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Design Risk Management In Ethiopian Federal Road Projects

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MSc Thesis

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Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

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Abstract

Project risks have significant impact on construction project's performance in terms of cost, time and quality. Thus, managing the risks has been recognized as a very important management process in order to achieve the project objectives. The objective of this research is to examine whether design risks are contributory to cost and time overruns, and poor quality of works, and make recommendation based on the findings. The research, thus, reviewed 10 Road construction projects performed during the last 14 years, and conducted interviews with professionals of the Ethiopian Roads Authority (ERA) who are involved in procurement, design review, and monitoring implementation of Road construction projects at Federal level.

The findings of this research revealed that design risks were contributory to cost and time overrun and poor quality of works. The underlying cause of the risks is that designers lack construction experience and fail to fully address constructability problems that surface during construction. And it was found that the breeding ground for design risks is the Design-Bid-Build project delivery method currently in place. This project delivery system is characterized by separation of phases which does not make use of construction experience in the development of design.

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.

Keywords: Risk management**,** Design Risk, Constructability, Quality management, Project delivery method

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1. Introduction

1.1 Background

Ethiopia is a land locked country, located in the eastern part of Africa, with a population estimate of more than 77 million, spread over a territory of 1.1 million km^2. Agriculture is the main economic activity and the backbone of the country's economy. About 80% of the population live in rural areas and depend on agricultural activities for their livelihood. However, there is a high potential for increased agricultural production, and the economic growth of the country, by and large, is linked to this potential. Economic growth is one of the means of reducing poverty, and infrastructure delivery is one of its key drivers.

It is apparent that quality of infrastructure has a direct impact on the level of people's life, and a well-functioning construction industry has an important role towards this end. The contribution of the Ethiopian construction industry to the economy has now reached 8.2%, and public construction projects share an average annual rate of 60% of the Government's capital budget. However, the present state of the construction industry falls short of meeting domestic and international quality standards and the performance demand expected from the sector (MoWUD 2006). Therefore, the Government of Ethiopia's (GOE) Plan for Accelerated and Sustained Development to End Poverty (PASDEP), issued in September 2006, aims at developing a competitive construction industry to ensure quality of design and workmanship, with increased efficiency in designs and constructions of infrastructure.

The country's transport infrastructure as measured by density of the road network in 2007 stands at 38.6km per 1000 sq. km and 0.55km per 1000 population (ERA, 2007). Proportion of area more than 5km from all weather road and average distance to all weather roads during the same period are 68% and 13km respectively. Despite considerable efforts to expand the road network over the past few decades, the density is still below the average density of 60 km per 1000 sq.

km for Africa. The road network during same period is about 42,429km and this comprises of 20,080km Federal roads and 22,349km Regional roads. It is estimated that about 70 % of the total area of the country is now more than 5km's walk from all-weather roads.

Being aware of the dire need to expand the road network in facilitating development and growth, the Government of Ethiopia (GOE) had launched the 10-years Roads Sector Development Program (RSDP) that run from July 1997-June 2007. The first phase of this program (RSDP I: July 1997-June 2002) was officially launched in September 1997, and completed in June 2002. This phase has focused on the restoration of the road network to an acceptable condition. The second phase of the program (RSDP II: July 2002-June 2007) aims to consolidate the achievements of the first phase, increase the network connectivity and provide a sustainable road infrastructure to rural areas (ERA 2007). During the 10 years period, a total of 78,569 km of roads were constructed, upgraded/rehabilitated and maintained; of which 10,282 km are federal roads and 10,523 km are newly constructed/maintained regional roads. However, many of the projects planned under RSDP I and II were not completed within the prescribed time and budget and did not meet the quality standard (Becker and Behailu, 2006)

The third phase of the Road sector Development program (RSDP III), has started in July 2007, and will be completed in July 2010 (ERA 2007). At the end of the program, the average distance to all weather roads will be 11 km, and the road density will also be 45.7 km/1000km^2 and 0.59km/1000 population. According to Ethiopian Roads Authority (ERA), RSDP III envisaged for the three years (2007 – 2010) includes planned expenditure of Birr 29.7 billion for Federal roads. It is believed that similar program will continue beyond 2010. The programs require not only capacity to execute, but also improvement of drawbacks from past performances.

Latham (1994) put forward that no construction project is risk free, and risk can only be managed, minimized, shared, transferred, or accepted: it can not be ignored. The risks can cause losses that lead to increased costs, time delays and lack of quality of projects (Simu 2006). And projects' objectives are most often related to time, cost, and quality (Hillson, 2004). Shehu and Sommerville (2006) has also stressed that construction is a risk-prone industry, with a poor track record of coping with risks, as a result of which clients have been enduring the agonizing outcomes of failure in the form of unnecessary delays in project completion, cost surpassing the budget and sometimes failing to meet quality standards and operational requirements.

A critical element for controlling the cost, schedule and scope of a project is gaining and maintaining control of the design process. Failure to control and manage this process will result in delay and increased construction costs. Hence, many problems that are encountered during construction can be traced back to the design process (Jergeas, 1989; Alshawi and Underwood, 1994; Madelsohn, 1997; Griffith and Sidwell, 1995). These problems can be as high as 75% of the total problems encountered during construction (Madelsohn, 1997). Angelo and Day (2001) have identified risk management as an important part of any project. The proper management of risks limits delays, budget overruns, and claims between parties. Thus, Risk management addresses such risk exposure, leading to an acceptable and manageable level of risk (Hillson 2003). This increases the chance of meeting project objectives, which in turn maximizes the likelihood of achieving broader goals in terms of the project benefits.

As the size and complexity of projects have increased, ability to manage risks throughout the construction process has become a central element preventing unwanted consequences (Maytorena et al. 2007). Hence, different project risks have to be allocated to the project's actors on the basis of who has the best qualifications for dealing with a specific risk (SOU 2000). How risks are shared among the actors in a construction project is to a large extent governed by the choice of project delivery option. As different project delivery options imply different ranges of responsibilities and liabilities in the project, selecting an appropriate project delivery option is a key issue for project actors.

The traditional Project delivery method widely applied in Ethiopia is design-bid-build (DBB) contracts. In this type of contract the client is responsible for the design and the contractor for the execution. However, it has been argued that traditional contractual arrangements do not support effective collaboration in construction projects (Kadefors 2004). Therefore, there is a need to examine the risk management practices to execute Federal road projects. The research, thus, briefly explores the underlying concepts of risk management, constructability, and project delivery methods with a view to enlighten management of design risks that have an impact on cost, time and quality objectives of projects.

1.2 Problem statement

The accomplishment of the first 10 years Road Sector Development Program reveals that the execution of most of the Federal road projects resulted in cost and time overruns as shown in Table 1 below. Becker and Behailu (2006) have also ascertained that the projects were not completed on time, within budget, and desired quality.

Table 1: Physical and Financial Accomplishment of some Road Projects

No.	Projects	Total Length (km)	Type of surfacing /Work	Physical (length - km)		Financial (million Br)		Completion Time (month)		%		
				Plan	Accom.	Budget	Disb.	Plan	Accom.	Phy. Accom.	Fin. Disb.	Compl. Time
1	A.A-Jimma	342	AC	342	342	405.9	650.1	36	73	100	160.16	203
2	A.A-Modjo-Awassa	263	AC	263	263	310.1	386.1	36	49	100	125.00	136
3	Modjo-Awash Arba	160	AC	160	160	227.4	375.4	36	68	100	165.00	188
4	Gewane-Mille	146	AC	146	146	249.0	357.6	40	51	100	143.61	128
5	Awash-Hirna	141	AC	141	141	256.5	297.4	36	62	100	115.94	172
6	Hirna Kulubi	91	AC	91	91	188.1	225.0	30	64	100	119.62	213
7	Kulubi-Dengego-Dire Dawa & Dengego-Harar	80	AC	80	80	162.2	220.5	36	63	100	135.94	210
8	Tarmaber-Kombolcha	187	AC	187	187	289.8	383.2	36	60	100	132.22	166
9	Woldia-Alamata	78	AC	78	78	150.3	230.9	36	62	100	153.63	172
10	Betemariam-Wukro	117	AC	117	117	203.4	240.5	36	67	100	118.24	186
11	Debremarkos-Merawi	220	AC	220	220	327.0	575.8	36	39	100	176.09	108
12	Awash Arba-Gewane	136	AC	136	136	192.0	192.0	30	38	100	100.00	131
	Total					2,961.7	4,134.5	424	696	100	139.60	164

Source: Ethiopian Roads Authority (Projects' completion reports)

Though there may be various reasons for such divergence, nonconformity to plans is observed. And there are presumptions that design problems or risks contribute to deviations from plan with a notion that the basic elements of a project plan, time and cost, are derivatives of design. ERA (2005) indicated that Design consultants lack own quality assurance system; they do not strive to create a methodology for the local conditions, instead, copy or adopt what has been previously developed. In some cases they don't have deep knowledge on the type of services ERA needs, and do not feel accountable for the services they render. Moreover, most of the consultants are newly formed and desperate to have a job at significantly lower price and win, consequently ending up producing low quality work. The study further reveals that Terms of Reference issued by ERA is not precise and clear. Hence, it is apparent that these problems reflect the existence of design risks which need to be addressed. Therefore, this research examines whether such design risks; i.e poor quality design, lack of experience, scope changes, etc. contribute to cost and time overruns, and sub standard quality of projects, and make recommendation on the findings.

1.3 Aim, objectives and the research questions

The aim of the research is to enlighten the need for design risk management to enhance achievement of project objectives, thereby contributing to effective implementation of the country's road infrastructure development program. The main objective is to examine whether design risks are contributory to cost and time overruns, and affect quality objectives of projects, and make recommendations based on the findings.

The specific objectives are:

i. to assess whether Road project risks are managed with formal Risk management system

ii. to find out the sources of risks in road construction projects, and impacts of design risks

iii. to evaluate design risk allocation practices and instruments employed to manage design risks,

iv. to assess the existing practices of design risk reduction/mitigation.

Hence, the research should address the following questions:

i) How are road construction risks managed? Do the approaches conform to the conceptual framework of Risk management system?

ii) What are the sources of risks in Road construction projects? Do design risks contribute to cost and time overruns, and poor quality of works?

iii) How are design risks allocated? Are there options to better allocate the risks?

iv) How are design risks mitigated? Are there better approaches to better minimize Design risks?

1.4 Scope of the study

The scope of the study is limited to assessment of design risks and its management practices in Federal road projects. The findings of the assessment are reviewed in light of previous research findings that could minimize design risks in general. Thus, specific tools and techniques of risk analysis are not dwelt in detail since the emphasis of this research is to enlighten the importance of design risk management to achieve project objectives.

1.5 Structure of the Thesis

This thesis consists of five chapters and an Appendix. Chapter 1 is an introduction to the research and includes seven sections that present the background; problem statement; aim, objectives and research questions; scope of the study; structure of the thesis; research methodology; and contributions of the research. Chapter 2 discusses the theoretical framework for the study. Chapter 3 presents the Research design and methodology in detail. Chapter 4 focuses on the analysis of results and discussions. Chapter 5 forwards conclusions and recommendations of the research. Appendix 1 contains the sample interview schedule.

1.6 Research methodology

The research strategy adapted for this research is qualitative research of exploratory type which diagnoses a situation, assess alternatives, and discover new ideas. The methodology followed for the research has four main parts as described hereunder.

i. *Establishing the basis of the research:* aimed at defining the theoretical basis, and formulating the research questions through the following steps.

- Literatures were reviewed to obtain a theoretical basis for the research and formulating the research questions and defining the scope. To this effect, the main authors of textbooks in the field of risk management in construction were identified. The books were then reviewed in order to get a general understanding of the research area. Thereafter relevant articles from journals and other publications were searched to conceptualize design risk management. The search was made by using the following keywords: risk management, design risk, constructability, quality management, and project delivery methods. Apart from searching in libraries, internet sources were used to obtain recent articles and research papers in the area.

- Risk-prone projects that were completed were selected for the case study to examine whether design risks were contributory to cost and time overruns, and poor quality of works.
- Interview schedule was prepared based on the findings of the literature review.

ii. Conducting the study: aimed at finding out how the design risks affect project objectives, and identifying the existing practices of risk management with the following approaches:

- Case study of 10 risk-prone completed projects to assess whether design risks were contributory to cost and time over runs, and sub standard quality of works,
- A desk study to get a picture of design risk allocation and reduction practices, and the project delivery method in use for federal road projects, and
- Interviewing key informants to get in-depth understanding of risk management processes being practiced, and to explore their opinions on design risk management.

iii. Analyzing the findings; aimed at analyzing the findings of case studies in relation to theoretical propositions, and that of the interview using descriptive statistics method of analysis.

iv. Conclusion and recommendation: aimed at concluding the research findings, and drawing recommendations.

Figure 1 below illustrates the foregoing approach to the research

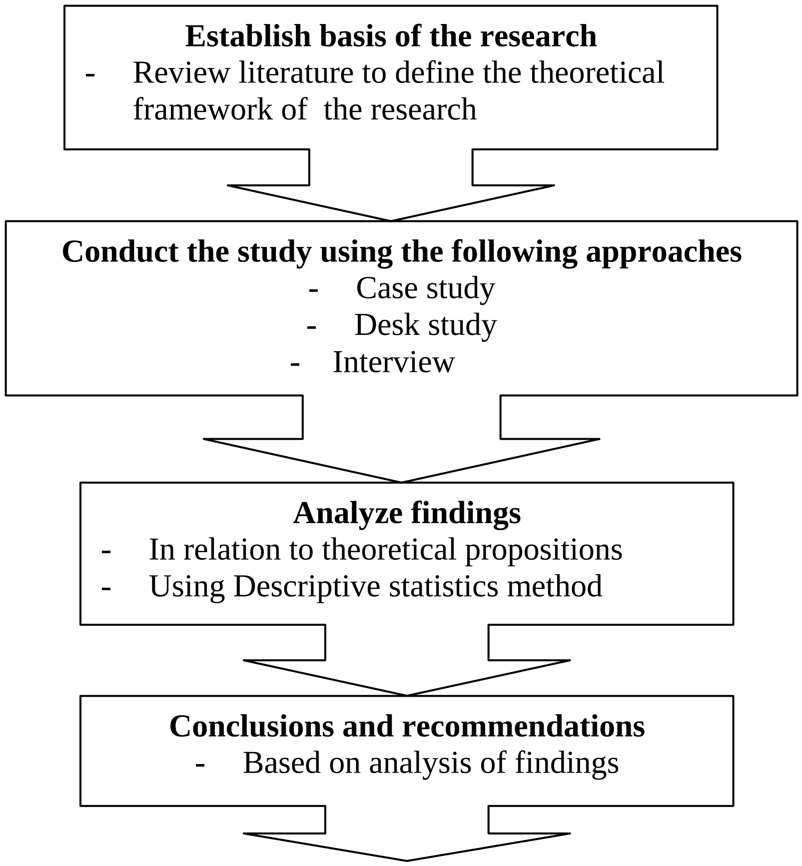

Fig.1. Research design

1.7 Contribution of the research

The results of the research will discover whether design risks are contributory to the risks that cause cost and time overrun, and affect quality objectives of projects. The findings may help Clients, Designers, and Contractors to revisit their risk management strategies. The better the risks are minimized, the better the quality of designs and improved control of cost and time overruns, which may improve performance of facilities, and save cost and time for other interventions. Besides, construction efficiency is enhanced and hence Contractors expedite completion time.

2. Literature Review

2.1 An overview of ‘’ Risk’’

2.1.1 Definitions and classifications of Risk

The word “risk ’’was known in the English language in the 17th century. It is believed that the word was originally a sailor’s term that came from the Spanish and meant “to run into danger or to go against a rock.” The money spent to fund shipments overseas was the first example of risk business in the early days of travel (Jannadi and Almishans, 2003). Nowadays, there are a number of definitions for risk.

Webster’s dictionary defines risk as “the possibility of loss, injury, disadvantages, or destruction’’. The Random House College Dictionary defines risk as “exposure to the chance of injury or loss” (Hertz and Thomas 1983). Jaafari (2006) defined Risk as the exposure to loss/gain, or the probability of occurrence of loss/gain multiplied by its respective magnitude. He further elucidate that events are said to be certain if the probability of their occurrence is 100% or totally uncertain if the probability of occurrence is 0%. In between these extremes the uncertainty varies quite widely.

The Association of Project Management (2004) argue that risk arises when uncertainty has the potential to affect objectives, and defined the term as “Any uncertain event or set of circumstances that, should it occur, would have an effect on one or more objectives”. There are uncertainties that cannot affect objectives, and which are therefore not risks. It is this relationship between risk, uncertainty and objectives that makes risk management such an important contributor to both project success and business benefits (Hillson, 2006). Oxford dictionary define ‘Uncertainty’ as the state of being uncertain and, a thing that is uncertain or causes one to be uncertain.

The definition of a risk given by Hilson as “an uncertainty which if it occurs would affect one or more objectives” also allows inclusion of opportunities as well as threats within the risk process, since an opportunity is simply an uncertainty with a positive effect on an objective. Thus, uncertainty is always present, even when information is perceived as complete (Smallman, 2000).

Risk can also be defined as the product of the probability and the eventual impact of a hazard (Smallman, 2000). Hazards can be defined as threats to people and the things that they value. In other words, risk is the product of the probability or likelihood of an undesired event and the consequences of that event. In the context of conventional risk management, uncertain events are usually considered as hazards, with the potential to have negative effects. However, uncertain events can also give attractive opportunities with positive effects. Including these positive opportunities is a rather modern extension of the common understanding of risk and risk management (Staveren, 2006).

In project management context, Niwa (1989) and Wideman (1992), Project Management Institute (PMI 2000), the Association for Project Management (APM 2000) defined project risk as the chance of certain occurrences adversely affecting project objectives or cause a failure to meet the project's objectives. Several definitions of project risk given by Baloi and Price (2003), Barber (2005), Chapman and Ward (2002), Flanagan and Norman (1993), IEC (2001), Jaafari (2001), PMI (2000), Smith et al. (2006) have a common feature: they define risk in terms of uncertain events and their impact on a project's objectives. Project risks are uncertain events or conditions that may have an impact on one or several project objectives (Osipova 2008).

Risk classification is a significant step in the risk management process, as it attempts to structure the diverse risks affecting a construction project. In order to manage risks effectively, many approaches have been suggested in the literature for classifying risks. According to Smith et al. (2006) all project risks can be divided into three main categories: known risks, known unknowns and unknown unknowns. The difference between the categories is the decreasing ability to predict or foresee the risks. A known is an item or situation containing no uncertainty. Unknowns are things we know but we do not know how they will affect us. A known-unknown is an identifiable uncertainty. An unknown-unknown is simply an item or situation whose existence has yet to be encountered or imagined. Taking into account the probability of the occurrence and the consequence for project objectives, those events that have high probability and high impact are subject to risk management.

The PMI (2000) classify risks as internal or external. Internal risks are those that arise within the scope and control of the project team. Most internal risks can be referenced to a specific project document such as a cost estimate or a schedule. Internal risks usually refer to items that are inherently variable External risks are items that are generally imposed on the project from establishments beyond the limits of the project. Interactions with regulators are typical external risks. Funding constraints and restrictions are other common external risks. External risks tend to refer to items that are inherently unpredictable but generally foreseeable (Caltrans 2007).

The risks for infrastructure projects, according to Yoyjie (2001), have a wide range of sources and can be classified into the following broad categories:

a. Technical, quality or performance risk such as employment of inexperienced designers, changes to the technology used or to industry standards during the project.
b. Organizational risks such as cost, time and scope objectives that are internally inconsistent, lack of prioritization of projects, inadequacy or interruption of funding, and resource conflicts with other projects in the organization.
c. External risks such as shifting legal or regulatory environment including institutional changes, poor geological conditions and weather, force majeure risks such as earthquake and floods.
d. Project management risks such as poor allocation of time and resources, inadequate quality of the project plan, poor use of project management disciplines.

In addition to the above, Caltrans (2007) includes design, construction, environmental, and right of way risks in its classifications. Hassan (2005) also includes planning and selection, financial, contractual, site, resource, technology, communications risks, etc in its generic checklist for transportation projects.

Since this research dwells on issues of risks in the context of project management, it adapts the APM's definition which defines risk as the chance of certain occurrences adversely affecting project objectives. The classifications of risk into known risks, known unknowns and unknown unknowns as forwarded by Smith et. al. (2006) is also adapted for this research.

2.1.2 Risk management

Possible risks that are involved in construction environment include external risk such as weather risk, and internal risk such as construction design risk. The typical losses of these risks are generally relevant to project delay, project cost overrun, and poor quality of work (Papageorge 1988). Thus, there is a considerable need to incorporate the risk management concepts into infrastructure construction practice in order to mitigate or eliminate risk consequence and enhance the performance of projects (Pipattanapiwong, 2004). Risk management is recognized as an essential tool to tackle the inevitable uncertainty associated with projects at all levels. Moreover, significant improvement to construction project management performance may be achieved by adopting the process of risk management (Hillson0 2006).

Shehu and Sommerville (2006) defined Risk management as a process of controlling the level of risk and to mitigate its effects. (Nummedal et al., 1996; PMI 2000; PRMHB 2007) define risk management as a systematic approach for identifying, evaluating and responding to risks encountered in a project. Kerzner (2003) defines same as the act or practice of identifying, analyzing, and evaluating risk. Angelo and Day (2001) see risk management as an important part of any project that limits delays, budget overruns, and claims between parties.

The overall objective of the risk management process is to maximize the opportunities and minimize the consequences of a risk event (Shehu and Sommerville, 2006). Dealing with risk involves planning for risk, assessing risk issues, developing risk handling strategies, and monitoring risks to determine how they have changed. PMI (2000) proposes six major processes for risk management i.e., risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control. (Al-Bahar et al. 1990; Flanagan and Norman 1993; Kahkonen 1996; Chapman 1997; and ICE 1998) categorize into three main processes i.e. risk identification, risk analysis and risk response.

According to PMI (2004) and Caltrans (2007), the typical risk management process has the following steps, which are undertaken iteratively throughout the project lifecycle.

2.1.2.1 Risk management planning

In this phase, the scope and objectives of the risk process are defined, the techniques and tools to be used, the thresholds of acceptable risk to various stakeholders are stated, roles and responsibilities are detailed, etc. The planning process should be completed early during project planning, since it is crucial to successfully perform the other processes. The outcome of the planning phase is a Risk Management Plan, which identifies and establishes the activities of risk management for the project.

Each risk plan should be documented, but the level of detail will vary with the unique attributes of each project. Large projects or projects with high levels of uncertainty will benefit from detailed and formal risk management plans that record all aspects of risk identification, risk analysis, risk response planning, and risk monitoring and control. Projects that are smaller or contain minimal uncertainties may require only the documentation of a red flag item list that can be updated at critical milestones throughout the project development and construction. The required documentation includes, but not limited to the following:

i) Red Flag Item Lists

A red flag item list is created at the earliest stages of project development and maintained as a checklist during project development. It is perhaps the simplest form of risk identification and risk management. It is a technique to identify risks and focus attention on critical items that can impact the project's cost and schedule. Issues and items that can potentially impact project cost or schedule in a significant way are identified in a list, or red flagged, and the list is kept updated as the project progresses through development and construction management. By maintaining a running list, the project team has a better perspective for setting proper contingencies and controlling risk. The red flag item list facilitates communication among planners, design engineers, and construction managers about these items.

ii) Risk Charters

The creation of a risk charter is a more formal identification of risks than the listing of red flag items. Typically, it is completed as part of a formal and rigorous risk management plan. The risk charter provides project managers with a list of significant risks and includes information about the cost and schedule impacts of these risks. It is similar to a list of red flag items, but typically contains more detailed information about the potential impact of the risks and the mitigation planning. This method may be more effective than simply listing potential problem areas through red flagging because it integrates with the risk monitoring and control processes. The terms "risk charter" and "risk register" are synonymous in the highway industry.

A risk charter is used as a management tool to identify, communicate, monitor, and control risks. It provides assistance in setting appropriate contingencies and equitably allocating risks. As part of a comprehensive risk management plan, the risk charter can help control cost escalation. It is appropriate for large or complex projects that have significant uncertainty.

iii) Formal Risk Management Plan

The formal plan should be developed during the planning and scoping process and updated at subsequent project development phases. The plan is the road map that tells the agency and contractor team how to get from where the project is today to where the public wants it to be in the future. Since it is a map, it may be specific in some areas, such as the assignment of responsibilities for project actors, and general in other areas to allow users to choose the most efficient way to proceed. Each risk plan should be documented, but the level of detail will vary with the unique attributes of each project.

2.1.2.2 Risk identification

Risk identification is the process of systematically and continuously identifying, categorizing, and assessing the initial significance of risks associated with a construction project (Al-Bahar and Crandall 1990). Risk identification involves identifying, categorizing and recording potential risks, together with information on their cause(s) and possible effect(s), which might affect the project objectives (Shehu and Sommerville 2006). It is the first step of the risk management process. It is aimed at determining potential risks, i.e. those that may affect the project.

Ward and Chapman (1995) suggest that it is often said that the real risks in any project are the ones that the project team fails to identify. Jenkins (1998) explains that risk identification at the operational level is very effective and can help with on-the-spot improvements and day-to-day management. Tasmania (2002) also suggests that before risks can be properly managed, they need to be identified. One useful way of doing this is defining categories under which risks might be identified: for example, in terms of risks external to the project and those that are internal.

Risk identification is ideally carried out during the appraisal of the project, although it can be carried out at any stage of the project (Smith 1999). It should also be performed on a regular basis throughout the project (Duncan 1996). The inputs of risk identification process include the project objective, risk management scope and plan and historical data related to project. The project related document, project participants and events occurring in the scope of project are some sources of information used to identify risk (Aleshin 2001). It is desirable to identify risk based on the determined objectives, which are generally related to time, cost and quality aspects.

The identification process will vary, depending on the nature of the project and the risk management skills of the team members, but most identification processes begin with an examination of issues and concerns created by the project development team. These issues and concerns can be derived from an examination of the project description, work breakdown structure, cost estimate, design and construction schedule, procurement plan, or general risk checklists. This is a practical way of addressing the large and diverse numbers of potential risks that often occur on highway design and construction projects. Risks are those events that team members determine would adversely affect the project (Caltrans 2007).

There are a number of tools and techniques for identifying the project risks (IEC 2001; PMI 2000; Vaughan 1997). These are brainstorming, expert opinion, structured interviews, questionnaires, checklists, historical data, previous experience, testing and modeling, evaluation of other projects. Empirical studies of risk management practice (Akintoye and MacLeod 1997, Lyons and Skitmore 2004, Uher and Toakley 1999) show that checklists and brainstorming are the most usable techniques in risk identification. They also highlight that risk identification often relies on individual judgments of the project participants. Brainstorming, scenario planning, and expert interviews are tools highway engineers commonly use in routine engineering and construction management tasks (Osipova 2008).

PMBOK (2000) stipulates that as many project stakeholders as possible should participate in the risk identification process. Participants in risk identification activities can include the following, where appropriate: project manager, project team members, risk management team (if assigned), subject matter experts both from the project and from outside the project team, customers, end users, other project managers, stakeholders, and risk management experts. While these personnel are often key participants for risk identification, all project personnel should be encouraged to identify risks.

After the risks are identified, they should be categorized into groups of like risks. There are several approaches to categorizing project risks and risk sources (Baloi and Price 2003, Jaafari 2001, Leung et al. 1998, Li et al. 2005, Mbachu and Vinasithamby 2005, Tah and Carr 2000, Zhi 1995). In general, the sources of risk in construction projects may be divided into three groups:

i. Internal or controllable risks (e.g. design, construction, management and relationships);
ii. External or uncontrollable risks (e.g. financial, economic, political, legal and environmental);
iii. Force majeure risks.

