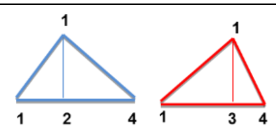
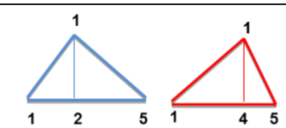
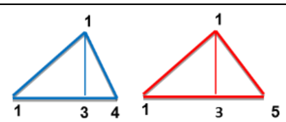
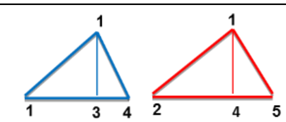
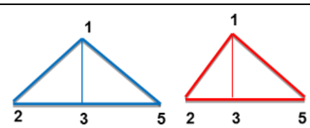
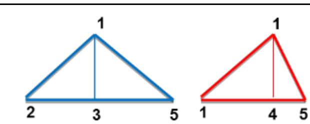
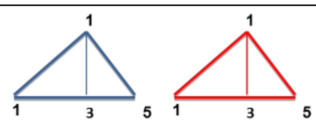
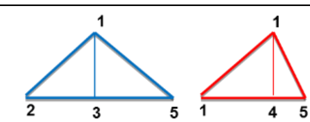
Best Fit Triangular Membership Value				
Risk Factor	**Occurrence Vs. Impact Owners Response**	**Graphical Representation**	**Occurrence Vs. Impact Local Contractors Response**	**Graphical Representation**
1	2, 4, 5 **and** 2, 4, 5		1, 5, 5 **and** 1, 4, 5	
2	1, 3, 5 **and** 1, 3, 5		2, 4, 5 **and** 2, 4, 5	
3	1, 3, 5 **and** 1, 3, 5		1, 3, 4 **and** 1, 3, 5	
4	3, 5, 5 **and** 2, 4, 5		1, 4, 5 **and** 2, 4, 5	
5	2, 3, 5 **and** 1, 3, 5		1, 4, 5 **and** 1, 4, 5	
6	1, 4, 5 **and** 2, 3, 5		1, 4, 5 **and** 2, 4, 5	
7	1, 3, 5 **and** 2, 3, 5		1, 1, 5 **and** 3, 5, 5	

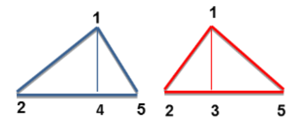
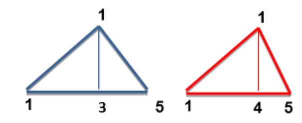
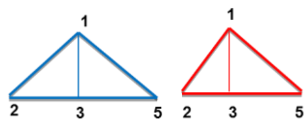
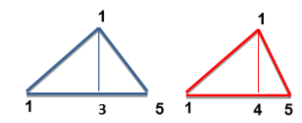
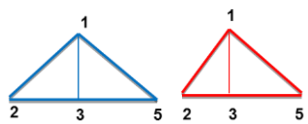
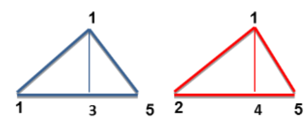
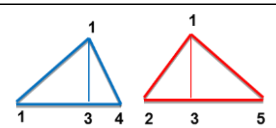
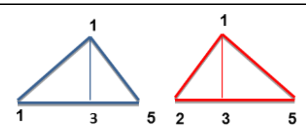
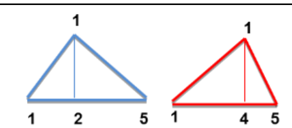
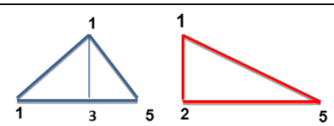
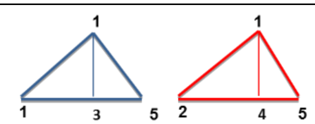
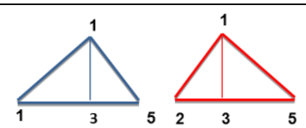
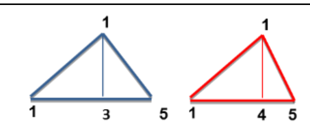
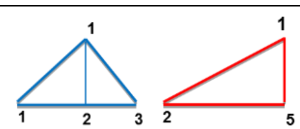
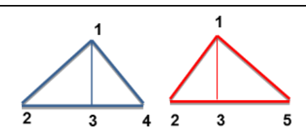
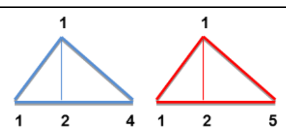
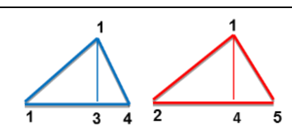
8	1, 1, 4 and 3, 5, 5		1, 3, 5 and 1, 4, 5	
9	1, 4, 5 and 1, 4, 5		1, 3, 5 and 2, 4, 5	
10	1, 2, 5 and 1, 3, 5		2, 3, 5 and 2, 3, 5	
11	2, 3, 5 and 1, 3, 5		1, 4, 5 and 1, 3, 5	
12	2, 3, 4 and 1, 3, 5		2, 3, 5 and 2, 4, 5	
13	1, 3, 4 and 1, 3, 5		2, 3, 5 and 1, 4, 5	
14	1, 5, 5 and 2, 3, 5		2, 3, 5 and 2, 4, 5	
15	2, 3, 4 and 2, 3, 5		2, 4, 5 and 2, 4, 5	
16	1, 5, 5 and 2, 3, 5		1, 3, 5 and 1, 4, 5	

