Determining Optimum Cost Contingency for Road Construction Project Using Monte Carlo Simulation: A Case of Access Road for Housing Projects

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Abstract

Road construction project is subjected to many substantial risks which affect the project cost and time. Most of the contractors and owners of such projects handle such risks by having a reserve budget which will be used for the instance called contingency. The practices of most of the project owners and contractors in determining the actual amount of cost contingency is by arbitrarily assigning a percentage values, mostly 10% to the total cost of the project. However, this reserve budget failed to achieve the objective of handling any uncertainties occurring during the courses of the project execution. Thus, this research aimed to determine realistic project cost contingency percentage for each work package by taking ten different access road construction projects containing thirty work packages found to be common for all projects. The research used three different probability distribution functions to model the variation of unit costs from project to project. Then, these probability distribution functions are used to run a Monte Carlo simulation for estimating the probability of occurrence of cost overrun and percentage deviation. The results of the study revealed that arbitrary assignment of project cost contingency to the total project cost is not feasible and inappropriate. Moreover, the result indicates different work packages have different uncertainties and the respective cost contingency varies from 0 – 35%.

Key words: Construction; Risk and Uncertainty; Contingency Assessment; Simulation

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Author's Declaration

I hereby declare that the work which is being presented in this thesis entitle "**Determining Optimum Cost Contingency for Road Construction Project Using Monte Carlo Simulation: A Case of Access Road for Housing 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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This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

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Abbreviations

AACRA – Addis Ababa City Road Authority

BoQ – Bill of Quantity

ERA – Expected Risk Analysis

MCS – Monte Carlo Simulation

PDF – Probability Distribution Functions

AHP – Analytical Hierarchy Process

PRM – Project Risk Management

JV – Joint Ventures

RM - Risk Management

CHAPTER ONE

INTRODUCTION

1.1. Background of the research

Risk is the Possibility that an unwanted circumstance will occur that can result in some loss. According to Latham (1994) “No construction project is risk free. Risk can be managed, minimized, shared, transferred or accepted but cannot be ignored”.

Construction is exposed to more risk and uncertainty than perhaps any other industry sector (Flanagan and Norman 1993). It involves numerous stakeholders, long production durations and an open production system, entailing significant interaction between internal and external environments (BS 6079-4:2006). Such organizational and technological complexity generates enormous risks (Zou et al. 2007).

Risk Management involves identifying, assessing, and responding to project risks in order to minimize the likelihood and impact of the consequences of adverse events on the achievement of the Project Objectives (e.g. time, cost, quality, safety, etc.). Waiting for unfavorable events to occur and then reacting to them can result in panic and costly responses. Managing risk includes taking action to prevent or minimize the chances of occurrence or the impact of such unfavorable events or negative events and maximizing the probability of positive events.

The effects of the project risks are evident in terms of time and cost overrun which will deviate from the planned schedule and budget. This will result in the dissatisfaction of the client and project stakeholders with the delayed services from the project and more costs from the planned one. The cost performance of construction projects is a key success criterion for project sponsors. Cost contingency is included within a budget estimate so that the budget represents the total financial commitment for the project sponsor. Therefore, the estimation of cost contingency and its ultimate adequacy is of critical importance to projects (Baccarini, 2005).

Contingency has been defined as the amount of money or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization (PMI, 2008).

In many construction projects, the owner plans for unexpected events that may affect project cost by adding a contingency to the estimated cost. Depending on the owner's organization and level of sophistication, this contingency is calculated in various ways. One of the most simple and common methods is to consider a percent of estimated cost, such as 10%, based on previous experience with similar projects. Such an approach will not quantify the degree of confidence that the contingency will provide against cost overruns (Touran, 2003).

Contingencies are often calculated as an across-the-board percentage addition on the base estimate, typically derived from intuition, past experience and historical data. This estimating method is arbitrary and difficult to justify or defend (Thompson and Perry 1992). It is an unscientific approach and a reason why so many projects are over budget (Hartman 2000). A percentage addition results in a single-figure prediction of estimated cost which implies a degree of certainty that is not justified (Mak et al 1998). The weaknesses of the traditional percentage addition approach for calculating contingencies has led for a search for a more robust approach (Baccarini, 2005).

Thus, this thesis aims on developing a decision support system for determine the optimum contingency allocation by taking road construction project as a case.

1.2. Statement of Problem

The national development agendas are usually centered on enhancing the business environment and improving the quality of societal life through various activities. These can be achieved by improving the infrastructural development.

The government of Ethiopia is currently embarking highly on infrastructural development. Accordingly, there are various planned and ongoing projects in the country. The Gross Fixed Capital Formation of the country has ranked the first from east African countries based on the World Bank report (E Iheanacho, 2014).

Road projects has been an invariable part of human life as a provision of access to connect one part to another. And Road is essential for the growth of the country. Housing is one of the basic needs for living. Proper housing is an important need for every human being. However, the type of accommodation largely depends on the economic development of the country. House Building Construction sector is predominantly booming in developing countries where substantial urban housing development is underway. In developing countries such as Ethiopia, housing inadequacies and backlog have been increasing mainly due to galloping increase in population; growth of cities, and other social and economic factors.

Consequently, the Government of Ethiopia implement pilot housing project in the main city Addis Ababa. Depending on the income generating, Housing Project Enterprise plans different scheme like 10/90, 20/80, 40/60 and 40/60 for Diaspora.

This opportunity is covering a most of the population of Addis Ababa. Most of the sites are allocated around boundary of the city. Most of the population working area is located in the central of the city so it is essential to construct Access Roads. The Addis Ababa City Road Authority under the department of Condominium Housing Projects Road Construction Contract Administrative Directory construct this access Roads by outsource for different contractors.

However, significant number of projects are failed to achieve the planned project goal due to cost and time overrun resulted by various risk factors. The failure of the project is usually expressed through project duration and costs.

Project management institute (PMI, 2008) has forwarded nine project planning processes used during the planning stages. Among these risk, time and cost are the three processes which can be regarded as some essential factors. Thus, effective planning should foresee the possible risk factors which might affect the project and the necessary preparation in form of costs and time should be allocated.

However, most of the projects in Ethiopia failed to consider the possible risk factors and the required allocation of budget for handling these risks.(Belachew, A. S., Mengesha, W. J., & Mohammed, M. (2017). Causes of Cost Overrun in Federal Road Projects of Ethiopia in Case of Southern District. *American Journal of Civil Engineering*, *5*(1), 27-40.) Consequently, most of the contractors during the bidding stage tend to add more profit margin which will affect the competitiveness of the firm. This will also have an overall impact on the inflation of project costs and decreases the competitiveness of the sector.

Likewise, those projects with marginal profit facing risk factors without proper cost contingency will be forced to run out of budget or to be terminated.

Different studies show that most of the road construction project in Ethiopia face cost overrun. (Belachew, A. S., Mengesha, W. J., & Mohammed, M. (2017). Causes of Cost Overrun in Federal Road Projects of Ethiopia in Case of Southern District. *American Journal of Civil Engineering*, *5*(1), 27-40.)More than 80% of the road construction project involved in cost overrun in Ethiopia. Thus, the need to determine optimum costs of the project considering the different risk factors are essential. The project costs are easy to determine, however, there is no systematic techniques to determine the optimum project cost contingency which are essential to shoulder the different risk factors encountered during the project execution.

Traditionally, during the pre-contract stage of project, most of these risks are not properly identified, assess the likelihood of its occurrence, asses it impacts on project performance. Rather a 10% contingency is added to the total project cost in order to accommodate the effect of unforeseen circumstances. 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.

1.3. Research Questions

1. Is the allocated project budget being sufficient for road projects?
2. What is the optimum contingency allocated for the road construction projects?

1.4. Objective

1.4.1. General Objective

The general objective of the study is to systematically model and identify the optimum cost contingency required for road construction Projects.

1.4.2. Specific Objective

The specific objectives of the study are:

1. Establish the allocated contingency for road projects.
2. Determine an optimum contingency that can be used for road construction projects.

1.5. Methodology

The overall methodology of this research follows four stage processes. The first process is identification of the research issues which should be addressed. Next the necessary data were collected. The data were analyzed using different tools and techniques and finally the results of the finding enables to conclude and recommend for the future research and for the practitioners.

This research uses ten different projects executed by Addis Ababa City Road Authority (AACRA) to determine the cost contingency of different work item involved in a project. The cases selected for study is access road for condominium housing projects which is executed in Addis Ababa. From the projects, thirty work items are used which are common for these ten road projects.

The costs of these work item are found from ten selected projects are found to be different. Accordingly, the probability distribution functions (PDF) are developed using Arena Input Analyzer. Among the different PDF, three probability distribution functions are used (normal, triangular and uniform distribution). The results of PDF from Arena Input analyzer are used to simulate the randomly generated project costs using Monte Carlo simulation which are simulated 1000 times.

1.6. Scope

The scope of this research is on the determination of effective cost contingency required for construction project. Thus, these research uses feeder road projects constructed for Housing construction project in Addis Ababa by taking as a case and demonstrate the effective project cost contingency.

This research will consider thirty work items which are common to ten feeder road projects built for housing construction to study the variation of costs.

This study uses the data mostly obtained from the Addis Ababa City Road Authority (AACRA) by collecting bill of quantity of the projects. It will emphasize on modelling Project cost contingency. In addition, it will focus only on road projects due to the fact that huge amounts of finance from the Ethiopian economy is allocated to this sector with substantial loss incurred as a result of mismanagement.

1.7. Organization of the Study

The thesis is organized in six major chapters. The first chapter discusses about an introduction to the research project. The second chapter is the theoretical framework of the study which discuss about the concept of project risk, risk management, risk analysis technique, project contingency, and contingency allocation methods conducted by the previous study obtained from different journal and books. The research design and methodology are discussed in chapter three. The 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

LITERATURE REVIEW

2.1. Introduction

Construction projects are initiated in complex and dynamic environments resulting in circumstances of high uncertainty and risk (Adedokun et al., 2013, Hamzaoui et al., 2015, Zhen-Yu and Lin-Ling, 2008). Risk and uncertainty are inherent in all construction work no matter what the size of the project (Tah and Carr, 2000, Jha and Devaya, 2008).

Project risk can be defined as effect of uncertainties on project objectives: cost, time and project performance (Hamzaoui et al., 2015). Although size can be one of the major causes of risk, other factors carrying risk with them include complexity, speed of construction, location of the project, technology being used and familiarity with the work. The process involves various kinds of people with various ideas, experience and skills. They usually have different interests, so coordinating project goals is very difficult (Dey and Ogunlana, 2004).

The definition of risk should consider both the positive and negative effects of a project objective (Adedokun et al., 2013). Risk is also defined as a measure of the probability, severity and the exposure to all hazards of an activity (Sarkar and Panchal, 2015). Risk is closely connected to uncertainty and is a commonly used term in all kinds of contexts, but is often related to the negative outcome of a certain event (Adedokun et al., 2013). Also, Oxford Dictionary defines risk as the chance of hazard, bad consequence, loss, and so on, or risk can be defined as the chance of a negative outcome.(Fowler, H. W., & Fowler, F. G. (1931). *The concise Oxford dictionary of current English*. Рипол Классик.)

In 2009, the ISO provided a broadly applicable definition of risk in its standard (ISO 2009 a) (Purdy, G. (2010). ISO 31000: 2009—setting a new standard for risk management. *Risk Analysis: An International Journal*, *30*(6), 881-886.)as the “effect of uncertainty on objectives” in order to cover the following considerations as noted in the standard:

- An effect is a deviation from the expected that can be positive and/or negative effect.

- Objectives can have different aspects, such as financial, health and safety, and environmental goals, and can apply at different levels, such as strategic, organization-wide, project, product, and process.
- Risk is often expressed in terms of a combination of the consequences of an event, including changes in circumstances, and the associated likelihood of occurrence as provided in the commonly used definition. Providing two definitions of risk should not cause any confusion since most of the coverage in this research focuses on the adverse domain of effects, that is, using the former definition; however, readers must become familiar and comfortable with the latter, because of its broad applicability (Ayyub, 2014).

Every human endeavor involves risk; the success or failure of any venture depends crucially on how to deal with it. Risks have an evolutive and stochastic nature (Hamzaoui et al., 2015). Science and engineering increasingly progress by major projects, many of them are high risk. For years, the engineering and construction industry has had a very poor reputation for coping with risk, with many major projects failing to meet deadlines, cost targets, and specifications (Dey and Ogunlana, 2004).

Unexpected risk involves the threat of uncontrollable, unpredictable and unanticipated events, which are especially considered by the management of large-scale projects, since these unexpected risk events (Hamzaoui et al., 2015, Huang et al., 2013). These risks have a direct influence on project success. Many projects tend to exhibit cost overruns and schedule delays (Al-Momani, 1996; Mahamid, 2011). Project risks primarily comprises of schedule and cost uncertainties. These risks would result in huge time and cost overrun which would ultimately reduce the probability of successful completion of the project within stipulated time and cost frame (Sarkar, 2012).

A general tendency of estimators in construction projects was to simply add a certain percentage of the total cost of the project to the budget in the form of a contingency. Yeo (1990) warns that this conventional method of contingency allocation is in danger of being overly simplistic and too heavily dependent on an estimator's faith in his=her own experience. Therefore, a systematic approach for quantifying the risk to attain the cost, schedule, and quality objectives of any project in terms of cost is very much essential and would serve the following important purposes: (1) it assists in decision-making during the planning stage for determining the commercial viability of a project proposal; and (2) it serves as a baseline for project control later in the construction phase.

2.2. Project Risk Management

While the financial and economic crisis is present at the global level and the competition in the market is more and more aggressive, the interest in risk management increases (Kendrick, 2015). Risk management is the identification, assessment, and prioritization of risks or uncertainties followed up by minimizing, monitoring and controlling the impact of risk realities or enhancing the opportunity potential by applying coordinated and economical resources. Effective risk management enables the project for reduced costs, improves the interactions with the stakeholders and provides a solid basis for decision-making in projects, bringing important benefits, such as: reduced costs, increased engagement with stakeholders and better change management (Bodea and Purnus, 2012).

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.

Project risk management aims to identify and assess risks in order to manage them effectively (Rasool et al., 2012). It is a dynamic process along the project life whose usual stages are risk identification, risk analysis (qualitative or quantitative) and risk mitigation (Huang et al., 2013, Hamzaoui et al., 2015). The importance of using a rigorous approach along all these stages has been pointed by many authors and synthetic guidelines which usually provide a general perspective on stakes, tools and methods used in research and practice of PRM (Hamzaoui et al., 2015).

Risks have their own life cycle including latent (where the risk is invisible and unable to detect the occurrence), outbreak (early stage of occurrences and effects of risk on the project features), development (Where the occurrences of risks has affected the scope and the project features), monitoring (the extent at which the risk will impact the project is analyzed) and handling (the courses of actions are solicited) as well as a construction project, and risk management works during the entire project life cycle (Zhen-Yu and Lin-Ling, 2008).

Hertz and Thomas (1983) proposed a step-wise procedure of risk identification, measurement, evaluation, and re-evaluation. (Hayes et al., 1987), Flanagan and Norman (1993), Raftery (2003)proposed frameworks for risk management comprised of risk identification, analysis, response planning, continuous monitoring, and action planning. There exists a consensus among all RM frameworks on the indispensable need for adequate identification and assessment of risks to ensure effective implementation of the subsequent phases (Bu-Qammaz et al., 2009).

Project risk management (PRM) is crucial to the success of projects. Unexpected conditions or planning errors may lead to delays, over costs and other failures, which can undermine the successful realization of the project (Fang and Marle, 2013). Project risk management primarily deals with cost and schedule uncertainties (Sarkar and Panchal, 2015). The pressure on project delay and cost, the need for improved performance in the construction industry and increasing contractual obligations, lead to the necessity of a more effective risk management approach. Improving the risk management process is therefore a key challenge in construction projects (Hamzaoui et al., 2015).

The dynamic nature of project risks is one of the main difficulties of risk management. To take into account this problem, the risk analysis needs to evolve along the project. Project risk analysis and management defines a number of phases of risk process description based on objectives, work packages and deliverables. In this case there are nine phases: define, focus, identify, structure, ownership, estimate, evaluate, plan, and manage (Chapman, 1997). The risk management process consists of three typical phases: (1) identification; (2) analysis; and (3) treatment (Jha and Devaya, 2008). The aim is to be able, during the project processing, to update at each new event and situation (addition of information and/or change of objectives), the risk representation and assessment (Hamzaoui et al., 2015).

Using a case study approach, Bing et al. (1999) have proposed a risk management model for international construction joint ventures (JVs). The risk management process consists of three typical phases: (1) identification; (2) analysis; and (3) treatment (Jha and Devaya, 2008). Peterson et al. (2005) worked on risk and uncertainty identification, risk and uncertainty analysis and decision analysis, which according to them are all integral to any responsible and respectable risk management process (Sarkar, 2012).

Akintoye and MacLeod (1997) Studied the construction industry's perception of risk associated with its activities and the extent to which the industry uses risk analysis and management techniques with the help of a questionnaire survey of general contractors and project managers. The authors concluded that risk management is essential to construction activities in minimizing losses and enhancing profitability. Construction risk is generally perceived as events that influence project objectives of cost, time and quality.

2.3. Contingencies

The cost performance of construction projects is a key success criterion for project sponsors. Construction projects are notorious for running over budget (Hester et al., 1991, Zeitoun and Oberlender, 1993). Cost contingency is included within a budget to represent the total financial commitment for the project sponsor. Therefore, the estimation of cost contingency and its ultimate adequacy is of critical importance to projects.

There is no standard definition for contingency as (Patrascu, 1988) observes, "Contingency is probably the most misunderstood, misinterpreted and misapplied word in project execution. Contingency can and does mean different things to different people". Contingency has been defined as: "An amount of money or time (or other resources) added to the base estimated amount to (1) achieve a specific confidence level, or (2) allow for changes that experience shows will likely be required".

"The amount of money or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization"(PMI, 2008).

The key attributes of the concept of project cost contingency are:

- Reserve- Cost contingency is a reserve of money (AACE 2000).
- Risk – The need and amount for contingency reflects the existence of risk in projects (Thompson & Perry, 1992). Contingency covers for two categories of risks – known unknowns and unknown unknowns (PMI 2000, Hillson 1999).

Contingency caters for events within the defined project scope that are unforeseen (Moselhi, 1997), unexpected (Mak et al., 1998), unidentified (Levine, 1995), or undefined (Clark and Lorenzoni, 1996).

- Risk Management – There is a range of risk management strategies for risk in projects such as risk transfer, risk reduction, and financial treatments for retained risks e.g. contingency (Standards Australia 1999). So contingency is used in conjunction with other risk treatment strategies.
- Total Commitment- Cost estimates are prepared and contingencies added in order to indicate the likely total cost of the project. The inclusion of contingencies within a budget estimate means that the estimate represents the total financial commitment for a project. Project Outcomes- Contingency can have a major impact on project outcomes for a project sponsor. If contingency is too high it might encourage sloppy cost management, cause the project to be uneconomic and aborted, and lock up funds not available for other organizational activities; if too low it may be too rigid and set an unrealistic financial environment, and result in unsatisfactory performance outcomes (Dozzi, 1996).