The deliverable of the identification process is risk category summary sheet (Al-Bahar and Crandall 1990) or risk log/risk register (Smith 1999) or risk standard data card (Aleshin 2001). By using these tools risk information are kept in the form of database. The Risk Register is subsequently amended with the results from qualitative risk analysis and risk response planning, and is reviewed and updated throughout the project. The desirable output of risk identification is the identified risks involved with the project or determined objectives. These identified risks may be classified based on the sources of risks (Caltrans, 2007)

2.1.2.3 Risk assessment

Risk assessment or analysis process is the vital link between systematic identification of risks and rational management of the significant risks. It has as its primary objective the systematic consideration of risk events, their likelihood of occurrence, and the consequences of such occurrences. The risk analysis process aims to evaluate the consequences associated with risks and to assess the impact of risk by using risk analysis and measurement techniques (Flanagan and Norman 1993). In this phase the probability of occurrence and severity of impact for each identified risk are estimated, and risks for further attention are prioritized; Figure 2 below demonstrates the risk matrix. The main input to risk analysis process is the identified risks from risk identification process. The probability and impact of identified risks are two key variables in assessing the risk.

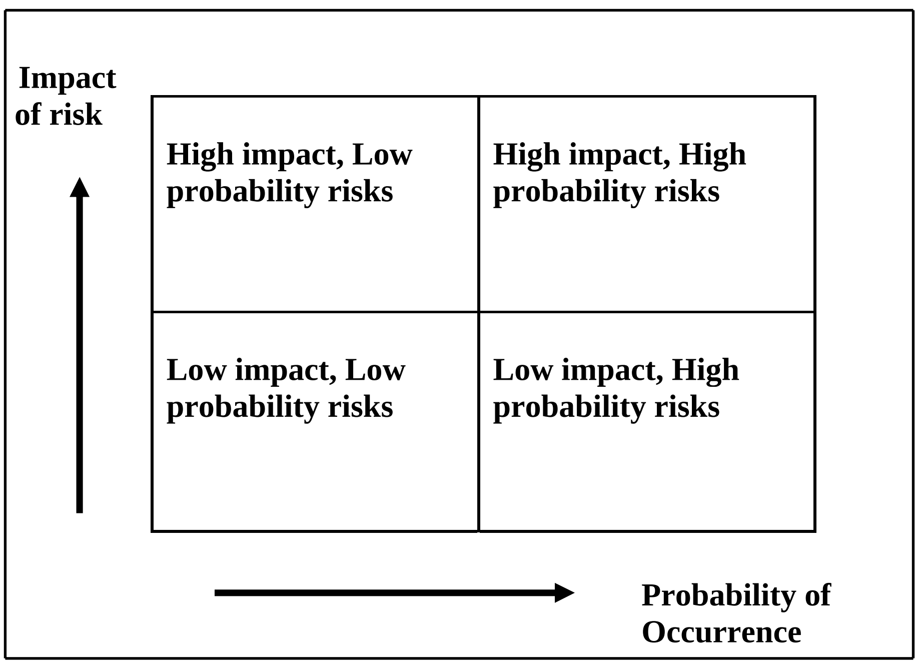

Fig. 2: Risk matrix, adapted from Caltrans (2007)

In assessment of risk, there are two general types: qualitative and quantitative risk assessment (Flanagan and Norman 1993 and Smith 1999). Qualitative Risk Analysis assesses the priority of identified risks using their probability of occurrence, the corresponding impact on project objectives if the risks do occur, as well as other factors such as the time frame and risk tolerance of the project constraints of cost, schedule, scope, and quality. Typically, a project's qualitative risk analysis will recognize some risks whose occurrence is so likely or whose consequences are so serious that further quantitative analysis is warranted. The analysis includes methods for prioritizing the identified risks for further action, such as quantitative risk analysis or Risk Response Planning (Caltrans 2007). The direct judgment, ranking options, comparing options and descriptive analysis are also considered as the qualitative risk measurement (Flanagan and Norman 1993).

Quantitative risk analysis is a way of numerically estimating the probability that a project will meet its cost and time objectives. The analysis is based on a simultaneous evaluation of the impact of all identified and quantified risks. A key purpose of quantitative risk analysis is to combine the effects of the various identified and assessed risk events into an overall project risk estimate. For quantitative risk assessment, probability analysis, sensitivity analysis, scenario analysis, simulation analysis, correlation analysis, portfolio theory, Delphi method, influence diagrams, decision trees, are lists of available techniques (Flanagan and Norman 1993 and Smith 1999).

Empirical research on risk assessment practice investigates the use of the different risk assessment techniques in construction projects. A study by Baker et al. (1998) shows that construction companies in UK use both qualitative and quantitative techniques for assessing the project risks. Personal and corporate experience and engineering judgment are the most successful qualitative techniques, while quantitative techniques include break-even analysis, expected monetary value and scenario analysis. The studies of risk management practice in the UK construction industry show that the practitioners rely mostly on professional judgment, intuition and experience (Akintoye and MacLeod 1997, Wood and Ellis 2003). A questionnaire survey conducted by Tang et al. (2007) shows that qualitative analysis is the most commonly used technique in the Chinese construction industry, while the use of quantitative methods is very low. The results of the study conducted by Simu (2006) show that the Swedish contractors mostly use professional experience and gut-feeling in risk assessment. Kähkönen (2007) argues that the quantitative methods used in risk management have advantages in comparison with the qualitative methods but their use is limited due to difficulties that practitioners face. He also discussed the elements that contribute to development of a workable solution for quantitative risk assessment.

Three basic risk analyses can be conducted during a project risk analysis: technical performance analysis (will the project work?), schedule risk analysis (when will the project be completed?), and cost risk analysis (what will the project cost?). This overall assessment of risks can be used by a Highway agency to make informed decisions about a project. More commonly, the overall risk assessment is used to determine cost and schedule contingency values and to quantify individual impacts of high-risk events. The ultimate purpose of the analysis, however, is not only to compute numerical risk values but also to provide a basis for evaluating the effectiveness of risk management or risk allocation strategies (Guo, 2004).

The ultimate deliverables of risk analysis process are probability of occurrence and impact level of risks. For the impact of risk, possible consequences of risk are defined and quantified in terms of (Smith 1999):

i. Increased cost: i.e. additional cost above the estimate of the final cost of the project;
ii. Increased time: i.e. additional time beyond the completion date of the project through delays in construction;
iii. Reduced quality and performance: i.e. the extent to which the project would fail to meet the user performance based on quality, standards and specification.

2.1.2.4 Risk response planning

Response is an action or activity that is implemented to deal with a specific risk or combination of risks (Osipova 2008). Risk Response Planning is the process of developing options or strategies to respond to each individual risk and to the overall risk exposure, and determining actions to enhance opportunities and reduce threats to the project's objectives. It focuses on the high-risk items evaluated in the qualitative and/or quantitative risk analysis. Risk response process aims to provide the efficient response to the identified and analyzed risks. In risk response process, the decision maker considers how the risk should be managed, for examples, by transferring it to another party or retaining it (Flanagan and Norman 1993). The risk response process is directed at identifying a way of dealing with the identified and assessed project risks (Caltrans 2007).

There are four main risk response strategies: risk avoidance, risk reduction, risk transfer and risk retention (IEC 2001, PMI 2000, Smith et al. 2006, Flanagan and Norman 1993 and Vaughan 1997). Risk avoidance deals with the risks by changing the project plan or finding methods to eliminate the risks. Risk reduction aims at reducing the probability and/or consequences of a risk event. Those risks that remain in the project after risk avoidance and reduction may be transferred to another party either inside or outside the project. Risk retention or acceptance indicates that the risk remains present in the project. Two options are available when retaining the risk: either to develop a contingency plan in case a risk occurs, or to make no actions until the risk is triggered. Several studies (Baker et al. 1999, Lyons and Skitmore 2004, Tang et al. 2007) have identified risk reduction as the most frequently used technique within the construction industry. The results of a questionnaire survey (Akintoye and MacLeod 1997) report that risk transfer is the most preferable strategy among the UK practitioners.

In Risk Response Planning parties are identified and assigned to take responsibility for each risk response. This process ensures that each risk requiring a response has an owner (risk officer or management team) monitoring the responses, although a different party may be responsible for implementing the risk handling action itself. The owner of the risk could be an agency planner, engineer, or construction manager, depending on the point in project development, depending on the contracting method and risk allocation. Risk planning and mitigation efforts may require that agencies set policies, procedures, goals, and responsibility standards. Formalizing risk mitigation and planning throughout a highway agency will help establish a risk culture that should result in better cost management from planning through construction and better allocation of project risks that align teams with Client-oriented performance goals. Nevertheless, the Project Development Team identify which strategy is best for each risk, and then design specific action(s) to implement that strategy (Caltrans, 2007).

According to Guo (2004) strategies for negative risks are as follows.

i. **Risk avoidance:** involves changing the project plan to eliminate the risk or to protect the project objectives (time, cost, scope, quality) from its impact. The team might achieve this by changing scope, adding time, or adding resources (thus relaxing the so-called "triple constraint"). These changes may require a Programming Change Request (PCR). Some negative risks (threats) that arise early in the project can be avoided by clarifying requirements, obtaining information, improving communication, or acquiring expertise.

   When an organization or parties or individual refuse to accept risk, then risk is avoided. This means the exposure of risk is not allowed to exist. If risk avoidance is used extensively, the opportunity to receive profit or achieve objectives may be decreased. A contractor not placing a bid or the owner not proceeding with project funding are two examples of eliminating risk totally. There are a number of ways through which risks can be avoided, for examples, tendering a very high bid, placing conditions on the bid, and not bidding on the high-risk portion of the contract (Baker, Ponniah, and Smith 1999).

ii. **Risk transfer:** Risk transfer requires shifting the negative impact of a threat, along with ownership of the response, to a third party. An example would be the team transfers the financial impact of risk by contracting out some aspect of the work. Risk transfer reduces the risk only if the contractor is more capable of taking steps to reduce the risk and does so. Risk transfer nearly always involves payment of a risk premium to the party taking on the risk. Transfer tools can be quite diverse and include, but are not limited to the use of: insurance, performance bonds, warranties, guarantees, incentive/disincentive clauses, A+B Contracts, etc.

   Risk transfer can take two basic forms (Thompson and Perry 1992):

   a. the property or activity responsible for the risk may be transferred, i.e. hire a subcontractor to work on a hazardous process; or
   b. the property or activity may be retained, but the financial risk transferred, i.e. methods such as insurance.

iii. **Risk Mitigation:** Risk mitigation implies a reduction in the probability and/or impact of an adverse risk event to an acceptable threshold. Taking early action to reduce the probability and/or impact of a risk is often more effective than trying to repair the damage after the risk has occurred. Risk mitigation may take resources or time and hence may represent a tradeoff of one objective for another. However, it may still be preferable to going forward with an unmitigated risk. Monitoring the deliverables closely, increasing the number of parallel activities in the schedule, early involvement of regulatory agencies in the project, early and continuous outreach to communities/advocacy groups, implementing value engineering, performing corridor studies, adopting less complex processes, conducting more tests, or choosing a more stable supplier are examples of mitigation actions (Caltrans 2007).

The strategies for positive risks, according to Guo (2004) or opportunities include the following.

i. **Exploit:** The organization wishes to ensure that the opportunity is realized. This strategy seeks to eliminate the uncertainty associated with a particular upside risk by making the opportunity definitely happen. Examples include securing talented resources that may become available for the project.

ii. **Share*:*** Allocating ownership to a third party who is best able to capture the opportunity for the benefit of the project. Examples include: forming risk-sharing partnerships, teams, joint ventures, etc

iii. **Enhance:** This strategy modifies the size of an opportunity by increasing probability and/or positive impacts, and by identifying and maximizing key drivers of these positive-impact risks. Seeking to facilitate or strengthen the cause of the opportunity, and proactively targeting and reinforcing its trigger conditions, might increase probability. Impact drivers can also be targeted, seeking to increase the project’s susceptibility to the opportunity.

The strategy for both threats and opportunities is **Risk acceptance**. It is a strategy that is adopted because it is either not possible to eliminate that risk from a project or the cost in time or money of the response is not warranted by the importance of the risk. When the project manager and the project team decide to accept a certain risk(s), they do not need to change the project plan to deal with that certain risk, or identify any response strategy other than agreeing to address the risk if and when it occurs.

Carter and Dohery (1974) described two acceptance methods, active and passive. Active acceptance sometimes is referred to as self- insurance, is a deliberate management strategy after a conscious evaluation of the possible losses and costs of alternative ways of handling risks. Second, passive acceptance, which sometimes is called non-insurance, occurs through neglect, ignorance or absence of decision. Flanagan and Norman (1993) stated that risks suitable for acceptance are those that occur frequently but have small losses.

According to Carter and Dohery (1974), there are two types of acceptance strategy:

- **Active acceptance**. The most common active acceptance strategy is to establish a contingency reserve, including amounts of time, money, or resources to handle the threat or opportunity. In this case, a response plan, also known as “Contingency Plan”, is developed by the project team that will only be executed under certain predefined conditions commonly called “triggers.”

- **Passive acceptance:** Requires no action leaving the project team to deal with the threats or opportunities as they occur. In this case a workaround plan is executed to recover the damage. Workaround is distinguished from contingency plan in that a workaround is a recovery plan that is implemented if the event occurs, whereas a contingency plan is to be implemented if a trigger event indicates that the risk is very likely to occur.

Risk response planning and mitigation efforts may require that agencies set policies, procedures, goals, and responsibility standards. Formalizing such a practice in a highway agency will help establish a risk culture that should result in better risk management from planning through construction and better allocation of project risks that align project teams with result-oriented performance goals.

2.1.2.5 Risk monitoring

Risk monitoring and control, according to Caltrans (2007) keeps track of the identified risks, residual risks, and new risks. It also monitors the execution of planned strategies on the identified risks and evaluates their effectiveness. Risk monitoring and control continues for the life of the project. The list of project risks changes as the project matures, new risks develop, or anticipated risks disappear. Typically during project execution there should be regularly held risk meetings during which all or a part of the Risk Register is reviewed for the effectiveness of their handling and new risks are discussed and assigned owners. Periodic project risk reviews repeat the process of identification, analysis, and response planning. The project manager ensures that project risk is an agenda item at all Project developing team meetings. Risk ratings and prioritization commonly change during the project lifecycle. If an unanticipated risk emerges, or a risk's impact is greater than expected, the planned response may not be adequate. The project manager and the Project developing team must perform additional response planning to control the risk. Caltrans further elaborate the essentials of Risk control to include the following:

- Choosing alternative response strategies
- Implementing a contingency plan
- Taking corrective actions
- Re-planning the project, as applicable

The individual or a group assigned to each risk or the risk owner reports periodically to the project manager and the risk team leader on the status of the risk and the effectiveness of the response plan. The risk owner also reports on any unanticipated effects, and any mid-course correction that the Project developing team must consider in order to mitigate the risk. Figure 3 below illustrates the Risk management processes.

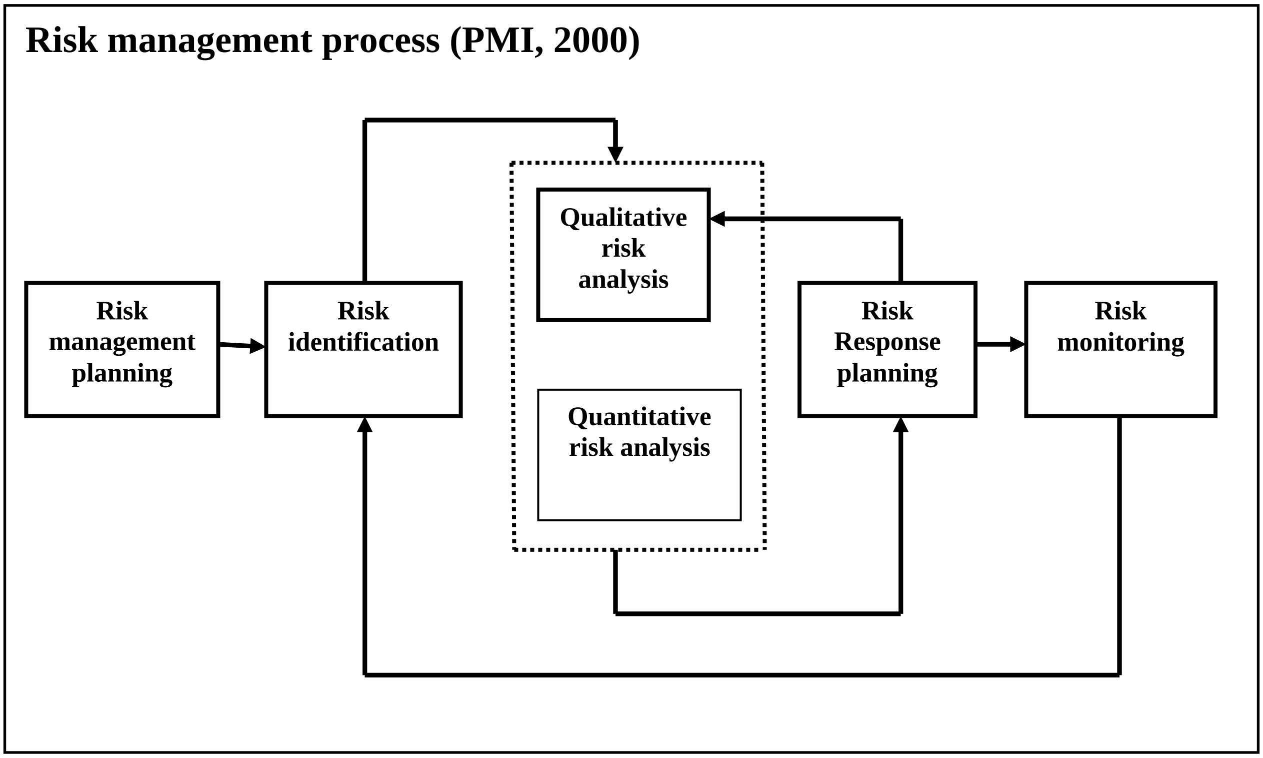

Fig. 3: Risk management processes, modified from Caltrans (2007)

2.1.3 Risk allocation

The importance of risk allocation should be recognized since unfair and misallocations of several inherent risks in construction contract inevitably affect all project parties - client, contractors, and consultant (Piattanapiwong 2004**)**. Basically, the principal means practically used for contractual allocation or reallocation of risks is the construction contract (Fisk 1997). It is important that the contract clauses allocating the risk are clear and unambiguous. The meaning the owner wishes to convey should be what the contractor interprets (Hartman and Snelgrove 1996). Unforeseen ground conditions, unknown utilities, and inclement weather are examples of typical construction risks facing problems regarding inappropriate risk allocation in contract occurring in practice (Macdonald 2001).

The contract is the vehicle for risk allocation. Whether the contract is for construction, construction engineering and inspection, design, design-build, or some other aspect of highway construction management, it defines the roles and responsibilities for risks. Risk allocation in any contract affects cost, time, quality, and the potential for disputes, delays, and claims (Youge, 2001). One measure of contract's efficiency and effectiveness is its ability to clearly assign risk between contracting parties. Clear risk assignment means that both contracting parties have the same understanding of risk apportionment and risk management accountability. Contracting parties who do not have an identical understanding of risk accountability may mismanage a risk event by assuming the event or its consequences are not their responsibility. Mismanaged events cause project inefficiencies and make contract relationships adversarial. The resulting impacts on project execution ultimately increase project costs (Hartman 1993).

2.1.3.1 Principle of Risk Allocation

Several literatures related to risk allocation inevitably describe the common principle that "the risks in a project should be apportioned to those project parties who can best manage them" (Macdonald 2001), though, this principle is too conceptual. The following principle for risk allocation in construction is the very first proposed principle (Abrahamsan 1973), which has been discussed and referred by many successive researchers. The contracting party should bear the risk in any one of the following five cases:

i. if the risk is of loss due to his/her own willful misconduct or lack of reasonable efficiency or care,
ii. if he can cover a risk by insurance and allow for the premium in settling his charges, and it is most convenient and practicable for the risk to be dealt with in this way,
iii. if the preponderant economic benefit of running the risk accrues to him,
iv. if it is in the interests of efficiency to place the risk on him, and
v. if, when the risk eventuates, the loss happens to fall on him in the first instance, and there is no reason under any of the above headings to transfer the loss to another, or it is impracticable to do so.

Whereas this principle was widely supported to be a useful first step in discussing the issue of risk allocation, this stated principle still does not provide the complete solution (Ward 1991). It does not provide the guidelines as to how economic benefits/rewards and risks ought to be matched. It just recognizes that these two terms should be matched.

In addition to above principle, guidelines described by Fisk (1997) recognized the following as criteria used for sharing of risks inherent in a construction project.

i. All risks are rightfully those of the owner unless and until contractually transferred to or assumed by the contractor or insurance underwriter for a fair compensation.
ii. The principal guideline for transferring a risk is whether the receiving party has both the competence to assess the risk fairly and the expertise necessary to control or minimize it.
iii. An additional guideline is the determination of whether the shift of the risk from the owner to another party will result in savings to the owner and the public.

Hartman and Snelgrove (1996) also stated that it is important that the contract clause allocating the risk be clear and unambiguous. The meaning the owner wishes to convey should be what the contractor interprets. Therefore, a balancing of the risk should be sought amongst owner, contractors, and other parties in order to utilize the incentive value of bearing a risk while minimizing the contingency charged for accepting the risk.

The objectives of risk allocation can vary depending on unique project goals, but four fundamental tenets of sound risk allocation should always be followed (Pipattanapiwong, 2004):

i. **Allocate risks to the party best able manage them**; A fundamental tenet of risk management is to allocate the risks to the party best able to manage them. The party assuming the risk should be able to best evaluate, control, bear the cost of, and benefit from its assumption. Inappropriate risk shifting from the owner to the contractor can result in misaligned incentives, mistrust, and an increase in disputes.
ii. **Allocate the risk in alignment with project goals***;* Risks should be allocated in a manner that maximizes the probability of project success. The definition of a clear and concise set of project objectives is essential to project success and these objectives must be understood to properly allocate project risks. Allocating risks in

alignment with project objectives begins with a clear understanding of the project objectives by the agency and a clear communication of these objectives to the contracting, consulting, or design community. While this idea seems simple, in practice it is often difficult to identify and prioritize concise objectives because of the complex nature of highway construction projects.

iii. **Share risk when appropriate to accomplish project goals**.

iv. **Ultimately seek to allocate risks to promote team alignment with customer-oriented performance goals;** while the concept of allocating risks in alignment with customer-oriented performance goals may seem to be a significant departure from traditional practices, highway agencies are already doing this through the use of alternative contracting techniques. For example, A+B (time plus cost) procurement is used on selected projects in the majority of highway agencies in the United States. In essence, A+B procurement passes the risk for early completion to the contractor to achieve a customer goal of satisfaction with the service. Agencies and the industry should strive to innovate and develop new risk allocation techniques that align all team members with customer goals.

2.1.3.2 Risk allocation approach

Theoretically, the approaches to allocate the risk can be classified into two main approaches i.e. qualitative and quantitative approaches (Yamguchi 2001). The quantitative approaches objectively focus on quantification of magnitude of the allocated risks, which is the main difference and extension from the qualitative approaches.

i) Qualitative approach

A common qualitative approach is considered as standardized form of contract, which specify the obligation of contractual parties and some relief such as time extension for the party bearing the risk associated with that obligations. Ashley (1977) cited by Yamaguchi et al., (2001) stated that the standardized form of contract provides a framework of risk allocation by a government owner based on the principle that each risk element should be distributed so that the total effect on the total expected cost is minimized.

ii) Quantitative Approach

The quantitative approaches to risk allocation have been developed to overcome the limitation of qualitative approaches especially the issue of how much risk should be borne by each party. Most of quantitative approaches discussed their risk allocation model based on the optimality of allocating the risk. The quantitative approaches could be classified into two different concepts of optimality: cooperative and competitive risk allocation considering the different aims and views (Yamaguchi 2001).

Cooperative risk allocation assumes that the stakeholders jointly search for an agreement that is mutually acceptable. Most cooperative risk allocations define the optimum solution as where the total contingency costs of the project are minimized. On the other hand, the competitive risk allocation is the allocation where each of the stakeholders employs the strategy that best achieve their own goals without any concern for the other stakeholders (Yamguchi 2001). The insurance theory for example is the concept, which the competitive risk allocation was relied on. Another model considered that actual risk allocation is relied on the combination of cooperative and competitive allocation of risks. It means the solutions provide room for negotiation. The potential solutions together constitute the negotiation space.

It is impossible to eliminate all potential risks in a construction project. Therefore, an appropriate allocation of risks among project actors is very important. Risk allocation influences the behavior of project actors and, therefore, has a significant impact on the project performance in terms of the total cost. Unclear allocation of the project risks leads to disputes between the client and the contractor. One of the problems identified in the literature is the actors' different perceptions of to whom a specific risk or group of risks should be allocated. Usually, contractors indicate that they have to bear the majority of project risks and price these risks through adding a contingency to the bid price (Andi 2006).

The contract can also be defined as a trade-off between the contractor's price for executing the project and his willingness to take the risks (Flanagan and Norman 1993). The objective of clients is to choose a strategy that ensures achievement of the project objectives in the most efficient way (Osipova 2008).

2.2 Risks in Construction projects

According to Turner (1992), a project is an endeavor in which human, material and financial resources are organized in a novel way; to undertake a unique scope of work of given specification, within constraints of cost and time, so as to achieve unitary, beneficial change, through the delivery of quantified and qualitative objectives. The definition suggests three key targets of the project, i.e. time, cost and quality, which are to be in focus when undertaking the project. It also highlights the importance of efficient organization of available resources in order to achieve a good final result.

Flanagan and Norman (1993) emphasize two aspects of any construction project: the process, i.e. project phases, and the organization, i.e. project actors. From the process perspective, any construction project comprises a number of sequential phases. Different authors suggest a different number of project phases (Chapman and Ward 2003, Flanagan and Norman 1993, Harris et al. 2006, PMI 2000, Smith et al. 2006). The simplest approach identifies two main phases – project development and project implementation. These two can be further detailed and developed into a larger number of phases, e.g. feasibility, design, procurement, construction, commissioning, and operation.

Another important aspect of the construction process is project organization. Different participants are usually involved in a construction project. These are clients or owners, consultants, contractors, sub-contractors, manufacturers and suppliers, local authorities, funding organizations etc. The more participants that are involved, the more complex the task of project management becomes. In this research three main groups of construction industry actors are in focus; clients, contractors and consultants.

According to PBL (1987), a client is a party that carries out or assigns others to carry out construction. There are two main groups of construction clients: public and private. Privately owned companies undertake the projects to make a profit. The public sector includes the central government and local authorities and undertakes the projects to provide a public service and/or benefit to the citizens. A contractor is an organization that provides a service for the client, i.e. executes the construction works. The contractor organizations have different complexities and provide different ranges of services. The role of consultants is to assist clients and contractors and provide engineering services.

The environment within which decision-making takes place can be divided into three parts: certainty, risk and uncertainty (Flanagan and Norman, 1993). According to Flanagan and Norman, certainty exists only when one can specify exactly what will happen during the period of time covered by the decision. This, they concluded, of course does not happen very often in the construction industry. Uncertainty, in contrast to risk, might be defined as a situation in which there are no historic data or previous history relating to the situation being considered by the decision-maker; in other words, where the situation is 'one of a kind'. Bennett and Ormerod (1984) argue that uncertainty is endemic in construction and needs to be explicitly recognized by construction managers.

Due to their dynamic nature, projects change continuously. Thus a great amount of risk and uncertainty is involved in construction activities (Chapman and Ward 2004). This uncertainty may have a significant impact on the project objectives and, therefore, has to be properly managed by the project actors during the whole project life cycle. Many time and cost overruns, according to Perry and Hayes (1985), are attributable to either unforeseen or foreseen events for which uncertainty was not appropriately accommodated. Thompson (1992) also identified an effect of risk on construction projects as failure to achieve the required quality and operational requirements. This is in addition to cost and time overruns which other authors also identified.