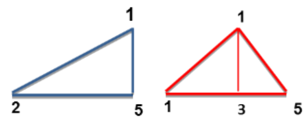
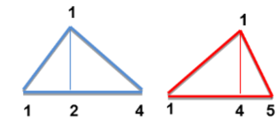
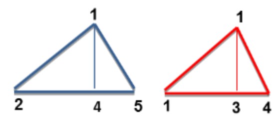
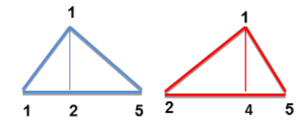
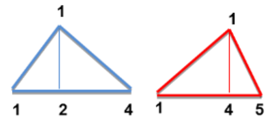
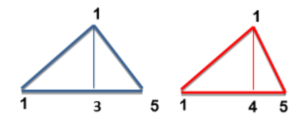
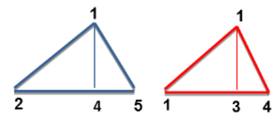
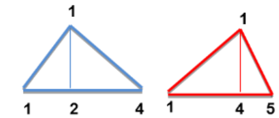
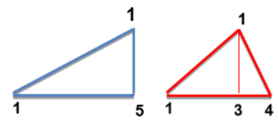
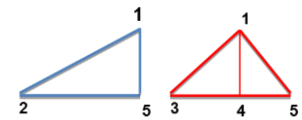
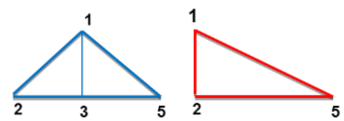
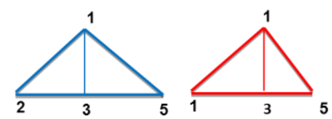
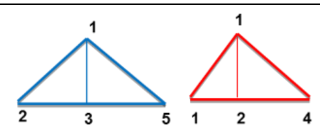
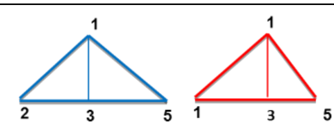
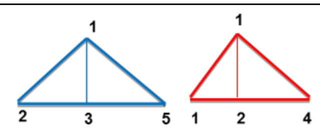
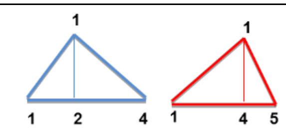
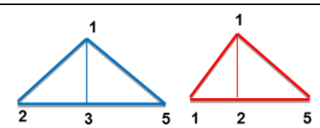
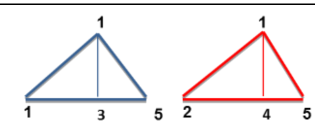
17	2, 3, 5 **and** 1, 3, 5		1, 3, 5 **and** 1, 3, 5	
18	2, 4, 5 **and** 1, 4, 5		1, 3, 5 **and** 2, 4, 5	
19	2, 4, 5 **and** 1, 3, 5		1, 4, 5 **and** 1, 4, 5	
20	1, 4, 5 **and** 2, 3, 5		1, 3, 5 **and** 1, 3, 5	
21	2, 3, 5 **and** 1, 3, 4		1, 3, 5 **and** 2, 4, 5	
22	2, 4, 5 **and** 2, 3, 5		1, 3, 5 **and** 3, 4, 5	
23	1, 3, 5 **and** 1, 3, 4		1, 3, 5 **and** 1, 3, 5	
24	2, 3, 5 **and** 1, 3, 5		1, 3, 5 **and** 1, 3, 5	
25	1, 3, 5 **and** 1, 4, 5		1, 3, 5 **and** 1, 4, 5	