Traditionally, cost estimates are point estimates. That is, single value estimates based on the most likely values of the cost elements. These point estimates may or may not accurately indicate the possible value of the estimate, and they certainly do not indicate the possible range of values an estimate may assume (Toakley, 1995). When estimating, the most common method of allowing for uncertainty and Risk is to add a percentage figure to the most likely estimate of the final cost of the known works. The amount added is usually called a contingency (Thompson and Perry, 1992).

Contingencies are often allowed in cost estimates. The objective of contingency allocation is to ensure that the estimated project cost is realistic and sufficient to contain any cost incurred by risks and uncertainties. However, Thompson and Perry (1992) pointed out several weaknesses of using a contingency amount:

- The percentage figure is, most likely, arbitrarily arrived at and not appropriate for the specific project.

- There is a tendency to double count risk because some estimators are inclined to include contingencies in their best estimate.
- A percentage addition still results in a single-figure prediction of estimated cost, implying a degree of certainty that is simply not justified.
- The percentage added indicates the potential for detrimental or downside risk; it does not indicate any potential for cost reduction and may therefore hide poor management of the execution of the project.
- Because the percentage allows for all risk in terms of a cost contingency, it tends to direct attention away from time, performance, and quality risks.
- It does not encourage creativity in estimating practice, al-lowing it to become routine and mundane, which can propagate oversights.

2.4. Contingency Allocation

In current practice, estimators add a large or small contingency allowance to the overall estimate to compensate for inaccuracies and risks. This allocation is based mainly on the estimator's perception of project risks. It is largely judgmental and arbitrary.

Common practice is such that a classification system is used whereby company policy dictates a class of contingency to be applied to different types of projects. This conventional method of contingency allocation may be argued to be too simplistic as it can easily reduce to a routine administrative procedure that requires little investigation and decision making by estimators and senior management.

2.5. Risk Contingency Assessment Method

Experience of many construction projects indicates poor performance in terms of achieving cost and time targets. In many of such instances, the cost and time over-runs are attributable to either unforeseen or foreseen events for which uncertainty was not suitably accommodated. Although risk and uncertainty have long been recognized in the construction industry, risk management has not been adequately practiced. Even in cases where they are practiced, their output has not been very satisfactory. This leads us to believe that the risk-management approaches taken so far have not been appropriate or do not cover risks sufficiently. This might be because of the complexity and uniqueness of construction projects, where not only does the number of risks exceed that of the other industries but where these risks vary from one construction project to the next. It is this subjectivity in assessing the riskiness of the projects that makes it difficult to adopt risk-management practices successfully. Thus, variation is accepted as an inevitable consequence of a construction project instead of taking a proactive risk-management approach. Variations are a major cause of disruption, delay, and disputes and generate significant cost impact. Variations issued during the construction period are time consuming and costly. Therefore, such variations that arise later in the project should be avoided by allocating suitable contingencies during the budget preparation stage to absorb the adverse consequences of such risks.

Two major categories of contingency can be identified for construction projects (Treasury, 1993):

- Design Contingency– this is for changes during the design process for such factors as incomplete scope definition and inaccuracy of estimating methods and data (Clark and Lorenzoni, 1996).
- Construction Contingency - this is for changes during the construction process.

Under a traditional procurement arrangement, the project sponsor procures professionals to produce the design before competitively selecting the construction contractor. A contract is signed between the project sponsor and the contractor, which typically contains a variations clause to allow for changes and provide a mechanism for determining and valuing variations. Construction contingency exists to cater for these variations allowable under the contract between the sponsor and contractor. Mak et al. (1998) state that contingency can be compared with the total approved value of contract variations to assess the accuracy of the contingency (Baccarini, 2004).

Traditionally cost estimates are deterministic i.e. point estimates for each cost element based on their most likely value (Mak et al., 1998). Contingencies are often calculated as an across-the-board percentage addition on the base estimate, typically derived from intuition, past experience and historical data. This estimating method is arbitrary and difficult to justify or defend (Thompson and Perry, 1992). It is an unscientific approach and a reason why so many projects are over budget (Hartman 2000). A percentage addition results in a single-figure prediction of estimated cost which implies a degree of certainty that is not justified. The weaknesses of the traditional percentage addition approach for calculating contingencies has led for a search for a more robust approach (Baccarini, 2005).

Another approach for determining project cost contingency is using individual risks expected value. The amount of contingency reserve can be based on the “expected value” for individual risk events. Expected value is the mean of a probability distribution of a risk. Firstly, a risk-free estimate of known scope is produced then risk events are identified and costed in terms of an average and maximum risk allowance is calculated(Baccarini, 2004). There are two types of risks:

- Fixed Risk – These are events that will either happen in total or not at all e.g. whether an additional access road will be required. If it happens, the maximum cost will be incurred; if not, then no risk will be incurred. The maximum risk allowance will be the cost if the risk eventuates, whilst the average cost = maximum cost * probability of its occurrence.
- Variable Risk – These are events that will occur but the extent is uncertain (e.g. depth of piling foundations). The maximum risk allowance, which is assumed to have a 10% chance of being exceeded, is estimated by the project team based on past experience or records (e.g. most expensive piling at the maximum length). The average risk allowance is estimated as the value that has a 50% chance of being exceeded, and may have a mathematical relationship to the maximum or estimated separately. This 50% level is chosen on the rationale that the worst values for all risks will not occur but rather there will be swings and roundabouts effects of the totality of the risk events identified.

The accuracy of contingencies was tested for completed ERA(Expected Risk Analysis) and non-ERA projects (i.e. using traditional percentage addition). It was found that the ERA-derived contingency was significantly more accurate (Baccarini, 2004).

Another method of determining the cost contingency is using method of moments. In this method, each cost item in an estimate is expressed by a probability distribution, reflecting the risk within the cost item. Each cost item distribution has its expected value and variance. The Expected values and variances for all cost items are added to arrive at the expected value and standard deviation for the total project cost. Total project cost can be assumed to follow a normal distribution based on the central limit theorem, but only if the cost items are independent. Then, using probability tables (z scores) for a normal distribution, a contingency can be derived from the probability distribution based on a desired confidence level i.e. level of probability of total project cost not being exceeded.

2.6. Risk Analysis Techniques

The cost performance of building construction projects is a key success criterion for project sponsors. Project cost performance is typically measured by comparing final cost against budget. A key component of the project budget for the construction contract is construction contingency, which caters for contract variations that arise during the implementation phase of projects. It is important for project sponsors to know the level of accuracy being achieved in estimating construction contingency. Statistical analysis of past projects provides a means for measuring the accuracy of construction contingency.

The study of Touran and Suphot (1997) proposes a probabilistic model for the calculation of project cost contingency by considering the expected number of changes and the average cost of change. The model assumes a Poisson arrival pattern for change orders and independent random variables for various change orders. The probability of cost overrun for a given contingency level is calculated.

The contingency sum, usually expressed as a percentage markup on the base estimate, is used in an attempt to allow for the unexpected. Construction and development is fraught with difficulty, and the basic notation of risk analysis is that it is useful to at least make an attempt to identify these risky items and attach some financial value to them. To determine these financial values can be use Monte Carlo simulation (MCS) Method, Expected Risk Analysis (ERA), fuzzy set theory or Expert Judgments depending on the experience of the Project Manager.

ERA (Expected Risk Analysis) is used to estimate the contingency of a project by identifying and costing risk events associated with a project. The starting point for the ERA process is a base estimate, which is an estimate of the known scope and is risk free. The contingencies as determined by the ERA process are added to the base estimate. The first step in the ERA process is to identify risks by the project team. These risk items are then categorized as either (1) fixed; or (2) variable. For each risk event, an average risk allowance and a maximum risk allowance will be calculated.

A number of systematic models have been proposed for use in the risk analysis techniques. Kangari and Riggs (1989) classified these methods into two categories: classical models, probability analysis and Monte Carlo simulation, and conceptual models, fuzzy-set analysis. It was pointed that the probability models suffer from two major limitations. Some models require detailed quantitative information, which is not normally available during the time of planning, and the applicability of such models to real project risk analysis is limited, because agencies participating in the project have a problem with making precise decisions. The problems are ill-defined and vague, and thus require subjective evaluations, which classical models cannot handle. As noted by Dey and Ogunlana (2004) there is a need for a subjective approach to project risk assessment with there being the necessary objectivity in the methodology. Analytical Hierarchy Process (AHP), developed by Wind and Saaty (1980), can be successfully used that will allow subjective as well as objective factors to be considered in the project risk analysis. Mustafa and Al-Bahar (1991) have used AHP quite effectively to determine the impacts of various risk factors on a large multi-purpose bridge construction project. Similarly, Dey et al.(1994) have illustrated the use of AHP in analyzing the risk of a petroleum pipeline construction project. Recently, the use of AHP in multi-criteria decision-making in various other fields such as GIS-application and Environmental Assessment studies indicates its flexibility and versatility. The use of AHP alone cannot complete the full work package of risk management. It can be used to the point at which the probability and severity of the risk on the project can be determined. Thereafter, a suitable method to estimate the cost risks based on the impact as determined from the risk analysis is essential. Monte Carlo analysis, simulation by random sampling, can be utilized to determine contingency by using the subjective probability of the risks.

Monte Carlo simulation is one of the powerful tools in risk analysis. Simultaneous consideration of threats and opportunities, and probability of selecting various criteria are two important properties of Monte Carlo simulation. Monte Carlo analysis is a statistical technique that could become increasingly important as a means for risk assessors to evaluate the uncertainty (Hayse, 2000). Although Monte Carlo simulation has been used since the 1940s, more powerful desktop computers have made it accessible and attractive for many new applications.

That availability has coincided with increasing dissatisfaction with the deterministic or point estimate calculations typically used in quantitative risk assessment; as a result, Monte Carlo simulation is rapidly gaining currency as the preferred method of generating probability distributions of exposure and risk (Poulter, 1998). Using Monte Carlo simulation, we obtain an unbiased and consistent point estimator (Usábel, 1998). In addition to the benefits of Monte Carlo simulation in quantitative risk analysis, there is some scarceness in this method such as inconsideration of uncertainties interactions which results in occurrence or permutations of uncertainties, that are impossible in the real world.

2.7. Past Studies corresponding with Risk Management in Ethiopia

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 2-1. Review of the academic papers reveals the risk assessment method is solely based on descriptive statistics.

Table 2-1Research related to Risk analysis on Ethiopian Construction Sector

No.	Author	Research Objectives	Factor Identification Method	Research Finding	Remarks
1	(Getachew, 2009)	-To examine whether design risks are contributory to cost and time overruns, and poor quality of works,	Document Review, Interviews with Professionals• Case study and interview • Descriptive Statistic analysis	Revealed that design risks were contributory to cost and time overrun and poor quality of works	Design-build Project delivery method allows collaborative efforts of Designers and Contractors in early phases and, therefore, lays the ground to minimize or manage the design risks by optimizing the design and construction personnel. Constructability problems which have an impact on time, cost, and quality are, therefore, better addressed with Design-Build project delivery method.
2	(Turkey Wakjira, 2011)	- To identify the extent of cost overrun - To identify the major risk factors leading to cost overrun -Its consequential effects in the Ethiopian Federal road construction sector	Literature Review, Desk Study, Questionnaire survey by using descriptive approaches for open ended questions		
3	(GETANEH, 2011)	-To identify shortfalls of the local construction conditions of contract	Questionnaire Survey, Interview and Desk Study	Performance of the local construction sector, construction management and contract	The research focuses on provisions related to Engineer's power, duty and responsibility; price adjustment; termination;

No.	Author	Research Objectives	Factor Identification Method	Research Finding	Remarks
		in Ethiopia -To find out provisions that have negative implication for the development of the sector.		administration practices do not meet the standards as stipulated in contract provisions	claim substantiation and dispute settlement procedures; conformity of selected clauses with Ethiopian law; understandability of contract forms and the practice of construction management in general and contract administration in particular.
4	(Addis, 2014)	-To identify the level of use of construction contract risk management techniques in Ethiopian building projects, -To test the level of awareness of different contractual parties involved in Ethiopian building construction projects, -To study the effect of different areas and causes of risk in meeting project objectives	Literature Review, Questionnaire Survey by random Sampling	-Indicated that most of the parties involved in the Ethiopian building construction projects have heard of the concept of risk management but lack adequate knowledge about the principles of the risk management -The common excuse given for not incorporating risk management techniques in projects was lack of awareness about their significance -The methods used to deal with risk in the Ethiopian building construction projects were found to be highly	

No.	Author	Research Objectives	Factor Identification Method	Research Finding	Remarks
				dependent on individual's judgment and past experience - Poor contract management was found to be one of the major causes of risk which has a high probability of occurrence and a high level of impact on project objectives	
5	(Getachew, 2014)	- To conduct an assessment of construction risk management practices and the use of construction insurance as a risk transfer tool in the Ethiopian Federal Road Projects.	Literature Review, Structured Questionnaire survey, Descriptive statistics method o Frequencies o Percentages o Mean scores		
6	(Temesgen, 2015)	-To identify the factors adversely affecting the objectives of AACRA road projects - To propose recommendation on how to deal with the problems	Case Study, Desk Study, interview responses from professionals from the client, consultants and contractors	- The research show that the major problem for non-achieving project objectives of AACRA roads is the slow clearance of obstructions from ROW construction limit. -There is no formal risk management entertained by any of the parties to address the issue.	- This thesis also introduces a Project Definition Rating Index (PDRI) tool which is believed by the researcher helpful to assess scope definition completeness at various stages of AACRA road pre-project planning process.

No.	Author	Research Objectives	Factor Identification Method	Research Finding	Remarks
	(Kidist, 2016)		literature review, data collection, and data analysis supported by logical discussion		

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

In order to determine the optimum cost contingency of road projects in Addis Ababa City Road Authority, this study uses desk study, document review and reviewing others study. The research design and methodology to be followed for this research are discussed as follows.

3.2. Research design

The data used for this research is obtained from the BoQ of different projects owned by AACRA. The overall approach, as described in Chapter 1 of this thesis, followed a four-stage process; having established the basis of the research, necessary data were collected, analyzed, and conclusions and recommendations were made based on the findings.

The basis of the research is established on the problem that AACRA`s project Managers faces on budget amount and due to the Work variance cost. As in Chapter 1 states to give a solution.

To attain the objective of the research, different ways are used for the research methodology. Quantitative Data are collected or simulated depending on the type and availability of data. The data are collected from Addis Ababa Housing Projects Access Road Construction Contract Administration Directory Offices. The target Population is the access roads construction projects which is conducted or supervised by AACRA.

The methods of data collections employed for the research were case study and desk study. The data is collected from AACRA. This research uses BoQ of different projects as a source of data. Common work packages are selected from different housing road access projects which are executed by different contractors for studying the unit rate variation from project to project. This research assumes execution period, project location and weather condition are the same. Thus, the costs of thirty common work packages are collected from ten different projects for the study.

The collected data has been re arranged by using Microsoft excel with in describing the work packages with its specific quantity and rate. These data are used to determine the probability distribution functions of the project costs for each work packages of the project. Arena Input Analyzer were used for determining the probability distribution functions. Three different distribution functions were used mainly normal, uniform and triangular distribution functions.

The three different probability distribution functions mentioned above are used to simulate the costs of thirty work packages using Monte Carlo Simulation. The next sections discuss the tools used for data collection and method of analysis.

3.3. Data Collection Procedure

Data collection for contingency estimation involved acquiring cost estimate or Bill of Quantities (BoQs) of the project. BoQs for the project were obtained from the Housing Road Construction Contract Administration Directory that prepared the contract and Status report. The BoQ, which contained line items or activities under each work package were further reviewed. Similar activities within the work package were combined. The aim was to produce a more concise base cost estimate that contained fewer line items for which the cost assessment had to be performed. A work book in excel was prepared based on the BoQ to define the distribution function.

Secondary data are collected from the contract Administrative office which is a Bill of Quantity of the Projects which include a variance. From this contract quantity, revised quantity and unit rate of each work item was collected. This data is helpful to estimate the contingency percentage or amount. The lists of BOQ used for this research are presented in table 3-1.

Table 3-1 Common Work packages Identified from BOQ

Pay Item No.	Description	Unit
	Bill No. 2	
	Section 200 Earthworks	
202 P4	Demolition and Removal	
202 P4.1	Plain Concrete Structures	m^3
202 P4.2	Reinforced Concrete Structures	m^3
202 P4.3	Masonry Structures	m^3
202 P4.4	Pipe culverts (Irrespective of sizes)	Lm
203 P1	Roadway Excavation	

Pay Item No.	Description	Unit
203 P1.1	Soft excavation to embankment	m^3
203 P10(a)	Borrow Excavation to Embankment with granular material min CBR 15, PI-12 & max grain size 150mm	m^3
203 P10(b)	Capping Layer Under subbase layer with maximum compacted layer 400mm (min CBR 15%) and as specified on the agreement and irrespective of the hauling distance.	m^3
204 P1.9	Rock fill under the subbase layer for swamp protection as specified on the agreement.	m^3
203P3	Cut to spoil material	
P3.1	Soft excavation to spoil including clearing and grubbing and existing pavement	m^3
P3.2	Intermediate excavation to spoil	m^3
P3.3	Hard excavation to spoil	m^3
205 P	Subgrade Preparation	
205 P1	Preparation of Cut subgrade	m2
	Bill No.3	
	Pavements	
	a. Carriageway	
301 P	Subbase	
301P1.1	Crushed Gravel Sub base	
ii)	compaction to 96% of AACRA Test S-11 Density (Compacted Layer thickness of maximum 250mm)	m^3
302 P	Base Course	
302 P1.2	Crushed Stone Base	
i)	98% of AACRA Test S-11 Density (Compacted Layer thickness of maximum 150mm)	m^3
401	Priming, Primer Sealing and Sealing	
401 P1.1	Supply and spray MC-30 Cut Back Asphalt Prime Coat (application rate 1lit/m^2)	Lit
403	Hot Laid Asphaltic Concrete Surfacing	
403 P1	Supply and apply Tack Coat (application rate 0.5lit/m2)	Lit
403 P3	Dense graded Asphalt AC in Intermediate (Binder) Course, 60mm Nominated Compacted Layer Thickness, 20mm Nominal Aggregate Size with Class 60/70 pen Bitumen	m^2

Pay Item No.	Description	Unit
403 P4	Dense graded Asphalt AC in Wearing Course, 40mm Nominated Compacted Layer Thickness, 14mm Nominal Aggregate Size with Class 60/700pen. Bitumen	m^2
	b. Side walk	
301 P	Subbase	
301P1.1	Crushed Gravel Sub base	
ii)	compaction to 96% of AACRA Test S-11 Density (Compacted Layer thickness of maximum 200mm)	m^3
	Foot Path and General Paving Works	
615 P14(a)	Foot path (Side walk) 300x300x60mm Pre-colored concrete block on Cement stabilized sand base including any jointing work (Optional for item 615 P14(b))	m^2
615 P14(b)	Foot path (Side walk) 100x100x100mm coble stone on fine (00) crushed aggregate 5cm thick base including any jointing work	m^2
	BILL No 4.1	
	DRAINS, CULVERTS and RETAINING WALLS	
601 P1.1	Excavation in soft material situated with in the following depth ranges below surface for retaining walls	
i	0m up to 1.5m	m^3
ii	From 1.5m and up to 3.0m	m^3
iii	From 3.0m and up to 4.5m	m^3
601 P2	Backfill for retaining walls	
601 P2.2	Using imported selected material	m^3
601 P4	Foundation fill consisting of	
601 P4 .1	Rock fill (*provisional sum*)	m^3
601 P4. 3	Compacted granular material (*provisional sum*)	m^3
601 P4.5	Concrete screed (C-20, 5cm thickness)	m^3
603 P1	Cast in situ concrete works for culverts and retaining walls including formwork and surface finish.	
603 P1.1	Concrete class C-25	m^3
603 P1.3	Concrete class C-40 (Provision)	m^3
604 P1	Reinforcement (Deformed Bar)	
604 P1.5	Grade 420 Reinforcement	ton
603 P1.3	Concrete class C-40 (Provision)	m^3
604 P1.5	Grade 420 Reinforcement	ton