Perry and Hayes (1985), Thompson and Perry (1992) and Akintoye and MacLeod (1997) have identified risk sources in construction at the pre-contract stage to include design risk, competitive tendering risk, tender evaluation risk and estimating risk among others. In addition, they also identified risk factors at the post-contract stage to include physical risk, site condition, inclement weather, legal risk, environmental risk, logistic risk, political risk, financial risk and contractual risk among others.

Hassun's (2005) and Caltrans' (2007) categorization of the sources of risks include planning and selection risks such as inadequate project planning and inefficient project delivery system; financial risks such as funding risks; design risks; construction risks; external risks such as price escalation; environmental risks such as incomplete environmental analysis; contractual risks such as ambiguities in contract formation process; project management risks such as lack of coordination/ communication; and force majeure risks such as severe weather.

Abdou (1996) classified construction risks into three groups, i.e. construction finance, construction time and construction design, and addressed these risks in detail in light of the different contractual relationships existing among the functional entities involved in the design, development and construction of a project. Nevertheless one major area where significant improvements could be made is in the elimination and reduction of risk at the design stage (Waldron 2005). Designers are in a unique position, she said, to influence and reduce the risks that arise during construction. Therefore, the following section discusses design risks which are the focus of this research.

2.3 Design Risks

It is in the design stage where the requirements of the client are identified and the constructive aspects and the standards of quality are defined through procedures, drawings and technical specifications (Luis et al. 1998). Many construction problems are due to design defects and can be traced back to the design process (Bramble and Cipollini, 1998; Jergeas, 1989; Alshawi and Underwood, 1994; Madelsohn, 1997; Griffith and Sidwell, 1995). These design defects necessitate the need for design changes at later stages (Bramble and Cipollini, 1995). And the problems can be as high as 75% of the total problems encountered during construction (Madelsohn, 1997). NCHRP (1983) reported on an exhaustive study of the underlying causes of construction disputes and claims. This report has identified changes in design and specification among the five principal causes of claims.

Luis et al. (1998) cited a study conducted at Purdue University for Construction Engineering Research Laboratory of the U.S. Army Corps of Engineers that focused on how to improve the design to ensure the quality of construction contract documents. This study reported that "approximately half of all construction contract modifications can be attributed to design deficiencies." The study further defined a design deficiency as "Any deficiency in the drawings and or specifications which results in the facility which would not adequately perform its intended mission."

A Questionnaire survey by Kumaraswamy (1997) on common categories and causes of claims in Hong Kong revealed variations due to design errors/ambiguities, and ground conditions are the first two among the top ten common categories of construction claims. Similarly inadequate site investigations, inaccurate design information, scope changes by client, inadequate contract documentation, and design documentation are among the top ten common causes of construction claims. Kumaraswamy has also came across findings as to common categories, sources and causes of claims and disputes from other countries, as background to the investigations in Hong Kong. He cited Heath et al. (1994), in the U.K, who identified specifications and drawings as one of the five main categories of claims. Diekmann and Nelson (1995) also found that ‘design errors’ and ‘discretionary or mandatory changes’ constituted common causes of claims.

According to Luis et al. (1998), the problems associated with the designs are mainly:

i. **Poor Design Quality**: Design drawings are generally incomplete and they are not explicit, requiring a number of specifications. Specifications are difficult to handle and sometimes are ignored. Very often design documents have inconsistencies, errors and omissions, or simply lack of clarity in the presentation. This implies that those that should carry out the work do not have the necessary information or have the wrong information to do the job.

ii. **Lack of Design Standards**: There is a lack of standards in the designs, and lack of suitability for the existing technology. In many projects of similar characteristics, or of the same type, the designs used are completely different with the consequent loss of efficiency in the construction phase.

iii. **Lack of Constructability**: An important proportion of the problems detected during construction is lack of constructability of the designs. The details not defined in the designs become problems that have to be solved by the contractor on site. Usually the problems are detected just before starting construction of the specific task and sometimes even after the task has been accomplished. The results are losses of different type and magnitude.

Based on the result of the interviews and surveys, Luis et al. (1998) concluded that the most important problems present in the designs were: defects of individual specialists and the lack of coordination among specialties, changes introduced by the owner and the designers, inconsistencies among drawings and specifications, designers with little construction knowledge and non technical specifications. These problems produce a series of impacts in the construction works such as: idle times, rework, abnormal use of machinery and equipment, delays, etc

According to Caltrans (2007) design risks include: incomplete design, unexpected geotechnical conditions, inaccurate assumptions on technical issues in planning stage, incomplete surveys, unforeseen design exceptions, sub-standard design, and incomplete quantity estimates. Touran (2006) associate design risks with the Design consultants, project/site, cost estimate and schedule, and right of way acquisition. The list of design risks that come under these categories include: limitations in Designer's qualifications, lack of professionals, lack of teamwork spirit, lack of understanding of cost/schedule management, design errors and omissions, unreliable geotechnical data and test results, inaccurate or inadequate surveys, incomplete or inaccurate engineer's estimate, omitted quantities, un-sound schedule estimation, delays in right-of-way appraisal and acquisition. In similar vein, Harthy and Amur Salim (2006) elucidate that design risks evolve at programming level, schematic or conceptual level, and detailed design level. They broadly list out the risks as being associated with site selection, and geotechnical survey, scope definition and control, Engineers estimate, and schedule of works.

Other literatures reveal that design changes are major risk to construction projects (Thomas et al. 1999; Finke 1998; Ng et al. 1998; Yates 1993; Hester and Kuprenas 1987). Design changes in their simple term are defined as any addition, omission or modification to the original design; drawings; specification; contract documents; programme; method and sequence of executing the work (Akinsola *et al.*, 1997). These design changes might have great effect especially on cost and time and are likely to be a cause of claims and disruptions. Baxendale and Schofield, (1996) defined same as any change to the basis on which the contract terms were initially defined and endorsed. Burati et al., (1992) also defined the change as a directed action altering the currently established requirements which includes changes in the design, fabrication, construction, etc. and materially affect the approved requirements, the basis of design, the existing scope of the contract plans and specifications.

It is common in the construction industry for almost all projects to go through various degrees of modifications at the design stage and more commonly during the construction. These changes are mostly caused by clients, in favour of getting new ideas or cost reduction on projects (Federal Construction Council, 1983; Kelvin, 1996). Design members have also been the main contributors of the design changes in the construction industry. They originate the changes to rectify their mistakes and to improve or optimize their design (Hibberd, 1982; Choy and Sidwell, 1991). Contractors may also introduce changes to adopt alternative construction methods that are of more familiarity (McDermott and Dodd, 1984; Yogeswaran, 1998) and suppliers, in order to meet the manufacturer's recommendation to use a specific material (Emmitt, 2001).

According to Harthy and Amur salim (2006), there are many reasons wherein consulting engineers introduce design changes which may require at later stage modifications to the original design and/or constructed works. Five causes have been identified to be of common occurrence as reasons for consultants' oriented design changes.

i. Improper design /part of design improvement (e.g. to rectify design mistakes, to adopt better detailing, to simplify the design for easy construction etc.)
ii. Inconsistent information in drawings
iii. Discrepancy between contracts documents (e.g. drawings/ specification, Bill of Quantities etc.)
iv. Lack of/insufficient geotechnical investigation or wrong interpretation of the findings (e.g. un-expected rock layers, loose soil, high water table etc.)
v. Insufficient detail of existing site condition (e.g. clashes with underground facilities, clashes with adjacent structures, flooding condition at site, etc.)

In general, the most common reasons that necessitate design changes include change of scope of work/clients' new requirements (Wilson, 1982), coordination problems (Bubshait *et al.*, 1998), unclear scope of work (Austin *et al.*, 2002), design errors (Leonard, *et al.*, 1988), unexpected site conditions (Essex, 1996) and insufficient design information at the design stage (Ogunlana, *et al.*, 1996). Experience of the design team with similar projects can also affect the project or may result in changes (Daoud 1997; Kartam 1996; Kagan et al. 1986). Incomplete drawings and incomplete specifications are other sources of design changes or risks (Smith and Bohn 1999; Mulholland and Christian 1999; Ardits and Gunaydin 1998; Yates 1993; Laufer and Cohenca 1990; vlatas 1986). Brief descriptions of these Design risks are discussed as follows.

2.3.1 Changes in scope of work/Clients new requirements

Wilson (1982) noted that clients normally initiate changes on scope of works due to various reasons, and this is the most common source of design changes. Many clients have no sufficient ability to visualize the proposed works from detailed drawings until they see them in reality. If the work does not satisfy their need, they introduce changes on the completed parts. Many ideas and new requirements come at later stages that clients are eager to agree to it. Hence changing the specification by clients is not unusual in order to enhance the quality of the work and extend its performance. However, frequent changes in scope affect some projects (Songer and Molenaar 1997; Wong and Longcher 1986). The possible changes could be minor related to design development which have no or relatively low cost effect on overall outlay and could be major related to new ideas or changing the principle of the original design which, in turn, requires re-planning and re-designing that leads to a major cost effect (Burati et al., (1992).

2.3.2 Lack of co-ordination

Coordination problems between design members at the initial stage also contribute to design changes (Bushait et al., 1998). Co-ordination is important and should start at the initial design stage where many important decisions take place at this stage. Constructability and conformity of the elements from different disciplines totally depend on the level of co-ordination between the design members of the disciplines. Pocock et al., (1997), based on a study of over 200 completed projects, found that projects with greater interaction between the project personnel performed better with respect to cost, schedule, and design deficiencies. Baldwin et al., (1999) added that by a better understanding of the flow of information among project participants, the design may be improved and hence chances for design errors may be reduced which, in turn, reduce chances for design modifications. Baldwin also found that non existent or ineffective design management may also produce conflicting construction details that result in delays and problems during construction. Austin et al., (2000) established the importance of effective design management to produce a coordinated design of less conflict and to ensure the smooth running of information that both reduce the chances of unnecessary design changes.

Poor project coordination among Road agencies and other entities also lead to cost overrun (FDOT 1996). When planning and designing transportation projects, a Road agency must coordinate with local governments, Utilities' Agencies, and other relevant entities to identify environmental and local requirements, utility lines that must be moved as a result of the project, and other factors that must be considered during the planning, designing and construction process. Failure to coordinate or poor project coordination may delay scheduled works and result in claims.

2.3.3 Unclear scope of work

Unclear scope of work is also a common source of design changes especially for fast track projects (Austin et al., 2002). With a view to save time, there are cases where the construction work starts before the completion of the design. The contractors submit tenders according to the available information to them. At later stage, they might get unexpected detail that may require different skills and resources than the planned ones which could have cost implications. In addition, the contractors may get hold because of unavailability of the details when they are needed.

Besides, it is widely acknowledged that deficiencies in the brief are often the source of uncertainties that cause risks (Tweeds, 1996). An important key to the development of any construction project is the briefing given to the project team by the client or his representative. One of the greatest sources of uncertainty is its limitation in defining the brief. Only the client can decide what he wants, when he wants it and how much he prepared to pay for it. Getting it right from the start with clearly defined project brief is extremely important.

2.3.4 Design errors and omissions

Leonard, et al., (1988) suggested that the three major causes of changes in the construction are design errors and omissions, design changes, and unforeseen conditions. According to Harthy and Amur salim (2006), the most common causes of design changes are design deficiencies. Bubshait et al., (1998) defined design deficiency as any deficiency in the drawings and/or the specifications that results in a facility which will not adequately perform its intended mission.

Lutz et al., (1990) have categorized design deficiencies as one of the following three types:

i. contract documents conflict (e.g. discrepancy between drawings and specifications);
ii. interdisciplinary co-ordination errors (e.g. conflict problems among different drawings); and finally
iii. technical compliance discrepancies (e.g. non-adherence to the appropriate design guidelines, technical specifications and codes). These deficiencies do not only lead to design changes but also result in altering the construction work which, in turn, may lead to contractual disputes, cost overruns, time delay, compromise to quality, frustration and client dissatisfaction (Mokhtar, 2002).

Kirby et al., (1988) have also identified three major causes of the contract modifications in which design deficiency being one of the causes, in addition to user requested changes, and unknown site conditions. His study has revealed that 56 percent of all contract modifications are concerned with correcting design deficiencies. Diekmann and Nelson (1992) examined construction claims for their frequency of occurrence, cost and type. They found that 46 percent of the claims were due to design changes as a result of design errors, and 26 percent were either non-compulsory or mandatory changes. Thus, 75 percent of all contract claims can be traced to design changes, extra work and errors.

According to FDOT (1996), causes of Design errors and omissions include, but not limited to, the following.

i. *Emphasis on meeting schedules and increased production volume*: Factors that contribute to the high prevalence of design errors and omissions are the increased volume of construction and the emphasis placed on meeting production schedules. However, this emphasis on production quantity can affect product quality arising from Design errors and omissions.

ii. *Design plans not always carefully reviewed:* It was found that there is a high correlation between the volume of construction projects and the average cost overruns of projects. In the years when construction volume has been the highest, projects have had the highest average percentage cost overrun. As the volume of construction has fallen in some years, average cost overruns have also decreased. A reason for this linkage between construction volume and cost overruns is that due to production pressures design plans are not always carefully reviewed before being released for bid.

iii. *Lengthy project development periods*: Other factors that contribute to design errors are the lengthy development periods for some projects. Some projects are not let for bid until several years have passed since site investigations were conducted and design plans developed. As a result, site descriptions in design plans may no longer match construction conditions.

2.3.5 Incomplete or Poor specifications

Early research by O'Connor, Hugo et al. (1999) identified that incomplete or poor specifications can cause construction rework and delays. Their findings suggested that 22% of all constructability problems were related to ineffective communication of engineering information, plans, and specifications, especially inadequacies in project specifications. Anderson et al. (1999) also confirmed the issue of inadequacies in project specifications in their research on state highways in the USA.

2.3.6 Inaccurate cost estimate

For the project sponsoring organization, accurate cost estimates are vital for decisions that include strategies for potential project screening, and resource commitment for further project development. Various cost estimates are made at different stages of the project development process and include: project planning, decision to build, tendering and contracting. Flyvbjerg, Holm et al. (2002) explain that, while cost estimates become more accurate over time, it is exactly the cost estimate at the time of making the decision to build that is of primary interest. This method is also the international standard for measuring the inaccuracy of cost estimates (National Audit Office/Department of Transport 1992; World Bank 1994; Nijkamp and Ubbels 1999)

Early estimates are critical to the initial decision-making process for the construction of capital projects, however they can also typically be plagued by limited scope definition and thus a high potential for scope change. Early estimates, even when grossly inaccurate, often become the basis upon which all future estimates are judged, with future estimates even sometimes being ‘‘corrected’’ to be consistent with early estimates. It was found that Transportation projects have historically experienced significant cost overruns from early planning estimates. A recent study of 258 infrastructure projects spanning a time period of more than 70 years found that project costs were underestimated in approximately 90% of the projects, and the actual costs averaged 28% higher than estimated (Flyvbjerg, Holm et al 2002). It can be argued that construction cost estimating for infrastructure projects has not increased in accuracy over the past 70 years with underestimation of costs today being in the same order of magnitude that it was then (Molenaar 2005; Flyvbjerg, Holm et al 2002).

2.3.7 Unforeseen design exception

Caltrans (2007) describes unforeseen design exception as one of the risks encountered in highway projects. According to FHWA (2008), Design exceptions are defined as designs which do not conform to the minimum criteria as set forth in the standards, policies, and standard specifications. Common reasons for considering exceptions are impacts to the natural environment, social or right-of-way impacts, preservation of historic or cultural resources, sensitivity to context or accommodating community values, and construction or right-of-way costs.

FHWA (2008) argue that relying solely on standards does not guarantee a facility free of risk. Thus identifying/defining the risk is essential for managing the risk. Common types of Design exceptions include shoulder width, vertical alignment, lane width, horizontal alignment, stopping sight distance, Bridge width, grade, horizontal clearance (lateral offset), super elevation, and design speed. The key to evaluating Design exceptions or evaluating the risk are to identify who is “at risk” and what is the core motivation (safety of facility users such as motorists, pedestrians, etc., tort liability concerns by Road agency). The risk analysis focuses on consideration of safety for accepting/approving a Design Exception. The variables that influence the risk include exposure, traffic volume, location of exception, duration, extent, degree of the exception, and severity.

2.3.8 Unforeseen ground conditions

Risks in highway construction projects are characterized by their linear complexity, with their greatest risk lying below ground level due to the relatively larger footprint of highway projects, as compared with building structures. Studies from around the world have consistently highlighted the recurring frequency of claims for unforeseen ground conditions. In the USA, studies by Halligan, Hester et al. (1987) on state highway construction projects indicated that claims for ground conditions accounted for only 20% of all claims when categorized by root cause, but they were responsible for approximately 35% of the total amount paid to contractors for claims. A study in Hong Kong by Kumaraswamy (1997), aimed at identifying root causes of claims for extension of time and extra payments on construction projects, found that unforeseen ground conditions were ranked fourth in the “top ten” common categories of construction claims as perceived by contractors, owners and consultants.

One of the sources of construction schedule risks is differing site conditions (Mulholland and Christian 1999; Ruff et al. 1996; Russell 1993). Essex (1996) has indicated that uncertainty of subsurface ground conditions in the construction industry continue to cause major disputes as a result of altering the original contract documents. In this regard, he added that owners have been unwilling to authorize adequate geologic exploration programs or to take the responsibility for unanticipated ground conditions, engineers have often prepared incomplete or inconsistent plans and specifications, and contractors have tended to be excessively optimistic in their attempts to be the low bidder.

A study by Hoek and Palmieri (1998) revealed that unforeseen geological conditions and the associated geotechnical problems are a major contributor to cost and schedule overruns on large civil engineering projects. However, the geological conditions cannot be blamed for all of the cost and schedule overruns. Many of these disasters are the result of inadequate geological data, inadequate site investigations, inappropriate interpretation of available data, and incompetence in dealing with the problems once they have arisen. In spite of numerous attempts to deal with these situations by the incorporation of various clauses in contract documents, the problems persist. In their conclusion they have suggested that the best solution is to define the geological conditions as early and as accurately as possible so that surprises are minimized. Where no local source of geological information is available, there is no option but to mount a geological and geotechnical site investigation program that will identify the overall conditions of the site and give some indication of potential problem areas.

2.3.9 Experience of the design team

The separation of design and construction phases in the design-bid-build contracting environment makes it difficult for designers to develop construction experience. Once the design is complete, most designers leave the project. Experienced designers have few mechanisms for passing their knowledge to newly hired personnel. It was evident from responses within the design community that a major issue with respect to facilitating the constructability process is the need of construction experience and knowledge among designers. This issue is resolved within most firms by assigning design review responsibilities to senior design personnel. However, it is apparent that this effort does not effectively bridge the gap between designers and contractors so that efficient constructability analysis results (Daud, 1997).

2.4 Design Risk allocation

2.4.1 Categorizing Design risks

As indicated in section 2.1.1 of this research, Niwa (1989) and Wideman (1992) defines project risk as the chance of certain occurrences adversely affecting project objectives. The Project Management Institute has also defined project risk as an uncertain event or condition that, if it occurs, has a positive or a negative effect on a project objective (PMI 2000). Similarly, the Association for Project Management defines risk as factors that may cause a failure to meet the project's objectives (APM 2000). Therefore, it is apparent that a successful project should achieve the project objectives; i.e. attains the required quality level, need to be completed on time and within the allocated budget (Chan and Kumaraswamy, 1999).

Further, according to Smith et al. (2006), all project risks can be divided into three main categories: known risks, known-unknowns and unknown-unknowns. The difference between the categories is the decreasing ability to predict or foresee the risks. A known is an item or situation containing no uncertainty. Unknowns are things we know but we do not know how they will affect us. A known-unknown is an identifiable uncertainty. An unknown-unknown is simply an item or situation whose existence has yet to be encountered or imagined. And those events that have high probability and high impact are subject to risk management.

In the opinion of the researcher, changes in which the owner directs the consultant or the contractor to do works that are not specified in the original contract or increases/decreases the specified scope of work can be categorized as known risks. Similarly, changes which are often identified after the fact and based on unexpected event and unplanned choice by the owner can be categorized as known-unknown risks since it involves uncertainty that may lead to risk. Despite the fact that known risks are managed by planned choice of the owner, the point of focus of this research tends to dwell on the other form of risk; known-unknown. In order to categorize the risks in such a form, this research has grouped all design deficiencies that cause changes as ''Design errors and omissions'' by adapting the definition given by GDOT (2006), which says Errors and Omissions are design deficiencies in the plans, specifications, and contract documents, which must be corrected in order for the project to function or built as intended.

Although omissions arising from unexpected site conditions could be encountered, ‘’Unforeseen ground conditions’’ are taken as the second group of risk because of the degree of uncertainties involved.

It is apparent that Design errors and omissions, and unforeseen ground conditions are encountered in most of the projects because of various reasons. There could be a risk because of either or both phenomena as the case may be, but one cannot be certain about the probability of occurrence and the severity of the impact. Hence known-unknown risks that require management are there. This research, therefore, assesses the ways and means to manage the risks from different points of view as discussed in the next section.

2.4.2 Risks of errors and omissions

GDOT (2006) defined Errors as items in plans or other contract documents that are shown incorrectly. Omissions are items in plans or other contract documents that are not shown or included. Errors and Omissions are design deficiencies in the plans and specifications, which must be corrected in order for the project to function or be built as intended. Similarly, NDOT (2007) defined Errors and/or omissions as “Deficiencies from the standard of care on the part of a design/construction engineering consultant in the performance of professional services. The “standard of care”, shall be the “duty to exercise the degree of learning and skill ordinarily possessed by a reputable design professional practicing in the same or similar locality and under similar circumstances.”

According to GDOT (2006), though consultants are accountable for the technical accuracy and quality of their work, design errors and/or omissions (E&O) do occur. Depending on their significance, E&O may result in increased design, construction, and maintenance costs. Because an E&O may affect the ability to deliver projects on time and within budget, controlling them is important. The significance of an E&O can be measured by how it affects the contract schedule and/or construction costs. An E&O discovered before construction is typically resolved more quickly and at a lower cost than one discovered during construction and at a major point in the project’s critical path.

GDOT's experience, when an E&O is identified during construction, emphasis is placed on providing a solution to correct the E&O as quickly as possible to avoid or minimize construction delays. Resolving an E&O discovered during construction requires a change to the original construction contract. Modifying the original contract not only adds to a project's cost, but also places an administrative burden. A clause in GDOT 's Professional Services Agreement states "the Department reserves the right to pursue reimbursement for these additional costs from the professional design consultant if the E&O is determined to be a result of "ordinary negligence or gross negligence" as defined hereunder.

Gross negligence is the absence of slight diligence or the degree of care which every man of common sense, however inattentive he may be, exercises under the same or similar circumstances. As applied to the preservation of property, the term 'slight diligence' means that care which every man of common sense, however inattentive he may be, takes of his own property. *Ordinary negligence* is the degree of care which is exercised by ordinary prudent persons under the same or similar circumstances. As applied to the preservation of property, the term 'ordinary diligence' means that care which every prudent man takes of his own property of a similar nature. The absence of such diligence is termed ordinary negligence

The purpose of GDOT's Errors and Omissions (E&O) policy is to recover additional project costs due to carelessness or negligence. A desired outcome of enforcing the policy is higher-quality plans and contract documents, which in-turn will enable to deliver projects according to approved schedules and within fiscal constraints. If E&O results in additional quantities being added to the project that would have been required anyway and no other quantities, delays, or costs are created, no compensation from the consultant is necessary. In order for the procedure of cost recovery to be effective if negotiation fail and the case is litigated, the evaluation of consultant liability due to E&O should be based on "ordinary or gross negligence", as defined in Georgia statutes, which, at a minimum, is the degree of care exercised by ordinary prudent persons under the same or similar circumstances.

The policy regarding recovery of E&O costs is summarized as, "the consultant should only be held accountable for the costs of the new design - not for additional construction costs resulting from such errors - unless the E&O are a result of gross negligence or carelessness". Further, GDOT realized that establishing benchmarks for professional design consultants' performance will be a valuable management tool to improve consultant project management. The effects may range from documenting results of E&O as part of a performance rating to recommending suspension/debarment for cases where gross negligence is proven**.**

According to Elieen et al., (2002) when client furnishes plans and specifications for a construction project, the client generally bears responsibility for any deficiencies in those specifications. That is, the client impliedly warrants the correctness of those plans and specifications; i.e., that the project can be constructed based on the plans and specifications. In that case, a contractor is bound to build according to plans and specifications provided to it by the client, and if the contractor does so it will not be responsible for the consequence of defects in the plans and specifications. As a consequence of the implied warranties, when the plans and specifications are defective and cause a contractor to engage in extra work and expenses not anticipated when entering into the construction contract, the contractor is able to recover for the extra work and expenses.

In order for a Client to hold a design professional responsible for any errors in the plans and specifications, the client must establish that the design professional failed to exercise the required degree of care, skill, and proficiency competently exercised by ordinarily careful and prudent design professionals. This standard is more difficult to prove than "ordinary" negligence because it often requires expert testimony regarding the knowledge and skill of a competent professional. Therefore, when the plans and specifications contain some defect, a client is faced with a dilemma. The client is responsible to the contractor for providing those specifications, under the theory of implied warranties of correctness, yet the client may encounter difficulty proving any liability on the part of the design professional. Therefore, it is important to consider this dilemma at the outset of a construction project and contractually allocate risks of design errors to both the contractor and the design professional where possible (Eileen et al., 2002).

While the client impliedly warrants the adequacy and sufficiency of the construction plans and specifications, contractors have a duty to review the construction documents before submitting their bids to identify obvious errors, in the contract documents. Implicit within the duty to review the documents prior to bidding is the contractor's duty to seek clarification of any errors or ambiguities it discovers while reviewing the construction documents. In addition to the obligation to disclose defects and seek pre-bid clarification, most construction contracts contain pre-bid site investigation clauses that require contractors to visit the site prior to submitting a bid (Eileen et al., 2002).

The GDOT's experience and Eileen's argument explained above aim at the need to allocate the risks of design errors and omissions. The nature and extent of these risks should be identified and assessed, with the approach required to manage those risks. Accordingly, assessment needs to be made of the nature and extent of the risks involved. Decisions are then given about those risks that are to be borne by the agency and those that are most appropriately transferred to the service provider. In order to protect the agency generally and in the event of a service provider not having sufficient resources to meet its liabilities, the agency can generally requires the insurable risk to be insured. In this connection, the New South Wales Construction Agency Coordination Committee has issued a Guideline for insurance for Government construction projects in October 2004. The Guideline suggested the following steps to assist agencies develop the approach required for a project.

i) Assessing the project risks

The nature and extent of the risks generally and with service providers should be identified and assessed, with the approach required to manage those risks. Table 2 show typical risks to be encountered with consultants engaged by the Agency.

Table 2: Typical risks to be encountered with consultants

The engagement period	The post engagement period
Financial loss and delay if the consultant fails to complete, such as when it goes into liquidation.	Consequences of defective documentation prepared by the consultant, such as bridge failure caused by miscalculation.
Consultant provides incorrect advice causing an accident, damage to property, and delay with consequent financial loss	Losses resulting from a dispute with the Consultant.

ii) Establish the risks that should be covered by insurance

Having identified the risks and the risk levels with the project, agencies should next determine which risks should be insured against and the party best able to arrange the insurance. Insurable and other risks can be categorized as follows:

- Those to be covered by insurance required by legislation, such as workers compensation insurance that is to be taken out by the agency and service provider to cover their employees;
- Risks to all parties where the main service provider should be required to take out insurance to cover the agency and all other service providers for property damage and personal injury costs arising from claims;
- Risks that are transferred to service providers through indemnity clauses under the contract, which the service providers may in turn insure against where insurance is available and they are insurable considering market conditions;
- Those where the level and/or nature of the risk is such that the agency accepts the risk, which may or may not be covered by insurance and/or be insurable considering market conditions; and
- Those where it is prudent for the agency to arrange insurance on behalf of the agency and/or service providers or to 'top up' the service providers' insurance.