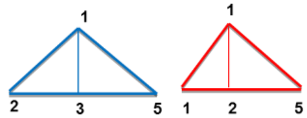
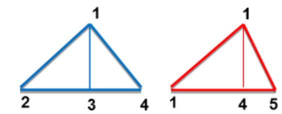
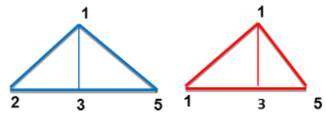
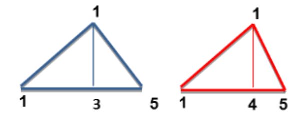
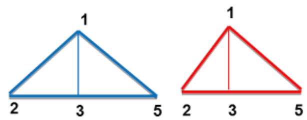
26	2, 3, 5 **and** 2, 3, 4		1, 3, 5 **and** 2, 4, 5	
27	2, 4, 5 **and** 2, 3, 5		1, 3, 5 **and** 1, 4, 5	
28	2, 4, 5 **and** 1, 3, 5		1, 3, 5 **and** 1, 4, 5	
29	2, 3, 5 **and** 1, 3, 5		2, 3, 5 **and** 2, 4, 5	
30	2, 3, 5 **and** 1, 3, 5		1, 3, 5 **and** 1, 4, 5	
31	2, 3, 5 **and** 1, 2, 5		1, 3, 4 **and** 1, 4, 5	
32	2, 3, 5 **and** 1, 3, 5		1, 3, 5 **and** 2, 4, 5	
33	2, 3, 4 **and** 2, 4, 5		2, 3, 5 **and** 1, 3, 5	
34	2, 4, 5 **and** 2, 3, 5		2, 3, 5 **and** 2, 4, 5	

35	2, 4, 5 **and** 1, 3, 5		1, 3, 5 **and** 1, 3, 5	
36	1, 3, 5 **and** 1, 2, 4		1, 3, 4 **and** 3, 4, 5	
37	2, 3, 5 **and** 2, 4, 5		2, 3, 4 **and** 2, 4, 5	
38	2, 3, 5 **and** 1, 3, 5		2, 3, 4 **and** 2, 4, 5	
39	1, 3, 5 **and** 1, 3, 5		1, 2, 4 **and** 3, 4, 5	
40	2, 3, 4 **and** 1, 2, 4		2, 3, 5 **and** 1, 4, 5	
41	2, 4, 5 **and** 2, 3, 5		1, 3, 5 **and** 1, 4, 5	
42	2, 4, 5 **and** 2, 3, 5		2, 3, 5 **and** 1, 4, 5	
43	2, 3, 5 **and** 2, 3, 5		1, 2, 5 **and** 1, 4, 5	