Pay Item No.	Description	Unit
606 P16	Steel railings	m
606 P16	Steel railings	
606 P19	Drainage pipes and weep holes	
606 P19.6	100mm dia. PVC weep holes (length as per design drawings)	No
610 P1	Excavation for culverts	
610 P1.1	Excavation in soft material situated with in the following depth ranges below surface	
i	0m up to 1.5m	m^3
II	From 1.5m and up to 3.0m	m^3
610 P1.2	Extra over sub item Pay item 610 P1.1 for excavation of hard material, irrespective of depth.	m^3
610	Side Drain	
610 P1	Excavation	
610 P1	Excavation in soft material situated with in the following depth ranges below surface	
i	0m up to 1.5m	m^3
ii	From 1.5m and up to 3.0m	m^3
610 P1	Side drain	
	Excavation	
610 P1.2	Extra over sub item Pay item 610 P1.1 for excavation of hard material, irrespective of depth.	
610 P2	Backfilling for culverts	
610 P2.2	Using imported selected material	m^3
610 P3.1	RC pipe Culverts on Class A bedding	
i	1070mm (42") internal diameter RC pipe culvert on class 'B' bedding	m
ii	1220mm (48") internal diameter RC pipe culvert on class 'B' bedding	m
611 P6	Storm Water Pipes	
i	1070mm (42") internal diameter RC pipe culvert on class 'B' bedding	m
ii	1220mm (48") internal diameter RC pipe culvert on class 'B' bedding	m
602 P1.1	Excavation in soft material situated with in the following depth ranges below surface for retaining walls	
i	0m up to 1.5m	m^3
ii	From 1.5m and up to 3.0m	m^3
iii	From 3.0m and up to 4.5m	m^3
602 P2	Backfill for retaining walls	

Pay Item No.	Description	Unit
602 P2.2	Using imported selected material	m^3
602 P4	Foundation fill consisting of	
602 P4 .1	Rock fill (*provisional sum*)	m^3
602 P4. 3	Compacted granular material (*provisional sum*)	m^3
602 P4.5	Concrete screed (C-20, 5cm thickness)	m^3
604 P1	Cast in situ concrete works for culverts and retaining walls including formwork and surface finish.	
604 P1.1	Concrete class C-26	m^3
604 P1.3	Concrete class C-40 (Provision)	m^3

In addition, the reports of Addis Ababa City Road Authority (AACRA) which is Published in 2008 E.C are used to identify the different access road projects conducted. This enables the researcher to capture general information and status of the projects which is under take by the organization. From this data, it was easy to select a target Population.

3.4. Target Population

The Target Population of the survey is contract or BoQ of Addis Ababa City Road Authority Access roads which is under taken or going on and completed in the budget year of AACRA in 2008 obtained from Housing Road Construction Contract Administration Directorate.

There were ten Projects executed and completed. This research uses all the ten projects to analyze the variation of the common work packages unit rate in order to determine the project cost contingency. The projects are presented in this research anonymously.

3.5. Method of Data Analysis

In this research, to identify the project cost contingency, it was essential to identify different work item which have similar or various unit rate from one project to another. This step helps to identify the similar work item on the work break down of the projects.

Microsoft excel is used to list out the BoQ work items which contains the quantity and its unit rate for the ten projects. In order to measure or estimate a contingency it`s essential to select common work items. Thus, 30 work items are identified as a common work item for further analysis. From this for each work item define its contract quantity, revised quantity and its unit rate.

The next step will be identifying the Probabilistic distribution function of each work item by using Arena Input Analyzer.

The following criteria should be taken into account when selecting a distribution:

- It shall use a minimal number of parameters
- It shall be able to represent symmetrical and asymmetrical distributions
- It shall allow mathematical analysis

The pros/cons of the available distributions are listed below:

- Normal: is always symmetrical and does not fit with expected cost deviations
- Triangle: is best when lack of data, extremely flexible, but less precise than normal distribution and therefore fits best with criteria.
- Uniform: sometimes called “no knowledge ``distribution, as in, “we have no idea what the uncertain value will be, except that it will be between some numbers.

Now a day estimating, Contingency is more and more considered to be a “management decision” instead of an estimating issue. In this situation; Monte Carlo analysis can be used to better understand and explain the concepts of certainty and accuracy of estimates.

Monte Carlo simulation is a virtual experiment repeated hundreds, thousands even millions of times all the while generating randomized data for each repetition of that experiment. Those randomized data are then collected, organized, and analyzed to help gain a fuller understanding of your project cost contingency.

Monte Carlo sampling refers to the traditional technique for generating random or pseudo-random numbers to sample from a probability distribution. The term Monte Carlo was introduced during World War II, as a code name for the simulation of problems associated with the development of the atomic bomb. Today, Monte Carlo techniques are applied to a wide variety of complex problems involving random behavior. A wide variety of algorithms are available for generating random samples from different types of probability distributions.

Monte Carlo simulations also give an answer to the question regarding the "correct" contingency:

- Low contingency amount:
  - High probability of cost overrun
  - Driver for creative solutions
  - Probably concessions on quality/safety
- High contingency amount:
  - High probability of cost under run
  - Project is probably less feasible
  - Negative impact on cost efficiency
  - Cost under run may be used for other purposes
- Correct amount of contingency:
  - Probability of over- or under- run estimate is 50%

The above idea is the reason for identifying the probabilities in different confidence interval. therefore, it is essential determine the values at each confidence interval.

This research uses @Risk due the benefits of using @Risk due to the ability of the software to integrate with MS Project and MS Excel with native Excel functions that allow full cell referencing capabilities.

@RISK uses a technique called "simulation" to combine all uncertainties identified in a given situation. The tool enables the researcher to include all known variables, including its full range of possible values and the likelihoods of their occurrence. @RISK uses all of this information, along with the Excel model, to generate a range of possible outcomes. In effect, @RISK enables the researcher to see the full range of what could happen in a given situation.

@RISK has sophisticated capabilities for specifying and executing simulations of Excel models. The options available for controlling and executing a simulation in @RISK are among the most powerful ever available. They include:

- Monte Carlo sampling
- Any number of iterations per simulation
- Any number of simulations in a single analysis

- Animation of sampling and recalculation of the spreadsheet
- Seeding of the random number generator
- Real-time results and statistics during a simulation

CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION

4.1. Data Presentation

This research is conducted by collecting BoQ from Housing Road Construction Contract Administration Directorate office of road contracts which are on progress or completed projects. In order to determine the allocated contingency for road projects and the optimum contingency that can be used for road construction projects, 30 work Packages which are found to be common from ten projects are selected. These work packages are summarized in Table 4-1.

Table 4-1 Summarized common work packages from BOQ

No.	Description	Unit
1	Clearing and Grubbing	Ha
2	Soft excavation to embankment	m^3
3	Intermediate excavation (Provisional)	m^3
4	Hard excavation (Provisional)	m^3
5	Borrow Excavation	m^3
6	Compacted to 95% of AACRA Test S-11 Density	m^3
7	Fill Using Imported Rock (Provisional)	m^3
8	40cm thick Capping Layer	m^3
9	25 cm thick Crushed stone	m^3
10	98% of AACRA	m^3
11	supply and spray MC-30	Lit
12	Supply and spray Application of Tack Coat at 0.3 ltr per sq. m	ltr
13	Dense graded asphalt AC in intermediate (Binder) course,	m^2
14	Dense graded asphalt AC in wearing course,	m^2
15	0m up to 1.5m	m^3
16	1.5m upto 3m	m^3
17	Using imported selected material	m^3
18	Foundation Fill Consisting of Compacted Granular Material	m^3
19	Concrete class C-25	m^3
20	Concrete class C-20	m^3
21	Concrete blinding C-7	m^3
22	Grade 420 Reinforcement	kg

No.	Description	Unit
23	910mm Internal Diameter RC Storm Pipe Including Class B Bedding	Lm
24	1060mm Internal Diameter RC Storm Pipe Including Class B Bedding	Lm
25	1220mm Internal Diameter RC Storm Pipe Including Class B Bedding	Lm
26	Type ``A`` (450mm x 170mm)	Lm
27	Type ``B`` (200mm x 300mm)	Lm
28	Foot Path (side walk) 300x300x60mm	m^2
29	Grouted Pitching	m^2
30	Cement mortared Stone walls	m^3

In order to answer the research questions raised in Chapter one, the collected data for each project are presented in Appendix 2.

4.2. Input Modeling

The next process for Monte Carlo Simulation model is to define the distribution function based on the available data. The unit costs of each work package vary from project to project. Thus, a curve fitting based on the availability of the data is done using Arena Input Analyzer. This tool enables to model the probability distribution function from the available data based on the predefined functions or the function enables to select the appropriate functions based on the minimum error.

This research uses an existing unit rates for certain work package collected from different Projects. However, there are some work package where the unit rate is not defined in the project documents. The Unit rates of each work packages are indicated in table 4-2.

Table 4-2 Unit rates of work packages for ten different projects

No.	Description	Unit Rate of Projects									
		P 1	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P 7**	**P 8**	**P 9**	**P 10**
1	Clearing and Grubbing	25,000.00	135,000.00	65,000.00	100,000.00	40,153.38	50,000.00	63,398.70	63,398.70	50,000.00	70,000.00
2	Soft excavation to embankment	60.00	60.00	75.00	84.00	79.70	57.00	76.78	76.75	64.00	100.00
3	Intermediate excavation (Prov)	215.00	185.00			128.91		36.87	86.87		
4	Hard excavation (Prov)	278.00	250.00	350.00	392.12	278.17		459.95	459.95		
5	Borrow Excavation	180.00	185.00	130.00		193.59	122.00	164.59	164.59		
6	Compacted to 95% of AACRA Test S-11 Density	262.00	285.00								
7	Fill Using Imported Rock (prov)	465.00	865.00		750.00	280.02				300.00	300.00
8	40cm thick Capping Layer			150.00	192.00			176.59	176.59	149.00	115.00
9	25 cm thick Crushed stone	260.00	245.00	380.00				300.70	300.70		
10	98% of AACRA test - 11 density	450.00	500.00	430.00	400.00	411.00	390.00	384.38	484.38	465.00	425.00
11	supply and spray MC-30	55.00	55.00	43.00	30.00	48.62	40.00	54.87	54.87	43.00	45.00
12	Supply and spray	55.00	55.00	43.00	35.00	48.10	40.00	59.92	59.92	43.00	45.00
13	Dense graded asphalt AC	420.00	400.00	350.00	300.00	304.00	384.00	315.70	315.70	375.00	420.00
14	Dense graded asphalt AC	400.00	420.00	275.00	212.00	261.13	465.00	303.26	302.26	231.00	380.00
15	0m up to 1.5m			85.00			57.00	110.69	110.69		
16	1.5m up to 3m			125.00			65.00	193.70	193.70		
17	Using imported selected material			175.00			159.00	324.68	324.68		
18	Foundation Fill Consisting of Compacted Granular Material			500.00	500.00		159.00	277.75	277.75	500.00	350.00
19	Concrete class C-25	8,500.00	6,500.00	3,500.00		4,646.81				3,400.00	

No.	Description	Unit Rate of Projects									
		P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10
20	Concrete class C-20	6,200.00	3,800.00	3,200.00	3,000.00	3,923.00					3,400.00
21	Concrete blinding C-7		6,200.00			2,765.33		2,331.17	2,331.17		
22	Grade 420 Reinforcement			42.00	38.00	37.68	52.00	55.35	55.35	34.00	
23	910mm Internal Diameter RC Storm Pipe	2,430.00	5,500.00	2,800.00	3,510.00	2,565.00	2,579.00	2,813.25	2,813.25	2,900.00	
24	1060mm Internal Diameter RC Storm Pipe	3,190.00	2,950.00	3,000.00	4,485.00	3,274.31	4,700.00	4,701.03	4,701.03	4,500.00	
25	1220mm Internal Diameter RC Storm Pipe	3,950.00	7,850.00		7,215.00			5,910.79	5,910.79	4,317.08	4,600.00
26	Type ``A`` (450mm x 170mm)	350.00	350.00	300.00	180.00	578.09	578.93	445.33	445.33	247.76	250.00
27	Type ``B`` (200mm x 300mm)	250.00	270.00	250.00	287.00	269.94	158.57	158.57	158.57	168.22	360.00
28	Foot Path (side walk) 300x300x60mm	205.00	200.00	250.00	290.00		179.60			297.42	350.00
29	Grouted Pitching	850.00	850.00	350.00	400.00						
30	Cement mortared Stone walls concrete under the structure	2,500.00	1,650.00	1,400.00	1,400.00	2,009.07		2,397.09			

Some of the unit costs for indicated project work packages are missing. However, this research uses the available data obtained from AACRA contract document. Thus, this research assumes that the available data is enough to capture the cost variation of work packages obtained.

Among thirty work packages found to be common for ten projects, nine work packages have unit rates for all the projects. Among these work packages clearing and grabbing work package account for highest unit costs which ranges from 25,000.00 to 135,000.00 ETB. On the other hand, the minimum costs among this projects with complete data is supply and spray MC-30 cut back Asphalt prime coat with the costs ranges from 30.00–55.00 ETB.

The data obtained for work package Compacted to 95% of AACRA Test S-11 Density is the minimum of all, which belongs to two projects only with the unit costs of 262.00 and 285.00 ETB.

Two project work packages have nine unit rates used for developing probability distribution functions. Six project work packages have different cost rates obtained from seven projects where three of the projects have no rates indicated in the contract document. Four work packages of the project have only six data on cost rate used for the analysis purpose. Likewise, three project work packages identified as common have only five cost rates. Five project work packages have five cost rates used for the analysis.

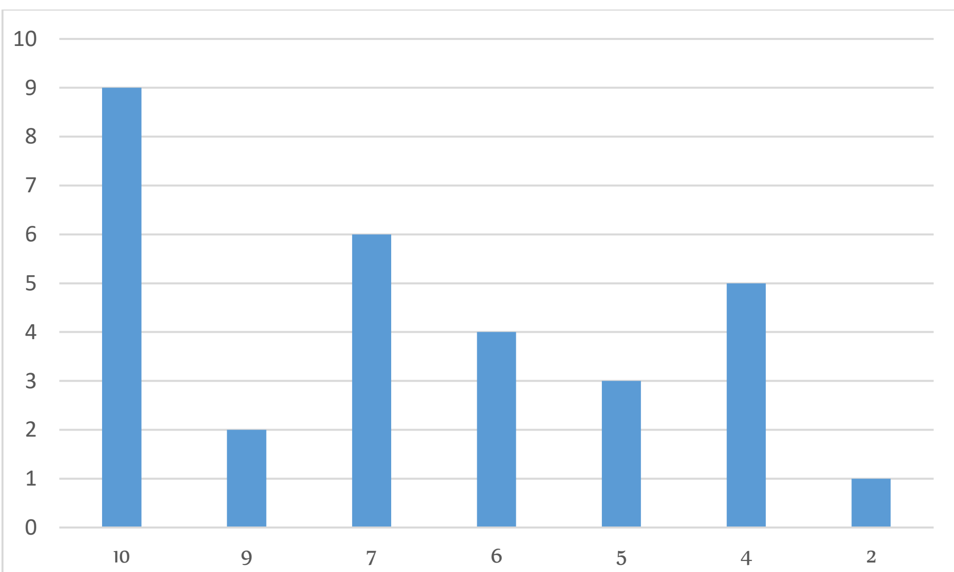

Figure 4-1Number of work packages vs data on unit rate

Once the data is purified and filtered for analysis purpose, the next is to determine the probability distribution function. The distribution function is defined by using Arena Input Analyzer by feeding the collected and summarized unit rate of the Work packages. The costs are defined in Notepad as a text file and then run it in to input Analyzer. The output of this input Analyzer specifies Types of the distribution, Functional expression, Square error, Kolmogorov-Smirnov Test (Test Statistic, corresponding P-value), Data Summary (Number of Data Point, Min and Max Data value, Sample mean and Sample standard deviation). This data is attached in the Appendix 1.

However, this research uses three probability distribution function mainly triangular, uniform and normal distribution functions. This is because triangular distribution function uses three point estimates namely, minimum, most likely and maximum, which is more practical for estimating unit costs of each work packages. Likewise, uniform distribution is suitable for two point estimates minimum and maximum, where in this research one work package have only two-point estimate. The third probability distribution function used to predict the cost contingency is normal probability distribution function due to the suitability of the function for representation of data obtained from different projects. The distribution function summery is shown in Table 4-3. which is helpful to define the distribution function in Monte Carlo simulation.