In deciding whether the service provider should be required to insure against the risk and the extent of insurance, the above mentioned Guideline recommended the following issues to be considered:

- the commercial availability of the insurance, including limitations on policy wording with exclusions and limits; and
- the cost of insurance premiums and excesses to the service provider.

Since the focus of this research is on design risk management, the experiences of New South Wales, and the Australian Procurement and Construction Council (APCC) with regard to professional indemnity insurance (PII) required for design errors and omissions are discussed as follows.

- **Professional indemnity insurance**

According the Guideline of the New South Wales Construction Agency Coordination Committee, Professional indemnity insurance (PII) covers professionals, such as architects, engineers and other consultants, and claims against them arising out of the professional services they provide. In basic terms professional indemnity insurance covers the insured's legal liability with any claim for compensation made against the insured for breach of professional duty in the conduct of the business practice carried on by or on behalf of the insured. Typically the cover includes, but not limited to:

- a breach of professional duty;
- bodily injury and property damage arising from service negligence;

Legal costs and investigation costs associated with defending an action are normally covered by PII.

The Australian Procurement and Construction Council (APCC) has also prepared similar Guidelines to assist Australian, State and Territory Government Agencies to determine the level of Professional Indemnity Insurance (PII) which may be appropriate to the services they require from consultants in the building and construction industry. The Guidelines are intended to guide Government agencies and public organizations involved in the procurement of design services, and other consultant services, etc. According to the Guideline the level and amount of cover are determined as described hereunder.

i) The level of cover

There are two approaches to determine the level of cover:

- A simplified method; and
- A risk Assessment based method.

a) Simplified Method

This method is considered appropriate for projects that agencies consider conventional non-construction consultancies and for all conventional projects, (including all projects up to $1 million) undertaken in the civil engineering and building industries. It is suggested that the amount of Professional Indemnity Insurance (PII) per event and in the aggregate, to be provided for typical projects by the consultant to the principal should be the greater of $1 million or ten times the fee.

b) Risk Assessment Based Method

This approach addresses particular risks associated with both the project type and the nature of the professional services being provided. The process suggested is as follows:

- Use the Project Risk Assessment to identify overall project risk
  - In carrying out a risk identification and analysis inherent in a project, each risk may be considered and defined in terms of consequences
- Use the Professional Service Risk Assessment to identify service risk
  - The Client is also exposed to risks associated with the service provided by consultants. In this regard the Guideline suggested that an analysis of the risk in the delivery of the service be undertaken in a similar manner as for the project risk recognizing that services risk may vary amongst agencies. In looking at a particular project, the risk associated with each consulting service may be analyzed and the risk profile identified.

Then the risk may be categorized *as extreme, high, moderate and low*, and these risk descriptors may vary by project depending on the level of complexity and criticality to the project.

ii) Amount of Cover

Having identified the project and service risk, tables are used to determine the amount of PII cover required for the project, exclusive of legal cost. The tables will indicate an amount in a range of $1 million to $10 million (exclusive of legal cost) with intermediate amounts of $2 million and $5 million in line with industry practice. The tables define the type of service, project value, project risk (as high, moderate, low), service risk, and the level of cover.

2.4.3 Risks of unforeseen ground conditions

It is evident that the elimination of all geological risks in construction project is unlikely, even with the most elaborate site investigation program. Differing site conditions, or changed conditions represents a very significant risk to the success of a project completion on time and on budget. Thus, geotechnical studies are fundamental to the design of a project, being the basis for construction contract documents. Besides, in considering construction expenses, the risk of extraordinary costs due to unanticipated subsurface conditions and other unexpected site conditions must be taken into account.

Unexpected conditions are of two types (Eileen et al., 2002). The first type is a site condition that differs materially from the conditions contemplated in the contract. In such a case the contract must indicate the presence of certain conditions, and these conditions must have differed materially from conditions actually encountered. The second type is unknown physical conditions of an unusual nature, differing materially from those ordinarily encountered and generally recognized as inherent in the work provided for in the contract. In this case, a claimant bears the burden of proving that the condition discovered was truly unusual. Left solely to a contractor, this risk will be reflected in the contractor’s bid, potentially inflating the actual construction cost. The inflated bid might also result in a high profit margin if the job is not hindered by any unexpected conditions.

Contracts inherently place certain risks on the contracting parties. Thus, various contractual provisions can be included in contracts, where desired, that shift the risk from one party to another. According to Eileen et al., (2002), the most widely used contractual clause to allocate that risk is the “differing site condition clause.” There are two types of such clauses. One seeks to shift all risk of the site to the contractor, providing that no adjustment in price will be permitted for any alleged differing site conditions. Such a clause carries the significant risk of higher bids. The second form of differing site condition clause is intended to relieve the contractor from the burden of extraordinary costs to complete its performance due to unexpected site conditions. This clause allows a contractor to seek additional compensation in the form of an equitable adjustment in its contract price when the site conditions encountered are different than reasonably expected.

A concept that is worthy of consideration is the Geotechnical Baseline Report that aims to establish a contractual understanding of the subsurface site conditions, referred to as a baseline (ASCE 1997). Risks associated with conditions consistent with or less adverse than the baseline are allocated to the contractor and those significantly more adverse than the baseline are accepted by the client. The more clearly defined the anticipated conditions, the more easily the encountered conditions can be evaluated. Therefore, the baseline statements are best described using quantitative terms that can be measured and verified during construction. Where the baseline has been set determines risk allocation and has a great influence on risk acceptance, bid prices, quantity of change orders and the final cost of the project. The interpretations and statements contained in the Geotechnical Baseline Report should reflect the risk allocation attitudes and preferences of the owner.

The following measures are recommended by the American Society of Civil Engineers (1997) to reduce geological risks:

i. Provide an adequate budget to explore subsurface conditions.
ii. Retain suitably qualified and experienced design consultants to investigate, evaluate potential risks, prepare drawings, specifications and a Geotechnical Baseline Report consistent with the risks.
iii. Allocate sufficient time and financial resources to prepare a clear Geotechnical Baseline Report that is consistent with other design documents.
iv. Develop unit price payment provisions that can be adjusted to the conditions encountered.
v. Review and discuss the baselines with the bidders before the bids are submitted. The authors recommend that this be done in the course of a pre-bid workshop following pre-qualification.
vi. Maintain an appropriate reserve fund, depending upon the perceived risks on the project.

In light of these, contractual provision is a vital step in minimizing cost and schedule overruns. The inclusion of a Geotechnical baseline Report in a contract and the development of Risk Sharing Packages are amongst the contractual arrangements that need to be considered to minimize the problems of unforeseen geological conditions (Hoek and Palmieri, 1998).

2.5 Design risk reduction

There have been reports that indicate many problems that are encountered during construction can be traced back to the design process (Madelsohn, 1997; Griffith and Sidwell, 1995). These problems can be as high as 75% of the total problems encountered during construction (Madelsohn, 1997). The consideration of constructability is basic to this phase, as it allows the detailed scrutiny of alternative design solutions and of the ergonomics of layout, both internally and externally. It also helps to determine how the design solution can directly increase ease of construction on site when the work is carried out (Hassun, 2005). The concept of constructability and its significance in design risk reduction is, thus, discussed hereunder.

2.5.1 Constructability

According to Russell *et al*. (1993), highway construction projects are characterized by, among others, changes of design, cost overruns, and time delays. Constructability is seen as one of the best solutions to these problems where it has demonstrated the potential to minimize the number and magnitude of changes, disputes, cost overruns, and delays during construction (Hassun 2005). For transportation facilities and other engineered structures, constructability involves the incorporation of construction knowledge in the facility's design. The need for an early start in incorporating construction knowledge is demonstrated by the fact that opportunities to influence cost and quality diminish with the passage of time during the life of the project (Construction Industry Institute 1986).

Folk (2005) cited Bruner & O'Connor who characterize constructability problems as a project risk affecting the expectation interests of the contracting parties. On the other hand, when constructability problems are rooted in some aspect of the project's design, and those problems are not discovered until after construction commences, then costs and delays can be expected to occur. When the contracting parties' expectations are frustrated, the groundwork has been laid for future claims and disputes with the design team.

Further, Folk emphasized that constructability problems arise from faulty drawings, incomplete specifications, and adversarial relationships between owners, designers and contractors. These problems result in poor quality, or even litigation. Poor quality in design or construction can require rework. Rework, "the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time," typically accounts for 3-23% of contract values (Love et al., 2004). This is a significant cost and no one wants to assume the cost or the responsibility often leading a project into litigation. Strategies can be implemented to avoid these problems. One of the most effective strategies used by design and construction firms is the implementation of constructability programs. Constructability practices not only ease the construction, but they can shorten the schedule and reduce the budget as well (Kriag L. 2006). A sound constructability program helps the designer and contractor work together in each stage of a project to avoid confusion or misunderstanding (Folk, 2005).

2.5.1.1 Definitions of Constructability

It is the proponents in the United Kingdom who originated the concept of "buildability" and defined it as "the extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building" (CIRIA, 1983). Ferguson (1989) defines buildability as "The ability to construct a building efficiently, economically and to agreed quality levels from its constituent materials, components and sub-assemblies."

"Buildability" stresses on integration of design and construction to achieve the project goal by enriching the knowledge of designers in construction operations and involving construction expertise in the design process (Hassun, 2005). The Construction Industry Institute (CII) in the United States proposed a similar concept to 'buildability' and labeled it as 'constructability'. Constructability is defined as "the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives" (CII, 1987). Constructability is also defined as a measure of the ease or expediency with which a facility can be constructed (Hugo *et al*., 1990).

Constructability is often portrayed as integrating construction knowledge, resources, technology and experience into the engineering and design of a project (Anderson *et al*., 1995). Eldin (1988) states that "Constructability is the integration of construction knowledge into all project phases as an effective means for reducing the project costs and the time required for its completion." Further, constructability may be described as "the ability of project conditions to enable the optimal utilization of construction resources" (O'Connor *et al*., 1986). Fisher (1997) defined Constructability as the extent to which the design facilitates ease of construction, subjected to the requirements of construction methods.

Although all definitions are quite similar, the definition given by the Construction Industry Institute (CII, 1987) which says "*the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives*" (CII, 1987)" is adopted in this research.

2.5.2.2 Historical background

Experienced construction personnel have provided input into construction projects to enhance constructability for many years (Edward, 1994). Legend has it that Hamid, one of the superintendents building the Great Pyramid, complained to the pharaoh that the blocks coming in were designed so large that installation into their final positions was too difficult, required too many men, led to unsafe work practices, and took too long. He also complained about the cutting of the blocks at the quarry. The blocks were not always true shapes, the surfaces were too rough, and required much rework at the site to make them fit. The blocks also arrived at the site too late. The pharaoh, as a result of these complaints, insisted on an aggressive constructability program. He brought in Hamid to sit down with the designers and the block supplier. The designers were forced to consider rigging and manpower constraints, and accordingly reduced the size of the blocks. The quarry had to improve their quality control and deliver on time. Further, the ensuing pyramids were installed 13.5% faster at an overall savings of 23.8%. These improvements lasted until the lessons learned were lost and design and construction went back to their old ways (ASCE, 1991).

Constructability was recognized in the mid seventies when it first appeared in "Building and Technology Bulletin", and "Constructability-It Works" (Proctor and Gamble, 1976 and 1977). Then about two years later, an NSF-ASCE (National Science Foundation - American Society of Civil Engineers) study identified constructability, among other topics, as a specific research need for structural engineering (ASCE, 1979). In 1983, the Business Roundtable published a series of studies, collectively called the Construction Industry Cost Effectiveness Project (CICE), to promote quality, efficiency, productivity, and cost effectiveness in the construction industry. This group of construction users intended the studies to motivate the construction industry to improve its work methods and cost effectiveness. In its summary report, “More Construction for the Money” the Business Roundtable defined a problem and proposed actions to address it (Business Roundtable 1983). The problem defined was that there is a lack of knowledge by owners with respect to opportunities for cost reductions and shortened schedules by integrating advanced construction methods and material into the planning, design, and engineering phases of the project.

The actions proposed were:

- Owners, individually, need to write contracts that give contractors an incentive to mesh engineering & construction expertise with the process called “constructability”, which can often save 10-20 times the cost it adds to a project.
- Owners, jointly, need to make concerted effort to help overcome the shortage of experts in “constructability” by helping to develop training materials & encouraging universities & colleges to add facet of construction management to their undergraduate curricula.
- The academia need to add “constructability skills to undergraduate curricula in construction management.

The construction Industry Institute (CII) grew out of Business round table’s effort. Based at the University of Texas, CII also includes many owner & construction companies as well as public & academic institutions. For many years, CII led the way in constructability research &

guidelines for implementing constructability. In addition, local and regional groups of construction users have been formed, resulting in increased awareness of the benefits to be gained through improved constructability programs (Pocock et al., 2006). By 1991, this body of work had grown to the point that the construction management committee of the ASCE authored its "constructability and constructability programs: white paper." This paper recognized the value of constructability and summarizes the best practices for implementing constructability programs as " The integration of experienced construction personnel into the earliest stages of project planning as full-fledged members of the project team will greatly improve the chances of achieving a better quality project, completed in safe manner, on schedule, for the least cost " (ASCE 1991). This endorsement by ASCE provided further emphasis & credibility to constructability, as demonstrated by the concerted industry effort & academic research since then.

In response to the continued interest in the area of constructability, the American Society of Civil Engineers (ASCE) Construction Institute formed a committee in 2002 consisting of representatives from industry and academia (Pocock et al., 2005). This Constructability Committee was created to provide a forum for the communication and discussion of topics related to the constructability of civil engineering projects; advance the engineering and construction industry's knowledge and state of practice of constructability; and act as an industry resource for constructability information, education, and research (Construction Institute 2003). Since its inception, the committee has produced an online constructability reference catalog (Construction Institute 2004) to provide practitioners and researchers a comprehensive listing of articles and works that relate to constructability.

2.5.1.3 Constructability Concepts in Highway Projects

Hassun (2005) argue that construction problems encountered in the field can be costly and many construction problems can be avoided with attention and consideration of the construction process during the design phase. He further elaborates that change orders, budget overruns, scope growth, and even litigation, in some instances, can be avoided by incorporating construction knowledge in the design process. Constructability requires a systematic process to create construction-oriented designs meeting the owners' project objectives in the areas of safety, cost, schedule, and maintainability. The goal of constructability is not to cheapen the design, change the project objectives, or improve upon or take over the designer's responsibilities. The goal of constructability is to obtain broader knowledge earlier into the decision processes used in design.

Concept is a significant, distinct and executable objective for enhancing constructability (Nima, 2001). Concepts are not specific or unique with respect to project type or organization. It presents a desperate need and requirement to improve the construction project constructability (O’Connor *et al.*, 1987). The term and concept of constructability has it's origin with a series of studies conducted by the Construction Industry Institute (CI1) in Austin, Texas. These studies examined numerous projects around the country and found that the design decision process lacked the necessary construction knowledge and experience to realize the full potential of constructability benefits without sacrificing the integrity of other design considerations.

According to Gibson et al., (1996), the constructability concept was born out of the realization that designers and contractors see the same project from different perspectives, and that optimizing the project requires that the knowledge and experience of both parties be applied to the project planning and design processes. They suggest that construction expertise would be incorporated from the moment of project inception during the pre-project planning to ensure the following:

i. Reduce cost
ii. Shorter schedules
iii. Improved quality
iv. Enhanced safety
v. Better control of risk
vi. Fewer change orders, and
vii. Fewer claims

These benefits are the results of an expansion of front-end planning and the investment of additional effort to anticipate and prevent potential problems. And such efforts must be owner driven (CII 1987). Edward (1994) has put forward the following as objectives of constructability

i. Enhance early planning

ii. Minimize scope changes
iii. Reduce design related change orders
iv. Improve contractors productivity
v. Develop construction-friendly specifications
vi. Enhance quality
vii. Reduce delays/meet schedules
viii. Improve public image
ix. Promote construction safety
x. Reduce conflicts/disputes, and
xi. Decrease construction/maintenance costs

When constructability reviews were not implemented, the most significant effects reported by ENR's "Top 500 Design Firms" as cited by Gibson et al., (1996) were:

i) Faulty working drawings
ii) Incomplete specifications
iii) Adversarial relationships
iv) Non-standardization, which presumably entails greater cost to construct
v) Resistance of the owner, and
vi) Budget limitations.

Similarly, the perceived benefits of constructability reviews were reported as:

i) Better relationships
ii) Fewer lawsuits
iii) Better reputations
iv) Professional satisfaction, and
v) Efficient design.

According to Gibson et al., (1996) the findings of this study and the perceived value of constructability reviews, held true for both large firms and smaller firms.

It is evident that a design & its construction plan are highly dependent on each other. Often, a design stipulates a certain construction method. Gee (1989) has made clear that considerable engineering input to back up construction staff on site is needed, because of or in spite of the fact that the method of construction is generally an assumed feature of the design. He further clarified that the conflict between design and construction lies between the need to base the design on an assumed method and sequence of construction and a desire, contractually, to leave the contractor as much freedom as possible to determine his own methods and sequence, thus making him totally responsible for all aspects of the construction. In general the concepts for improving constructability of projects vary between countries. It depends on the nature of the construction industry (Rosli Mohamad Zin, 2004). Jargeas and Van deer Put (2001) concluded that improving constructability can lead to the most significant gains when:

i. construction personnel are involved at the start of design;
ii. project parties maintain mutual trust, respect, and credibility;
iii. alternative constructing methods are used that bring the contractor into the project earlier;
iv. the project team is willing to try new approaches to achieve significant gains in project

CII identified thirteen concepts of constructability to be implemented throughout the project life cycle (CII, 1986). Out of the thirteen constructability concepts, six concepts are meant for implementation during conceptual stage, seven concepts during engineering and procurement stage and one concept during construction stage were almost similar to the one for highway project (Hassun, 2005). Construction Industries Research and Information Association (CIRIA) identified seven concepts of constructability concepts for implementation during design phase and called them “Buildability Concepts” (CIRIA 1983). These concepts are:

i. The thoroughness of design and investigation.
ii. Planning for site production requirements.
iii. Planning for practical sequence of operations and early enclosure.
iv. Planning for simplicity of assembly and logical trade sequences.
v. Detailing for maximum repetition and standardization.
vi. Detailing for achieving tolerances; and
vii. Specify robust and suitable materials.

Another basic study in this field is the study of O'Connor et al. (1987) which presented seven concepts for improving constructability. These concepts have been adopted by CII in August 1987 and listed below:

i. Constructability is enhanced when design and procurement schedules are construction-driven.
ii. Constructability is enhanced when designs are configured to enable efficient construction.
iii. Constructability is enhanced when design elements are standardized and repetition is taken advantage of.
iv. Constructability is enhanced when pre-assembly work scoped in advance and module pre-assembly designs are prepared to facilitate fabrication, transport, and installation.
v. Constructability is enhanced when designs promote accessibility of manpower, materials and equipment.
vi. Constructability is enhanced when design facilitate construction under adverse weather conditions when they exist; and
vii. Constructability is enhanced when owner, designer, and contractor personnel review specifications in detail. It also serves to simplify the field construction process.

Other study by Boyce (1991) provided ten concepts for improving constructability during the design phase which he called them "The Ten Commandments of KISS Design". These concepts are:

i. Keep it straight and simple
ii. Keep its specification simple
iii. Keep it shop standard
iv. Keep its standards simple
v. Keep it standard size
vi. Keep it same size
vii. Keep it square and squatty
viii. Keep it support simple
ix. Keep it site suitable, and
x. Keep its schedule sacred

Nima (2001) forwarded twenty three concepts according to the construction project process. Project constructability enhancement during conceptual planning phase comprises concepts C1 to C7.

i. Concept C1: The project constructability program should be discussed and documented within the project execution plan, through the participation of all project team members.
ii. Concept C2: A project team that includes representatives of the owner, engineer and contractor should be formulated and maintained to take the constructability issue into consideration from the outset of the project and through all its phases.
iii. Concept C3: Individuals with current construction knowledge and experience should achieve the early project planning so that interface between design and construction can be avoided.
iv. Concept C4: The construction methods should be taken into consideration when choosing the type and the number of contracts required for executing the project.
v. Concept C5: The master project schedule and the construction completion date should be construction-sensitive and should be assigned as early as possible.
vi. Concept C6: In order to accomplish the field operations easily and efficiently, major construction methods should be discussed and analyzed in-depth as early as possible to direct the design according to these methods.
vii. Concept C7: Site layout should be studied carefully to perform the construction, operation and maintenance efficiently, and to avoid the interfaces between the operations performed during these phases.

Project constructability enhancement during design and procurement phases comprises concepts C8 to C15.

i. Concept C8: Design and procurement schedule should be dictated by construction sequence. Thus, the construction schedule must be discussed and developed prior to the design development and procurement schedule.
ii. Concept C9: Advanced information technologies are important to any field including the field of construction industry. Therefore, the usage of those technologies will overcome

the problem of fragmentation into specialized roles in this field, hence enhancing constructability.

iii. Concept C10: Designs, through design simplification by designers and design review by qualified construction personnel, must be configured to enable efficient construction.

iv. Concept C11: Projects elements should be standardized to an extent that will never affect the project cost negatively.

v. Concept C12: The project technical specifications should simplify and configured to achieve efficient construction without sacrificing the level or the efficiency of the project performance.

vi. Concept C13: The capability of modularization and preassemblies for project elements should be taken into consideration and studied carefully. Modularization and preassembly design should be prepared to facilitate fabrication, transportation and installation.

vii. Concept C14: Project design should take into consideration the accessibility of construction personnel, materials and equipment to the required position inside the site.

viii. Concept C15: Design should facilitate construction during adverse weather conditions. Good effort should be given to planning the construction of the project under suitable weather conditions. Otherwise, the designer must increase the project elements that could be pre-fabricated in workshops.

Project constructability enhancement during field operations phase comprises concepts C16 to C23.

i. Concept C16: Field task sequencing should be configured in order to minimize damages or rework of some project elements, minimize scaffolding needs, formwork used, or congestion of construction personnel, material and equipment.

ii. Concept C17: Innovation of a temporary construction materials/systems, or implementing innovative ways of using available temporary construction materials/systems, which have not been defined or limited by the design drawings and technical specifications.

iii. Concept C18: Innovation of new methods in using off-the-shelf hand tools, or modification of the available tools, or origination of new hand tools that reduce labour-intensity, increase mobility, safety or accessibility.

iv. Concept C19: Innovative uses of new methods in using the available equipment or modification of the available equipment to increase their productivity.

v. Concept C20: Encouragement of the usage of contractor-optional preassembly in order to increase the productivity, reduce the need for scaffolding, or improve the project constructability under adverse weather conditions.

vi. Concept C21: Encouragement of the innovation of temporary facilities.

vii. Concept C22: Contracts should not be awarded based on low bids only, but by considering other project variables such as materials and time. Also, good contractors should be considered for future construction works.

viii. Concept C23: Evaluation documentation and feedback of the issues of the constructability concepts used throughout the project.

These twenty three constructability enhancement concepts usher the ways in which construction knowledge and experience may be used efficiently through the process of engineered construction. The implementation of these concepts in a project will greatly improve its constructability. The design phase constructability concepts identified by Rosli Mohamad Zin (2004) is a combination of various constructability concepts identified by previous researchers. Thus, it is more thorough and, therefore, the following eighteen concepts have been adopted for the purpose of this study.

i) Carry out thorough investigation of the site

Constructability is improved when the information gathered from site investigation is thorough and complete. In this context CIRIA (1983) recommended that thorough site surveys including determination of ground conditions, underground hazards and other potential problems are essential to avoid risk of delays and design changes during construction.

ii) Design for minimum time below ground

Constructability is improved when the design minimize work below ground. According to Adams (1989) the application of this concept is important especially when the ground is hazardous, poor or wet. In those conditions the speed and flow of the project can be increased when less work are carried out below ground.

iii) Design for simply assembly

Constructability is improved when designs are simplified and configured to enable efficient construction. Adams (1989) mentioned that designers should endeavor to produce the simplest possible details with the overall requirements for the particular element, or group of elements. This open the way to efficient, defect-free work that will satisfactorily perform its end function. The implementation of this concept in the highway project was accomplished by simplifying the design of the piers and decks. It is clear that designs can be simplified and configured to enable efficient construction through different means and methods. Also, one might properly suggest that it is wise to seek opinion from experienced construction personnel on a continuous basis to review the designs to ensure that this constructability principle is effectively implemented.

iv) Encourage standardization/repetition

O'Connors *et al.* (1987), stated that the standardization of components is based on recognition that savings can be realized when the number of variations of components is kept minimum. Many construction project elements have potential for standardization. Construction systems, material types, construction details, dimensions and elevations may be standardized for increased field efficiency. This concept supports standardization of the project's components. The consultants need to make good use of this concept by standardizing the majority of the project's elements. Examples include piers, crossbeams, and decks. All elements including, pile types, pier columns, pier cross beams, girders, parapets, handrails, guardrails and drainage system can be standardized.

v) Design for preassembly and/or modularization

Preassembly is a process by which various materials, prefabricated components and/or equipment are joined together at a remote location for subsequent installation as a unit. Preassembly often involves decoupling sequential activities into parallel activities. A module is a product resulting from a series of remote assembly operations; it is usually the largest transportable unit or component of a facility. Modules may contain prefabricated components or preassemblies and are usually constructed away from the job site (Tatum et al., 1985).