44	2, 3, 5 **and** 2, 3, 5		2, 3, 4 **and** 2, 4, 5	
45	1, 4, 5 **and** 1, 3, 4		2, 3, 4 **and** 1, 3, 5	
46	1, 4, 5 **and** 1, 2, 4		1, 3, 5 **and** 2, 4, 5	
47	2, 4, 5 **and** 1, 3, 5		1, 2, 4 **and** 1, 2, 5	
48	1, 2, 4 **and** 1, 2, 4		1, 3, 5 **and** 1, 5, 5	
49	1, 2, 4 **and** 1, 3, 4		1, 2, 5 **and** 1, 4, 5	
50	1, 3, 4 **and** 1, 3, 5		1, 3, 4 **and** 2, 4, 5	
51	2, 3, 5 **and** 2, 3, 5		2, 3, 5 **and** 1, 4, 5	
52	1, 3, 5 **and** 1, 3, 5		2, 3, 5 **and** 1, 4, 5	

53	2, 4, 5 **and** 2, 3, 5		1, 3, 5 **and** 1, 4, 5	
54	2, 3, 5 **and** 2, 3, 5		1, 3, 5 **and** 1, 4, 5	
55	2, 3, 5 **and** 2, 3, 5		1, 3, 5 **and** 2, 4, 5	
56	1, 3, 4 **and** 2, 3, 5		1, 3, 5 **and** 1, 5, 5	
57	1, 3, 5 **and** 2, 3, 5		1, 2, 5 **and** 1, 4, 5	
58	1, 3, 5 **and** 2, 2, 5		1, 3, 5 **and** 2, 4, 5	
59	1, 3, 5 **and** 2, 3, 5		1, 3, 5 **and** 1, 4, 5	
60	1, 2, 3 **and** 2, 5, 5		2, 3, 4 **and** 2, 3, 5	
61	1, 2, 4 **and** 1, 2, 5		1, 3, 4 **and** 2, 4, 5	

62	2, 5, 5 **and** 1, 3, 5		1, 2, 4 **and** 1, 4, 5	
63	2, 4, 5 **and** 1, 3, 4		1, 2, 5 **and** 2, 4, 5	
64	1, 2, 4 **and** 1, 4, 5		1, 3, 5 **and** 1, 4, 5	
65	2, 4, 5 **and** 1, 3, 4		1, 2, 4 **and** 1, 4, 5	
66	1, 5, 5 **and** 1, 3, 4		2, 5, 5 **and** 3, 4, 5	
67	2, 3, 5 **and** 2, 2, 5		2, 3, 5 **and** 1, 3, 5	
68	2, 3, 5 **and** 1, 2, 4		2, 3, 5 **and** 1, 3, 5	
69	2, 3, 5 **and** 1, 2, 4		1, 2, 4 **and** 1, 4, 5	
70	2, 3, 5 **and** 1, 2, 5		1, 3, 5 **and** 2, 4, 5	

71	**2, 3, 5 and 1, 2, 5**		**2, 3, 4 and 1, 4, 5**	
72	**2, 3, 5 and 1, 3, 5**		**1, 3, 5 and 1, 4, 5**	
73	**2, 3, 5 and 2, 3, 5**			

ANNEX 2: Questionnaire

Dear Sir or Madam,

I would like to invite you to take part in MSc research work on Risk identification and analysis in road construction projects using fuzzy logic from owners and contractors perspective.

I am aware that you are under tremendous business pressure and have very little time for attending this kind of request, but I can guarantee that you will not take more than 40 minutes from your time to answer this questionnaire.

I hope you can give your contribution to this research which is an MSc thesis that is being conducted in Addis Ababa Institute of Technology Department of Industrial Engineering. With your participation, I hope to understand, identify, explore and rank the major risk factors which cause delay and cost overrun in road construction projects.

Please refer to the questionnaire attached to this letter for details about the objective of the survey as well as instructions on answering the questionnaire

Yours Sincerely,

Kidist Girma

MSc Student AAiT

Tel No.: 0911720837

Jan 2015 - March2016

SURVEY

This survey is being undertaken by a research student from Addis Ababa Institute of Technology Department of Mechanical and Industrial Engineering, Industrial Engineering major.

The general objectives of this survey is to asses and improve the process of risk analysis techniques currently being practiced in Ethiopian road construction industries by identifying and assessing key risk factors that have high likelihood of occurrence and degree of impact on road construction projects and prioritizing them in accordance with cost contingency estimation.