Table 4-3 Probability Distribution Functions of each work packages

Work package	**Description**	**Normal PDF**	**Triangular PDF**	**Uniform PDF**
1	Clearing and Grubbing	NORM(6.62e+004, 2.97e+004)	TRIA(2.5e+004, 3.86e+004, 1.35e+005)	UNIF(2.5e+004, 1.35e+005)
2	Soft excavation to embankment	NORM(73.3, 12.7)	TRIA(57, 61.3, 100)	UNIF(57, 100)
3	Intermediate excavation (Prov)	NORM(131, 64.5)	TRIA(36, 197, 215)	UNIF(36, 215)
4	Hard excavation(Prov)	NORM(353, 81.3)	TRIA(250, 271, 460)	UNIF(250, 460)
5	Borrow Excavation	NORM(163, 25.3)	TRIA(122, 187, 194)	UNIF(122, 194)
6	Compacted to 95% of AACRA	NORM(274, 11.5)	TRIA(262, 264, 285)	UNIF(262, 285)
7	Fill Using Imported Rock (prov)	NORM(493, 233)	TRIA(280, 335, 865)	UNIF(280, 865)
8	40cm thick Capping Layer	NORM(160, 25.2)	TRIA(115, 173, 192)	UNIF(115, 192)

Work package	Description	Normal PDF	Triangular PDF	Uniform PDF
9	25 cm thick Crushed stone	NORM(297, 46.9)	TRIA(245, 258, 380)	UNIF(245, 380)
10	98% of AACRA test - 11 density	NORM(434, 37.8)	TRIA(384, 396, 500)	UNIF(384, 500)
11	supply and spray MC-30	NORM(46.9, 7.93)	TRIA(30, 42.5, 55)	UNIF(30, 55)
12	Supply and spray	NORM(48.4, 8.2)	TRIA(35, 57.5, 60)	UNIF(35, 60)
13	Dense graded asphalt AC	NORM(358, 45.1)	TRIA(300, 312, 420)	UNIF(300, 420)
14	Dense graded asphalt AC	NORM(325, 81.5)	TRIA(212, 237, 465)	UNIF(212, 465)
15	0m up to 1.5m	NORM(90.8, 22.2)	TRIA(57, 106, 111)	UNIF(57, 111)
16	1.5m up to 3m	NORM(144, 53.7)	TRIA(65, 181, 194)	UNIF(65, 194)
17	Using imported selected material	NORM(246, 79)	TRIA(159, 176, 325)	UNIF(159, 325)
18	Foundation Fill Consisting of Compacted Granular Material	NORM(366, 127)	TRIA(159, 466, 500)	UNIF(159, 500)
19	Concrete class C-25	NORM(5.31e+003, 1.95e+003)	TRIA(3.4e+003, 3.91e+003, 8.5e+003)	UNIF(3.4e+003, 8.5e+003)
20	Concrete class C-20	NORM(3.92e+003, 1.07e+003)	TRIA(3e+003, 3.32e+003, 6.2e+003)	UNIF(3e+003, 6.2e+003)
21	Concrete blinding C-7	NORM(3.41e+003, 1.62e+003)	TRIA(2.33e+003, 2.72e+003, 6.2e+003)	UNIF(2.33e+003, 6.2e+003)
22	Grade 420 Reinforcement	NORM(44.9, 8.42)	TRIA(34, 36.2, 56)	UNIF(34, 56)
23	910mm Internal Diameter RC Storm Pipe	NORM(3.1e+003, 896)	TRIA(2.43e+003, 2.74e+003, 5.5e+003)	UNIF(2.43e+003, 5.5e+003)
24	1060mm Internal Diameter RC Storm Pipe	NORM(3.94e+003, 761)	TRIA(2.95e+003, 4.53e+003, 4.7e+003)	UNIF(2.95e+003, 4.7e+003)
25	1220mm Internal Diameter RC Storm Pipe	NORM(5.68e+003, 1.37e+003)	TRIA(3.95e+003, 4.34e+003, 7.85e+003)	UNIF(3.95e+003, 7.85e+003)
26	Type ``A`` (450mm x 170mm)	NORM(373, 130)	TRIA(180, 220, 579)	UNIF(180, 579)
27	Type ``B`` (200mm x 300mm)	NORM(233, 65.7)	TRIA(158, 178, 360)	UNIF(158, 360)

Work package	Description	Normal PDF	Triangular PDF	Uniform PDF
28	Foot Path (side walk) 300x300x60mm	NORM(253, 57.6)	TRIA(179, 196, 350)	UNIF(179, 350)
29	Grouted Pitching	NORM(613, 238)	TRIA(350, 400, 850)	UNIF(350, 850)
30	Cement mortared Stone walls	NORM(1.89e+003, 444)	TRIA(1.4e+003, 1.51e+003, 2.5e+003)	UNIF(1.4e+003, 2.5e+003)

4.3. Monte Carlo Simulation

After the probability distribution functions for each work package are defined, the next process is to run the Monte Carlo simulation. This research uses @Risk tool for Monte Carlo simulation. The respective probability distribution functions indicated in Table 4-4 are used to simulate the result. The simulation iteration is set to be 1000 times and simulation mean.

After defining the distribution function the next step is to add output which means add the current selected cell (or range of cells) as a simulation output. Once distribution functions have been entered into the spreadsheet model, the cells need to be designated for which simulation results are displayed. Typically, these output cells contain the "bottom-line" results of spreadsheet model. Then the calculation of distribution functions is set to be random in the software. In effect, the computer tries a wide range of valid combinations of the values of input variables to simulate a wide range of possible values of your output variables. Thus, different results indicating "what-if" analysis of the project costs are indicated for three different probability distribution function.

The results of the simulated mean rate revealed that the difference between the results obtained from triangular and normal distribution function is more or less insignificant unlike that of uniform distribution functions. The results of the simulated mean using three different probability distribution function is shown in table 4-4.

Table 4-4 Simulated mean rate for each work package using three different probability distribution functions

Description	Unit	Simulated Mean Rate		
		Uniform	Triangular	Normal
Clearing and Grubbing	Ha	40,839.56	66,200.00	66,200.00

Description	Unit	Simulated Mean Rate		
		Uniform	Triangular	Normal
Soft excavation to embankment	m^3	69.72	72.77	73.30
Intermediate excavation (Prov)	m^3	204.48	149.33	131.00
Hard excavation(Prov)	m^3	252.78	327.00	353.00
Borrow Excavation	m^3	164.62	167.67	163.00
Compacted	m^3	284.46	270.33	274.00
Fill Using Imported Rock (prov)	m^3	749.50	493.33	493.00
40cm thick Capping Layer	m^3	161.60	160.00	160.00
25 cm thick Crushed stone	m^3	356.34	294.33	297.00
98% of AACRA test - 11 density	m^3	426.53	426.67	434.00
supply and spray	Lit	31.85	42.50	46.90
Supply and spray	ltr	49.29	50.83	48.40
Dense graded asphalt AC in intermediate (Binder) course,	m^2	309.76	344.00	358.00
Dense graded asphalt AC in wearing course,	m^2	443.04	304.67	325.00
0m up to 1.5m	m^3	105.18	91.33	90.80
1.5m upto 3m	m^3	72.63	146.67	144.00
Using imported selected material	m^3	231.31	220.00	246.00
Foundation Fill Consisting of Compacted Granular Material	m^3	443.27	375.00	366.00
Concrete class C-25	m^3	3,612.60	5,270.00	5,310.00
Concrete class C-20	m^3	6,055.45	4,173.33	3,920.00
Concrete blinding C-7	m^3	4,066.47	3,750.00	3,410.00
Grade 420 Reinforcement	kg	46.32	42.07	44.90
910mm Internal Diameter RC Storm pipe	Lm	2,902.22	3,556.67	3,100.00
1060mm Internal Diameter RC Storm pipe	Lm	4,538.24	4,060.00	3,940.00
1220mm Internal Diameter RC Storm pipe	Lm	6,568.18	5,380.00	5,680.00
Type ``A`` (450mm x 170mm)	Lm	262.14	326.33	373.00

Description	Unit	Simulated Mean Rate		
		Uniform	Triangular	Normal
Type ``B`` (200mm x 300mm)	Lm	290.52	232.00	233.00
Foot Path (side walk) 300x300x60mm	m^2	316.59	241.67	253.00
Grouted Pitching	m^2	754.35	533.33	613.00
Cement mortared Stone walls	m^3	1,438.57	1,803.33	1,890.00

CHAPTER FIVE

RESULT AND DISCUSSION

5.1. Introduction

This chapter discuss about the result of the simulation model by defining three different distribution function namely uniform, normal and triangular distribution functions with different confidence interval.

5.1.1. Result of Confidence Interval

Monte Carlo Simulation Model were developed to quantify the impacts of the work packages on Contingency. It was performed using data of 30 Work Packages from 10 different projects. The analysis result is presented using four different confidence intervals (95%, 90%, 85% and 80%). These intervals show the range of values which is likely to contain the population parameter of interest. It shows the range of the estimates and how likely the resulting outcomes are. The percentages show how confident the values are laying on the values. This boundary is defined by selecting the cells and giving a function to the cell reference. To get the upper boundary of the interval the syntax RiskCIMean (the selected cell, the confidence level, False) are used. On the other hand, to find the lower boundary the syntax RiskCIMean (the selected cell, the confidence level, True) are used. By using this, the results of ranges of values based on different confidence interval and defined distribution function are shown in Table 5-1, Table 5-2 and Table 5-3.

Table 5-1 Confidence Interval for Uniform Distribution Function

Work package	95%		90%		85%		80%	
	Lower boundary	Upper boundary	Lower boundary	Upper boundary	Lower boundary	Upper boundary	Lower boundary	Upper boundary
1	78,028.36	81,971.38	78,345.79	81,653.94	78,552.50	81,447.24	78,711.48	81,288.26
2	77.73	79.27	77.85	79.15	77.93	79.07	78.00	79.00
3	122.29	128.71	122.81	128.19	123.14	127.85	123.40	127.60
4	351.23	358.76	351.84	358.16	352.23	357.76	352.54	357.46
5	156.71	159.29	156.92	159.08	157.05	158.95	157.16	158.84

Work package	95%		90%		85%		80%	
	Lower boundary	**Upper boundary**	**Lower boundary**	**Upper boundary**	**Lower boundary**	**Upper boundary**	**Lower boundary**	**Upper boundary**
6	273.09	273.91	273.15	273.85	273.20	273.80	273.23	273.77
7	562.02	582.99	563.71	581.30	564.81	580.20	565.65	579.36
8	152.12	154.88	152.34	154.66	152.49	154.51	152.60	154.40
9	310.08	314.92	310.47	314.53	310.72	314.28	310.92	314.08
10	439.92	444.08	440.26	443.74	440.47	443.53	440.64	443.36
11	42.05	42.95	42.12	42.88	42.17	42.83	42.21	42.79
12	47.05	47.95	47.12	47.88	47.17	47.83	47.21	47.79
13	357.85	362.15	358.20	361.80	358.42	361.58	358.59	361.41
14	333.97	343.04	334.70	342.31	335.17	341.83	335.54	341.47
15	83.03	84.97	83.19	84.81	83.29	84.71	83.37	84.63
16	127.19	131.81	127.56	131.44	127.80	131.20	127.99	131.01
17	239.02	244.97	239.50	244.49	239.81	244.18	240.05	243.94
18	323.39	335.61	324.37	334.63	325.01	333.98	325.50	333.49
19	5,858.63	6,041.44	5,873.34	6,026.72	5,882.93	6,017.14	5,890.30	6,009.77
20	4,542.67	4,657.38	4,551.91	4,648.14	4,557.92	4,642.13	4,562.55	4,637.50
21	4,195.66	4,334.38	4,206.83	4,323.21	4,214.10	4,315.94	4,219.69	4,310.35
22	44.61	45.39	44.67	45.33	44.71	45.29	44.74	45.26
23	3,909.96	4,020.00	3,918.81	4,011.14	3,924.58	4,005.37	3,929.02	4,000.93
24	3,793.65	3,856.38	3,798.70	3,851.33	3,801.99	3,848.04	3,804.52	3,845.51
25	5,830.05	5,969.84	5,841.30	5,958.59	5,848.63	5,951.26	5,854.27	5,945.62
26	372.35	386.65	373.50	385.50	374.25	384.75	374.82	384.17
27	255.38	262.62	255.96	262.04	256.34	261.66	256.63	261.37
28	261.44	267.56	261.93	267.07	262.25	266.75	262.50	266.50
29	591.03	608.96	592.48	607.51	593.42	606.57	594.14	605.85
30	1,930.30	1,969.73	1,933.47	1,966.55	1,935.54	1,964.49	1,937.13	1,962.90

Table 5-2 Confidence Interval for Normal Distribution Function

Work package	95%		90%		85%		80%	
	Lower boundary	**Upper boundary**	**Lower boundary**	**Upper boundary**	**Lower boundary**	**Upper boundary**	**Lower boundary**	**Upper boundary**
1	64,362.63	68,046.43	64,659.19	67,749.86	64,852.31	67,556.74	65,000.84	67,408.22
2	72.52	74.10	72.65	73.97	72.73	73.89	72.79	73.83
3	127.01	135.03	127.66	134.38	128.08	133.96	128.40	133.64
4	347.97	358.05	348.78	357.24	349.31	356.71	349.71	356.30
5	161.43	164.57	161.69	164.32	161.85	164.15	161.98	164.03
6	273.29	274.72	273.40	274.60	273.48	274.53	273.54	274.47
7	478.57	507.51	480.90	505.18	482.42	503.67	483.59	502.50
8	158.44	161.58	158.70	161.33	158.86	161.16	158.99	161.03
9	294.11	299.93	294.58	299.46	294.88	299.16	295.12	298.92
10	431.65	436.35	432.03	435.97	432.28	435.73	432.47	435.54
11	46.41	47.39	46.49	47.31	46.54	47.26	46.58	47.22
12	47.89	48.91	47.97	48.83	48.03	48.77	48.07	48.73
13	355.21	360.81	355.66	360.36	355.96	360.06	356.18	359.84
14	319.93	330.08	320.75	329.26	321.28	328.73	321.69	328.32
15	89.42	92.18	89.65	91.96	89.79	91.81	89.90	91.70
16	140.65	147.32	141.19	146.78	141.54	146.43	141.81	146.16
17	241.10	250.89	241.88	250.10	242.40	249.59	242.79	249.20
18	358.02	373.81	359.29	372.53	360.12	371.71	360.76	371.07
19	5,189.50	5,431.65	5,208.99	5,412.16	5,221.69	5,399.47	5,231.45	5,389.70
20	3,853.29	3,986.14	3,863.98	3,975.45	3,870.95	3,968.48	3,876.31	3,963.12
21	3,310.30	3,511.39	3,326.49	3,495.20	3,337.03	3,484.65	3,345.13	3,476.55
22	44.38	45.42	44.46	45.34	44.52	45.29	44.56	45.24
23	3,044.47	3,155.57	3,053.41	3,146.62	3,059.24	3,140.80	3,063.72	3,136.32
24	3,893.25	3,987.77	3,900.86	3,980.16	3,905.82	3,975.21	3,909.63	3,971.40
25	5,594.74	5,764.67	5,608.42	5,750.99	5,617.32	5,742.08	5,624.18	5,735.23
26	364.92	381.08	366.22	379.78	367.07	378.93	367.72	378.28
27	228.94	237.08	229.59	236.43	230.02	236.00	230.35	235.67
28	249.40	256.55	249.98	255.98	250.35	255.60	250.64	255.31
29	598.31	627.85	600.68	625.47	602.23	623.92	603.42	622.73
30	1,862.15	1,917.30	1,866.59	1,912.86	1,869.48	1,909.97	1,871.71	1,907.74

Table 5-3Confidence Interval for Triangular Distribution Function

Work package	95%		90%		85%		80%	
	Lower boundary	Upper boundary	Lower boundary	Upper boundary	Lower boundary	Upper boundary	Lower boundary	Upper boundary
1	64,682.41	67,723.01	64,927.20	67,478.22	65,086.60	67,318.83	65,209.19	67,196.23
2	72.17	73.37	72.26	73.27	72.33	73.21	72.37	73.16
3	146.84	151.83	147.24	151.43	147.50	151.17	147.70	150.97
4	324.07	329.93	324.54	329.46	324.85	329.15	325.08	328.92
5	166.66	168.67	166.82	168.51	166.92	168.40	167.01	168.32
6	270.01	270.66	270.06	270.60	270.10	270.57	270.12	270.54
7	485.14	501.52	486.46	500.20	487.32	499.34	487.98	498.68
8	158.98	161.02	159.15	160.85	159.25	160.75	159.33	160.66
9	292.45	296.23	292.75	295.92	292.95	295.73	293.11	295.57
10	425.05	428.28	425.31	428.02	425.48	427.85	425.61	427.72
11	42.18	42.82	42.23	42.77	42.27	42.73	42.29	42.71
12	50.48	51.18	50.54	51.13	50.58	51.09	50.61	51.06
13	342.32	345.67	342.59	345.40	342.77	345.23	342.90	345.09
14	301.13	308.19	301.70	307.63	302.07	307.26	302.35	306.97
15	90.58	92.09	90.70	91.97	90.78	91.89	90.84	91.83
16	144.87	148.47	145.16	148.18	145.34	147.99	145.49	147.84
17	217.68	222.31	218.05	221.94	218.30	221.70	218.48	221.51
18	370.24	379.76	371.01	379.00	371.51	378.50	371.89	378.11
19	5,198.88	5,341.29	5,210.35	5,329.83	5,217.81	5,322.36	5,223.55	5,316.62
20	4,128.65	4,217.99	4,135.84	4,210.79	4,140.52	4,206.11	4,144.13	4,202.51
21	3,696.01	3,804.02	3,704.70	3,795.32	3,710.36	3,789.66	3,714.72	3,785.31
22	41.76	42.37	41.81	42.32	41.84	42.29	41.87	42.27
23	3,513.86	3,599.54	3,520.76	3,592.65	3,525.25	3,588.15	3,528.71	3,584.70
24	4,035.57	4,084.48	4,039.50	4,080.54	4,042.07	4,077.98	4,044.04	4,076.00
25	5,325.56	5,434.44	5,334.32	5,425.67	5,340.03	5,419.96	5,344.42	5,415.57
26	320.76	331.90	321.66	331.00	322.24	330.42	322.69	329.97
27	229.18	234.82	229.63	234.36	229.93	234.07	230.15	233.84
28	239.28	244.05	239.66	243.67	239.91	243.42	240.10	243.22
29	526.35	540.31	527.47	539.18	528.21	538.45	528.77	537.89
30	1,787.95	1,818.66	1,790.42	1,816.19	1,792.03	1,814.58	1,793.27	1,813.34

5.1.2. Differences of the Confidence interval

On Uniform Distribution Function, the difference between the upper and lower confidence interval is presented in Table 5-4 to depict the range of costs between the interval. These changes value show different costs starting from 0.89 ETB up to 3,943.02 ETB on 95% confidence interval. Likewise, on 90% confidence interval it ranges from 0.69 ETB up to 3,308.15 ETB. Also, on 85% confidence interval it ranges from 0.61 ETB up to 2,894.74 ETB. and for 80% confidence interval it ranges from 0.54 ETB up to 2,576.79 ETB. Even if the values have high ranges for the work packages, its impact is varied from project to project.

On the contrary, the confidence interval of Normal Distribution Function is presented in Table 5-4 to depict the range of costs between the interval. These changes value show various costs of thirty work packages under consideration starting from 0.98 ETB up to 3683.80 ETB on 95% confidence interval. Likewise, on 90% confidence interval it ranges from 0.83 ETB up to 3,090.66 ETB. Similarly, on 85% confidence interval it ranges from 0.72 ETB up to 2,704.44 ETB. and for 80% confidence interval it ranges from 0.64 ETB up to 2,407.38 ETB. Even if the values have high ranges for the work packages, its impact is varied from project to project.

Furthermore, the difference between the upper and lower confidence interval of Triangular Distribution is presented in Table 5-4 to depict the range of costs between the interval. These changes value show variety costs starting from 0.61 ETB up to 3,040.59 ETB on 95% confidence interval. Likewise, on 90% confidence interval it ranges from 0.52 ETB up to 2,551.02 ETB. Also, on 85% confidence interval it ranges from 0.45 ETB up to 2,232.23 ETB. and for 80% confidence interval it ranges from 0.41 ETB up to 1,987.04 ETB. Even if the values have high ranges for the work packages, its impact is varied from project to project.

Generally, the range of confidence interval obtained from triangular distribution function is lesser than the uniform and normal distribution functions.