This concept advocates using prefabrication, preassembly, and modularization. However, as O'Connor *et al*. (1987) warned, lifting limitations and delivery route restrictions should be studied when planning to implement this concept.

vi) Analyze accessibility of the jobsite

The effect of accessibility can sometimes be quite serious such as delay in progress, slowed productivity and increased damaged to completed work. This concept highly promotes accessibility to enhance project constructability.

vii) Employ any visualization tools to avoid physical interference

Constructability is improved when visualization tools are employed to visualize any possibility of physical interference during construction. Ghanah *et al.*,(2000) highlighted that computer visualization allows investigations to iron out difficulties that may occur before construction commences on site. This concept advocates the consultants to employ the capabilities of advanced information technology. The concept was well used during the design and preparation of the plans. Examples of application of this concept include using the internet and developing models (software) to test the structural behavior in the early stages of the conceptual design.

viii) Investigate any unsuspected unrealistic or incompatible tolerances

Particular attention should be given to the problems of fit which occur at the interfaces between different products, methods of construction, materials and method of manufacture, and suitable jointing methods should be adopted.

ix) Investigate the practical sequence of construction

Constructability is improved when adequate consideration of practical sequence of construction is given. The method of construction of project should encourage the most effective sequence of construction operations. Simple sequences enable each operation to be completed independently and without interruption. The sequence should assist the coordination of trades and minimize delay (CII 1987, 1993).

x) Plan to avoid damage to work by subsequent operations

Constructability is improved when the damage to work by subsequent operations is considered. The design should enable work to be carried out in a workmanlike manner without risk of damage to adjacent finished elements and with minimum requirement for special protection.

xi) Consider storage requirement at the jobsite

Constructability is improved when storage requirement is adequately considered. Consideration should be given during the design stage to be location of material storage and unloading facilities. The space occupied by shoring, scaffolding, formwork, plant, compounds and workshops for example can be considerable. Their efficient location and distribution is necessary for good constructability.

xii) Investigate the impacts of design on safety during construction

Constructability is improved when the impact of design on safety during construction is adequately considered. The design produced by the designers should enable the contractor to carry out their works in a safe like manner. The design should be arranged so as to facilitate safe working in works such as foundation and earth works, when materials and components are being handled, and wherever traversing for access is necessary.

xiii) Design to avoid return visit by trade

Constructability is improved when the design enable a trade or specialist to complete all its work at a work place with as few return visit as possible. As for this concept, Boyce (1991) proposed using the ‘‘performance type specification approach.’’ This can be achieved by selecting a vendor with a good reputation and experience in the required specialization who will supply the item with a guarantee. This approach was used for many items in the project rather than implementing ‘‘gold-plated’’ off-the-shelf specifications that O’Connor and Miller (1994) considered one of the barriers to constructability implementation. The best example is the elastomeric bearing pads for the viaduct and the approach ramps.

xiv) Design for the skills and resources available

Constructability is improved when the technology of the design solution matched with the skills and resources available. With regard to this constructability concept Adams (1989) highlighted that any design is only good as skills available to execute it, either off-site or on-site. Labour and skills requirements vary between projects, and between localities. Design must include a realistic assessment of the level of skill likely to be available from appropriately chosen contractors and specialists.

xv) Consider suitability of designed materials

Constructability is improved when suitable and robust materials are used. According to Adams (1989), products and materials should be selected with care, particularly, any which have not long been established and accepted within the industry. They should be proven to be suitable for the use for which they are selected. Products and materials should be selected which utilize normal site assembly methods and sequences, with subsequent operation and wear and tear in mind. Care should be taken to ensure that manufacturer recommendations on handling, storage, application, assembly and protection are complied with.

xvi) Provide detail and clear design information

Constructability is improved when thorough and clear presentation of design information before the start of construction. Sufficient time and resources must be allowed for this in design budget. Complete project information should be planned and coordinated to suit the construction process and to facilitate the best possible communication and understanding on site. According to Ghanah *et al.,* (2000) communication between designers and other participants in construction project are normally performed using traditional methods i.e. paper based drawing, schedule, written statements etc. In order to improve constructability, priority must be given on the reliability of the information communicated through these methods. Therefore, the accuracy, understandability and clarity of information generated during the design process must be checked at all times.

xvii) Design for early enclosure

Although it is not more relevant to the road construction, constructability is improved when the design enables early enclosure of the constructed building. CIRIA (1983) suggests that the construction and detailing of a building shell, including the roof (whether framed or loading bearing construction), should facilitate the enclosure of the building at the earliest possible stage. Following operations can then commence early in the programmed, and they can be carried out without hindrance from weather.

xviii) Consider adverse weather effect in selecting materials or construction methods

Constructability is improved when the effect of adverse weather is considered. Project constructed in localities where weather conditions are adverse presents a great challenge to both the designer and the contractor. Designers should investigate ways in which the exposure to temperatures extreme and the effects of rain may be minimized. This concept encourages facilitating construction under adverse weather conditions through design. This concept was practiced through using the pre cast units for the girders and drainage systems for roadsides and manholes.

From the foregoing discussions, it can be learnt that many of the design decisions made early in the design process affect the construction of the project. Thus, construction expertise is often incorporated in the design process to improve the constructability of the design. Among the constructability concepts that are applicable in all phases of construction project, the design phase concepts developed by Rosli Mohamad Zin (2004) are more thorough with respect to ease of construction.

2.5.1.4 Overview of Constructability in Highway Project

Highway project constructability can be particularly challenging for a variety of reasons. It is known that highway construction technologies are changing rapidly, and, as with most construction, the work force and site conditions can vary greatly. In the local construction industry most projects are tendered out in open competitive bidding, thereby separating the design and construction phases. As a result, designs prepared by the designers often lack constructability consideration (Rosli Mohamad Zin, 2004).

According to Hugo et al. (1990) constructability is considered important element for improving project performance. Constructability has been successfully implemented to reduce project durations (Eldin, 1996). His study highlighted several examples of projects that have successfully applied constructability concepts to reduce project durations without increasing project cost. CII (1992) on the other hand analyzed five projects that have implemented constructability, and reported 11% to 30% reductions in project duration directly attributed to constructability. Constructability reviews that focus on improving plans and specifications and other design information can help reduce problems that surface during construction. According to Edward (1994), early constructability efforts result in a significant payback to the project. CII research has cited cost reductions of between 6 and 23 percent, benefit/cost ratios of up to 10:1.

Constructability reviews of highway projects during design have the potential to minimize the number and magnitude of changes and delays during construction and thereby reducing durations (Anderson and Fisher 1997). A constructability analysis of six highway projects suggests that benefits may be as large as 25 times greater than costs (Ibid). Further, early research by O'Connor *et al.* (1991) identified that poor specifications can cause construction rework and delays. In fact, these authors state that 22% of all constructability problems are related to ineffective communication of engineering information, plans, and specifications, especially inadequacies in project specifications. This latter problem was confirmed in a national level study by Anderson *et al.* (1999).

Discovering and addressing design errors and omission in a timely manner is, thus, critical for projects (Ford and Sterman 1998; Cooper 1993). Constructability problems are one type of these errors and omissions. Constructability problems that are not identified and addressed during design can have a negative impact on project schedule performance by slowing construction operations and generating unplanned delays. This impact was cited as an important issue for highway projects in a National Cooperative Highway Research Program project (Russel and Anderson, 2000). The same research identified "constructability" and "methods to minimize project duration" as two critical issues necessary for improving construction and the quality of highway projects. Therefore, reviewing designs and specifications to identify and address constructability issues is a primary means of reducing highway project durations, cost overrun, and quality problems (Hassun, 2005). Fisher and Rajan (1996) described the constructability of designs as the integration of construction knowledge, resources, technology, and experience into the engineering and design of a project.

Hassun (2005) described that highway project constructability can be particularly demanding for a range of reasons, including the following.

- some of the highway construction technologies are varying hastily, and, as with most construction, the personnel is transient and site conditions can vary to the highest degree.
- Nearly all projects are subjected to severe public scrutiny involving open competitive bidding, thereby separating the planning and execution phases and largely precluding a fast-tracked approach to construction.
- Designs standards, authored by a multitude of organizations abound and often limit, if not discourage selective innovation.
- The prerequisite for nonproprietary specifications often leads to vagueness. In general, the perception is that project durations are longer than necessary and that construction costs can possibly be lowered. As a result, specifications supportive of constructability become an important element for improving project performance (Hugo *et al*., 1990).

Edward (1994) suggests that constructability reviews should be separate and distinct from typical design checks and reviews. The literature suggests, however, that constructability reviews coincide with design reviews that occur at discrete points during design completion. Thus, integration of a constructability review process into the design phase is considered essential to capture the full benefits of constructability reviews. On larger and more complex projects, constructability reviews may be performed on a continuous basis as design information is released for constructability reviews. The ultimate outcome suggested by the literature is more efficient and faster construction through improved plans and specifications.

2.5.1.5 Implementation

To gain the greatest benefit from constructability, a process should be in place at onset of project (ASCE 1991: CII 1987; CII 1993) with a defined set rule for how to implement constructability. The benefits of constructability are realized to their greatest extent when measures are taken early in the project life cycle (ASCE 1991), in the planning stages, not as a review of the project design (CII 1987). Dedicated efforts should continue through the various stage of the entire project (fox 2002).

O'Conner & Miller (1994) as well as construction industry institute (CII 1987) stress the need to start a project with a self-assignment of how constructability is approached in the company. A constructability team is an important asset & should include personnel from owners, designers, contractors, subcontractors, vendors & consultants (Radtke & Russell 1993). However, it's critical that an experienced construction person, a "Dean of constructability," be a full-fledged member of the project team from the onset of planning (ASCE 1991; CII 1987). Because of the required initial investment, constructability efforts required high-level corporate recognition & backing (O'Connor & miller 1994).

From the onset of a project, constructability is effective if it's included as an integral part of the project execution plan (CII 1987; CII 1993). The process of constructability can be enhanced with checklist, workbooks, & reviews of lesson learned (CII 1987). The construction industry institute developed guidelines to implementing constructability for this purpose (CII 1987). From the Construction Industry Institute studies, it was found that the most successful constructability programs have the following (Construction Industry Institute, 1987):

i. Clear communication of senior management's commitment and support of constructability.
ii. Single point executive sponsorship of the program.
iii. A permanent corporate program and a tailored implementing program within each project.
iv. User friendly procedures and methodologies.
v. A corporate "lessons learned" database.

vi. Training where necessary.
vii. Easy appraisal and feedback.

Constructability is most cost-effective if implemented in the design and planning phases. One study showed that 65% of process changes implemented for constructability purposes occur during the design and planning phases (Songer et al., 2005). These changes are effectively implemented by incorporating construction expertise in the design, planning and documentation (Kriag 2006).

The benefits of formal constructability reviews at project inception, and at the 30, 60, and 90 percent design development stages have been demonstrated by empirical evidence (ASCE, 2004). Hugo et al., 1990; Ellis et al., 1992 add one step to conduct review at 100% design completion stage. The poor clarity of plans and specification is a major constructability issue of concern for highway agencies, designers, and contractors.

Anderson and Fisher (1997) developed a constructability review process for transportation facilities. This process explicitly describes an approach to integrating constructability reviews into the planning, design, and construction phases of highway projects. The process recognizes that highway agencies often perform design reviews at 30, 60, 90, and 100% of design completion and provides explicit actions to ensure proper constructability analysis at these design milestones. The authors recommend that on more complex projects constructability reviews should commence at 15% design completion and, perhaps, these reviews should be continuous throughout the design process for extremely large and complex projects.

2.5.2 Quality management system

Certain clients have underestimated the impacts of substandard consultancy service to the success of a construction project (Hattan and Lalani, 1997; Barber *et al*., 2000). In reality, many delays, cost overruns, reworks, variations, claims and disputes can be traced back to erroneous design, poor contract administration and/or lax supervision of the client's representative (Tan and Lu, 1995; Chini and Valdez, 2003). Deming (1982) argued that 85 per cent of the problems in the delivery of goods and service are caused by the system, and firms which do not have a clear definition of responsibilities; good communication and feedback channel; and comprehensive training programme for staff are more likely to produce unsatisfactory products or service (Duncan *et al*., 1990; Dissanayaka *et al*., 2001).

However, errors induced by a system can be prevented or at least minimized through the implementation of a Quality management system (QMS) (CIRIA, 1987; Latham, 1994). Among various QMSs, ISO 9000 certification has been widely adopted by the construction industry of many countries (Jensen, 1994; Henry, 2000; Landin, 2000; Langford *et al*., 2000; Ofori and Gang, 2001). For instance, in Hong Kong all consultants must have a certified ISO 9000-based QMS before they can bid for public construction projects (Works Bureau, 2001). While ISO 9000-based QMSs could improve the service quality of the firm, and hence the client's satisfaction, market share, revenue as well as workers' morale (Caldwell and Hagen, 1994; CIRIA, 1987), researchers claimed that the primary reason for certain consultants to seek certification is simply to satisfy the mandatory requirement of the client rather than taking the full advantage of ISO 9000-based QMSs to enhance their practices on a continuous basis (Shammas-Toma *et a*l., 1996; Tang and Kam, 1999).

Nevertheless, as the business environment is becoming more and more competitive, the success of a consultant depends on whether the quality of professional service to preserve the interests of their clients at different stages of a project. With the release of ISO 9000:2000, an unprecedented emphasis is placed on customer satisfaction and continual improvement (Goetsch and Davis, 2002; Murphy, 2002). "Satisfaction" can be measured by comparing the difference between what is expected and actually received (Day, 1984; Hill et al., 2002), and clients would satisfy with the performance of a consultant when the quality of service provided exceeds or at least meets their expectations. Continual improvement can only be realized if consultants are aware of their weaknesses/deficiencies and make corresponding adjustments to satisfy the expectations of their clients (Culp *et a*l., 1993; Flood, 1993; Love *et a*l., 1998).

2.6 Optimizing Project delivery method for Constructability

As mentioned earlier, constructability has been interpreted by the proponents in the United States (CII, 1987) and Australia (CII Australia, 1996) as the optimal integration of construction knowledge and experience into design to bring about benefits of reducing costs and improving overall quality of the built products. In this regard, the project delivery method involving contract documents that determine the duties of project stakeholders and their timings of involvement in a project provides the focal point to bring about improvement in constructability.

A project delivery method is a system for organizing and financing design, construction, operations and maintenance activities that facilitates the delivery of a good or service (Koppinent and Lahdenpera, 2004). Project delivery involves processes required to complete a good or service according to the contract. CSI (2005) see project delivery as the contractual relationships between the owner, the designer, the contractor, and management service used in a project. These relationships create the framework in which a project progresses from an idea to completed facility.

Different project deliveries have been developed to effectively address the unique demands in each project caused by cost, extent, and time constraints. The benefits and limitations of each delivery system need to be understood when choosing a delivery system. This decision will determine the relationships between participants and how they will work together to complete a project. In optimizing project delivery method for constructability the three most common project delivery systems namely; Design-Bid-Build (DBB), Design-Build (DB), and Construction Management (CM) are discussed here under. The key difference between these project delivery methods lies in the way risks and responsibilities are allocated to the parties to the contract.

2.6.1 Design-Bid-Build

Design-bid-build project delivery is characterized by distinct design and construction phases. The owner has separate contracts with the designer and contractor; first with a designer, then, usually after the design is completed with a contractor for construction. The contractor is hired either through a bidding process or by a process of pre-selection and negotiation (CSI, 2005). This approach is designed to provide complete design prior to bidding and to achieve a low price through contractor competition. A contractor is typically selected based on the bid price and enters into an agreement with the owner to construct the road in accordance with the plans (Gransberg and Molenaar, 2007).

Gransberg and Molenaar, (2007) describe this type of project delivery as being managed based on ready-made designs, leaving constructability issues to the client. Design and potential deficiencies in it, delays and price effects, soil conditions and weather risks also remain with the client. The designer acts merely as a consultant with no risks on structural solutions as long as his conduct is professional. The client controls the over all project delivery process, which provides complete documentation allowing preparation of bills of quantities before construction. Hence, tender evaluation is less difficult.

Forms of this project delivery method, according to Gransberg and Molenaar (2007) include a single contract or separate contract.

i. **Single contract**, the project is awarded as one entity to one consultant/contractor, who has the responsibility for delivering the project either in-house or with the help of sub consultant/subcontractors.
ii. **Separate contract** (‘multiple prime’), the client divides the project into portions and awards contracts to a few different consultant/contractors. One consultant/contractor is given the responsibility for coordination of works. The fixed lump-sum and the unit price contract are commonly used as a basis of payment. Some design responsibility may also be given to the contractor, if alternative designs are allowed at the tender stage.

Construction is a fragmented industry and the owner, contractor, and designer may have differing and sometimes conflicting objectives. These conflicts are prevalent in the design-bid-build system where the participants do not work closely together and often have conflicting interests (Arditi et al., 2002). In design-bid-build projects the designer, contractor, and owner all want to minimize costs. Cost savings however, can come at the expense of the other participants, and may lead to litigation. Most participants in construction are very familiar with their roles within a design-bid-build delivery system. It is also the required system in most government contracts as it effectively achieves low price and fair competition, upholding the best interests of tax payers (CSI, 2005). Early completion of the design eases planning and facilitates scheduling. The timing also allows the owner to work closely with the designer during the design phase. However, this project delivery system is characterized by lengthy process and ineffective information transfer because of separation of phases and roles of project participants. Besides, prescriptive specifications and one design solution are mentioned as its weaknesses.

Dougalas (2006) mentioned that one large survey of general contractors in the southeastern U.S. found that 78 percent of respondents were involved in traditional design/bid/build projects. The general contractors participating in this survey reported the following frequencies of specific problems caused by a lack of contractor input during the design phase:

- Specification problems (100 percent)
- Unrealistic schedules (84 percent)
- Physical interference problems (75 percent)
- Tolerance problems (73 percent)
- Weather-related problems that could have been avoided by considering weather during the design phase (56 percent)

This same survey reported that 75 percent of responding general contractors attributed the lack of constructability reviews to design without contractor input, and 66 percent of respondents believed that design professionals lack sufficient construction experience and knowledge of construction technologies to provide this service. All too often, however, project designers mask this lack of contractor input during the design process, and thereby exacerbate the problem, by resorting to performance specifications for more difficult or less understood aspects of the work.

Similarly, Folk (2005) support the above argument that design/bid/build delivery method does not provide for contractor input during the design phase, hence lack buildability of design, and most standardized contract documents do not include a method or procedure for formal design reviews by construction professionals to assure that the owner’s program requirements are realized in a “buildable” set of plans. One tool to remedy this problem is the use of alternative delivery methods, such as design-build, program management, and construction manager at-risk, where appropriate.

While DBB is a well-known project delivery method that promotes competition and ensures transparency, there are significant problems with the process as well. It does not allow co-operation between different project participants thereby hindering industry innovations. As each party has its strict responsibilities, technological improvements and integration of systems are blocked. Moreover, competition is based solely on price (Koppinen and Lahdenpera, 2004). Recognizing that constructability problems stem from the absence of effective communication among the owner, designer, and contractor before the commencement of construction, one may readily conclude that the traditional design/bid/build project delivery system is a breeding ground for constructability claims and disputes (Dougalas, 2006).

According to Gransberg and Molnaar (2007), DBB is considered suitable for projects:

- that are small, simple and/or highly constrained
- where the owner wants to carefully settle upon a design before committing to funding construction
- where environmental, geotechnical, or regulatory issues leave no freedom for innovations
- that are unique, and of which only the client has experience, and/or
- where it is appropriate to take advantage of existing designs.

2.6.2 Design-Build

Design-build is one of several innovative project deliveries that have potential application in the highway construction industry. Design-Build (DB) entity or consortium is contractually responsible for both design and construction based on the pre-design and design standards provided by the client (Gransberg and Molnaar, 2007). In DB, as Gransberg and Molnaar, (2007) explained, prospective bidders are provided 0–80% of the design, including mandatory requirements, in a Request for Proposal (RFP). The client identifies the project's desired end result, and defines clearly the scope of work and the requirements of the technical proposals. In return, bidders prepare a technical and price proposal showing how they intend to complete the remaining design and all construction.

The client has an opportunity to assess both the price and technical solution offered by the bidders. Combining design and construction creates a single point of responsibility and allows overlapping of design and construction. DB allows commencement of construction before completion of designs. Constructability could be enhanced by using this method, because of the involvement of construction experts in the design stage (Gransberg and Molnaar, 2007).

Design-Build comes in many forms. These forms can be described in terms of formations of contract, structure of the business entity, and operational variations. Brief descriptions of these variations, according to Lewis (2007) are discussed hereunder.

2.6.2.1 Design - Build contract variations

i. **Design-Build with a Warranty** (5, 10, 20 years) - the contractor provides an integrated design and construction process whose product is guaranteed to meet specified material and workmanship or performance standards over a prescribed timeframe. This usually applies to highway pavement. The inclusion of a warranty shifts more project risk to the design-build team and reduces the extent to which the contracting agency needs to conduct inspection and testing.

ii. **Design-Build-Operate-Maintain (DBOM)** - the contract team is responsible for design, construction, operation, and maintenance of the facility for a specified period of time, whereby payment beyond project completion is predicated on meeting certain prescribed performance standards relating to physical condition, capacity, congestion, and/or ride quality. This is an extension of design-build that provides an inherent incentive for the design-builder to provide a better quality plan and project by creating a lifecycle responsibility and accountability for the performance of the facility by the design-builder.

iii. **Design-Build-Finance-Operate (DBFO)** - this is an extension of the DBOM project delivery method in which the contract team is also responsible for the financing of the project and takes the risks of financing the project during the contract term.

iv. **Build-Operate-Transfer (BOT)** - this is a project delivery method similar to DBFO whereby the contract team acquires ownership of the facility until the end of the contract term at which time ownership of the facility is returned to the original public sector contracting agency.

v. **Full Delivery or Program Management** - the construction entity provides a wide variety of services to the contracting agency beyond construction, starting at the planning stage and potentially continuing through facility operations and maintenance, thereby leveraging the resources of the contracting agency to a great extent.

Many of the DB project delivery approaches described above extend far beyond the scope of design-build contracting by placing increasing functional responsibilities for highway infrastructure under a single contract vehicle. The choice of which approach to use for a particular project, according to Finnish Road Enterprise (2002) depends on a number of factors, such as:

- Size and complexity of the project;
- Available budget for the project;
- Legal and regulatory ability to use various innovative project delivery techniques;
- Sources of funding for the project;
- Capability and creativity of the contracting agency; and
- Urgency of completing the project.

2.6.2.2 Design-build business entity variations

There are several business entity variations as well. A design-build entity can be formed on a project by project basis by contractually binding the Engineering entity with a Contractor entity for the purpose of completing a single project or it can be performed by an ongoing business entity containing complete facilities services from design to construction. Additionally, each of these business entities can use various forms of contracts on a project by project basis (Lewis, 2007).

Such entity or structural variations are used to identify the role played by different parties in a design-build arrangement. Identifying the type of the design-build organization can be a factor affecting a potential relationship between the procurement of the design-build team and the project performance. Beard et al. (2001) emphasized the importance of the design-build structural variations and how they relate to the structure of the design-build organization and the different arrangements undertaken within the entity. According to Beard et al. (2001), there are five structural design-build entity variations as described below.

i. **Joint Venture Design-Builder –** This is a design-build entity that has been formed through a contractual agreement between two or more parties for the purpose of carrying out design-build service. Following this arrangement, the owner contracts with a joint venture. The joint venture could be project specific, formed for the purpose of the project only; or temporarily formed, existing through a specific time period that covers the project duration.

ii. **Contractor Led Design-Builder –** This is a design-build entity in which a contractor hires a design consultant to perform professional design services through a subcontract arrangement. In this structure, the owner directly contracts with a contractor for all design and construction services necessary to complete the project.

iii. **Designer Led Design-Builder –** This is a design-build entity in which the Designer provides and is responsible for all aspects of the project including those outside of design services. The owner signs a design-build contract with the Designer. Construction services are performed by a contractor under a subcontract arrangement with the prime Designer. In this design-build method, the Designer is responsible for construction cost, schedule, and means and methods of construction.

iv. **Integrated Firm Design-Builder –** This is a design-build entity which provides design services and construction services under one roof. The owner contracts with an integrated design-build firm acting as a single source of responsibility. These entities are not formed on a project by project basis; rather they are a single established entity that can provide all required construction services to an Owner. With the exception of any services rendered to an Owner prior to contracting with an Integrated Design-Builders (such as programming or conceptual design); these entities can accept all risk of the construction project including design, schedule, construction cost, and the means and methods of construction.

v. **Developer-Led Design-Builder –** This is a design-build entity in which a Developer accepts the risk of construction services and separately contracts for Designer and construction services. The owner contracts with an independent Developer to design and build the facility that will be owned and operated by the owner. The Developer subcontracts the design and construction tasks to external designers and contractors.

2.6.2.3 Design-Build Operational Variations

In addition to the alternative types of design-build contract, and business entity formations there are alternative operational variations. Operational variations for design-build delivery systems refer to the level of design completion at the time of team procurement. These variations range from minimal design performed, reaching only 10%, to a preliminary design phase where the design completed amounts to 35%. This level is dependent on two factors. In some instances, the owner decides to achieve some design work prior to contracting with the design-builder, whether from within its organization or through a consultant. Also, the owner's decision regarding when to communicate their requirements to the design-build team determines the amount of design work the design-builder will have to complete. It is a critical decision regarding the selected procurement method, affecting the project performance (Beard et al. 2001).

Beard lists three basic types of "operational variations". The basic difference between the variations is the timing of the contract formation within the design life cycle. All Design-Build entities described above can contract a project using any of the operational variations. All operational variations can have slightly alternative methodologies; below is a basic listing of the alternative types.

i. **Direct Design-Build: -** In this form of design-build, the Design-Builder is contracted with the Owner at the inception of the project or at the earliest possible time during the facility development process. A direct design-build arrangement often results in the owner contracting with an integrated design-build firm, where the design-build team can assist the owner in defining their requirements, program, and conceptual design and set a budget, through estimates and financial feasibility studies.
ii. **Design Criteria Design-Build: -** In this form of design-build, the Owner, assisted by professional consultants, determines the facility criteria and the required performance

standards. Hence, the Owner presents a Design-Builder with a defined list of problems and parameter for design. The owner states to the Design-Builder a list of measurable performance criteria that need to be met. This type of procurement is most often used in the competitive design-build selection process in which the Owner details a program and design parameters in a Request for Proposal (RFP) prior to contracting with a design-build entity. Levels of Owner details can vary with this approach. Design-Builders respond to the RFP with their own design solutions.

iii. **Preliminary Design-Build: -** In this form of design-build the Owner completes some degree of design or a preliminary design prior to contracting with the Design-Builder. Design completeness may vary; for example the design may be limited to single line drawings or may be much further defined in conceptual drawings or schematic design. This preliminary design information is included in the RFP for the design-builder's Designer to complete the design accordingly. The Design-Builder is contracted to complete the project from the already completed design and criteria given. This operational variation is mostly applicable for a series of projects that should have similar layout and design and where the project should be completed based on the design concept provided by the owner.

iv. **Bridging Design-Build: -** This form of design-build is what Beard refers to as a "mutation" position between design-build delivery and traditional design-bid-build. Using this approach the Owner presents the Design-Builder with partially complete designs (30% to 80%); the Design-Builder is contracted or the RFP are issued to the prospective contractors to complete the design and construction of the project with the given design percentage. This system is very similar to the traditional approach where the owner manages two separate contracts with the designer and the bridging construction firm respectively.

The bridging contractor is expected to complete the detailed design, provide costs and value engineering services, obtain the necessary permits and finally construct the facility. Some advantages of this arrangement are the possibility of the owner's organization to maintain control of the project scope, while transferring the errors and omissions risk to the design-build firm. However, this system is characterized by several inefficiencies. It can be competitively bid in a very similar manner as the traditional approach. Furthermore, it eliminates the possible innovation that should be associated with the design-build delivery system and does not necessarily allocate risks to the party in the best position to undertake them (Beard et al.2001; Molenaar and Gransberg 2001).

Tender evaluation is more difficult than in DBB due to different technical proposals. Selection can be based solely on technical/quality assessment, solely on price or on a combination of price and quality. The contract is, in practice, a fixed lump sum contract which lets the client know early in the process the final price of the project relatively accurately (Lewis, 2007).

In general, risks should be allocated to the party, who can best manage them. DB assigns a much greater risk to the contractor who is responsible for design and construction risks. The design firm that usually subcontracts to the contractor often also assumes greater risks than in DBB. The designer's role differs significantly from DBB, where the designer's main interest is to protect his own and the owner's interests. In DB, the designer is a co-worker of the contractor expected to benefit the DB team (Gransberg and Molenaar, 2007).

There have been numerous research studies which came to the conclusion that Design-Build is a viable and acceptable model to use for road projects. Design-Build is especially applicable:

- for time critical projects
- usually within allocated budget
- to increase the potential for innovation
- to optimize the constructability

The objective of Design-Build is to bring the contractor earlier into the process, and Koppinen & Lahdenpera (2004) show that Design-Build has an "economic efficiency" much greater than the traditional model and also demonstrates the attributes that can make Design-Build even more effective. One recommendation by Hughes (2006) indicates that early involvement by the contractor is required in order for the project to be effectively integrated.

FHWA (2006) summarizes the results of comparing Design-Build to the DBB model and highlights the benefits of the Design-Build as reducing the overall duration of the project and usually having a positive impact on project costs. In addition, the quality is essentially equivalent to DBB and is highly aligned to projects that have more performance specifications. Greater satisfaction is noted by having lower levels of design development before the tendering process. Warne (2005) also concludes that Design-Build is more aligned to reduced time of construction, improved cost control, equal or better quality, and overall client satisfaction.