The specific objectives of the research are:

- Identify major risk factors that have high frequency occurrence and assess the magnitude of the consequences of occurrence in road construction projects.
- Provide a method for gaining reliable measures for probability and impact of a risk occurring.
- Examining the risk management method efficiency that are applied in the industry by each category (contractors and owners).
- Providing practical suggestions and recommendations pointing toward upgrading the risk management process in construction and improve the performance of contracting companies and owners in this field.

There is no right or wrong answers. Your replies will be anonymous and all information provided in this questionnaire will be treated in strict confidence.

INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE:

- Only one answer is required for each question
- For questions which require an opinion, there is a grid of line to show grades of opinion. Please mark the box which most closely fits your opinion.
- **ONLY** if you do not fully understand a question or it is unclear omit and move on to the next, **OTHERWISE** please answer the best possible choice.
- The questionnaire is anonymous.
- Any information provided in this questionnaire will be treated in strict confidence.

TERMS USED IN THIS QUESTIONNAIRE (GENERAL INFORMATION)

1. Risk Management

Risk management may be described as "a systematic way of looking at areas of risk and consciously determining how each should be treated. It is a management tool that aims at identifying sources of risk and uncertainty, determining their impact, and developing appropriate management responses.

2. Risk Identification

Risk identification deals with identification of potential risks affecting the project objectives. Classification of risks helps in deciding which category of risks is to be focused more for analysis and risk response.

3. Risk Assessment

The risk assessment helps in risk management by measuring, conducting quantitatively and qualitatively in order to estimate the significance level of the industrial risk factors to the project and then to estimate of the risk of the potential factors to project success.

4. Sources of Risk Factors

I. Financial and Economic Risks

A financial risk is related to a project's failure due to a financial or economic cause. A cause of this nature is related to the funding of the project and the commercial, competition, loan, and demand issues, etc. (e.g. cost overruns, taxation, imposition of restrictions, etc.).

II. Physical/Environmental Risks

Physical risk is related to a project's failure due to natural environment such as the 'weather conditions', 'ground conditions and contaminants' or natural disaster etc.

III. Resource Risks

Resource risks are related to a project's failure due to productivity and availability of resource such as 'productivity of labor and plant', 'availability of labor and plant', and 'defective materials and material shortage'.

IV. Technical Risks

A technical risk is related to a project's failure due to a technical cause. Failure is considered as a shortfall in succeeding to meet the project's requirements. Technical cause is anything associated with the process of the project's development and operation. Therefore, the category of technical risks comprises all the aspects that may endanger project's success (e.g. material and equipment failure, deviations from designs and schedule, limited expertise of labor and personnel, etc.).

V. Personal and Managerial Risks

Personal and managerial risks are related to a project's failure due poor communication amongst project team", "lack of commitment", and "organization and co-ordination", competence of consultants and contractors", and "quality and performance control etc.

VI. Government and Political Risks

Government and political risks are related to a project's failure due "change of government" and "change of government policy" or problems related to government agencies.

VII. Safety and Security

Safety and security risks are related to a project's failure due accidents and injuries, theft on site and vandalism etc.

VIII. Environmental Regulation Risks

Environmental regulation risks are related to factors that might have an impact on the residences/community due to "waste disposal", "Pollution" or "interference form environmental protection groups" which results in project delay.

IX. Contractual and Legal Risks

A legal risk is related to a project's failure due to deficiencies in the legal and institutional framework such as "contract flaws" and "local laws" etc.

5. Likelihood of occurrence (Level of probability):

The level of probability of occurrence of risk/loss that might affects the project objectives

6. Risk Consequence (Impact)

The magnitude of the potential loss

7. Risk Allocation

Risk allocation is a means of assigning risks to the party best able to manage them. These actions are taken to lower the impact of the risk or reduce the likelihood of the risk materializing, or both of these.