Table 5-4The Difference Between Upper and Lower Confidence Intervals

Work package	Uniform Distribution				Normal Distribution				Triangular Distribution			
	95%	**90%**	**85%**	**80%**	**95%**	**90%**	**85%**	**80%**	**95%**	**90%**	**85%**	**80%**
1	3,943.02	3,308.15	2,894.74	2,576.79	3,683.80	3,090.66	2,704.44	2,407.38	3,040.59	2,551.02	2,232.23	1,987.04
2	1.54	1.29	1.13	1.01	1.58	1.33	1.16	1.03	1.20	1.01	0.88	0.78
3	6.42	5.38	4.71	4.19	8.02	6.73	5.89	5.24	5.00	4.19	3.67	3.27
4	7.53	6.32	5.53	4.92	10.08	8.46	7.40	6.59	5.86	4.92	4.30	3.83
5	2.58	2.17	1.89	1.69	3.14	2.63	2.30	2.05	2.01	1.69	1.48	1.32
6	0.82	0.69	0.61	0.54	1.43	1.20	1.05	0.93	0.65	0.54	0.47	0.42
7	20.97	17.59	15.39	13.70	28.94	24.28	21.24	18.91	16.38	13.74	12.02	10.70
8	2.76	2.32	2.03	1.80	3.13	2.63	2.30	2.05	2.03	1.71	1.49	1.33
9	4.84	4.06	3.55	3.16	5.82	4.89	4.28	3.81	3.78	3.17	2.77	2.47
10	4.16	3.49	3.05	2.72	4.70	3.94	3.45	3.07	3.23	2.71	2.37	2.11
11	0.90	0.75	0.66	0.59	0.98	0.83	0.72	0.64	0.63	0.53	0.47	0.41
12	0.90	0.75	0.66	0.59	1.02	0.85	0.75	0.66	0.70	0.59	0.51	0.46
13	4.30	3.61	3.16	2.81	5.59	4.69	4.11	3.66	3.35	2.81	2.46	2.19
14	9.07	7.61	6.66	5.93	10.14	8.51	7.45	6.63	7.07	5.93	5.19	4.62
15	1.94	1.62	1.42	1.26	2.75	2.31	2.02	1.80	1.51	1.27	1.11	0.99
16	4.62	3.88	3.39	3.02	6.66	5.59	4.89	4.36	3.60	3.02	2.64	2.35
17	5.95	4.99	4.37	3.89	9.80	8.22	7.19	6.40	4.63	3.88	3.40	3.02
18	12.22	10.26	8.97	7.99	15.78	13.24	11.59	10.31	9.52	7.99	6.99	6.22
19	182.81	153.38	134.21	119.47	242.16	203.17	177.78	158.25	142.41	119.48	104.55	93.07
20	114.70	96.23	84.21	74.96	132.85	111.46	97.53	86.82	89.34	74.96	65.59	58.38
21	138.72	116.38	101.84	90.65	201.09	168.71	147.63	131.41	108.01	90.62	79.30	70.59
22	0.79	0.66	0.58	0.52	1.04	0.88	0.77	0.68	0.61	0.52	0.45	0.40
23	110.04	92.32	80.79	71.91	111.10	93.21	81.56	72.60	85.68	71.89	62.90	55.99
24	62.73	52.63	46.05	40.99	94.52	79.30	69.39	61.77	48.91	41.04	35.91	31.96
25	139.79	117.28	102.63	91.35	169.93	142.57	124.76	111.05	108.88	91.35	79.93	71.15
26	14.30	12.00	10.50	9.35	16.16	13.56	11.86	10.56	11.14	9.34	8.18	7.28
27	7.24	6.07	5.32	4.73	8.14	6.83	5.98	5.32	5.64	4.73	4.14	3.69
28	6.13	5.14	4.50	4.01	7.15	6.00	5.25	4.67	4.77	4.01	3.50	3.12
29	17.92	15.04	13.16	11.71	29.54	24.78	21.69	19.30	13.96	11.71	10.25	9.12
30	39.43	33.08	28.95	25.77	55.14	46.26	40.48	36.04	30.71	25.76	22.54	20.07

5.2. Estimated Contingency

The total costs of each work package are the product of unit rate and the respective quantity. Thus, the cost of the work packages is dependent on both the unit rate and the given quantity which varies from project to project. Consequently, the project cost contingency is determined by assigning the relative weights of each work package. The Contingency is obtained by normalizing the change in the Upper boundary with the Lower boundary divided by the total change in the cost. Then, the value of each work package given is the Contingency of the Work packages. Table 5-5 to Table 5-7 shows the summary of Contingency for each work package, and based on uniform, normal and triangular distribution function. The result shows that each work package has different percentage for different project. It indicates the contingency amount is diverse from work package to work package not only project to project. Moreover, the values are dependent of the type of probability distribution functions used.

The result of uniform distribution function allocate different contingency amount the result shown Table 5-5. For Project 1 the contingency estimate has a range from 0% up to 17%. Work package 3 has the highest contingency rather than others. This mean that the amount which is allocated for work package 3 is not adequate, and it requires more than the budgeted amount in 17 percent. 0 % contingency allocated work packages indicate the allocated budget is adequate therefore there is no need for any extra budget allocation. Three work packages (3, 14 and 25) required contingency more than 10%. Six work packages (1, 4, 5, 9, 11 and 27) requires equal values of cost contingency, which is 2%.

The cost contingency prediction obtained from this analysis for Project 2 also ranges from 0% up to 17%. The same work packages like that of Project one (work package 3, 14 and 25) require more than 10% contingency. The highest cost contingency is required for work package 14. Work packages requiring contingency budget between 0-5% constitute 56.7% of the total work packages. This means that these work packages require less budget allocation than the others.

A significant contingency allocation is needed for Project 3, where work package 23 requires 33%. This value is the second most significant cost contingency requirements among all projects. Nine work packages require cost contingency between 1-5%. Among thirty work packages in the project, only three of them (Work package 13, 14, and 23) have contingencies above 10%.

On Project 4 the estimated contingency is ranged from 0% up to 31%. Among these, ten work packages have contingencies between 1 – 5%. Three work packages (13, 14 and 28) requires contingencies above 10% and specifically work package 13 and 14 requires quite substantial cost contingencies 15 and 31% respectively.

On Project 5, only two work packages are greater than the traditional estimation of contingency which is 15% contingency interval. Which is work package 14 and 23 which is require 26% and 35% respectively additional add up amount. The rest of the work packages show below it some of the work packages shows it is not needed to allocate an extra amount. The most significant percentage of contingencies among all work package of different project is required by work package 23 of project 5.

Likewise, Project 6 have also two work packages which shows their result more than 11% contingency. Which are work package 14 and Work package 23 which have 23% and 26% contingency allocated respectively. Correspondingly, Project 7 have two work packages which have greater amount of contingency allocated more than 9%. This Work packages are work package 14 and work package 23 having 18% and 27% contingency respectively.

Project 8 show there are two Work packages are show more than 8% contingency allocation. These work packages are work package 14 and 23 by having 16% and 28 % contingency allocation amount. On the other hand, Project 9 shows two work packages have more than 12 % contingency allocated. The others result shows below 12%. Work package14 and 24 require 24% and 20% respectively.

Lastly, the result of Project 10 show most of the work packages have less than 12% contingency allocation. Only for two work packages for work package 14 and Work package 20 shows 23% and 25% contingency allocation respectively.

In general, the total result shows from 0% up to 35% contingency were required for the Work Packages, which means there are some work packages which have adequate budget and there are some others which need additional budgets as shown in table 5-5 using Uniform Distribution Function. However, there are few work packages with a missing data where the contingency is not computed.

Table 5-5 Summary of Contingency for each Project Work packages for Uniform Distribution

Work package	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	2%	3%	3%	3%	2%	1%	2%	2%	2%	4%
2	5%	8%	6%	2%	8%	5%	6%	7%	0%	0%
3	17%	14%			1%		4%	5%		
4	2%	1%	0%	3%	0%		4%	4%		
5	2%	0%	2%		2%	1%	3%	1%		
6	1%	1%								
7	7%	1%		0%	0%				0%	0%
8	0%		5%	6%			3%	4%	6%	10%
9	2%	3%	2%				3%	3%		
10	1%	1%	2%	4%	2%	2%	2%	2%	2%	2%
11	2%	2%	3%	3%	3%	2%	2%	2%	2%	2%
12	0%	1%	1%	1%	1%	1%	1%	0%	1%	1%
13	7%	8%	11%	15%	3%	11%	9%	8%	12%	11%
14	15%	17%	17%	31%	26%	23%	18%	16%	24%	23%
15			0%			2%	1%	1%		
16			0%			1%	2%	1%		
17			0%			1%	2%	4%		
18			0%	0%		0%	0%	0%	0%	0%
19	1%	3%	2%		1%				4%	
20	0%	2%	0%	5%	1%					25%
21		0%		0%	0%		0%	0%		
22			0%	1%	0%	2%	0%	1%	1%	
23	9%	4%	33%	1%	35%	26%	27%	28%	7%	
24	5%	8%	2%	0%	4%	4%	2%	1%	20%	
25	11%	11%		0%			2%	1%	0%	1%
26	3%	5%	9%	5%	7%	9%	6%	7%	5%	5%
27	2%	2%		5%	3%	2%	1%	2%	5%	5%
28	5%	6%	3%	10%		7%			9%	12%
29	0%	0%	0%	0%						
30	2%	2%	0%	5%	2%		0%			

On the other hand, the contingency percentage of each work packages are estimated using Normal distribution function as shown in table 5-6.

Project 1 shows the allocated contingency amount is for 28 work packages have less than 11%. Two work packages have the contingency percentage of more than 11% which are work package 3 and work package 14 having 18 % and 14 % respectively. The same work packages on project 2 show significant value like that of project 1 except the respective value have different 15% and 16 % for work package 3 and work package 14 respectively.

The results show that every project work package 14 have more than 14% contingency is allocated. Also, work package 23 show similar to work package 14 except for work package 23 for on project 1, 2, 4, 9 and 10 have less than 14% is allocated. On the other hand, the rest of the work packages on the projects have less than 14% contingency is allocated.

Table 5-6 Summary of Contingency for each Project Work packages for Normal Distribution

Work package	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	1%	2%	2%	2%	1%	1%	1%	1%	1%	3%
2	4%	7%	5%	2%	8%	4%	6%	6%	0%	0%
3	18%	15%			1%		4%	5%		
4	2%	1%	1%	4%	0%		4%	4%		
5	2%	0%	2%		2%	1%	3%	1%		
6	1%	1%								
7	8%	1%		0%	0%				0%	0%
8			5%	5%			3%	4%	5%	10%
9	2%	3%	3%				3%	3%		
10	1%	1%	2%	4%	2%	2%	2%	2%	2%	2%
11	1%	2%	2%	3%	3%	2%	2%	2%	2%	2%
12	0%	0%	1%	1%	1%	1%	1%	0%	1%	1%
13	8%	9%	13%	16%	3%	12%	10%	9%	12%	12%
14	14%	16%	17%	30%	26%	22%	18%	15%	22%	23%
15			0%			2%	1%	2%		
16			0%			1%	3%	1%		
17			1%			1%	3%	6%		
18			0%	0%		0%	0%	0%	0%	0%
19	1%	3%	2%		2%				4%	
20	0%	2%	0%	5%	1%					25%
21		0%			0%		0%	0%		
22			0%	1%	0%	3%	0%	1%	1%	

Work package	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
23	8%	3%	29%	1%	32%	23%	24%	25%	6%	
24	6%	10%	3%	0%	5%	6%	2%	2%	24%	
25	11%	11%		0%			2%	1%	0%	1%
26	3%	4%	9%	5%	7%	9%	6%	7%	5%	5%
27	2%	2%		5%	3%	2%	1%	2%	5%	5%
28	5%	6%	3%	10%		7%			9%	12%
29	0%	0%	0%	0%						
30	2%	2%	0%	6%	3%		0%			

Furthermore, triangular distribution function shows the result of the Monte Carlo simulation model to estimate contingency. From this result work package 14 needs more than 15% contingency to be allocated. And work package 23 on project 5,6,7 and 8 have greater than 25 % contingency allocated. On contrarily, the other work packages show less than 15% contingency.

Table 5-7 Summary of Contingency for each Project Work packages for Triangular Distribution

Work package	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	2%	3%	3%	3%	2%	1%	2%	2%	2%	4%
2	5%	8%	6%	2%	8%	5%	6%	7%	0%	0%
3	17%	14%			1%		4%	5%		
4	2%	1%	0%	3%	0%		4%	4%		
5	2%	0%	2%		2%	1%	3%	1%		
6	1%	1%								
7	7%	1%		0%	0%				0%	0%
8			5%	5%			3%	3%	5%	9%
9	2%	3%	2%				3%	3%		
10	1%	1%	2%	4%	2%	2%	2%	2%	2%	2%
11	1%	2%	2%	3%	2%	2%	2%	2%	2%	2%
12	0%	1%	1%	1%	1%	1%	1%	0%	1%	1%
13	7%	8%	11%	15%	3%	11%	9%	8%	12%	11%
14	15%	17%	17%	31%	26%	23%	18%	16%	25%	23%
15			0%			2%	1%	2%		
16			0%			1%	2%	1%		
17			0%			1%	2%	4%		

Work package	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
18			0%	0%		0%	0%	0%	0%	0%
19	1%	3%	2%		1%				4%	
20	0%	2%	0%	5%	1%					25%
21		0%			0%		0%	0%		
22			0%	1%	0%	2%	0%	1%	1%	
23	9%	4%	33%	1%	35%	26%	27%	28%	7%	
24	5%	8%	2%	0%	4%	4%	2%	1%	20%	
25	11%	11%		0%			2%	1%	0%	1%
26	3%	5%	9%	5%	7%	9%	6%	7%	5%	5%
27	2%	2%		5%	3%	2%	1%	2%	6%	5%
28	5%	6%	3%	10%		7%			9%	12%
29	0%	0%	0%	0%						
30	2%	2%	0%	5%	2%		0%			

In general, it can be summarized that the costs of work package 14 are uncertain and requires significant percentage of contingencies. The result indicates that; this work package requires more than 15% contingency in every distribution function. Also, work package 23 on Project 5, 6, 7 and 8 have high impact on the contingency allocation.

On the other hand, there are some work package with scores of 0% contingency allocation. It means there is no need of contingency allocation on these work packages or it doesn't have value or work package is executed on the Projects.

The results of this research has also revealed that, the works clearing and grubbing (work package 1), hard excavation (work package 4), borrow excavation to embankment with granular material (work package 5), compacted to 95% of AACRA test s-11 density (work package 6), 25 cm thick crushed stone base compaction to 96% of AACRA test s-11 density (work package 9), 98% of AACRA test - 11 density (work package 10), supply and spray MC-30 cut back asphalt prime coat (work package 11), supply and spray application of tack coat (work package 12), (work package 15), (work package 16), foundation fill consisting of compacted granular material (work package 18), concrete class C-25 (work package 19), concrete blinding C-7 (work package21), grade 420 reinforcement (work package 22) and 1060mm internal diameter RC storm pipe including class-B bedding (work package 29) the allocated contingency has to be ranged from 0 up to 5%.

Similarly, for work supply and spray application of tack coat (work package 12), foundation fill consisting of compacted granular material (work package 18), concrete blinding C-7 (work package21) and grouted pitching (work package29) can be concluded it has 0% contingency is allocated which means the allocated budget is adequate.

Furthermore, from this research findings can be concluded that, for the works soft excavation to embankment (work package 2), fill using imported rock (work package 7), 40cm thick capping layer under the subbase layer (work package 8), using imported selected material (work package 17), type “a” (450mm x 170mm) (work package 26), type “b” (200mm x 300mm) (work package 27) and cement mortared stone walls (work package 30) the allocated contingency is between 5 - 10%.

On the other hand, from this research findings can be concluded that, dense graded asphalt ac in intermediate (binder) course (work package 13), 1220mm internal diameter RC storm pipe (work package 25) and foot path (side walk) 300x300x60mm pre-colored concrete block (work package 28) the allocated contingency has to be between 10-15%.

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The allocated contingency amount for Access road project is not sufficient for all projects. However, there are some work package which have a sufficient budget allocated. Each work package has their own contingency estimation. Thus, it is not right to allocate same contingency value throughout the work packages of the Project.

This paper presents a model to estimate cost contingency for a road construction project based on Monte Carlo simulation model. It focuses on road construction project and assists in judgment of contingency amounts.

Traditionally cost contingency estimates are 5–10% from the cost estimated by considering past similar project. However, such method does not have a sound basis and is difficult to justify or defend. It is possible to say that the budget would not be sufficient to accommodate different variation of costs. According to this study, this study shows additional contingency is necessary to add up on the initial set prices.

This research used 3 different PDFs' to predict the contingency. However, the results found by using this PDF are almost similar. Thus, it can be concluded that the type of PDF used are independent of the result for the allocated contingency or budget. Moreover, this research have demonstrated that the dependent relationship between project cost contingency and volume of work package (quantity).

On the other hand, from this research findings can be concluded that, intermediate excavation (work package 3), dense graded asphalt ac in wearing course (work package 14), concrete class c-20pipe (work package 20), 910mm internal diameter rc storm pipe (work package 23) and 1060mm internal diameter RC storm pipe (work package 24) the allocated contingency has to be more than 15%.

Based on the findings this research findings can be recommended that, for the works Clearing and Grubbing (work package 1), Hard excavation (work package 4), Borrow Excavation to Embankment with granular material (work package 5), Compacted to 95% of AACRA Test S-11 Density (work package 6), 25 cm thick Crushed stone base compaction to 96% of AACRA Test S-11 density (work package 9), 98% of AACRA test - 11 density (work package 10), supply and spray MC-30 cut back Asphalt prime coat (work package 11), Supply and spray Application of Tack Coat (work package 12), (work package 15), (work package 16), Foundation Fill Consisting of Compacted Granular Material (work package 18), Concrete class C-25 (work package 19), Concrete blinding C-7 (work package21), Grade 420 Reinforcement (work package 22) and 1060mm Internal Diameter RC Storm pipe Including Class B Bedding (work package 29) the allocated contingency has to be ranged from 0 up to 5%.

Moreover, from this research findings can be recommended that, for the works Soft excavation to embankment (work package 2), Fill Using Imported Rock (work package 7), 40cm thick Capping Layer under the subbase layer (work package 8), Using imported selected material (work package 17), Type "A" (450mm x 170mm) (work package 26), Type "B`` (200mm x 300mm) (work package 27) and Cement Mortared Stone walls (work package 30) the allocated contingency has to be more than 5% and less than 10%.

And from this research findings can be recommended that, Dense graded asphalt AC in intermediate (Binder) course (work package 13), 1220mm Internal Diameter RC Storm pipe (work package 25) and Foot Path (side walk) 300x300x60mmpre- colored concrete block (work package 28) the allocated contingency has to be more than 10% and less than 15%.

Finally, from this research findings can be recommended that, Intermediate excavation (work package 3), Dense graded asphalt AC in wearing course (work package 14), Concrete class C-20pipe (work package 20), 910mm Internal Diameter RC Storm pipe (work package 23) and 1060mm Internal Diameter RC Storm pipe (work package 24) the allocated contingency has to be more than 15%.

Monte Carlo simulation technique is found to be suitable technique for determining the project cost contingency. The techniques used for determining the cost contingency of ten project can also be used to determine the other project costs.

6.2 Recommendation

Contingency budget has to be allocated independently for each work package based on the associa. Then by dividing the project on time interval to prepare report for the conception of the contingency budget. After, having the report this model is helpful to forecast the future contingency to estimate. Thus, the project will be completed within the budgeted costs and ultimately enhance project success.

Further studies for the whole work packages and on another construction projects are recommended to study the variation from project to project.

It's essential to forecast contingency for ongoing projects. Moreover, it is recommended to include the risk matrix with the corresponding work packages to effectively study the impacts of each risk on project cost and ultimately define contingency.

Based on the findings this research findings can be recommended that, for the works Clearing and Grubbing (work package 1), Hard excavation (work package 4), Borrow Excavation to Embankment with granular material (work package 5), Compacted to 95% of AACRA Test S-11 Density (work package 6), 25 cm thick Crushed stone base compaction to 96% of AACRA Test S-11 density (work package 9), 98% of AACRA test - 11 density (work package 10), supply and spray MC-30 cut back Asphalt prime coat (work package 11), Supply and spray Application of Tack Coat (work package 12), (work package 15), (work package 16), Foundation Fill Consisting of Compacted Granular Material (work package 18), Concrete class C-25 (work package 19), Concrete blinding C-7 (work package21), Grade 420 Reinforcement (work package 22) and 1060mm Internal Diameter RC Storm pipe Including Class B Bedding (work package 29) the allocated contingency has to be ranged from 0 up to 5%.