The Design-Build method can also be utilized in the wrong form or abused, and basically any method can fail if the method is not understood and applied correctly. Koppinen & Lahdenpera (2004) and FHWA (2006) include many suggestions, considerations, and recommendations for good practices for Design-Build. It is important to note that in order to make the Design-Build method more effective, the design progress should not be advanced too far prior to the tendering phase.

The clients who employed Design and Build procurement approach have a single point of contact for all questions regarding the design and delivery of the facility (P.Chan et al., 1997; Keith Potts, 1995; Beard et al., 2001; Shawn S.N.Chong, 2002). The Design and Build entity is responsible for quality, budget, schedule, and performance of the completed facility. With the single point of contact, clients can concentrate on definition of needs and timely decision-making rather than on coordination between designer and contractor. Besides, the Design and Build entity has total responsibility for the finished product and cannot shift design errors or construction defects to another party. Therefore, it will likely to end up with the expected or higher quality of end product. Unlike Design and Build approach, traditional approach contracts rely on restrictive wording, adversarial audit and inspection requirements and the legal system to attain project quality. Therefore, every negligence or problem will put on contractor’s hand. This means nobody is to blame except the contractor, even though it may be supplier or sub contractor causing a problem, but main contractor has to bear the risk. A client retains a responsibility during the contract through his representative (Jeffrey L. Beard et al., 2001).

Acting as a single entity driven by profit, the design-build firm may have a conflict of interest with the owner. A design-build firm may cut costs at the owner's expense if there is no independent agent to check for quality design and construction as in the construction phase of design-bid-build when the owner, contractor, and designer work together. In order to curb this limitation, owners can hire an administrative professional with construction experience to act in their interests (CSI, 2005). The single point of accountability lessens confusion for both the owner and the design-build firm. Without competitive competition however, this project delivery is more expensive than other systems.

An ideal design-build approach reduces constructability problems and allows changes to be implemented easily as the interface between the contractor and the designer is more frequent than in the design-bid-build. The long-term partnership between the contractor and designer throughout the project minimizes constructability problems because the designer understands what the partnering contractor requires of the design (Arditi et al., 2002).

Design and Build process also allows the contract to assign risks in a way that produces the most efficient agreement among the parties. Risks can be assigned, as appropriate to the owner, to the design builder, shared between the two principal parties or mitigated by the securing of insurance coverage. All risks can be accounted for discussed and dealt with in a manner that is more clear and comprehensive than with other delivery method (Beard et al., 2001). The other factor associated with the strength of Design and Build is design efficiency. Construction efficiency may be improved because design efficiencies can be woven into the entire construction process. The designer as a member of the Design and Build teams, are participate directly in troubleshooting and resolving design related issues that surface during construction. The early input of the design teams to the contractor will increase the constructability of the entire design (P. Chan et al., 1997; Keith Pots, 1995).

The Design and Build method elicits creative responses from the project teams (NSPE, 1995). Normally, the ability to innovate in design and construction is severely curtailed by the user of prescriptive specifications. With Design and Build, performance requirements are stated and the design builder may use different solutions to meet the client's ultimate project goals. In fact, the selection process often encourages comparison to see which proposal provides the most value to the client.

Design and Build allows better control of quality particularly in designer led Design and Build team. However, in considering quality, the client has no direct control over the contractor's performance. Therefore, the standard of quality must be properly selected at the tender stage to ensure that the contractor's proposal do meet his requirements. This also means that the client ha little say in the choice of specialist subcontractors (Clamp & Cox 1989). This is because some proprietary Design and Build products lack aesthetic appeal.

Innovations may be encouraged through contractor involvement at an earlier stage, when project scope is adequately defined, but there are still plentiful opportunities for alternative solutions. However, early contractor involvement is somewhat difficult because of long lead times and the competitive pricing desired at the tender stage. Thus, performance-based standards may be improved to encourage innovations. Appropriate specifications that guide the innovation process and sharing of resulting savings reduce client reluctance to accept innovations. When the industry sees continuity in the DB project delivery, companies will be more interested in investing in the development of their operations and products to gain a competitive advantage (P. Chan et al., 1997).

Design and Build has a considerable ability to improve quality in construction. When procured in isolation, design has always pre supposed that the client himself has identified his genuine needs, defined his requirements and specified them clearly, the client often has little clear definition of what he wants. Unlike traditional approach which only appoints a single unit of design team to come out with the design ideas, Design and Build will produce much more different design ideas from the design builder who enter the tender (P. Chan et al., 1997).

The owner's administrative burdens may be reduced because the procurement of design and construction services is consolidated into a single selection process. After award of the Design and Build contract, the owner will not be required to spend time and effort coordinating and arbitrating between separated design and construction contracts. While the process does require the owner to provide prudent oversight of the design and construction process, this responsibility is considerable less time consuming and exposes the owner to far fewer risks than the traditional approach (P. Chan et al.. 1997; Dennis Turner, 1986).

Design and Build is also considered to be the fastest project delivery system because the procurement of design and construction services is consolidated into a single selection process and the fast track procedures may be implemented more readily. Generally, Design and Build encourage overlapping of design and construction phases. Bidding periods and redesign, two events that can occur with traditional approach are eliminated. Materials, equipment procurement and advance construction work may progress concurrently before construction document are completed (Beard et al., 2001).

In supporting the above, Masterman (1992) highlights that many studies have proved that design projects were associated with shorter overall project time than conventional system. It is also reckoned that the reduction of the overall project period is attributed to the system's ability to overlap the design and construction phases, improved communications between the various members of the project team, the integration of the two basic functions of design and construction and the improvement in buildability and the use of contractor's resources.

Cost and completion time is firmer under the Design and Build procurement method. This means the client knows his total financial commitment in the early stage of the project, provided he does not introduce any changes throughout the project. Because there is no provision for bill of quantities, adequate arrangements for evaluating any changes on the price or on cost basis can be carried out earlier by including in the contract (Mastermann, 1992).

Jerry Adanison (2001) explained that several financial considerations make Design and Build desirable. Cost has always become the key considerations affecting adoption of Design and Build procurement method. Whilst project time is relatively easy to interpret and potential savings clearly identified, project cost is more ambiguous and therefore difficult to evaluate. A prominent consideration for the client, in any procurement form, is that final cost does not exceed the project budget. In this respect, Design and Build certainly presents a better chance of the client obtaining his completed building within budget.

Real cost savings can also be made in Design and Build. According to Mastermann (1992), when using this system, the initial and final costs are lower than other methods of procurement because of diminished design costs, the integration of the design and construction elements and in built buildability of the detailed design. Cost savings may also result in timesaving. The overall effects is reduction in the employer's financing charges, lesser effect of inflation and faster construction operation, which, in a commercial context, produces an earlier return on the capital, invested, (Frank 1998).

In terms of certainty in time, Design and Build can provide complete contractual certainty on completion for clients from the very earliest stages of their projects if there are not many changes by the client (Bennett and Grice, 1992). The NEDO report (1995), faster building for industry, highlights that in most cases, non-traditional procurement method including Design and Build tend to be quicker both in term of site construction and total project time.

Time savings with Design and Build are maximized at the pre contract stage with the procurement process up to commencement on site. Studies by Fitchie (1996) indicate that procurement time under the traditional process can be up to twice as long as that of Design and Build. These benefits are accrued simply because of the ability of Design and Build to integrate the project team members, produce open communication and encourage effective cooperation.

Effective communication is never been ignored as one the driven factors on selection of Design and Build procurement method. Direct contact between the client and the contractor as provided by a Design-Build method lines of communication enables the contractor to respond and to adapt more promptly to the client's needs. Integration and interchange is thereby encouraged inherently within the system (Griffith, 1989). The client and contractor will communicate closely during the process stage of the project. Communication between them will start at the beginning stage of the project. Therefore, it provides the client and contractor an opportunity to interact more often and more directly than traditional contract. The system allows understanding on the requirements of clients clearly and any misunderstanding or conflict that may be occurred during the design and construction stage can be avoided.

Design and Build approach is also known to have less adversarial relationship compared to traditional approach. The project may proceed more efficiently because designers and contractors are members of the same team and thus much less disputes might be created. Apart from less disputes, the approach also benefit from the good communication that can be occur between the design team and the construction team (Keith Potts, 1995).

Claims for errors or omissions or for time delays tend to disappear because the Design-Build team would have no one to blame for these shortcomings but it self. At the same time, the burden on the owner to mediate disputes between the designer and the contractor is eliminated because a sole design builder may be held contractually accountable and responsible for the entire project (Beard et al., 2001). Further, all parties are being treated as professionals regardless of designer or contractor. The method places the designer and contractor on equal professional footing so that they can provide unified recommendations and jointly developed solutions to the client (Beard et al., 2001).

The project costs of the Design-Build delivery method can be lowered because of the close working relationship between the designer and the contractor who are on the same team. This may lead to the incorporation of more economical design features and the application of cost saving construction methods (Beard et al., 2001). Therefore, the contractor can take full advantage of his own judgment and expertise in procuring only those sub contractor and suppliers with whom he expects to have a successful working relationship and the clients is not involved in this relationship at all (Griffith, 1989.)

In summary, as Grasberg and Molenaar (2007) emphasized, proponents of design-build contracting proclaim a number of advantages over typical contracting arrangements such as design-bid-build including:

- **Time savings** through:
    - Early contractor involvement that enables construction engineering considerations to be incorporated into the design phase and enhances the constructability of the engineered project plans;
    - Fast-tracking of the design and construct portions of the project, with overlapping or concurrency of design and construction phases for different segments of the project; and
    - Elimination of a separate construction contractor bid phase following completion of the design phase.
- **Cost savings** from:
    - Communication efficiencies and integration between design, construction engineering, and construction team members throughout project schedule;
    - Reduced construction engineering and inspection (CEI) costs to the contracting agency when these quality control activities and risks are transferred to the design-builder;
    - Fewer change and extra work orders resulting from more complete field data and earlier identification and elimination of design errors or omissions that might otherwise show up during the construction phase;
    - Reduced potential for claims and litigation after project completion as issues are resolved by the members of the design-build team; and
    - Shortened project timeline that reduces the level of staff commitment by the design-build team and motorist inconvenience due to reduced lane closures.
- **Improved quality** through:
    - Greater focus on quality control and quality assurance through continuous involvement by design team throughout project development; and
    - Project innovations uniquely fashioned by project needs and contractor capabilities.

Design-build contracting is also one of the most controversial of the innovative highway project delivery approaches, since it changes the fundamental way key stakeholders in the highway construction industry compete and cooperate with each other (Grasberg and Molenaar, 2007). They cited the following limitations of design-build project delivery method:

- Reduces competition for construction services by excluding smaller firms unable to lead the larger projects most amenable to the design-build approach;
- Favors large national engineering and construction firms in competing for larger design-build contracts that are too big for smaller local or regional firms to pursue;
- Provides an opportunity for favoritism to enter into the contract award process by including non-price factors in the basis for selection;
- Undermines the inherent checks and balances between design and construction teams in the traditional delivery systems, with the design team no longer independent of the construction contractor;
- Strikes at the foundation of the traditional quality assurance/quality control roles through the combination of engineering and construction; and
- Increases project costs due to the elimination of the low bid contractor selection criteria.

The strengths of this type of project delivery, according to APSEC (2006), include performance-based specifications, and more efficient risk management; while the weaknesses include less client control of the delivery process, and difficulty in approving alternative technical concepts during selection of DB team.

Generally, according to Gransberg and Molnaar (2007), DB is considered applicable in projects:

- Where early completion and utilization of the facility are of significant value.
- That has well-defined, well-understood construction objectives.
- That is large and technologically complex, and offers the most opportunities for innovation. This maximizes the scope for a designer/contractor team to benefit from matching design and method for the best possible results.
- That requires expertise not available in-house.
- Projects, which suffer many and/or major third party interfaces, and in which the consequential risks can be better quantified by designing the works in detail, are ill-suited for DB.

2.6.3 Construction Management

Construction Management (CM) is based on an owner's agreement with a qualified construction firm to provide leadership and perform administration and management for a defined scope of services. A construction manager (CMr) works throughout the various phases of a project and cooperates with the owner and a designer in furthering the interests of the owner. Design and construction can usually overlap, but they are purchased in phases through many separate contracts (Gransberg and Molnaar, 2007).

The construction management project delivery system introduces professional management throughout the project acting as an agent of the owner. The owner has separate contracts with the contractor, designer, and construction manager. The role of construction manager as an agent of the owner does not bear any financial risk. The construction manager works closely with the designer and contractor during the design and construction phases in the best interest of the owner. The construction management entity has expertise in construction and allows the owner to execute complex projects which require extensive coordination between project participants (CSI, 2005). The CMr conducts constructability reviews, construction estimates and contract packaging, etc. depending on the scope of services. Generally the financial risk of the CMr is small, but the risk of loss of reputation is high. Designers' and contractors' roles remain much the same as in DBB (Gransberg and Molnaar, 2007),

The construction manager's expertise and involvement improves efficiency of even the most complex projects by minimizing rework, change orders, and cost overruns. The construction manager advises the owner in the design and construction stage allowing the owner to have influence throughout the project. This involvement facilitates constructability, integrating construction knowledge during the design phase. The construction manager oversees design implementation during construction, often diminishing the designer's role in construction, but the involvement of the designer in construction differs in each project. In expensive, complex projects the extra cost of hiring a construction manager is offset by avoiding general contracting fees, savings in cost management, and the reduction of cost overruns.

CM is, from the organizational point of view, very much like DBB except for an external project manager and multiple contracts. Thus, this project delivery method which promotes (price) competition and ensures transparency is familiar to the industry. However, in some markets there may be a lack of competent project managers. And the method does not allow co-operation between all project participants restricting the number of industry innovations, technological improvements and integration of systems.

The inherent cost emphasis can be reduced by adopting best value contractor selection instead of pure price competition and by emphasizing the importance of CMr references in selection. In life-cycle CM, the CMr is hired for the long term to procure and manage design, construction and maintenance for the client. The somewhat limited competition of CMr contracts can be improved by increasing project size to encourage international competition. Cost certainty and performance can be improved by using increasingly target cost contracts, and innovativeness can be enhanced by allowing contractor value engineering. Unnecessary duplication of quality control cost and improvement of ownership of the work can be enhanced by using quality-assured construction contracts.

The general CM variations are CM-at-fee and CM-at-risk

i. In CM-at-fee, the construction manager is responsible for project and site management, but is not involved in actual construction work. Contracts are between the client and the contractors. The CMr monitors cost, time, quality and safety, but does not take responsibility for them. Often large construction companies are not interested in CM-at-fee contracts, as they rather do the construction work. The CMr is paid a fixed or time based fee for services provided.
ii. In CM-at-risk, the CMr is also responsible for construction means and methods and delivery of the completed work, including quality and performance of the asset. All procurement in the project is done by the CMr, and the contracts are between the CMr and subcontractors. Still, the client retains the final decision in project delivery. The CMr is paid a fixed or time based fee for services provided and construction is paid based on cost and fee or guaranteed maximum price.

Despite potential improvements there are some explicit problems with CM delivery. As design is done before construction, contractor contributions are not possible and separation of roles is encouraged. This does not facilitate market development which mostly results from cooperation between different trades. CM will also always lead to the purchase of small work packages reducing the need for and motivation of companies to develop their capabilities and resources which reduces their margin potential.

The strengths of this type of project delivery, according to Gransberg and Molnaar (2007) include client control over project delivery, client determined quality level, flexibility, CMr contributions to design, better relationships between the CMr and contractors, less burden some for client, accurate price information for client, shortened delivery process, procurement scheduled optimally, and less Change Orders. The weaknesses include no contractor-designer cooperation, separation of roles, lack of innovations, and limited technological improvements and integration of systems.

CM is seldom used in road building. The reason is that generally the number of trades and, subsequently, contractors involved in a road project is relatively small and easy to manage. However, when CM is used, the client tends to select it because of its flexibility with regard to the schedule and changes and the judiciary relationship with the contractor before and during construction, while it also ensures competition for the work. CM is suitable also when early completion is required.

2.6.4 Comparing project delivery method for constructability

All definitions of constructability focus on the issue that its benefits are best achieved through the integration of the construction knowledge and experience into each phase of the project delivery (CII, 2001). The essence in adapting and enhancing constructability lies in allowing contractors to have early involvement in the design stage. Independent studies confirmed that early contractor involvement and integration of construction knowledge into the design process improves the chances of achieving a better quality project, completed in a safe manner, on schedule, for the least cost (Arditi et al., 2002). Certain characteristics of project delivery systems provide better opportunities for constructability practices during the design. The three methods discussed above are the basic frameworks used in most projects.

However, each project delivery method has its weaknesses that need to be addressed to ensure efficient project delivery (Gransberg and Molnaar, 2007). In most of the approaches, the contractor has no influence in the design and is confined to a rigid role only within the construction phase as in design-bid-build. Designers are also divorced from the responsibility of construction, preventing any knowledge of local innovations and construction from improving the design and construction (Trigunarsyah, 2004). Despite the improvements available, some weaknesses in DBB and CM project delivery cannot be prevented from limiting their applicability in the future. With DBB these problems include prescriptive specifications, separation of roles, lack of innovations, slow project delivery and extensive client surveillance. With CM, separation of roles, lack of contractor contributions, small work packages, lack of industry development, and reduced industry profitability act as hindrances. With DB, other problems may be largely eliminated, but the potential loss of client experience remains (Gransberg and Molnaar, 2007),

In design-build and construction management approaches, construction knowledge is integrated throughout the project. This is achieved in design-build because the contractor works together with the designer and it is achieved in construction management by a construction manager who lends construction expertise to the designer throughout the design stage. Professionals working in the design-bid-build systems also recognize the importance of construction knowledge in the design phase, but no contractor is bound contractually to assist in design. In design-bid-build, contractors are usually hired after the design is finished. To incorporate construction knowledge into the design the design-bid-build system relies on teaming practices to involve contractors earlier in the process. These teaming practices do take considerable effort and extra costs to implement, but can eliminate many recurring problems in construction (Songer et al., 2005).

Constructability is presumably less of a problem in the design-build and construction management delivery systems where designers and contractors are in constant communication (Jergeas and Vander Put, 2001). Unfortunately the most common approach, design-bid-build, does not facilitate early incorporation of construction knowledge so constructability programs must be added at an extra cost to the owner. Due to its structure and limited interfacing between participants, the design-bid-build project delivery approach has higher instances of rework and disputes than in design-build delivery (Love et al., 2004). According to Kriag (2006), many participants in the industry have abandoned the design-bid-build system or adapted it to bring construction personnel into the project from the beginning.

Design-build reduces risk, cost overruns, and potential length of a project mainly by using a contractual method that unites the Designer with the Contractor. With Designer and Contractor contractually bound to a “single responsibility” for the cost, quality, and length of a project the design-build projects are delivered with less litigation, fewer change orders and lower cost (Gransberg and Molnaar, 2007). Scott (1997) has also emphasized the reduction in the overall project duration by integrating design and construction. A 2005 study conducted by the department of Architectural Engineering at Penn State University revealed that required change orders on design-build projects were 90% less than what was required on equivalent design-bid-build projects. The survey estimated that the resulting decrease in change orders resulted in a net cost savings. The change order savings was not only attributed to less change order but was also the result of a 50% reduction in the average size of change orders and a 77% reduction in the number of field generated change orders. Field generated change orders are typically due to design errors or poor project coordination and can usually be avoided (Lewis, 2007).

Several studies have researched the continuously growing trend towards the use of the design-build delivery method and the shift from other traditional delivery methods. The reasons and factors promoting this trend have been outlined. Sanvido and Konchar (1998) conducted an empirical study whose goal was to compare the different delivery systems that are widely used in the United States. Construction management at risk, design-build, and design-bid-build were the three main delivery approaches compared. In conclusion, the study revealed that the design-build delivery system often resulted in time and cost savings. With regard to quality performance and owner satisfaction, the design-build delivery led to a higher or equal quality product than construction management at risk and design-bid-build systems. In another study that emphasized the importance of the design-build delivery system, Songer and Molenaar (1996) pointed out the rapid growth of this delivery approach and becomes a more popular method of design and construction contracting for many reasons. Design-Build Institute of America (DBIA, 1994) list several advantages of design-build over the more traditional method of design-bid-build:

i. **Single Responsibility**: - Both the Design and Construction are the responsibility of a single entity. Litigation issues are removed between Designer and Contractor allowing the Owner to focus on scope, need definitions, and decision making rather than coordination between Designer and Contractor.

ii. **Quality**:- The Owners expectations and needs are documented with performance specifications and the Design-Builder responsibility to produce an end product in accordance to those specifications. The Design-Builder warrants that the design is free from error rather than the Owner as in the traditional system. This allows the design-builder to focus on quality and project performance.

iii. **Cost Savings: -** Design and construction teams working and communicating as a team can better evaluate alternative methods and material options more efficiently. Value engineering and constructability are utilized continuously and more effectively when design and construction teams work together.

iv. **Time Savings**: - Design and construction can be overlapped. Material/equipment procurement and construction can begin before designs are fully complete. The resulting time savings can lead to reduce project cost and earlier facilities utilization.

v. **Early Knowledge of Firm Cost:-** Guaranteed construction cost can be known far earlier using design-build than other delivery systems because the entity responsible for design is continuously able to better estimate cost based on the current project details. Having the design and construction services under one entity allows for the Design-Builder to guarantee those costs earlier in the project. Owners can decide to proceed with a project prior to substantial design expenditures and with superior knowledge of a project's final cost at a substantially earlier phase.

vi. **Improved Risk Management: -** Performance aspects of cost, schedule, and quality and responsibility of risk are more appropriately balanced. Individual risks are managed by the party in the best position to manage those risks. Change orders due to omissions and errors are reduced because the Design-Builder has the single source responsibility of designing and producing a functional facility.

3. Research design and methodology

3.1 Introduction

As mentioned in section 1.3 of this thesis the aim of the research is to enlighten the need for design risk management to enhance achievement of project objectives, thereby contributing to effective implementation of the country's road infrastructure development program. The main objective is to examine whether design risks are contributory to cost and time overruns, and affect quality objectives of projects, and make recommendations based on the findings. The research design and methodology to be followed towards this end are discussed as follows.

3.2 Research design

The research strategy adapted for this research is qualitative research of exploratory type which diagnoses a situation, assess alternatives, and discover new ideas. 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 methods of data collections employed for the research were case study, desk study, and interview. The case study and desk study were analyzed in relation to theoretical propositions, and the responses obtained from the interview were also analyzed using descriptive statistics method. The next sections discuss the tools used for data collection and method of analysis.

3.3 Data collection

3.3.1 Interview

The 1st research question was "How are road construction risks managed? The answer for this question and supplementary information for other research questions were searched from key informants in order to deepen the findings of the case study and desk study. The interview schedule shown in the Appendix consists of four main questions as enumerated from No. 2 to 5, Question 1 being inquiry about the informants' profile. The questions (2-5) focus on the following issues.

Question No.2 focused on whether a formal risk management system is in place for Federal road projects. If not, "How are risks that may have an impact on time, cost and quality managed?", and "what are the reasons for not establishing a system?" were the questions raised for the key informants. These questions were intended to achieve the 1st specific objective of the research to assess whether Road project risks are managed with formal Risk management system.

Question No. 3 was meant to investigate the sources of risks in road construction projects, and design risks in particular, and evaluate their impact on time, cost, and quality objectives of road projects. These questions were intended to achieve the 2nd specific objective of the research to find out whether design risks are contributory to cost and time overruns, and poor quality of works.

Question No. 4 dealt with assessment of the existing practices on how design risks allocated, namely, Design errors and omissions, and unforeseen ground conditions. The instruments employed to manage the risks, whether there are experiences to recover damages from professional indemnity insurance, the practice in managing risks arising from latent defects, and the reasons for overlapping responsibilities of designer and design reviewer in shouldering risks, were the questions raised to the informants. These questions were intended to achieve the 3rd specific objective of the research to evaluate design risk allocation practices and instruments employed to manage design risks,

Question No. 5 looked into the existing practices to reduce design risks, the reason to adapt the practice, and explores the opinions of informants on constructability concepts and alternative project delivery methods. These questions were intended to achieve the 4th specific objective of the research to assess the existing practices of design risk reduction/mitigation, and other alternatives.

The following steps were followed in preparing the semi-structured questionnaire for the interview schedule:

i. *The general purpose and specific requirements were first determined:* The general purpose of the interview was to assess the practices and perceptions of key informants who influence the process of Risk management in general, and design risk management in particular. The specific requirements were focused on performances of Federal road projects.

ii. *The questions that need to be asked were then developed:* Semi-structured questions with open and closed-ended questions were formulated so that they could generate relevant answers to the research questions.

iii. *The questionnaire was structured in two main parts:* The first part was a covering letter with information about the research project, contents of the questionnaire, and how the responses would be utilized. The second part was the questionnaire.

The type of sampling adapted for this research is selected sampling. The key informants targeted for this research were professionals from procurement, design, and contract implementation departments of the Ethiopian Roads Authority (ERA). Those professionals who specifically worked in procurement processing, design review, and monitoring implementation of road projects were selected for the interview. Accordingly, 10 key Informants were interviewed with pre-distributed questionnaire. The Informants profile is shown in Table 2 below.

Table 2: Informants’’ profile

a) Educational status

Descriptions	**Number of Informants**			
	Civil Eng.	**Highway Eng.**	**Construction mgt**	**Total**
MSc	**-**	**1**	**2**	**3**
BSc	**7**	**-**	**-**	**7**
Total	**7**	**1**	**2**	**10**

b) Experience in the road sector (years)

Descriptions	Number of Informants
0-5 years	**4**
6-10 years	**6**
Total	**10**

3.3.2 Case study

The 2nd research question was "what are the sources of risks in Road construction projects? Do design risks contribute to cost and time overruns, and poor quality of works?" In order to obtain answer for this question, study of cases of completed projects was chosen as one of the tools to find out the answer for these questions. The approach used to select samples/projects for the case study was Non probability of sampling (Criterion-based sampling) in which, a case that serves the real purpose and objectives of the research is selected. Thus, 10 projects which experienced cost and time overruns were selected to discover whether design risks were contributory to these effects.

3.3.3 Desk study

The 3rd and 4th research questions examine "How design risks are allocated?" and "How design risks are mitigated?" respectively. Desk study was chosen as one of the instruments to assess the practices from relevant studies, reports and documents.

3.4 Data analysis

The case study and desk study were analyzed in relation to the theoretical propositions. The method used to analyze the interview data is descriptive statistics method. This method of analysis helps to analyze the responses in actual numbers. Accordingly, Frequency distribution was used to distribute the data into categories and determine the number of individual or cases belonging to each category, which were presented in the form of table.

4. Results and Discussions

4.1 Risk management in Federal Road projects

A response by all Informants to a question that inquires whether formal risk management system is in place has revealed "No formal risk management system is in place to manage risks that may occur in Federal road projects". Besides, "No formal risk management plan for road projects is also required from consultants". However, Quality assurance plan is required from a supervision consultant. Quality assurance plan is a plan to be submitted by a supervision consultant, which spells out how inspections are carried out to ensure quality of works.