Table A2: 1 Risk Likelihood Descriptors

Rating	Description	Likelihood of Occurrence
1	Rare	Highly unlikely, but it may occur in exceptional circumstances. It could happen, but probably never will.
2	Unlikely	Not expected, but there's a slight possibility it may occur at some time.
3	Possible	The event might occur at some time as there is a history of casual occurrence in similar institutions.
4	Likely	There is a strong possibility the event will occur as there is a history of frequent occurrence in similar institutions.
5	Almost Certain	Very likely. The event is expected to occur in most circumstances as there is a history of regular occurrence in similar institutions.

PART I: ORGANIZATION PROFILE

1. The position of the respondent?

   Director ☐ Project Manager ☐

   Deputy Director ☐ Site/office Engineer ☐

   Other ________________

2. Number of executed projects in the last 5 years?

   2 Projects or less ☐ 3 - 5 Projects ☐

   5 - 7 Projects ☐ 7 - 9 Projects ☐

   More than 10 Projects ☐

   Other ________________

3. Experience of the organization in road construction (Years)?

   1 year or less ☐ 1 – 3 years ☐

   3 – 5 years ☐ 5 – 10 years ☐

   More than 10 years ☐

   Other ________________

4. Work volume in the last 5 years (ETB)?

   More than 10 million ☐ 5 - 10 million ☐

   3 - Less than 5 million ☐ 500,000 - Less than 5 million ☐

   Other ________________

5. Type of contract or engineering procurement method used?

   Traditional (Lump-Sum) ☐ Design Bid Build ☐

   Design and Build ☐ Construction Management ☐

   Other ________________

6. Percentage share of the road sector in the total GDP?

   ____

7. How does the company estimate the cost contingency?

   Business as usual (10% of the total cost) ☐

   Through different risk assessment methods ☐

   Other (please specify) ____

8. Do you assess risk prior to the beginning of any project?

   Yes ☐ No ☐

9. If yes, how do you assess risks?

   ____

PART II RESPONDENT PROFILE

1. The position of the respondent

   Quantity Surveyor ☐ Project Manager ☐

   Architects ☐ Site Manager ☐

   Office Engineer ☐

   Other ________________

2. Experience and Educational Qualifications

   Education level: ______________________

   Working Experience in years (In the sector): ______________________

   Working Experience in years (In current position): ______________________

3. Professional background

   Civil/structure engineer ☐ Architect ☐

   Quantity surveyor ☐ other ________________

4. Number of executed projects participated?

   2 Projects or less ☐ 3 - 5 Projects ☐

   5 - 7 Projects ☐ 7 - 9 Projects ☐

   More than 10 Projects ☐

   Other _______________

Table A2: 2: Financial and Economic Risks

No.	Financial and Economic Risks
1	Fluctuation of inflation rate (buying power of money)
2	Currency exchange risks/Lack of currency
3	Fluctuation of interest rate
4	Increase of tax rate
5	Price escalation (Rise in fuel price, material, labor, equipment)
6	Liquidity risk/cash flow problems
7	Delay in payment to contractor
8	Change in bank formalities and regulations
9	Delay of bank in project fund allocation
10	Bankruptcy
11	Insufficient insurance amount and occurrence
12	Absence of price index

Table A2: 3 Physical/Environmental Risks

No.	Physical/Environmental Risks
1	Exceptionally adverse climatic condition
2	Difficult terrain (mountainous)
3	Remoteness/accessibility of site
4	Act of God (flood, earthquake…)
5	Geotechnical fault (contaminated soil)
6	Change in physical condition
7	Landslide

Table A2: 4 Resource Risks

No.	Resource Risks
1	Availability/shortage of skilled labor (managerial)
2	Unavailability of specialized sub-contractors
3	Availability/shortage of construction material at site (site produced)
4	Availability/shortage of material in the market (imported/processed material)

5	Shortage of equipment at site
6	Low quality of material (below standard)
7	Lack of maintenance for equipment
8	Machinery downtime due (spare parts, fuel, machine interdependence, maintenance system)
9	Low productivity of machineries
10	Wastage of material