Moreover, from this research findings can be recommended that, for the works Soft excavation to embankment (work package 2), Fill Using Imported Rock (work package 7), 40cm thick Capping Layer under the subbase layer (work package 8), Using imported selected material (work package 17), Type “A” (450mm x 170mm) (work package 26), Type “B`` (200mm x 300mm) (work package 27) and Cement Mortared Stone walls (work package 30) the allocated contingency has to be more than 5% and less than 10%.

And from this research findings can be recommended that, Dense graded asphalt AC in intermediate (Binder) course (work package 13), 1220mm Internal Diameter RC Storm pipe (work package 25) and Foot Path (side walk) 300x300x60mmpre- colored concrete block (work package 28) the allocated contingency has to be more than 10% and less than 15%.

Finally, from this research findings can be recommended that, Intermediate excavation (work package 3), Dense graded asphalt AC in wearing course (work package 14), Concrete class C-20pipe (work package 20), 910mm Internal Diameter RC Storm pipe (work package 23) and 1060mm Internal Diameter RC Storm pipe (work package 24) the allocated contingency has to be more than 15%.

Bibliography

1. ADDIS, M. 2014. *A Study on Construction Contract Risk Management Practices in Ethiopian Building Construction Projects 0.* AAU.
2. ADEDOKUN, O. A., OGUNSEMI, D. R., AJE, I. O., AWODELE, O. A. & DAIRO, D. O. 2013. Evaluation of qualitative risk analysis techniques in selected large construction companies in Nigeria. *Journal of Facilities Management,* 11**,** 123-135.
3. AKINTOYE, A. S. & MACLEOD, M. J. 1997. Risk analysis and management in construction. *International journal of project management,* 15**,** 31-38.
4. AYYUB, B. M. 2014. *Risk Analysis in Engineering and Economics,* Maryland, CRC Press.
5. BACCARINI, D. Accuracy in estimating project cost construction contingency-A Statistical Analysis. Proceedings of the Construction and Building Research Conference of RICS, 2004. 7-8.
6. BACCARINI, D. Estimating project cost contingency–beyond the 10% syndrome. 2005 Australian Institute of Project Management Conference, 2005.
7. BELACHEW, A. S., MENGESHA, W. J., & MOHAMMED, M. (2017). Causes of Cost Overrun in Federal Road Projects of Ethiopia in Case of Southern District. American Journal of Civil Engineering, 5(1), 27-40.
8. BING, L., TIONG, R. L.-K., FAN, W. W. & CHEW, D. A.-S. 1999. Risk management in international construction joint ventures. *Journal of construction engineering and management,* 125**,** 277-284.
9. BODEA, C.-N. & PURNUS, A. 2012. PROJECT RISK SIMULATION METHODS - A COMPARATIVE ANALYSIS. *Management & Marketing,* 7**,** 565-580.
10. BRITISH STANDARD, B. S. 6079-4: 2006,". *Project Management–part 4: guide to the project management in construction industry*.
11. BU-QAMMAZ, A. S., DIKMEN, I. & BIRGONUL, M. T. 2009. Risk assessment of international construction projects using the analytic network process. *Canadian Journal of Civil Engineering,* 36**,** 1170-1181.
12. CHAPMAN, C. 1997. Project risk analysis and management—PRAM the generic process. *International Journal of Project Management,* 15**,** 273-281.
13. CLARK, F. & LORENZONI, A. B. 1996. *Applied cost engineering,* CRC Press.
14. DEY, P. K. & OGUNLANA, S. O. 2004. Selection and application of risk management tools and techniques for build-operate-transfer projects. *Industrial Management & Data Systems,* 104**,** 334-346.
15. DOZZI, S. 1996. Cost control of capital projects and the project cost management system requirements. *Canadian Journal of Civil Engineering,* 23**,** 311-311.
16. FANG, C. & MARLE, F. 2013. Dealing with project complexity by matrix-based propagation modelling for project risk analysis. *Journal of Engineering Design,* 24**,** 239-256.
17. FLANAGAN, R. & NORMAN, G. 1993. *Risk management and construction,* Wiley-Blackwell.
18. FOWLER, H. W., & FOWLER, F. G. (1931). *The concise Oxford dictionary of current English*. Рипол Классик
19. GETACHEW, T. 2009. *Design Risk Management In Ethiopian Federal Road Projects.* aau.
20. GETACHEW, Y. 2014. *THE PRACTICE OF CONSTRUCTION RISKS MANAGEMENT THROUGH INSURANCE IN THE ETHIOPIAN FEDERAL ROAD PROJECTS.* AAU.

21. GETANEH, G. 2011. *Assessment of Conditions of Contract Problems in Ethiopian Construction Industry.* aau.
22. HAMZAOUI, F., TAILLANDIER, F., MEHDIZADEH, R., BREYSSE, D. & ALLAL, A. 2015. Evolutive Risk Breakdown Structure for managing construction project risks: application to a railway project in Algeria. *European Journal of Environmental and Civil Engineering,* 19**,** 238-262.
23. HAYES, R. W., PERRY, J. G., THOMPSON, P. A. & WILLMER, G. 1987. *Risk management in engineering construction Implications for project managers,* United Kingdom.
24. HAYSE, J. W. 2000. Using monte carlo analysis in ecological risk assessments. *Argonne National Laboratory, USA, Oct*, 27.
25. HERTZ, D. B. & THOMAS, H. 1983. *Risk analysis and its application,* Chichester, UK, John Wiley & Sons.
26. HESTER, W., KUPRENAS, J. & CHANG, T. 1991. Construction changes and change orders, Source document 66. Construction Industry Institute, Austin, Texas.
27. HUANG, Y.-L., HUANG, P.-H. & HSIEH, C.-H. 2013. Management of unexpected project risk events by the icss and dummy garch model. *Journal of Information and Optimization Sciences,* 34**,** 261-279.
28. IHEANACHO, E. 2014. Long-run Dynamics of Economic Growth, Gross Fixed Capital Formation and Financial Sector Development: An ARDL Analysis.
29. JHA, K. N. & DEVAYA, M. N. 2008. Modelling the risks faced by Indian construction companies assessing international projects. *Construction Management and Economics,* 26**,** 337-348.
30. KANGARI, R. & RIGGS, L. S. 1989. Construction risk assessment by linguistics. *IEEE transactions on engineering management,* 36**,** 126-131.
31. KENDRICK, T. 2015. *Identifying and Managing Project Risk: Essential Tools for Failure-Proofing Your Project*, AMACOM.
32. KIDIST, G. 2016. *Risk Assessment and Contingency Allocation on Ethiopian Federal Road Projects.* AAU.
33. LATHAM, S. M. (1994). Constructing the team. Final Report the Government/Industry review of procurement and contractural arrangements in the UK Construction Industry. HMSO
34. LEVINE, H. 1995. Risk management for dummies: managing schedule, cost and technical risks and contingency. *PM Network***,** 30-32.
35. MAK, S., WONG, J. & PICKEN, D. 1998. The effect on contingency allowances of using risk analysis in capital cost estimating: a Hong Kong case study. *Construction Management & Economics,* 16**,** 615-619.
36. MOSELHI, O. 1997. Risk assessment and contingency estimating. *AACE International transactions***,** 90.
37. MUSTAFA, M. A. & AL-BAHAR, J. F. 1991. Project risk assessment using the analytic hierarchy process. *IEEE transactions on engineering management,* 38**,** 46-52.
38. PATRASCU, A. 1988. *Construction cost engineering handbook*, CRC Press.
39. PMI, A. 2008. guide to the project management body of knowledge Project Management Institute. *Newton Square, PA.*
40. POULTER, S. R. 1998. Monte Carlo simulation in environmental risk assessment--science, policy and legal issues. *Risk,* 9**,** 7.

41. PURDY, G. (2010). ISO 31000: 2009—setting a new standard for risk management. Risk Analysis: An International Journal, 30(6), 881-886.
42. RAFTERY, J. 2003. *Risk analysis in project management*, Routledge.
43. RASOOL, M., FRANCK, T., DENYS, B. & HALIDOU, N. 2012. Methodology and tools for risk evaluation in construction projects using Risk Breakdown Structure. *European Journal of Environmental and Civil Engineering,* 16**,** s78-s98.
44. SARKAR, D. 2012. Decision tree analysis for project risk mitigation options for underground metro rail project. *International Journal of Decision Sciences, Risk and Management,* 4**,** 25.
45. SARKAR, D. & PANCHAL, S. 2015. INTEGRATED INTERPRETIVE STRUCTURAL MODELING AND FUZZY APPROACH FOR PROJECT RISK MANAGEMENT OF PORTS. *International Journal of Construction Project Management,* 7**,** 17-31.
46. TAH, J. & CARR, V. 2000. A proposal for construction project risk assessment using fuzzy logic. *Construction Management & Economics,* 18**,** 491-500.
47. TEMESGEN, T. 2015. *Right of Way Risk Management of Road Construction Projects in Urban Areas, A Case Study of Addis Ababa.* AAU.
48. THOMPSON, P. & PERRY, J. G. 1992. *Engineering construction risks: A guide to project risk analysis and assessment implications for project clients and project managers,* Thomas Telford.
49. TOAKLEY, A. 1995. Risk management applications-a review. *Australian Institute of Building Papers,* 6**,** 77-85.
50. TOURAN, A. 2003. Probabilistic model for cost contingency. *Journal of construction engineering and management,* 129**,** 280-284.
51. TOURAN, A. & SUPHOT, L. 1997. Rank correlations in simulating construction costs. *Journal of Construction Engineering and Management,* 123**,** 297-301.
52. TREASURY, H. 1993. Managing risk and contingency for works projects. Guidance Note.
53. TREVINO, L. K., HARTMAN, L. P., & BROWN, M. (2000). Moral person and moral manager: How executives develop a reputation for ethical leadership. *California management review*, *42*(4), 128-142.
54. TURKEY WAKJIRA, W. 2011. *Risk Factors Leading to Cost Overrun in Ethiopian Federal Road Construction Projects & its Consequences.* AAU.
55. USÁBEL, M. A. 1998. Applications to risk theory of a Monte Carlo multiple integration method. *Insurance: Mathematics and Economics,* 23**,** 71-83.
56. WIND, Y. & SAATY, T. L. 1980. Marketing applications of the analytic hierarchy process. *Management science,* 26**,** 641-658.
57. ZEITOUN, A. A. & OBERLENDER, G. D. 1993. *Early warning signs of project changes*, Construction Industry Institute.
58. ZHEN-YU, Z. & LIN-LING, D. An integrated risk management model for construction projects. Management of Engineering & Technology, 2008. PICMET 2008. Portland International Conference on, 27-31 July 2008 2008. 1389-1394.
59. ZOU, H., HASTIE, T., & TIBSHIRANI, R. (2007). On the “degrees of freedom” of the lasso. *The Annals of Statistics*, *35*(5), 2173-2192.

Appendix 1

Data Summary of Probability Distribution Functions

A. Normal Distribution Function

1. Distribution Summary

Expression:

NORM(6.62e+004, 2.97e+004)

Square Error: 0.080087

Kolmogorov-Smirnov Test

Test Statistic = 0.332

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 2.5e+004

Max Data Value = 1.35e+005

Sample Mean = 6.62e+004

Sample Std Dev = 3.13e+004

Histogram Summary

Histogram Range = 2.5e+004 to 1.35e+005

Number of Intervals = 5

2. Distribution Summary

Distribution: Normal

Expression:

NORM(73.3, 12.7)

Square Error: 0.145911

Kolmogorov-Smirnov Test

Test Statistic = 0.249

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 57

Max Data Value = 100

Sample Mean = 73.3

Sample Std Dev = 13.3

Histogram Summary

Histogram Range = 57 to 100

Number of Intervals = 5

3. Distribution Summary

Distribution: Normal

Expression:

NORM(131, 64.5)

Square Error: 0.120020

Kolmogorov-Smirnov Test

Test Statistic = 0.199

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 36.9

Max Data Value = 215

Sample Mean = 131

Sample Std Dev = 72.1

Histogram Summary

Histogram Range = 36 to 215

Number of Intervals = 5

4. Distribution Summary

Distribution: Normal

Expression:

NORM(353, 81.3)

Square Error: 0.158563

Kolmogorov-Smirnov Test

Test Statistic = 0.352

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 250

Max Data Value = 460

Sample Mean = 353

Sample Std Dev = 87.8

Histogram Summary

Histogram Range = 250 to 460

Number of Intervals = 5

5. Distribution Summary

Distribution: Normal

Expression:

NORM(163, 25.3)

Square Error: 0.193562

Kolmogorov-Smirnov Test

Test Statistic = 0.236

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 122

Max Data Value = 194

Sample Mean = 163

Sample Std Dev = 27.3

Histogram Summary

Histogram Range = 122 to 194

Number of Intervals = 5

6. Distribution Summary

Distribution: Normal

Expression:

NORM(274, 11.5)

Square Error: 0.363580

Kolmogorov-Smirnov Test

Test Statistic = 0.5

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 2

Min Data Value = 262

Max Data Value = 285

Sample Mean = 274

Sample Std Dev = 16.3

Histogram Summary

Histogram Range = 262 to 285

Number of Intervals = 5

7. Distribution Summary

Distribution: Normal

Expression:

NORM(493, 233)

Square Error: 0.234674

Kolmogorov-Smirnov Test

Test Statistic = 0.333

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6

Min Data Value = 280

Max Data Value = 865

Sample Mean = 493

Sample Std Dev = 255

Histogram Summary

Histogram Range = 280 to 865

Number of Intervals = 5

8. Distribution Summary

Distribution: Normal

Expression: NORM(160, 25.2)

Square Error: 0.056872

Kolmogorov-Smirnov Test

Test Statistic = 0.209

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6

Min Data Value = 115

Max Data Value = 192

Sample Mean = 160

Sample Std Dev = 27.6

Histogram Summary

Histogram Range = 115 to 192

Number of Intervals = 5

9. Distribution Summary

Distribution: Normal

Expression: NORM(297, 46.9)

Square Error: 0.176934

Kolmogorov-Smirnov Test

Test Statistic = 0.319

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 245

Max Data Value = 380

Sample Mean = 297

Sample Std Dev = 52.4

Histogram Summary

Histogram Range = 245 to 380

Number of Intervals = 5

10. Distribution Summary

Distribution: Normal

Expression: NORM(434, 37.8)

Square Error: 0.065852

Kolmogorov-Smirnov Test

Test Statistic = 0.142

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 384

Max Data Value = 500

Sample Mean = 434

Sample Std Dev = 39.8

Histogram Summary

Histogram Range = 384 to 500

Number of Intervals = 5

11. Distribution Summary

Distribution: Normal

Expression: NORM(46.9, 7.93)

Square Error: 0.116743

Kolmogorov-Smirnov Test

Test Statistic = 0.232

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 30

Max Data Value = 55

Sample Mean = 46.9

Sample Std Dev = 8.36

Histogram Summary

Histogram Range = 30 to 55

Number of Intervals = 5

12. Distribution Summary

Distribution: Normal

Expression: NORM(48.4, 8.2)

Square Error: 0.131292

Kolmogorov-Smirnov Test

Test Statistic = 0.212

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 35

Max Data Value = 59.9

Sample Mean = 48.4

Sample Std Dev = 8.65

Histogram Summary

Histogram Range = 35 to 60

Number of Intervals = 5

13. Distribution Summary

Distribution: Normal

Expression: NORM(358, 45.1)

Square Error: 0.156381

Kolmogorov-Smirnov Test

Test Statistic = 0.226

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 300

Max Data Value = 420

Sample Mean = 358

Sample Std Dev = 47.5

Histogram Summary

Histogram Range = 300 to 420

Number of Intervals = 5

14. Distribution Summary

Distribution: Normal

Expression: NORM(325, 81.5)

Square Error: 0.101751

Kolmogorov-Smirnov Test

Test Statistic = 0.288

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 212

Max Data Value = 465

Sample Mean = 325

Sample Std Dev = 85.9

Histogram Summary

Histogram Range = 212 to 465
Number of Intervals = 5

15. Distribution Summary

Distribution: Normal
Expression: NORM(90.8, 22.2)
Square Error: 0.206240
Kolmogorov-Smirnov Test
Test Statistic = 0.251
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 4
Min Data Value = 57
Max Data Value = 111
Sample Mean = 90.8
Sample Std Dev = 25.6

Histogram Summary
Histogram Range = 57 to 111
Number of Intervals = 5

16. Distribution Summary

Distribution: Normal
Expression: NORM(144, 53.7)
Square Error: 0.207264
Kolmogorov-Smirnov Test
Test Statistic = 0.251
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 4
Min Data Value = 65
Max Data Value = 194
Sample Mean = 144
Sample Std Dev = 62

Histogram Summary
Histogram Range = 65 to 194
Number of Intervals = 5

17. Distribution Summary

Distribution: Normal
Expression: NORM(246, 79)
Square Error: 0.366780
Kolmogorov-Smirnov Test
Test Statistic = 0.451
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 4
Min Data Value = 159
Max Data Value = 325
Sample Mean = 246
Sample Std Dev = 91.3

Histogram Summary
Histogram Range = 159 to 325
Number of Intervals = 5

18. Distribution Summary

Distribution: Normal
Expression: NORM(366, 127)
Square Error: 0.141096
Kolmogorov-Smirnov Test
Test Statistic = 0.232
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 7
Min Data Value = 159

Max Data Value = 500

Sample Mean = 366

Sample Std Dev = 137

Histogram Summary

Histogram Range = 159 to 500

Number of Intervals = 5

19. Distribution Summary

Distribution: Normal

Expression: NORM(5.31e+003, 1.95e+003)

Square Error: 0.112771

Kolmogorov-Smirnov Test

Test Statistic = 0.397

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 3.4e+003

Max Data Value = 8.5e+003

Sample Mean = 5.31e+003

Sample Std Dev = 2.18e+003

Histogram Summary

Histogram Range = 3.4e+003 to 8.5e+003

Number of Intervals = 5

20. Distribution Summary

Distribution: Normal

Expression: NORM(3.92e+003, 1.07e+003)

Square Error: 0.163029

Kolmogorov-Smirnov Test

Test Statistic = 0.527

Corresponding p-value = 0.046

Data Summary

Number of Data Points = 6

Min Data Value = 3e+003

Max Data Value = 6.2e+003

Sample Mean = 3.92e+003

Sample Std Dev = 1.17e+003

Histogram Summary

Histogram Range = 3e+003 to 6.2e+003

Number of Intervals = 5

21. Distribution Summary

Distribution: Normal

Expression: NORM(3.41e+003, 1.62e+003)

Square Error: 0.443629

Kolmogorov-Smirnov Test

Test Statistic = 0.657

Corresponding p-value = 0.0353

Data Summary

Number of Data Points = 4

Min Data Value = 2.33e+003

Max Data Value = 6.2e+003

Sample Mean = 3.41e+003

Sample Std Dev = 1.87e+003

Histogram Summary

Histogram Range = 2.33e+003 to 6.2e+003

Number of Intervals = 5

22. Distribution Summary

Distribution: Normal

Expression: NORM(44.9, 8.42)