According to the Informants, the traditional practice to deal with risks that may have an impact on cost, time, and quality include the following:

- Reducing scope of the work or allocation of additional budget
- Monitoring the works by project engineers and consultants
- Acquisition of Performance security & Professional indemnity insurance
- Giving timely solution upon occurrence, as much as practicable
- Supervision with Quality assurance plan
- Allocation of risks to parties through contract documents

The main impediments to establish the formal risk management system, according to the Informants, include:

- More engagement in routine works
- Lack of Organizational structure for risk management
- Lack of risk experts
- Lack of know-how in risk management, and
- Lack of initiatives

Papageorge (1988) has clearly stated that construction projects involve risks that result in delay, cost overrun, and poor quality of works. The Federal road projects are not free of such risks as discussed in the case studies of projects cited in section 4.3.2 of this thesis. The need to incorporate Risk management concepts into infrastructure construction practice to mitigate the consequences and enhance performance of projects is indispensable as indicated by Pipattanapiwong (2004). Hilson (2006) also emphasized that significant improvement to construction project management performance may be achieved by adopting the process of Risk management. Therefore, administering Federal road projects without having such a system could be the reason to see project delays, cost overrun, and poor quality of works. The continuing occurrence of these impacts of risks shows the ineffectiveness of the traditional practices to minimize the risks. The impediments to establish a formal Risk management system, as explained by the Informants, are not basic that limit to adopt the system; rather they can be resolved with better understanding of the system.

4.2 Risks in Road construction projects

Several literatures identified sources of risks of projects from different perspectives. Among others, categorization of the sources of the risks by Hassun (2005) and Caltrans (2007) include planning and selection risks such as inadequate project planning and inefficient project delivery system; financial risks such as funding risks; design risks; construction risks; external risks such as price escalation; environmental risks such as incomplete environmental analysis; contractual risks such as ambiguities in contract formation process; project management risks such as lack of coordination/ communication; and force majeure risks such as severe weather. The Informants were asked to identify the sources of the risks in the road construction projects, and the design risks in particular. In order to rank the risks, the questions were formulated to seek responses in terms of probability of occurrences and impact of the risks on time, cost, and quality of the works. The responses obtained are shown in the next sections.

4.2.1 Sources of risks

The Informants responses with regard to sources of risks in road construction are shown in Table 3 below. The numbers indicated in the table are the actual number of responses that fell in same category.

Table: 3 Sources of risks ranked by the Informants

Sources of risks	Probability of occurrence			Impact								
				Time			Cost			Quality		
	High	**moderate**	**Low**	**High**	**moderate**	**Low**	**High**	**moderate**	**Low**	**High**	**moderate**	**Low**
Planning and selection risks	**4**	**4**	**1**	**9**			**7**	**2**		**3**	**4**	**2**
Financial risks	**2**	**2**	**5**	**5**	**3**	**2**	**4**	**2**	**3**	**1**	**2**	**6**
Design risks	**8**			**8**			**8**			**7**		**1**
Construction risks	**3**	**5**		**5**	**3**		**6**	**2**		**2**	**4**	**2**
External risks	**9**			**1**	**8**		**8**				**5**	**3**
Environmental risks	**3**	**4**	**2**	**1**	**5**	**3**	**1**	**4**	**4**	**1**	**3**	**5**
Contractual risks	**3**	**5**	**1**	**5**	**2**	**3**	**4**	**4**		**4**	**4**	**1**
Project management risks	**4**	**5**		**6**	**2**	**1**	**4**	**3**	**2**	**3**	**5**	**1**
Force majeure risks	**2**	**4**	**2**	**6**	**2**		**2**	**5**	**1**		**6**	**2**

The mean scores of these responses were further categorized in the form of risk matrix; i.e. high impact-low probability of occurrence, low impact-low probability occurrence, high impact-high probability of occurrence, and high impact-low probability of occurrence. The risk matrices in Figure 4, 5, and 6, below, show the impact from time, cost, and quality perspectives.

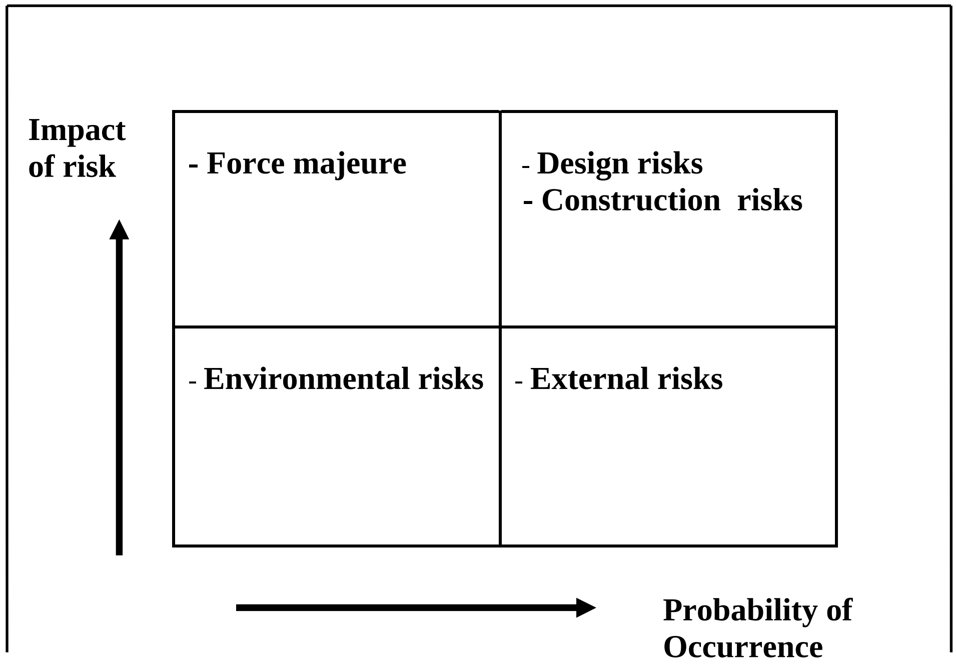

Fig 4: Sources of risks that have an impact on time

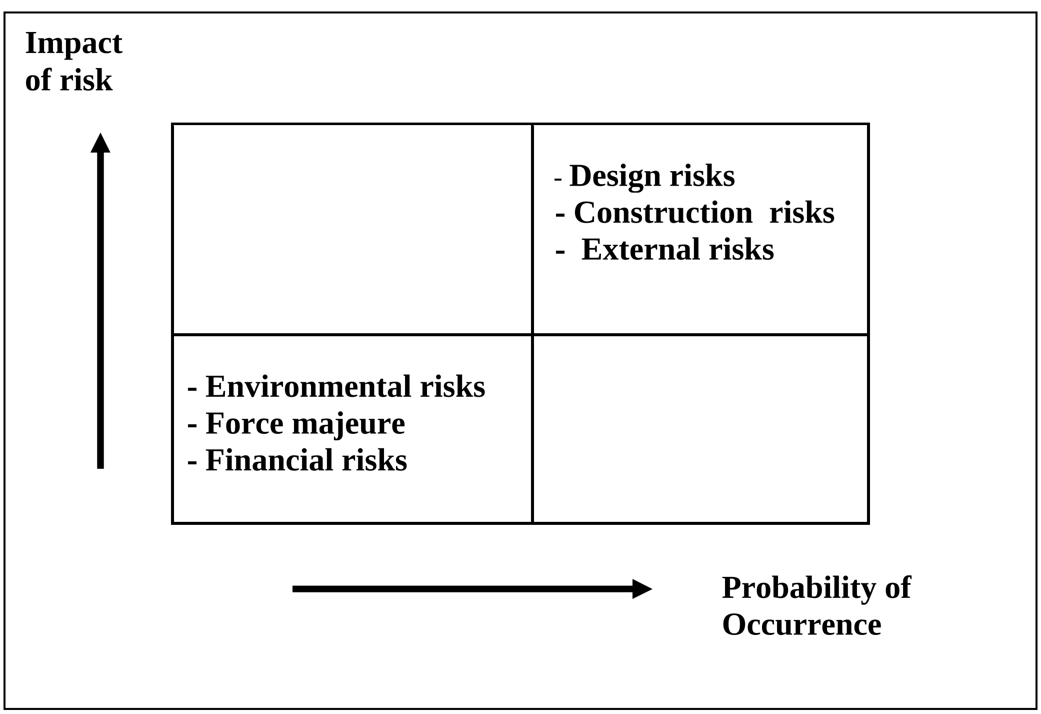

Fig 5: Sources of risks that have an impact on cost

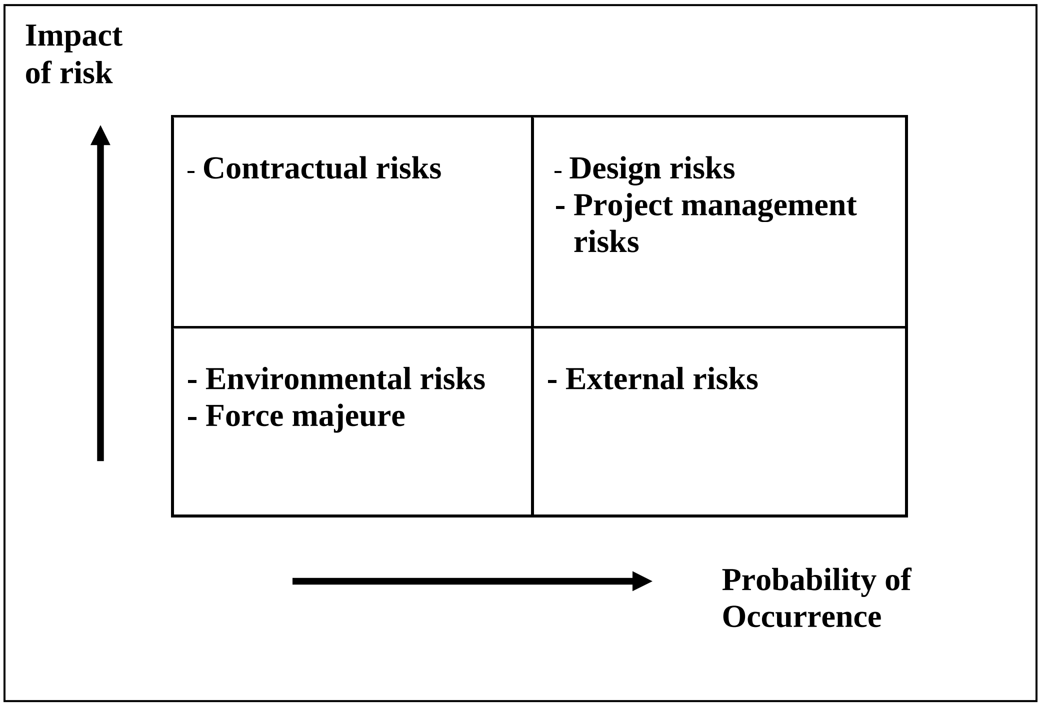

Fig 6: Sources of risks that have an impact on quality

The matrices reveal that design risks, construction risks, and project management risks are of high impact-high probability of occurrence. Design risks are found to be the most significant sources which have an impact on time, cost, and quality of projects. Construction risks are the other significant source with an impact on time and quality. Project management risks are also significant with an impact on quality of projects. Therefore, the need to look into the underlying causes of these risks is worthwhile in order to minimize the impacts. Although the risks are interrelated, emphasis was given to design risks as the focus of this research lies on design risk management.

4.2.2 Causes of Design risks

A number of researchers ascertained that many construction problems are traced back to design process. And the problems can be as high as 75% of the total problems encountered during construction (Madelsohn, 1977). Luis et al., (1998) also cited a study which reported ‘’ approximately half of all construction contract modifications can be attributed to design deficiencies''. Other literatures reveal that design changes are major risks to construction projects (Thomas et al., 1999). Therefore, it is essential to examine the underlying causes of this risk with a view to minimize the risks. To this effect, the Informants were asked to identify the causes in terms probability of occurrence and impact. The responses obtained are shown in Table 4 below. The numbers indicated in the table are the actual number of responses that fell in same category

Table: 4 Underlying causes of design risks ranked by the Informants

Underlying causes of Design risks	**Probability of occurrence**			**Impact**								
				Time			**Cost**			**Quality**		
	High	**moderate**	**Low**	**High**	**moderate**	**Low**	**High**	**moderate**	**Low**	**High**	**moderate**	**Low**
Changes in scope of work/Clients new requirement	**2**	**7**	**1**	**5**	**5**		**5**	**5**		**1**	**2**	**6**
Unclear scope of work	**1**	**4**	**5**	**4**	**3**	**2**	**4**	**3**	**2**	**2**	**5**	**2**
Unforeseen design exceptions	**2**	**2**	**3**	**3**	**2**	**1**	**3**	**2**		**1**	**3**	**1**
Unexpected sub-surface conditions/Inadequate geo-technical information	**4**	**5**	**1**	**4**	**5**		**5**	**3**	**1**	**5**	**2**	**2**
Design error and/or omissions												
• Inaccurate assumptions on technical issues	**2**	**5**	**1**	**5**	**2**	**1**	**4**	**3**	**1**	**3**	**2**	**3**
• Incomplete/inadequate survey data	**5**	**4**		**7**	**2**		**6**	**3**		**5**	**3**	**1**
• Inadequate hydrological/ hydraulic study	**4**	**4**	**2**	**4**	**2**	**2**	**5**	**3**	**1**	**4**	**1**	**4**
• Incomplete or poor specifications	**4**	**4**	**1**	**6**	**2**	**1**	**6**	**2**	**1**	**5**	**1**	**3**
• Design not up to standards (non conformance to codes and standards)		**6**	**3**	**1**	**4**	**3**	**1**	**5**	**2**	**2**	**4**	**2**
• Incomplete/inaccurate quantity estimates	**7**	**1**	**1**	**5**		**3**	**8**		**1**	**2**		**7**

• Inaccurate cost estimate	**2**	**4**	**3**	**1**	**3**	**5**	**4**	**2**	**3**	**1**	**1**	**6**
• Emphasis on meeting schedules & increased production volume (tight schedule)	**3**	**1**	**4**	**2**	**3**	**3**	**3**	**2**	**3**	**2**	**1**	**5**
• Lengthy project development period (change in site conditions due to late bidding)	**4**	**2**	**3**	**5**	**2**	**3**	**3**	**3**	**3**	**2**	**3**	**4**
• Lack of coordination among design members' disciplines	**5**	**2**	**2**	**6**	**2**	**1**	**5**	**1**	**2**	**5**	**1**	**3**
• Lack of experience of the design team	**3**	**5**	**1**	**4**	**5**		**4**	**4**		**6**	**1**	**2**

The mean scores of these responses were further categorized in the form of risk matrix; i.e high impact-low probability of occurrence, low impact-low probability occurrence, high impact-high probability of occurrence, and high impact-low probability of occurrence. The risk matrices shown in Figure 7, 8, and 9, below, are drawn in order to see the impact from time, cost, and quality perspectives.

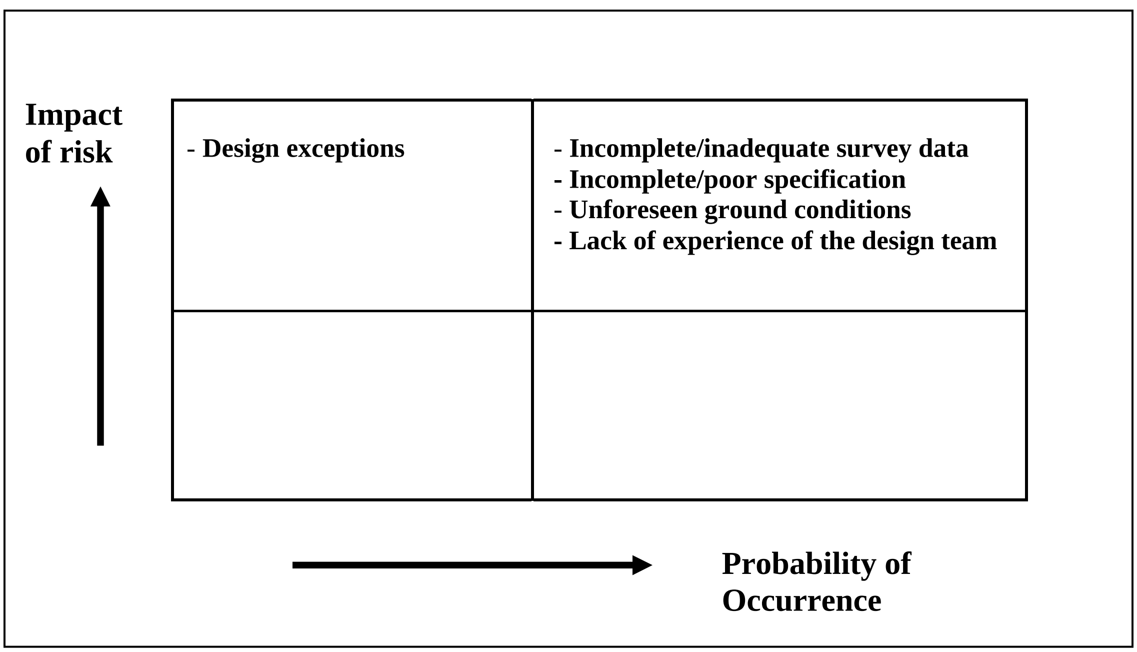

Fig 7: Design risks that have an impact on time

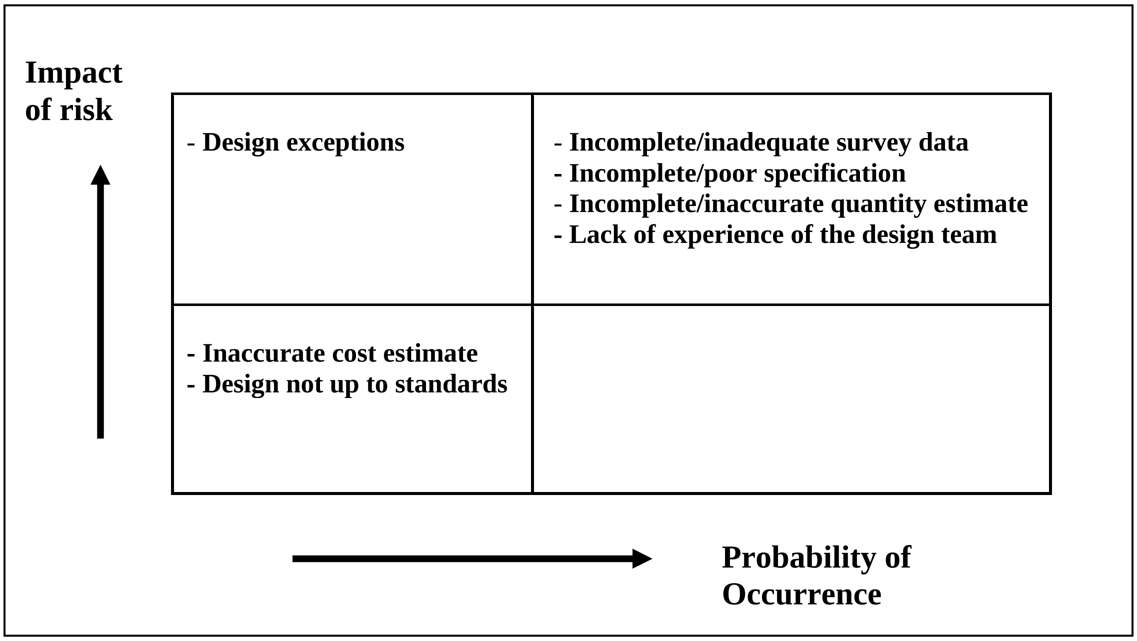

Fig 8: Design risks that have an impact on cost

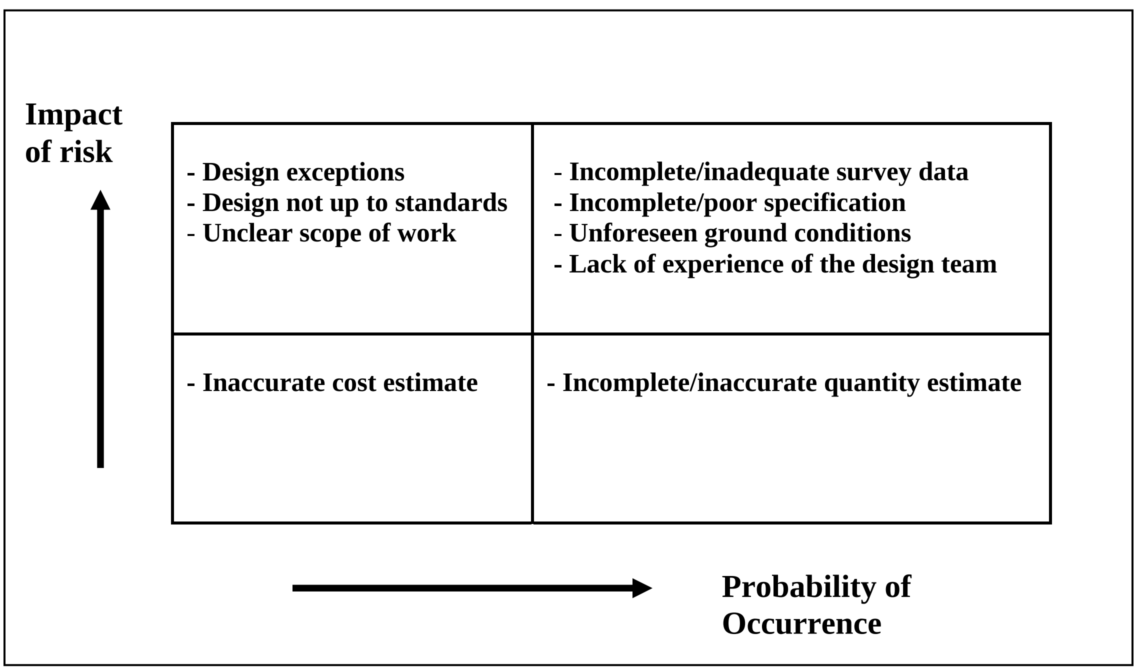

Fig 9: Design risks that have an impact on quality

It can be learnt from the matrices that:

- Incomplete/inadequate survey data,
- Incomplete/poor specifications,
- Unforeseen ground conditions,
- Lack of experience of the design team, and
- Incomplete/inaccurate quantity estimate, are of high impact-high probability of occurrence, and these risks are subject to risk management. Therefore, the need to address these risks, in particular, and design risks in general is paramount in order to minimize the impacts. Besides the interview, case studies were undertaken to further examine whether design risks were contributory to time and cost overruns, and poor quality of projects. The findings are discussed hereunder with an introduction of overview of Federal road projects implementations.

4.3 Case study of risk-prone road projects

4.3.1 Overview of road project implementations

In Ethiopia, the key parties involved in road projects implementations are the Government of Ethiopia represented by the Ethiopian Roads Authority, Contractors and Consultants. The Ethiopian Roads Authority (ERA) is charged with the duties and responsibilities of providing adequate road infrastructure to support the socio-economic development of the country. The task involves improving the condition of existing roads and expanding the network. ERA was established in 1951 as Imperial Highway Authority and was responsible for the design and implementation of road projects for about 40 years from its establishment by making use of in-house design and own force unit for construction. Later, the Authority is restructured and the in-house design preparation was transferred to consultants who are entrusted with the task through competitive bidding. In addition the responsibility of the own force unit was reduced and most projects have been put for competitive bidding for Contractors.

Currently, the Contractors taking part in road projects implementations are National and international companies. Most of the local Contractors are of limited capacity and rarely do meet the requirements to participate in donor financed projects. Hence, international Contractors, who meet the requirements, have been participating in donor financed projects. The contracting company after wining the contract will take the responsibility to complete construction of the project in accordance with the contract document. Consultants, like Contractors, will take the responsibility for the design and/or supervision services they render in accordance with the contract document. International Consultants' have also been participating in donor financed projects.

The project delivery method widely practiced by ERA is the traditional design-bid-build approach. This approach has three separate phases. First, the feasibility and/or design of a project is undertaken by a Consultant, then a bid is floated to procure a Contractor, and finally the selected Contractor completes the construction.

4.3.2 Case study of the Road Projects

For this research, 10 Federal Road projects were selected for case study. All of these projects are delivered by international Consultants and Contractors. These projects are selected on the basis of their performances on cost and schedule. As it has been illustrated in the problem statement all of these projects experienced cost and time overrun. The procurement of services and works were made on international competitive bidding, and the projects were delivered with design-bid-build project delivery method. The list of these projects is described hereunder..

i. Addis – Jima Road Project
ii. Addis-Mojo-Awassa
iii. Modjo – Awash – Mille Road Rehabilitation Project:
Contract 1: Modjo – Awash Arba
iv. Gewane - Mille
v. Awash – Hirna – Kulubi – Dengego – Dire Dawa and Dengego – Harar Road Upgrading Project - Contract 1: Awash – Hirna
vi. Awash – Hirna – Kulubi – Dengego – Dire Dawa and Dengego – Harar Road Upgrading Project - Contract 2: Hirna – Kulubi
vii. Awash – Hirna – Kulubi – Dengego – Dire Dawa and Dengego – Harar Road Upgrading Project - Contract 3: Kulubi – Dengego – Dire Dawa and Dengego – Harar
viii. Tarmaber-Kombolcha Road project

ix. Woldia – Adigrat – Zalambessa Road Upgrading Project:
Contract 1: Woldia – Alamata
x. Woldia – Adigrat – Zalambessa Road Upgrading Project **;**
Contract 2: Betemariam – Wukro

The features of theses road projects; i.e. brief descriptions of the location, length, the designer and contractors, nature of works, contract type, commencement and completion time, original and final contract price, and reasons of variation orders are described as follows.

4.3.2.1 Addis Ababa – Jimma Road

Addis Ababa – Jima Road reconstruction project starts at Addis Ababa Ring road and runs in south-west direction to Jima approximately 336km away. A feasibility study of the project to rehabilitate the road was completed by PLANCO consulting GmbH of Germany in collaboration with DIWI in February 1995. The detailed engineering design and tender document were prepared by Studio Pietrangeli (Italy) between May 1995 and September 1997. The work comprises of two Lots; namely:

- Lot 1 – km 10+600 – km 185+700 (Gibe river)
- Lot 2 - km 185+700 – km 336+400 (Jima)
  a) Lot 2A from Gibe river – Jima (km 185.7 – 270 & km 282 – 336.4)
  b) Lot 2B new realignment road around Gilgel Gibe dam (km 270 – 282)

The nature of works involves rehabilitation of 309km existing road and the construction of 33.33 km of new road, with two-lane single carriage way standard. The contractor was Dragados – J & P (Hellas) Joint venture. DIWI Consult international GmbH and Tecnica Y Proyectos S.A. Joint Venture in Association with Associated Engineering Consultants was the supervision consultant. The original Contract price for Lot 1 & 2, with discount of 14.7%, totals ETB 405,973,872.12. The Contract period was 36 months with 12 months maintenance period. The type of Contract was Unit price contract subject to re-measure (Article 49.1 of SCC). The actual commencement date was 1st May 1999 and the completion date was scheduled to be 30th April 2002.

The Terms of reference for the supervision consultant charges the consultant with the duty to satisfy him self as to the nature and scope of the works, of all information and design data available and of contract documents to be used for the works contractor. DIWI, therefore, reviewed the design during Contractor's mobilization period, and found design errors and omissions in connection with following particulars.

- Technical issues with cold asphalt patching and inadequate patching quantities,
- Pavement design analysis and deflection survey interpretation,
- Inaccurate quantities, particularly in relation to black cotton soil sections,
- Topographical survey,
- Lack of cross sections and the constructability of the design , particularly in mountainous areas,
- Existing/final design levels and the constructability of the design based on existing conditions,
- Lack of design details , e.g. retaining walls, extension details for culvert, construction details/locations for guard rails, road markings, and
- Lack of offset and invert details for drains.

Variation order No. 5, amounting ETB 243,603,432.01 (include ETB 187,800,529.99 for the revised pavement design) was issued on 28th March 2002 to accommodate the following design changes.

- Addition of parking lanes and pedestrian walkway in the major town sections
- Addition of parking lanes and 1.5 m shoulders in the minor town sections
- Addition of shoulders in the rural section between km 10+600 – km 26+000
- Increasing the design height of the new road construction across Awash plain by 1.5 m
- Counter measures to deal with expansive sub-soils

As a result, the nature of the works changed from what was originally a rehabilitation project to a major earth works project. And, the total quantity of earth works increased from 268,400m^3 to 568,865m^3; i.e. 112%. The contract completion date has also been extended by 1126 days (37 months) from April 30, 2002 to 31st May 2005. The total **r**evised contract price including other variation orders was ETB 650,092,897.13 (May associates, 2005; ERA, 2002).