Table A2: 5 Technical Risks

No.	Technical Risks
1	Poor judgment in estimating time and resource
2	Underestimation of quantities
3	Poor material handling on site
4	Inappropriate construction method
5	Mistakes during construction
6	Equipment frequently out of order or damaged
7	Bad preparing and approval of shop drawings
8	Inaccurate prediction of equipment production rate
9	Unclear specifications
10	Poor design (lack of design information/designer experience)
11	Delay in design work
12	Slow drawing revision and distribution
13	Frequent design changes (error and omissions in design drawings)
14	Defective workmanship and rework
15	Design complexity
16	Change in scope of work
17	Inadequate/Poor construction site survey (sub surface characterization, material identification and location, surveying
18	Poor documentations
19	Imposed unrealistic time planning due to
20	insufficient and incorrect information
21	Poor work schedule not tailored to scope of work and resource deployed
22	Insufficient supervision
23	Late internal approval process from owner
24	Construction complexity

Table A2: 6 Personal and Managerial Risks

No.	Personal and Managerial Risks
1	Poor provision of information to project participants
2	Unethical behavior/practice used by contractors and owners
3	Suspension of work by contractor
4	Low speed of decision making within each project team
5	Unrealistic project duration imposed by owners
6	Owner interference
7	Lack of personal training and management support
8	Lack of technical and managerial skill of staff
9	Inadequate contractor experience
10	Contractor un-commitment to consultants instructions
11	Low harmony between technical team of contractor and consultants which may lead to controversy
12	Poor communications and misunderstanding
13	Absence of consultant's site staff
14	Owner has no priority/urgency to complete the project
15	Antagonistic relation between owner, contractor and consultant
16	Problems arising due to clients'/owner lack of experience
17	Lack of experience on the part of the consultant's site staff; (managerial and supervisory personnel)
18	Labor problem and dispute (workers strike)
19	Absenteeism (forearm, staff)
20	Brawls (forearm, staff)
21	Unaccountability of work by consultant
22	Incompetence and lack of responsibility of site engineer, superintendent, foreman
23	Subcontractors takes job in several projects
24	Subcontractors abandon project
25	Slow site handover
26	Poor material management and planning
27	Poor equipment management and planning
28	Poor labor planning
29	Corruption and lack of respect for law
30	Protest and interference by local community
31	Unresponsive/not impartial consultant
32	High human resource turnover

Table A2: 7 Government and Political Risks

No.	Government and Political Risks
1	Slow permit approval by government agencies (excessive procedure)
2	Bureaucracy in government agencies
3	Government intervention/political
4	Changes in laws and regulations
5	Lack of cooperation from government
6	Custom and import restrictions
7	Change in priority and focus by the state
8	Delay in right of way (ROW) obstruction removal
9	Monopolistic client
10	Collusion/no free completion
11	Corruption

Table A2: 8 Safety and Security

No.	Safety and Security
1	Accident and injuries
2	Theft on site
3	Vandalism
4	Corruption and bribery
5	Epidemic/deadly diseases

Table A2: 9 Environmental Regulation Risks

No.	Environmental Regulation Risks
1	Environmental protection pressure of other groups
2	Serious noise pollution caused by construction
3	Water pollution caused by construction
4	Serious air pollution due to construction activities
5	Prosecution due to unlawful disposal of construction waste

Table A2: 10 Contractual and Legal Risks

No.	Contractual and Legal Risks
1	Contract modifications (addition of new work to the project and change in specification)
2	Mistakes and discrepancy in contract documents
3	Inappropriate type of contract used (traditional, design-build, etc.)
4	Contract flaws
5	Unfair and unreasonable stipulation or inappropriate risk allocation in contract
6	Local laws
7	Ambiguous conditions of contract (Insufficient details in contract documents)
8	Lack of clear understanding of contract document by all stakeholders
9	Legal jurisdiction of settlement of disputes
10	Prolonged court case
11	Absence of alternative dispute resolution (ADR) clauses in the contract
12	Prolonged ADR process
13	Third party delays

ANNEX 3: Organization Structure of Ethiopian Road Authority