Square Error: 0.265607

Kolmogorov-Smirnov Test

Test Statistic = 0.271

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 34

Max Data Value = 55.4

Sample Mean = 44.9

Sample Std Dev = 9.09

Histogram Summary

Histogram Range = 34 to 56

Number of Intervals = 5

23. Distribution Summary

Distribution: Normal

Expression: NORM(3.1e+003, 896)

Square Error: 0.345786

Kolmogorov-Smirnov Test

Test Statistic = 0.594

Corresponding p-value < 0.01

Data Summary

Number of Data Points = 9

Min Data Value = 2.43e+003

Max Data Value = 5.5e+003

Sample Mean = 3.1e+003

Sample Std Dev = 951

Histogram Summary

Histogram Range = 2.43e+003 to 5.5e+003

Number of Intervals = 5

24. Distribution Summary

Distribution: Normal

Expression: NORM(3.94e+003, 761)

Square Error: 0.377537

Kolmogorov-Smirnov Test

Test Statistic = 0.351

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 9

Min Data Value = 2.95e+003

Max Data Value = 4.7e+003

Sample Mean = 3.94e+003

Sample Std Dev = 807

Histogram Summary

Histogram Range = 2.95e+003 to 4.7e+003

Number of Intervals = 5

25. Distribution Summary

Distribution: Normal

Expression: NORM(5.68e+003, 1.37e+003)

Square Error: 0.194455

Kolmogorov-Smirnov Test

Test Statistic = 0.317

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 3.95e+003

Max Data Value = 7.85e+003

Sample Mean = 5.68e+003

Sample Std Dev = 1.48e+003

Histogram Summary

Histogram Range = 3.95e+003 to 7.85e+003

Number of Intervals = 5

26. Distribution Summary

Distribution: Normal

Expression: NORM(373, 130)

Square Error: 0.052502

Kolmogorov-Smirnov Test

Test Statistic = 0.196

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 180

Max Data Value = 579

Sample Mean = 373

Sample Std Dev = 137

Histogram Summary

Histogram Range = 180 to 579

Number of Intervals = 5

27. Distribution Summary

Distribution: Normal

Expression: NORM(233, 65.7)

Square Error: 0.141830

Kolmogorov-Smirnov Test

Test Statistic = 0.24

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 159

Max Data Value = 360

Sample Mean = 233

Sample Std Dev = 69.3

Histogram Summary

Histogram Range = 158 to 360

Number of Intervals = 5

28. Distribution Summary

Distribution: Normal

Expression: NORM(253, 57.6)

Square Error: 0.149991

Kolmogorov-Smirnov Test

Test Statistic = 0.229

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 180

Max Data Value = 350

Sample Mean = 253

Sample Std Dev = 62.3

Histogram Summary

Histogram Range = 179 to 350

Number of Intervals = 5

29. Distribution Summary

Distribution: Normal

Expression: NORM(613, 238)

Square Error: 0.366751

Kolmogorov-Smirnov Test

Test Statistic = 0.447

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 4

Min Data Value = 350

Max Data Value = 850

Sample Mean = 613

Sample Std Dev = 275

Histogram Summary

Histogram Range = 350 to 850

Number of Intervals = 5

30. Distribution Summary

Distribution: Normal

Expression: NORM(1.89e+003, 444)

Square Error: 0.117887

Kolmogorov-Smirnov Test

Test Statistic = 0.341

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6

Min Data Value = 1.4e+003

Max Data Value = 2.5e+003

Sample Mean = 1.89e+003

Sample Std Dev = 486

Histogram Summary

Histogram Range = 1.4e+003 to 2.5e+003

Number of Intervals = 5

B. Triangular Distribution Function

1. Distribution Summary

Expression: TRIA(2.5e+004, 3.86e+004, 1.35e+005)

Square Error: 0.058220

Kolmogorov-Smirnov Test

Test Statistic = 0.198

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 2.5e+004

Max Data Value = 1.35e+005

Sample Mean = 6.62e+004

Sample Std Dev = 3.13e+004

Histogram Summary

Histogram Range = 2.5e+004 to 1.35e+005

Number of Intervals = 5

2. Distribution Summary

Distribution: Triangular

Expression: TRIA(57, 61.3, 100)

Square Error: 0.144938

Kolmogorov-Smirnov Test

Test Statistic = 0.224

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 57

Max Data Value = 100

Sample Mean = 73.3

Sample Std Dev = 13.3

Histogram Summary

Histogram Range = 57 to 100

Number of Intervals = 5

3. Distribution Summary

Distribution: Triangular

Expression: TRIA(36, 197, 215)

Square Error: 0.138272

Kolmogorov-Smirnov Test

Test Statistic = 0.31

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 36.9

Max Data Value = 215

Sample Mean = 131

Sample Std Dev = 72.1

Histogram Summary

Histogram Range = 36 to 215

Number of Intervals = 5

4. Distribution Summary

Distribution: Triangular

Expression: TRIA(250, 271, 460)

Square Error: 0.180902

Kolmogorov-Smirnov Test

Test Statistic = 0.312

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 250

Max Data Value = 460

Sample Mean = 353

Sample Std Dev = 87.8

Histogram Summary

Histogram Range = 250 to 460

Number of Intervals = 5

5. Distribution Summary

Distribution: Triangular

Expression: TRIA(122, 187, 194)

Square Error: 0.196321

Kolmogorov-Smirnov Test

Test Statistic = 0.272

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 122

Max Data Value = 194

Sample Mean = 163

Sample Std Dev = 27.3

Histogram Summary
Histogram Range = 122 to 194
Number of Intervals = 5

6. Distribution Summary
Distribution: Triangular
Expression: TRIA(262, 264, 285)
Square Error: 0.416049

Kolmogorov-Smirnov Test
Test Statistic = 0.5
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 2
Min Data Value = 262
Max Data Value = 285
Sample Mean = 274
Sample Std Dev = 16.3

Histogram Summary
Histogram Range = 262 to 285
Number of Intervals = 5

7. Distribution Summary
Distribution: Triangular
Expression: TRIA(280, 335, 865)
Square Error: 0.212793
Kolmogorov-Smirnov Test
Test Statistic = 0.321
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 6
Min Data Value = 280
Max Data Value = 865
Sample Mean = 493
Sample Std Dev = 255

Histogram Summary
Histogram Range = 280 to 865
Number of Intervals = 5

8. Distribution Summary
Distribution: Triangular
Expression: TRIA(115, 173, 192)
Square Error: 0.043674
Kolmogorov-Smirnov Test
Test Statistic = 0.341
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 6
Min Data Value = 115
Max Data Value = 192
Sample Mean = 160
Sample Std Dev = 27.6

Histogram Summary
Histogram Range = 115 to 192
Number of Intervals = 5

9. Distribution Summary
Distribution: Triangular
Expression: TRIA(245, 258, 380)
Square Error: 0.182716
Kolmogorov-Smirnov Test
Test Statistic = 0.278
Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 245

Max Data Value = 380

Sample Mean = 297

Sample Std Dev = 52.4

Histogram Summary

Histogram Range = 245 to 380

Number of Intervals = 5

10. Distribution Summary

Distribution: Triangular

Expression: TRIA(384, 396, 500)

Square Error: 0.040494

Kolmogorov-Smirnov Test

Test Statistic = 0.199

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 384

Max Data Value = 500

Sample Mean = 434

Sample Std Dev = 39.8

Histogram Summary

Histogram Range = 384 to 500

Number of Intervals = 5

11. Distribution Summary

Distribution: Triangular

Expression: TRIA(30, 42.5, 55)

Square Error: 0.181600

Kolmogorov-Smirnov Test

Test Statistic = 0.4

Corresponding p-value = 0.0617

Data Summary

Number of Data Points = 10

Min Data Value = 30

Max Data Value = 55

Sample Mean = 46.9

Sample Std Dev = 8.36

Histogram Summary

Histogram Range = 30 to 55

Number of Intervals = 5

12. Distribution Summary

Distribution: Triangular

Expression: TRIA(35, 57.5, 60)

Square Error: 0.140494

Kolmogorov-Smirnov Test

Test Statistic = 0.322

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 35

Max Data Value = 59.9

Sample Mean = 48.4

Sample Std Dev = 8.65

Histogram Summary

Histogram Range = 35 to 60

Number of Intervals = 5

13. Distribution Summary

Distribution: Triangular

Expression: TRIA(300, 312, 420)

Square Error: 0.193827
Kolmogorov-Smirnov Test
Test Statistic = 0.344
Corresponding p-value = 0.149
Data Summary
Number of Data Points = 10
Min Data Value = 300
Max Data Value = 420
Sample Mean = 358
Sample Std Dev = 47.5
Histogram Summary
Histogram Range = 300 to 420
Number of Intervals = 5

14. Distribution Summary
Distribution: Triangular
Expression: TRIA(212, 237, 465)
Square Error: 0.078272
Kolmogorov-Smirnov Test
Test Statistic = 0.275
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 10
Min Data Value = 212
Max Data Value = 465
Sample Mean = 325
Sample Std Dev = 85.9
Histogram Summary
Histogram Range = 212 to 465
Number of Intervals = 5

15. Distribution Summary
Distribution: Triangular
Expression: TRIA(57, 106, 111)
Square Error: 0.202160
Kolmogorov-Smirnov Test
Test Statistic = 0.5
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 4
Min Data Value = 57
Max Data Value = 111
Sample Mean = 90.8
Sample Std Dev = 25.6
Histogram Summary
Histogram Range = 57 to 111
Number of Intervals = 5

16. Distribution Summary
Distribution: Triangular
Expression: TRIA(65, 181, 194)
Square Error: 0.202160
Kolmogorov-Smirnov Test
Test Statistic = 0.5
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 4
Min Data Value = 65
Max Data Value = 194
Sample Mean = 144
Sample Std Dev = 62
Histogram Summary

Histogram Range = 65 to 194

Number of Intervals = 5

17. Distribution Summary

Distribution: Triangular

Expression: TRIA(159, 176, 325)

Square Error: 0.416049

Kolmogorov-Smirnov Test

Test Statistic = 0.5

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 4

Min Data Value = 159

Max Data Value = 325

Sample Mean = 246

Sample Std Dev = 91.3

Histogram Summary

Histogram Range = 159 to 325

Number of Intervals = 5

18. Distribution Summary

Distribution: Triangular

Expression: TRIA(159, 466, 500)

Square Error: 0.155505

Kolmogorov-Smirnov Test

Test Statistic = 0.429

Corresponding p-value = 0.112

Data Summary

Number of Data Points = 7

Min Data Value = 159

Max Data Value = 500

Sample Mean = 366

Sample Std Dev = 137

Histogram Summary

Histogram Range = 159 to 500

Number of Intervals = 5

19. Distribution Summary

Distribution: Triangular

Expression: TRIA(3.4e+003, 3.91e+003, 8.5e+003)

Square Error: 0.102716

Kolmogorov-Smirnov Test

Test Statistic = 0.396

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 3.4e+003

Max Data Value = 8.5e+003

Sample Mean = 5.31e+003

Sample Std Dev = 2.18e+003

Histogram Summary

Histogram Range = 3.4e+003 to 8.5e+003

Number of Intervals = 5

20. Distribution Summary

Distribution: Triangular

Expression: TRIA(3e+003, 3.32e+003, 6.2e+003)

Square Error: 0.127160

Kolmogorov-Smirnov Test

Test Statistic = 0.396

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6
Min Data Value = 3e+003
Max Data Value = 6.2e+003
Sample Mean = 3.92e+003
Sample Std Dev = 1.17e+003

Histogram Summary
Histogram Range = 3e+003 to 6.2e+003
Number of Intervals = 5

21. Distribution Summary
Distribution: Triangular
Expression: TRIA(2.33e+003, 2.72e+003, 6.2e+003)
Square Error: 0.418827
Kolmogorov-Smirnov Test
Test Statistic = 0.626
Corresponding p-value = 0.0494

Data Summary
Number of Data Points = 4
Min Data Value = 2.33e+003
Max Data Value = 6.2e+003
Sample Mean = 3.41e+003
Sample Std Dev = 1.87e+003

Histogram Summary
Histogram Range = 2.33e+003 to 6.2e+003
Number of Intervals = 5

22. Distribution Summary
Distribution: Triangular
Expression: TRIA(34, 36.2, 56)
Square Error: 0.262535
Kolmogorov-Smirnov Test
Test Statistic = 0.392
Corresponding p-value > 0.15

Data Summary
Number of Data Points = 7
Min Data Value = 34
Max Data Value = 55.4
Sample Mean = 44.9
Sample Std Dev = 9.09

Histogram Summary
Histogram Range = 34 to 56
Number of Intervals = 5

23. Distribution Summary
Distribution: Triangular
Expression: TRIA(2.43e+003, 2.74e+003, 5.5e+003)
Square Error: 0.350617
Kolmogorov-Smirnov Test
Test Statistic = 0.575
Corresponding p-value < 0.01

Data Summary
Number of Data Points = 9
Min Data Value = 2.43e+003
Max Data Value = 5.5e+003
Sample Mean = 3.1e+003
Sample Std Dev = 951

Histogram Summary
Histogram Range = 2.43e+003 to 5.5e+003
Number of Intervals = 5

24. Distribution Summary
Distribution: Triangular
Expression: TRIA(2.95e+003, 4.53e+003, 4.7e+003)
Square Error: 0.395062
Kolmogorov-Smirnov Test
Test Statistic = 0.408
Corresponding p-value = 0.0756
Data Summary
Number of Data Points = 9
Min Data Value = 2.95e+003
Max Data Value = 4.7e+003
Sample Mean = 3.94e+003
Sample Std Dev = 807
Histogram Summary
Histogram Range = 2.95e+003 to 4.7e+003
Number of Intervals = 5

25. Distribution Summary
Distribution: Triangular
Expression: TRIA(3.95e+003, 4.34e+003, 7.85e+003)
Square Error: 0.196321
Kolmogorov-Smirnov Test
Test Statistic = 0.297
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 7
Min Data Value = 3.95e+003
Max Data Value = 7.85e+003
Sample Mean = 5.68e+003
Sample Std Dev = 1.48e+003
Histogram Summary
Histogram Range = 3.95e+003 to 7.85e+003
Number of Intervals = 5

26. Distribution Summary
Distribution: Triangular
Expression: TRIA(180, 220, 579)
Square Error: 0.073827
Kolmogorov-Smirnov Test
Test Statistic = 0.275
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 10
Min Data Value = 180
Max Data Value = 579
Sample Mean = 373
Sample Std Dev = 137
Histogram Summary
Histogram Range = 180 to 579
Number of Intervals = 5

27. Distribution Summary
Distribution: Triangular
Expression: TRIA(158, 178, 360)
Square Error: 0.144938
Kolmogorov-Smirnov Test
Test Statistic = 0.374
Corresponding p-value = 0.0933
Data Summary
Number of Data Points = 10
Min Data Value = 159
Max Data Value = 360

Sample Mean = 233
Sample Std Dev = 69.3
Histogram Summary
Histogram Range = 158 to 360
Number of Intervals = 5
28. Distribution Summary
Distribution: Triangular
Expression: TRIA(179, 196, 350)
Square Error: 0.155505
Kolmogorov-Smirnov Test
Test Statistic = 0.292
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 7
Min Data Value = 180
Max Data Value = 350
Sample Mean = 253
Sample Std Dev = 62.3
Histogram Summary
Histogram Range = 179 to 350
Number of Intervals = 5
29. Distribution Summary
Distribution: Triangular
Expression: TRIA(350, 400, 850)
Square Error: 0.416049
Kolmogorov-Smirnov Test
Test Statistic = 0.5
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 4
Min Data Value = 350
Max Data Value = 850
Sample Mean = 613
Sample Std Dev = 275
Histogram Summary
Histogram Range = 350 to 850
Number of Intervals = 5
30. Distribution Summary
Distribution: Triangular
Expression: TRIA(1.4e+003, 1.51e+003, 2.5e+003)
Square Error: 0.127160
Kolmogorov-Smirnov Test
Test Statistic = 0.324
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 6
Min Data Value = 1.4e+003
Max Data Value = 2.5e+003
Sample Mean = 1.89e+003
Sample Std Dev = 486
Histogram Summary
Histogram Range = 1.4e+003 to 2.5e+003
Number of Intervals = 5

C. Uniform Distribution Function

1. Distribution Summary

Distribution: Uniform

Expression: UNIF(2.5e+004, 1.35e+005)

Square Error: 0.120000

Kolmogorov-Smirnov Test

Test Statistic = 0.391

Corresponding p-value = 0.0729

Data Summary

Number of Data Points = 10

Min Data Value = 2.5e+004

Max Data Value = 1.35e+005

Sample Mean = 6.62e+004

Sample Std Dev = 3.13e+004

Histogram Summary

Histogram Range = 2.5e+004 to 1.35e+005

Number of Intervals = 5

2. Distribution Summary

Distribution: Uniform

Expression: UNIF(57, 100)

Square Error: 0.140000

Kolmogorov-Smirnov Test

Test Statistic = 0.272

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 57

Max Data Value = 100

Sample Mean = 73.3

Sample Std Dev = 13.3

Histogram Summary

Histogram Range = 57 to 100

Number of Intervals = 5

3. Distribution Summary

Distribution: Uniform

Expression: UNIF(36, 215)

Square Error: 0.080000

Kolmogorov-Smirnov Test

Test Statistic = 0.232

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 36.9

Max Data Value = 215

Sample Mean = 131

Sample Std Dev = 72.1

Histogram Summary

Histogram Range = 36 to 215

Number of Intervals = 5

4. Distribution Summary

Distribution: Uniform

Expression: UNIF(250, 460)

Square Error: 0.106122

Kolmogorov-Smirnov Test

Test Statistic = 0.294

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 250

Max Data Value = 460

Sample Mean = 353

Sample Std Dev = 87.8

Histogram Summary

Histogram Range = 250 to 460

Number of Intervals = 5

5. Distribution Summary

Distribution: Uniform

Expression: UNIF(122, 194)

Square Error: 0.146939

Kolmogorov-Smirnov Test

Test Statistic = 0.306

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 122

Max Data Value = 194

Sample Mean = 163

Sample Std Dev = 27.3

Histogram Summary

Histogram Range = 122 to 194

Number of Intervals = 5

6. Distribution Summary

Distribution: Uniform

Expression: UNIF(262, 285)

Square Error: 0.300000

Kolmogorov-Smirnov Test

Test Statistic = 0.5

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 2

Min Data Value = 262

Max Data Value = 285

Sample Mean = 274

Sample Std Dev = 16.3

Histogram Summary

Histogram Range = 262 to 285

Number of Intervals = 5

7. Distribution Summary

Distribution: Uniform

Expression: UNIF(280, 865)

Square Error: 0.188889

Kolmogorov-Smirnov Test

Test Statistic = 0.35

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6

Min Data Value = 280

Max Data Value = 865

Sample Mean = 493

Sample Std Dev = 255

Histogram Summary

Histogram Range = 280 to 865

Number of Intervals = 5

8. Distribution Summary

Distribution: Uniform

Expression: UNIF(115, 192)

Square Error: 0.077778

Kolmogorov-Smirnov Test

Test Statistic = 0.3

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6

Min Data Value = 115

Max Data Value = 192

Sample Mean = 160

Sample Std Dev = 27.6

Histogram Summary

Histogram Range = 115 to 192

Number of Intervals = 5

9. Distribution Summary

Distribution: Uniform

Expression: UNIF(245, 380)

Square Error: 0.160000

Kolmogorov-Smirnov Test

Test Statistic = 0.289

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 245

Max Data Value = 380

Sample Mean = 297

Sample Std Dev = 52.4

Histogram Summary

Histogram Range = 245 to 380

Number of Intervals = 5

10. Distribution Summary

Distribution: Uniform

Expression: UNIF(384, 500)

Square Error: 0.040000

Kolmogorov-Smirnov Test

Test Statistic = 0.203

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 384

Max Data Value = 500

Sample Mean = 434

Sample Std Dev = 39.8

Histogram Summary

Histogram Range = 384 to 500

Number of Intervals = 5

11. Distribution Summary

Distribution: Uniform

Expression: UNIF(30, 55)

Square Error: 0.140000

Kolmogorov-Smirnov Test

Test Statistic = 0.395

Corresponding p-value = 0.0681

Data Summary

Number of Data Points = 10

Min Data Value = 30

Max Data Value = 55

Sample Mean = 46.9

Sample Std Dev = 8.36

Histogram Summary

Histogram Range = 30 to 55

Number of Intervals = 5

12. Distribution Summary

Distribution: Uniform

Expression: UNIF(35, 60)

Square Error: 0.100000

Kolmogorov-Smirnov Test

Test Statistic = 0.2

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 35

Max Data Value = 59.9

Sample Mean = 48.4

Sample Std Dev = 8.65

Histogram Summary

Histogram Range = 35 to 60

Number of Intervals = 5

13. Distribution Summary

Distribution: Uniform

Expression: UNIF(300, 420)

Square Error: 0.100000

Kolmogorov-Smirnov Test

Test Statistic = 0.2

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 300

Max Data Value = 420

Sample Mean = 358

Sample Std Dev = 47.5

Histogram Summary

Histogram Range = 300 to 420

Number of Intervals = 5

14. Distribution Summary

Distribution: Uniform

Expression: UNIF(212, 465)

Square Error: 0.060000

Kolmogorov-Smirnov Test

Test Statistic = 0.239

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 212

Max Data Value = 465

Sample Mean = 325

Sample Std Dev = 85.9

Histogram Summary

Histogram Range = 212 to 465

Number of Intervals = 5

15. Distribution Summary

Distribution: Uniform

Expression: UNIF(57, 111)

Square Error: 0.175000

Kolmogorov-Smirnov Test

Test Statistic = 0.494
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 4
Min Data Value = 57
Max Data Value = 111
Sample Mean = 90.8
Sample Std Dev = 25.6
Histogram Summary
Histogram Range = 57 to 111
Number of Intervals = 5

16. Distribution Summary

Distribution: Uniform
Expression: UNIF(65, 194)
Square Error: 0.175000
Kolmogorov-Smirnov Test
Test Statistic = 0.498
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 4
Min Data Value = 65
Max Data Value = 194
Sample Mean = 144
Sample Std Dev = 62
Histogram Summary
Histogram Range = 65 to 194
Number of Intervals = 5

17. Distribution Summary

Distribution: Uniform
Expression: UNIF(159, 325)
Square Error: 0.300000
Kolmogorov-Smirnov Test
Test Statistic = 0.498
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 4
Min Data Value = 159
Max Data Value = 325
Sample Mean = 246
Sample Std Dev = 91.3
Histogram Summary
Histogram Range = 159 to 325
Number of Intervals = 5

18. Distribution Summary

Distribution: Uniform
Expression: UNIF(159, 500)
Square Error: 0.106122
Kolmogorov-Smirnov Test
Test Statistic = 0.429
Corresponding p-value = 0.112
Data Summary
Number of Data Points = 7
Min Data Value = 159
Max Data Value = 500
Sample Mean = 366
Sample Std Dev = 137
Histogram Summary

Histogram Range = 159 to 500

Number of Intervals = 5

19. Distribution Summary

Distribution: Uniform

Expression:

UNIF(3.4e+003, 8.5e+003)

Square Error: 0.080000

Kolmogorov-Smirnov Test

Test Statistic = 0.38

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 5

Min Data Value = 3.4e+003

Max Data Value = 8.5e+003

Sample Mean = 5.31e+003

Sample Std Dev = 2.18e+003

Histogram Summary

Histogram Range = 3.4e+003 to 8.5e+003

Number of Intervals = 5

20. Distribution Summary

Distribution: Uniform

Expression:

UNIF(3e+003, 6.2e+003)

Square Error: 0.188889

Kolmogorov-Smirnov Test

Test Statistic = 0.545

Corresponding p-value = 0.0364

Data Summary

Number of Data Points = 6

Min Data Value = 3e+003

Max Data Value = 6.2e+003

Sample Mean = 3.92e+003

Sample Std Dev = 1.17e+003

Histogram Summary

Histogram Range = 3e+003 to 6.2e+003

Number of Intervals = 5

21. Distribution Summary

Distribution: Uniform

Expression:

UNIF(2.33e+003, 6.2e+003)

Square Error: 0.425000

Kolmogorov-Smirnov Test

Test Statistic = 0.638

Corresponding p-value = 0.044

Data Summary

Number of Data Points = 4

Min Data Value = 2.33e+003

Max Data Value = 6.2e+003

Sample Mean = 3.41e+003

Sample Std Dev = 1.87e+003

Histogram Summary

Histogram Range = 2.33e+003 to 6.2e+003

Number of Intervals = 5

22. Distribution Summary

Distribution: Uniform

Expression: UNIF(34, 56)

Square Error: 0.187755

Kolmogorov-Smirnov Test

Test Statistic = 0.256
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 7
Min Data Value = 34
Max Data Value = 55.4
Sample Mean = 44.9
Sample Std Dev = 9.09
Histogram Summary
Histogram Range = 34 to 56
Number of Intervals = 5

23. Distribution Summary

Distribution: Uniform
Expression: UNIF(2.43e+003, 5.5e+003)
Square Error: 0.429630
Kolmogorov-Smirnov Test
Test Statistic = 0.625
Corresponding p-value < 0.01
Data Summary
Number of Data Points = 9
Min Data Value = 2.43e+003
Max Data Value = 5.5e+003
Sample Mean = 3.1e+003
Sample Std Dev = 951
Histogram Summary
Histogram Range = 2.43e+003 to 5.5e+003
Number of Intervals = 5

24. Distribution Summary

Distribution: Uniform
Expression: UNIF(2.95e+003, 4.7e+003)
Square Error: 0.306173
Kolmogorov-Smirnov Test
Test Statistic = 0.432
Corresponding p-value = 0.049

Data Summary
Number of Data Points = 9
Min Data Value = 2.95e+003
Max Data Value = 4.7e+003
Sample Mean = 3.94e+003
Sample Std Dev = 807
Histogram Summary
Histogram Range = 2.95e+003 to 4.7e+003
Number of Intervals = 5

25. Distribution Summary

Distribution: Uniform
Expression: UNIF(3.95e+003, 7.85e+003)
Square Error: 0.146939
Kolmogorov-Smirnov Test
Test Statistic = 0.262
Corresponding p-value > 0.15
Data Summary
Number of Data Points = 7
Min Data Value = 3.95e+003
Max Data Value = 7.85e+003

Sample Mean = 5.68e+003

Sample Std Dev = 1.48e+003

Histogram Summary

Histogram Range = 3.95e+003 to 7.85e+003

Number of Intervals = 5

26. Distribution Summary

Distribution: Uniform

Expression: UNIF(180, 579)

Square Error: 0.020000

Kolmogorov-Smirnov Test

Test Statistic = 0.198

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 10

Min Data Value = 180

Max Data Value = 579

Sample Mean = 373

Sample Std Dev = 137

Histogram Summary

Histogram Range = 180 to 579

Number of Intervals = 5

27. Distribution Summary

Distribution: Uniform

Expression: UNIF(158, 360)

Square Error: 0.140000

Kolmogorov-Smirnov Test

Test Statistic = 0.349

Corresponding p-value = 0.138

Data Summary

Number of Data Points = 10

Min Data Value = 159

Max Data Value = 360

Sample Mean = 233

Sample Std Dev = 69.3

Histogram Summary

Histogram Range = 158 to 360

Number of Intervals = 5

28. Distribution Summary

Distribution: Uniform

Expression: UNIF(179, 350)

Square Error: 0.106122

Kolmogorov-Smirnov Test

Test Statistic = 0.277

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 7

Min Data Value = 180

Max Data Value = 350

Sample Mean = 253

Sample Std Dev = 62.3

Histogram Summary

Histogram Range = 179 to 350

Number of Intervals = 5

29. Distribution Summary

Distribution: Uniform

Expression: UNIF(350, 850)

Square Error: 0.300000

Kolmogorov-Smirnov Test

Test Statistic = 0.5

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 4

Min Data Value = 350

Max Data Value = 850

Sample Mean = 613

Sample Std Dev = 275

Histogram Summary

Histogram Range = 350 to 850

Number of Intervals = 5

30. Distribution Summary

Distribution: Uniform

Expression: UNIF(1.4e+003, 2.5e+003)

Square Error: 0.077778

Kolmogorov-Smirnov Test

Test Statistic = 0.273

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 6

Min Data Value = 1.4e+003

Max Data Value = 2.5e+003

Sample Mean = 1.89e+003

Sample Std Dev = 486

Histogram Summary

Histogram Range = 1.4e+003 to 2.5e+003

Number of Intervals = 5

Appendix 2

Raw Data Obtained from AACRA Project Office

	Description	Unit	Project 1		Project 2		Project 3		Project 4		Project 5	
			Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate
1	Clearing and Grubbing	Ha	6.66	25,000.00	7.98	135,000.00	11.22	65,000.00	19.17	100,000.00	8.35	40,153.38
2	Soft excavation to embankment	m3	41168.59	60.00	64385.39	60.00	60974.6	75.00	33270.43	84.00	100867.91	79.70
3	Intermediate excavation (Prov)	m3	35951.06	215.00	26247.47	185.00					2112.99	128.91
4	Hard excavation(Prov)	m3	3120.9	278.00	1185.42	250.00	1034.15	350.00	11090.91	392.12	90.5	278.17
5	Borrow Excavation to Embankement with granular material min CBR 15,P1-12 & max grain size 150 mm	m3	10800	180.00	10	185.00	14192.98	130.00			12918	193.59
6	Compacted to 95% of AACRA Test S-11 Density	m3	11508.96	262.00	8924.97	285.00						
7	Fill Using Imported Rock (prov)	m3	4300	465.00	457	865.00			100	750.00	130.27	280.02
8	40cm thick Capping Layer under the subbase layer with maximum compacted layer thickness 300mm and as Specified on the agreement and irrespective of the hauling Distance	m3					28185.22	150.00	54015.71	192.00		
9	25 cm thickCrushed stone base compaction to 96% of AACRA Test S-11 density (Compacted layer thickness of maximum 150mm)	m3	6663.2	260.00	6459.15	245.00	8121.5	380.00				
10	98% of AACRA test - 11 density (compacted layethickness of maximum 150mm)	m3	4005.89	450.00	3944.68	500.00	6091.11	430.00	26775.99	400.00	9644.86	411.00
11	supply and spray MC-30 cut back Asphalt prime coat (application rate llit/m2)	Lit	23113.88	55.00	22541.04	55.00	44990.8	43.00	91512.29	30.00	54170	48.62
12	Supply and spray Application of Tack Coat at 0.3 ltr per sq. m	ltr	6934.16	55.00	6762.31	55.00	9019.05	43.00	27453.69	35.00	11912	48.10

	Description	Unit	Project 1		Project 2		Project 3		Project 4		Project 5	
			Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate
13	Dense graded asphalt AC in intermediate (Binder) course, 60mm nominated compated layer thickness, 20mm nominal aggregate size with class 60/70 pen bitumen	m2	22890.8	420.00	22541.04	400.00	40395.73	350.00	91512.29	300.00	11912	304.00
14	Dense graded asphalt AC in wearing course, 40mm nominated compacted layer thickness, 14mm nominal aggregate size with class 60/700pen. Bitumen	m2	22890.8	400.00	22541.04	420.00	30063.51	275.00	91512.29	212.00	54170	261.13
15	0m up to 1.5m	m3					231.76	85.00				
16	1.5m upto 3m	m3					176.66	125				
17	Using imported selected material	m3					1227.75	175.00				
18	Foundation Fill Consisting of Compacted Granular Material	m3					42	500.00	20	500.00		
19	Concrete class C-25	m3	54.3	8,500.00	168.17	6,500.00	156.64	3,500.00			142.46	4,646.81
20	Concrete class C-20	m3	14	6,200.00	194	3,800.00	7.4	3,200.00	1218.9	3,000.00	188.28	3,923.00
21	Concrete blinding C-7	m3			28.98	6,200.00					12.44	2,765.33
22	Grade 420 Reinforcement	kg					660.92	42.00	17860	38.00	8009.19	37.68
23	910mm Internal Diameter RC Storm pipe Including Class B Bedding	Lm	1112	2,430.00	452	5,500.00	4726.77	2,800.00	240	3,510.00	5906	2,565.00
24	1060mm Internal Diameter RC Storm pipe Including Class B Bedding	Lm	1000	3,190.00	1480	2,950.00	497.24	3,000.00	55	4,485.00	1150	3,274.31
25	1220mm Internal Diameter RC Storm pipe Including Class B Bedding	Lm	1060	3,950.00	940	7,850.00			78	7,215.00		
26	Type ``A`` (450mm x 170mm)	Lm	3216.72	350.00	4033.41	350.00	9740.33	300.00	9900.62	180.00	9037.65	578.09
27	Type ``B`` (200mm x 300mm)	Lm	3216.72	250.00	3127.71	270.00		250.00	19401	287.00	7067	269.94
28	Foot Path (side walk) 300x300x60mmpre- coloured concrete block on cement stabilized sand base including any jointing work (optional for item 615 P14(b)	m2	11332.8	205.00	9290.22	200.00	6686.8	250.00	42802.78	290.00		
29	Grouted Pitching	m2	34	850.00	185.5	850.00	53.69	350.00	45.08	400.00		

	Description	Unit	Project 1		Project 2		Project 3		Project 4		Project 5	
			Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate
30	Cement mortared Stone walls (1:3 OPC cement :sand Ratio) for side ditch, crossing ditch and retaining structures , geometry as detailed in the drawings. The cost shall also include that of the 0.1m thick lean concrete under the structure	m3	629	2,500.00	2893.1	1,650.00	118.5	1,400.00	3385	1,400.00	1128.63	2,009.07

	Description	Unit	Project 6		Project 7		Project 8		Project 9		Project 10	
			Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate
1	Clearing and Grubbing	Ha	6.8	50,000.00	10.06	63,398.70	3.88	63,398.70	9.84	50,000.00	17.89	70,000.00
2	Soft excavation to embankment	m3	60446.47	57.00	99166.78	76.78	39685.38	76.75	1000	64.00	100	100.00
3	Intermediate excavation (Prov)	m3			15014.06	36.87	6468	86.87				
4	Hard excavation(Prov)	m3			12431.5	459.95	4216.49	459.95				
5	Borrow Excavation to Embankement with granular material min CBR 15,P1-12 & max grain size 150 mm	m3	8844.13	122.00	30862.43	164.59	4334.48	164.59				
6	Compacted to 95% of AACRA Test S-11 Density	m3										
7	Fill Using Imported Rock (prov)	m3							100	300.00	100	300.00
8	40cm thick Capping Layer under the subbase layer with maximum compacted layer thickness 300mm and as Specified on the agreement and irrespective of the hauling Distance	m3			27745.4	176.59	11378.64	176.59	48300.5	149.00	71565.38	115.00
9	25 cm thickCrushed stone base compaction to 96% of AACRA Test S-11 density (Compacted layer thickness of maximum 150mm)	m3			13587.74	300.70	5110.35	300.70				

	Description	Unit	Project 6		Project 7		Project 8		Project 9		Project 10	
			Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate
10	98% of AACRA test - 11 density (compacted layethickness of maximum 150mm)	m3	7043.44	390.00	12325	384.38	4012.16	484.38	9451.97	465.00	7664.65	425.00
11	supply and spray MC-30 cut back Asphalt prime coat (application rate llit/m2)	Lit	51651.89	40.00	48380	54.87	16568.9	54.87	63013.16	43.00	51097.68	45.00
12	Supply and spray Application of Tack Coat at 0.3 ltr per sq. m	ltr	14086.88	40.00	14514	59.92	4785.89	59.92	18903.95	43.00	15329.3	45.00
13	Dense graded asphalt AC in intermediate (Binder) course, 60mm nominated compated layer thickness, 20mm nominal aggregate size with class 60/70 pen bitumen	m2	46956.27	384.00	48380	315.70	15732.92	315.70	63013.16	375.00	51097.68	420.00
14	Dense graded asphalt AC in wearing course, 40mm nominated compacted layer thickness, 14mm nominal aggregate size with class 60/700pen. Bitumen	m2	46956.27	465.00	48380	303.26	15092	302.26	63013.16	231.00	51097.68	380.00
15	0m up to 1.5m	m3	19049.58	57.00	14580.9	110.69	6691.89	110.69				
16	1.5m upto 3m	m3	2827.12	65.00	11665.89	193.70	2156.67	193.70				
17	Using imported selected material	m3	1964.55	159.00	9208.89	324.68	5757.23	324.68				
18	Foundation Fill Consisting of Compacted Granular Material	m3	108.08	159.00	250	277.75	228.11	277.75	168.78	500.00	44.44	350.00
19	Concrete class C-25	m3							505.66	3,400.00		
20	Concrete class C-20	m3									4362.03	3,400.00
21	Concrete blinding C-7	m3			50	2,331.17	13.21	2,331.17				
22	Grade 420 Reinforcement	kg	52917.95	52.00	9569.91	55.35	7416.62	55.35	26460	34.00		
23	910mm Internal Diameter RC Storm pipe Including Class B Bedding	Lm	4438.58	2,579.00	5928	2,813.25	2209.4	2,813.25	1520	2,900.00		
24	1060mm Internal Diameter RC Storm pipe Including Class B Bedding	Lm	1298.3	4,700.00	700	4,701.03	200	4,701.03	7310	4,500.00		
25	1220mm Internal Diameter RC Storm pipe Including Class B Bedding	Lm			330	5,910.79	54	5,910.79	5	4,317.08	97	4,600.00

	Description		Project 6		Project 7		Project 8		Project 9		Project 10	
		Unit	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate	Revised Quantity	Rate
26	Type ``A`` (450mm x 170mm)	Lm	12283.35	578.93	9602.63	445.33	4292.04	445.33	8833.51	247.76	7156.54	250.00
27	Type ``B`` (200mm x 300mm)	Lm	6141.67	158.57	4967.12	158.57	2200.33	158.57	17667.01	168.22	14313.08	360.00
28	Foot Path (side walk) 300x300x60mmpre-coloured concrete block on cement stabilized sand base including any jointing work (optional for item 615 P14(b)	m2	19918.07	179.60					34071.39	297.42	38323.26	350.00
29	Grouted Pitching	m2										
30	Cement mortared Stone walls (1:3 OPC cement :sand Ratio) for side ditch, crossing ditch and retaining structures , geometry as detailed in the drawings. The cost shall also include that of the 0.1m thick lean concrete under the structure	m3			101.63	2,397.09						