4.3.2.2 Addis-Ababa – Modjo – Awassa Road

Addis Ababa – Modjo – Awassa road is part of interstate highway network, connecting Addis Ababa, via Moyale at the southern boarder, with Nairobi, the capital of Kenya. The length of the project is 263km. The feasibility study to rehabilitate the road section between Modjo and Awassa was conducted by Scott Wilson Kirkpatrick of UK. Initial design for this work was prepared by Transport construction Design Enterprise (TCDE) of Ethiopia in 1993. Thereafter DHV consultants BV of Dutch did the evaluation of the previous studies including detailed investigations, and produced a design for the rehabilitation of the road.

The Contractor was Dragados – J&P. DHV consultants BV resumed the supervision of the works. The original Contract price was ETB 310,079,872.92. The Contract period was 36 months with 12 months maintenance period. The type of contract was Unit price contract. The original commencement date of the works was 15th October 1997(work started in April 1998) and completion date was scheduled to be 14th October 2000. A pavement condition survey performed at the start of the construction phase in 1997 revealed that the sections as indicated in the DHV's pavement condition survey report of May 1995 were deteriorated that repair and overlay as was foreseen in the tender documents would became a very costly operation. Therefore, a complete change of treatment became necessary on the Addis – Ababa – Modjo section, and Rider No.1 was signed in February 1999 to implement a revised strategy.

The strategy covered:

- Reconstruction of 59.5km of Addis Ababa – Modjo road
- 36.5km of normal section 7.30m wide in rural sections as per typical cross section drawings
- 13.1km of town road sections 12.3m wide
- 10.4km of road with 3.5m wide climbing lanes to accommodate traffic driving at low speed in some locations
- Amendment to the edge of pavement/kerb detail at paved ditch locations within town sections in the Addis Ababa – Modjo road section.

Rider No.1 was agreed at ETB 29,706,300.82, resulting 9.6% increase in the contract price (May associates, 2005; DHV, 2004). Other modifications to designs, which resulted in variations amounting ETB 41,825,061.00 include:

- Change of vertical alignment at Modjo bridge approaches between km 68+610 and km 69+740 (Variation order No. 1A: ETB 1,015,763.14)
- Additional base course material, one layer of 200mm thick, km 88 – km 110 (Variation order No. 2: ETB 1,438,656,000) and one continuous layer of 180mm thick, km 110 – km 275 (Variation order No. 9: ETB 5,815,584.00)
- Thermoplastic road markings and reflective road studs (Variation order No. 6: ETB 1,728,270,00)
- Road traffic signs along Addis – Modjo section (Variation order No. 7: ETB 472,650.93)
- Full width sealing of shoulders Addis Ababa – Modjo section (Variation order No. 8: ETB 296,800.00)
- Improvements to the vertical alignment of Shashemene bypass (Variation order No. 10: ETB 1,375,663.60)
- Modjo bridge traffic control (Variation order No. 11: ETB 142,485.00)
- Improvements to the approaches to Kaliti interchange on the Addis Ababa ring road (Variation order No. 12: ETB 2,273,567.24)
- Painting of kerbstones of medians and traffic islands with road marking paint (Variation order No. 13: ETB 202,260.00)
- Change of vertical design from km 10+500 – km 12+160 & km 261+300 – km 262+790 (Variation order No. 19: ETB – 2,092,773.69 and Variation order No. 20: ETB 1,633,944.80)
- Optimizing and detailing of vertical alignment of Modjo – Awassa section (Variation order No. 21: 9,148,815.17)
- Quantity changes due to finalized geometric design Addis Ababa – Modjo section (Variation order No. 22: 3,743,905.70)
- Change of layout of town sections along Modjo – Awassa section (Variation order No. 23: ETB -620,977.85)
- Additional bus parking lanes for schools outside Kuyira town (Variation order No. 24: ETB 165,373.61)

- Provision of footpaths and widening of parking lanes in town section between Addis Ababa – Modjo section (Variation order No. 25: ETB 6,250,719.32)
- Additional drainage works at Modjo junction (Variation order No. 26: ETB 927,319.52)
- Inclusion of major and minor junctions (Variation order No. 27: ETB 3,675,492.93 & Variation order No. 28: ETB 3,256,403.48)
- Provision of heavy duty parapet railing on Hora Kelo and Shorima bridges (Variation order No. 29: ETB 281,763.18)
- Partial rehabilitation of the existing Shashemene town road (Variation order No. 30: ETB 684,373.41)
- Erosion protection works at high embankments Melka Uda and Shashemene
- Erosion protection works near borrow-pit km 256+400
- Modification of unpaved ditch design along Modjo – Awassa section

The changes of specifications include:

- Asphalt requirements and bitumen specifications
- Surface treatment on shoulders, single layer
- Surface treatment on shoulders, double layer
- Application rate for road marking paint

The total revised contract price was ETB 386,197,700.00, and the project was completed after 49 months (1486 days).

4.3.2.3 Modjo – Awash – Mille Road Rehabilitation project; Contract 1: Modjo – Awash Arba

Modjo – Awash Arba road is part of the road connecting Addis Ababa to the port of Djibouti. Gauff Ingenieure GmbH produced the original design in August 1997. Nor Consult made a design review and revised the Bidding document in June 1998. Nor consult assessed that the condition of the pavement had deteriorated in those following ten months. The works involve rehabilitation, which comprised of 16km of overlay and 144.3km of reconstruction of which 13.5km are on new alignment. The total length of the project is 160.3km and is a two way single lane asphalt concrete road with a 7m carriage way and 1.5m gravel shoulder on both sides. The contractor was Keangnam Enterprise limited (KEL) and CBI supervised the construction works.

The type of contract was unit price contract subject to re-measure. The original contract price was ETB 227,449,546. The commencement date was 1st April 1999 with total contract duration of 36 months and the completion date was scheduled to be 1st April 2002.

The drawings issued at the commencement of the works were dated back to December 1997. Carl Bro international (CBI), therefore, decided that the information shown and the basis on which it was based were questionable by the time the works did commence. The consultant (CBI), after carrying out a visual pavement condition survey in August 1999, reported that the condition of the pavement had deteriorated further, and recommended that some lengths to be overlaid in the original design should be reconstructed. CBI also expressed concern that no provision had been allowed in the design for the construction of climbing lanes especially on the Modjo – Nazareth section.

Therefore, Variation order No.1 was issued on 28 February 2001 through which the overlay sections between km 16 and km 150 were changed to reconstruction. This variation awarded an extension of time of five months. Variation order No. 3 was also issued on 4th September 2002 for the change from overlay to reconstruction at km 150 to km 160.5.

Other Variation orders include the following:

- Introduction of additional bridge which was not included in the original design.
- Request for modification of part of the road section by a regional government to conform to the city master plan, and
- Drainage requirements in certain sections

The total project costs at completion increased to ETB 375.43 million. The cost increase was caused by variation orders amounting ETB 43.97 million and additional 101 million due to price adjustment. The project was completed in December 2004 after 68 months (CBI, 2006; Becker and Behailu, 2006).

4.3.2.4 Modjo – Awash – Mille Road Rehabilitation Project Contract 3: Gewane - Mille

Gewane – Mille is the last section of Modjo – Awash – Mille Road Rehabilitation Project and it is located in Afar region. This road is part of the primary route connecting Djbouti port to Addis

Ababa. The length of the road is 146.025km. Gauff Ingenieure GmbH designed the road in 1997, and Nor consult performed the design review in mid 1998. The project consists of rehabilitation of existing road with a two-lane asphalt concrete carriageway of 7m width and 1.5m gravel shoulders on both sides of the carriageway. For town sections, 3m wide additional asphalt concrete lanes had been added on both sides for parking purposes. The construction contract for the works was awarded to the LTA/CCC/BB joint venture in April 1999 and it was scheduled to be commenced on 02 April 1999 and completed on 31st July 2002. The type of contract was Unit price contract. The supervision consultant SHELADIA Associates, inc. in association with Metaferia Consulting Engineers (MCE) carried out a general design review of the construction drawing and documents during the mobilization phase of the project.

During the design review, identification of the location of the bench marks was very difficult. Most of the benchmarks had been displaced and also the markings were not very clear and accurate. Both the contractor and consultant had difficulty in analyzing the designs. The drawing, did not clearly define the design elevations of the road and the existing elevations. The major reason for the differences was the variation of the benchmark elevations from the supplied elevations on the drawings. The difference between both the levels was checked for the whole length (146.025km) of the project. The average difference was around 840mm which was unlikely as the pavement design required a difference from 190mm to 290mm. Therefore, the consultant had to perform a new design, which had clearly identified the existing ground level, the design level, and the contractor had to construct & place new benchmarks which clearly marked with steel pins in the location and the pins pointed permanent marking elevation.

The project encountered significance increase in the volume of GCS, which warranted a time extension of 490 days with an additional cost for time related preliminary & General costs of ETB 31,299,894 plus an additional cost associated with adjusting the rate for processing the thicker than foreseen sub-base equal to ETB 5,136,654. The total revised contract price was ETB 357,600,000.74 (Sheladia, 2002), and the project was completed on March 6, 2002 after 39 months.

4.3.2.5 Awash – Hirna – Kulubi – Dengego – Dire Dawa and Dengego – Harar Road Upgrading Project: Contract 1: Awash – Hirna

Awash – Hirna road project t is an important strategic route of the National transport net work of Ethiopia and also forms an international road link between Ethiopia, Djibouti, and Somalia. The total length of the contract is 141km. The design of the project was done by DHV consultants BV of Netherland in 1998. Gauff Engineers of Germany reviewed the design in 1999. The Supervision consultant was Consulting Engineering Services (CES) of India in association with DANA consult plc.. The nature of work involve upgrading of the road with 7m wide asphalt paved carriageway and 1.5 m wide shoulder on both sides in the plain/rolling terrain and 6.5m wide paved carriageway with 1m wide shoulder in mountainous terrain. The work also includes rehabilitation of existing bridges and other cross drainage structures, widening, replacement, and reconstruction of drainage structures along with the necessary safety measure.

The commencement date of the project was June 08, 1999 (work started 10 February 2000) with contract duration of 36 months with 12 months of maintenance period. The original completion date was scheduled to be June 07 2002. The original contract amount was ETB 256,542,439.10. However, the project was completed in August 06, 2004 after 62 months. The total project costs at completion increased to ETB 297,426,124.01 including 70,141,558.78 price adjustments (CES and DANA, 2005, and Becker and Behailu, 2006). The cost increase was caused by variation orders amounting ETB 13.745 million for additional works. Nevertheless, there was a saving of ETB 6.517million in the sum total of BOQ due to actual work done on site. The Variation orders include the following:

- Increase in quantity of metal culverts and execution of new diversion from km 123+500 – 125+500 (Variation order No. 10),
- Additional work due to request of local administration through which the road passes,
- Masonry work which was missing in the bill of quantity,
- Additional work due to land slide.
- Provision of miscellaneous items required for the project but not included in the Bill of Quantity.

The contractor was given time extension of 487 days on account of increase in quantity of metal pipe culverts and execution of new diversion from km 123+500 – 125+500 against Variation order No. 10**.** Thus, the revised date of completion was 06 August 2004, which amounts to an overrun of 72.17%. The project has also experienced significant under estimation of quantities in the BOQ as detailed in Table 5 below.

Table 5: Increase in quantity of works

No.	**Cost item**	**Increase in %**
1	Road bed preparation	108.96
2	Lower sub base	50.86
3	Placing of Metal pipe culvert	405.42
4	Concrete B-15 for culverts	66.85
5	Concrete for Box culverts	621.79
6	Re bar for Box and Slab culverts	578.53
7	Masonry for parapet, abutment, toe walls	288.02
8	Concrete B-15 for new Bridges	1116.97
9	Concrete B-30 for new Bridges	229.33
10	Re bar for Bridges	164.89

4.3.2.6 Awash – Hirna – Kulubi – Dengego – Dire Dawa and Dengego – Harar Road Upgrading Project: Contract 2: Hirna – Kulubi

Hirna - Kulubi road connects Addis Ababa with the eastern part of the country. The total length of the project is 91km and is a two way single lane asphalt concrete road with a 7m carriage way and 1.5m gravel shoulder on both sides. The construction work was carried out by a Korean based company named Keagnam Enterprise Limited and the supervision consultant was Scott Wilson Kirkpatrick & Co. Ltd (UK).

The commencement date of the project was June 05, 1999 with total contract duration of 30 months and the completion date was scheduled to be December 04, 2001. The original contract amount was ETB 188.08 million. The project was completed in September 30, 2004 after 64 months. The total project costs at completion increased to ETB 224.76 million. The cost increase was caused by variation orders amounting ETB 20.0 million and additional 33.27 million due to price adjustment (Becker and Behailu, 2006). The Variation orders include the following:

- Additional work due to land slide.
- Provision of miscellaneous items required for the project but not included in the Bill of Quantity.

4.3.2.7 Awash – Hirna – Kulubi – Dengego – Dire Dawa and Dengego – Harar Road Upgrading Project: Contract 3: Kulubi – Dengego – Dire Dawa & Dengego – Harar

Kulubi – Dengego – Dire Dawa & Dengego – Harar connects Addis Ababa with the eastern part of the country. The total length of the project is 80km and is a two way single lane asphalt concrete road with a 7m carriage way and 1.5m gravel shoulder on both sides. The contractor was a Chinese company named China Road and Bridge Corporation and the supervision consultant was Wilbur Smith Associates Inc. of USA. The commencement date of the project was June 08, 1999 with total contract duration of 30 months thereby establishing a completion date of December 07, 2001. The original contract amount including contingency was ETB 162.18 million. The project was completed in September 18, 2004 after 63 months. The total project costs at completion increased to ETB 220.5 million. The cost increase was caused by variation orders amounting ETB 15.92 million and additional 48 million due to price adjustment (Becker and Behailu, 2006).

The Variation orders include the following:

- Errors in the estimation of the quantities of work in the bill of quantities.
- Additional length requirement of paved ditch than specified in the original design.
- Additional work required due to protection of road from erosion.
- Repair work for a bridge due to damage.
- Provision of miscellaneous items required for the project but not included in the Bill of Quantity.

4.3.2.8 Addis-Ababa – Woldiya Road; Lot 2: Tarmaber tunnel – Kombolcha

Tarmaber – Kombolcha road (187km) is part of Addis Ababa – Woldiya Road that links Addis Ababa with the northern regions of Tigray and Amhara Regions. The road also provides alternative route to Djibouti port. The detailed Engineering design and preparation of tender document of the entire road (519km) was done by COWI consult of Denmark from June 1996 up to January 1998. The nature of work involves rehabilitation of the road section between Tarmaber tunnel – Kombolcha (km 182 – 369). The contractor was Dragados – J & P (Hellas) Joint venture. H.P Gauff Ingenieure GmbH & Co rendered the supervision services.

The original Contract price was ETB 289,838,439.05. The Contract period was 36 months with 12 months maintenance period. The type of Contract was Unit price contract subject to re-measure. The actual commencement date was 15th March 2001and the completion date was scheduled to be 14th March 2004. The design review made by Gauff revealed the following design deficiencies.

- Survey setting out information was totally inadequate (amendments to the horizontal and vertical alignments were necessary to ensure that the center line of the road coincided with the centerline of bridges and large culvert structures)
- Inadequate drainage details with no provision for extensions to existing structures and the need for additional culvert structures
- Presence of black cotton soil from km 340-369

Therefore, variation order 9 amounting ETB 92,093,703.19 was issued on 13th March 2004 to accommodate the revised design (Design update). Time extension of 24.42 months was also granted and the contract completion date was extended from 14th March 2004 to 28th March 2006. The revised contract including other variations totals ETB 383,215,319.60 (May associates, 2005).

4.3.2.9 Woldia-Adigrat-Zalambessa Road Upgrading Project: Contract 2: Woldia - Alamata

Woldiya – Alamata Road is the first section of Woldiya – Adigrat – Zalambessa road. The road connects Addis Ababa with the northern part of the country. The total length of the project is 78.3km and is a two way single lane asphalt concrete road with a 7m carriage way and 1.5m gravel shoulder on both sides. The project was designed by BCEOM of France and the construction work was carried out by the Chinese company China Wanbao Engineering Corporation. The supervision consultant was Dar Al Handasah Shair and Partners of Lebanon. The commencement date of the project was April 04 1999 with total contract duration of 36 months, and the completion date was scheduled to be April 03 2002. The original contract amount was ETB 150.3 million. The project was completed in June 2004 after 62 months. The total project costs at completion increased to ETB 230.9 million. The cost increase was caused by variation orders amounting ETB 21.8 million and additional 62.43 million due to price adjustment (Dar Al-Handasah, 2004, Becker and Behailu, 2006).

As a result of several events and due to differences between the contract drawings and the actual site conditions construction of additional works became essential. The Variations in this connection include the following:

- Errors in the estimation of the quantities of work in the bill of quantities.
- Collapse of existing bridge and requiring replacement which was not in the design.
- Heavy repair to another bridge which was not foreseen in during design of the project.
- Change in requirement of unlined ditch to lined ditch.
- Foundation protection work for a number of bridges.

4.3.2.10 Woldia-Adigrat-Zalambessa Road Upgrading Project: Contract 1: Betmariam- Wukro

Betemariam-Wukro Road is a section of Woldiya-Adigrat - Zalambessa road. The road connects Addis Ababa with the northern part of the country. The total length of the project is 117.2km and is a two way single lane asphalt concrete road with a 7m carriage way and 1.5m gravel shoulder on both sides. The project was designed and supervised by BCEOM, and the contractor was

China Wanbao Engineering Corporation. The type of contract was unit price contract subject to re-measure. The commencement date of the project was April 04 1999 with total contract duration of 36 months the completion date was scheduled to be April 03 2002. The original contract amount was ETB 203,410,054.65. The project was completed on October 25, 2004 after 67 months. The total project costs at completion increased to ETB 240.5 million (BCEOM, 2004; Becker and Behailu, 2006). The cost increase was caused by variation orders amounting ETB 1.36 million and additional 66.5 million due to price adjustment. Contrary to this a quantity over estimation in the original bill of quantity has resulted in a reduction of ETB 17.59 million. The Variation orders include the lined ditches in different sections of the road which was not included in the original design. Table 6 & 7 below shows some of the cost items which have been over-estimated and under-estimated.

Table 6: Overestimated quantities of the project

No.	Cost item	Over-estimation in %
1	Embankment from rock excavation	78.72
2	Granular backfill	84.55
3	Structural excavation of rock material	86.80
4	Concrete ditch lining	84.16
5	Grouted stone pitching	98.51
6	Precast concrete ditch cover slab	71.50

Table 7: underestimated quantities of the project

No.	Cost item	Increase in %
1	Removal of existing road after scarification	359.87
2	Granular backfill	524.21
3	Class ‘A’ concrete	200.45
4	Class ‘C’ concrete	1,788.89
5	Class ‘P’ concrete	305.52
6	Kerb (all types)	1,096.12

4.3.3 Summary of findings

Summary of the reasons for variation orders in the road projects considered for the case study are as follows.

- Errors in estimation of Quantities
- Inadequate subsurface investigation and interpretation
- Poor pavement investigation and interpretation
- Inadequate/Inaccurate topographic survey data
- Lack of design details
- Omission of works
- Change of alignment
- Poor specification
- Late implementation of design
- Poor drainage assessment
- Additional works from local administration

Although each project may have unique characteristics, most of the problems that required variation orders are found to be common. Except "late implementation of design" which may happen due to various reasons such as late securing of budget, others problems are traced back to design; i.e. design errors and omissions, and/or inadequate subsurface investigation. The occurrence of these problems or design risks had contributed to cost and time overrun.

Table 9 shown below illustrates the design problems that gave rise to cost and time overruns by projects. The numbers in the table below designate the list of the projects in the same order as described above.

Table 8: Design problems by selected projects

Variation Orders (VO)	**Projects that encountered VO**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Errors in estimation of Quantities	√			√	√	√	√		√	√
Inadequate subsurface investigation and interpretation	√							√		
Poor pavement investigation and interpretation	√									
Inadequate/Inaccurate topographic survey data	√			√				√		
Lack of design details	√	√						√		
Omission of works		√	√	√	√	√	√	√	√	√
Change of alignment		√								
Poor specification		√								
Late implementation of design/scope change	√	√	√						√	
Poor drainage assessment			√					√	√	
Additional works from local administration			√		√					

It can be learnt from the table that:

- 90% of the projects encountered omissions of works,
- 70% of the projects faced errors in estimation of quantity,
- 30% of the projects were found with inadequate/incomplete survey data, lack of design details, and poor drainage assessment, and
- 40% of the projects encountered scope changes due to late implementation of design.

In general, the case study revealed that design risks particularly design errors and omissions contribute to time and cost overruns of projects. Although it lacks detail analysis, Becker and Behailu, (2006) argue that poor design and technical specifications were among the factors identified as causes for quality problems. Therefore, the need to revisit the existing practice of design risk management is indispensable to enhance performance of road construction projects.

4.4 Design risk allocation practices in Federal road projects

Risk allocation presupposes identification, and assessment of risks followed by response planning. As a generic approach to design and construction contracts, common risks that may arise as a result of failure to meet obligations/requirements are mitigated by allocating the risks to the party who could best manage it. The importance of risk allocation, as mentioned in section 3.1.3 of this thesis, should be recognized since misallocation of inherent risks in construction contract inevitably affect all project parties, namely client, consultant, and contractors. The principal means of risk allocation is the construction contract as it defines the responsibilities of parties to the contract. Before discussing the issues in the contract, a highlight of the scope of liability from civil code of Ethiopia is introduced to frame the context. Liability is a risk created by contract or law, and arises from contract and/or tort (damage caused to unrelated party). The Ethiopian civil code of 1960 stipulates the scopes of the two liabilities as follows.

4.4.1 Contractual liability

Article 1790 (1) of the civil code states the following with regard to damage arising out of non performance. "*Apart from or in addition to the enforcement or cancellation of the contract, a party may require that the damage caused to him by the other party, failing to perform his obligation be made good*". Article 1791(1) also states that "*the party who fails to perform his obligation shall be liable to pay damages notwithstanding that he is not at fault*". Proof of fault is the basis to claim damage as per article 1795 of the civil code, which states "*A party may not claim damages on the ground of non-performance of the contract by the other party, unless he can show that the other party is in default*".

4.4.2 Extra-contractual liability

Article 2031 of the civil code stipulates the following with regard to "*professional fault*".

i. A person practicing a profession or a scientific activity shall, in the practice of such profession or activity, observe the rules governing the practice.
ii. He shall be liable where, due regard being had to scientific facts or the accepted rules of the practice of his profession; he is guilty of imprudence or of negligence constituting definite ignorance of his duties.

The law puts clearly that the damage, in both cases, be compensated by the party who fails to perform his obligations and found to be faulty because of negligence. Moreover, Article 3039 of the civil code states the following.

i. The contractor shall guarantee during ten years from its delivery the proper execution and the solidity of the work done to him.
ii. He shall be liable during this period for such loss or deterioration of the work as is due to a defect in its execution or to the nature of the soil on which the work has been done.
iii. Any provision shortening the period laid down in sub article (i) due by the contractor shall be of no effect.

The two entities who are accountable for professional liability are consultants and contractors. What the general/standard conditions of contract stipulate for each of them include, but not limited to the following.

4.4.3 General conditions of contract

i) For Consultancy contract

The General Conditions of Contract (GCC) formulated by the Public Procurement Agency (PPA) of Ethiopia (Jan. 2006) stipulates the following with respect to obligations of the supplier, in this case the consultant.

GCC clause 17: Perform its duties with generally accepted professional techniques and practices.

GCC clause 20: Insurance to be taken out by the supplier

- Take out and maintain insurance against the risks as specified in the Special Conditions of Contract (SCC)

GCC clause 20.1: Risks and coverage

- Third party motor vehicle liability insurance
- Third party liability insurance with a minimum coverage of ETB 200,000/occurrence
- Employer's liability and workers compensation insurance
- Professional liability insurance with a minimum coverage equal to the contract ceiling.

According to article 11.14 (5) of the procurement guidelines of PPA issued in Hamle 1997EC, and clause 20.1 of GCC mentioned above, a consultant has to submit professional indemnity insurance before a contract award. In this connection Article 1924 (1) of the civil code states "a guarantee may not exceed the amount owned by the debtor, nor be constructed on more burdensome terms".

ii) For Construction contract

As per clause 10.1 of the particular conditions of contract for Roadwork contracts (ERA, 2002), the contractor shall provide performance security within 28 days after the receipt of the letter of acceptance for his proper performance of the contract, in the sum of 10% of the contract price according to 11.14 (1) of Public Procurement Guideline (Hamle 1997EC). The security/bond shall remain valid until a date 28 days from the date of issue of the taking over certificate, as per clause 10.2 (ERA, 2002).

Clause 8 of the GCC (ERA, 2002) state the following as part of the responsibilities of contractors

- The contractor shall take full responsibility for the adequacy, stability, and safety of all site operations and methods of construction, provided that the contractor shall not be responsible, except as may be expressly provided in the contract for the design or specification of the permanent works, or for the design or specifications of any temporary works not prepared by the contractor (clause 8.2).

- The contractor shall give prompt notice to the Engineer, with a copy to the Employer of any error, omission, fault and other defect in the design of or specifications for the works which he discovers when reviewing the contract documents or executing the works (Clause 8.1).

In connection with site inspection by the contractor, clause 11.1 of same GCC stipulates the following:

- The contractor shall be deemed to have inspected and examined the site and its surroundings and information available in connection therewith, and satisfied himself before submitting his tender as to all matters necessary for the due performance of the contract including the form and nature of the site, hydrological, sub-surface and climatic conditions, the extent and nature of the work and materials necessary for the execution and completion of the works, and remedying of any defects therein, and the means of access to the site and the accommodation he may require, and in general shall be deemed to have obtained all necessary information as to the risk, contingencies and all other circumstance which may influence or affect his tender.

Similarly, clause 12.2 put the following condition related to sufficiency of tender.

- If, however, during the execution of the works the contractor encounters physical conditions or obstructions, which were, in his opinion, not foreseeable by an experienced contractor, the contractor shall forthwith give written notice thereof to the Engineer with a copy to the Employer. On receipt of such notice, the Engineer shall, if in his opinion, such conditions or obstructions could not have been reasonably foreseen by an experienced contractor, then the Engineer shall certify and the Employer shall pay the additional cost to which the contractor shall have been put by reason of such conditions, including the proper and reasonable cost.

4.4.4 Risk allocation practices of ERA

According to Pipattanapiwong (2004), the underlying principle in allocating risk is that the party assuming the risk should be able to best evaluate, control, bear the cost of, and benefit from its assumption. In other words risks should be allocated to the party who best able to manage them. The design risks categorized as "Design errors and omissions" and "unforeseen ground conditions" are risks that need to be allocated.

In the existing practice of ERA, Design errors and omissions are allocated to the design consultant. Thus, designers are required to submit professional indemnity insurance (PII) upon contract award as per the GCC 20.1 of the general conditions of contract (PPA, 2006). The maximum amount of liability is the contract amount which is in line with article 1924 (1) of the civil code of Ethiopia. And the period of liability is the duration of the services or contract. In this case the contractor is not liable for design errors, omissions, and deficiencies in specifications unless provided in the contract.

In practice, however, design risks may materialize during construction, or service period. The maximum risk that may surface during feasibility and design stages will be failure to meet the requirements or obligations spelt out in the contract. The effectiveness of the professional indemnity policy being practiced, particularly in the road sector, for these phases is examined case by case as discussed hereunder.

Case 1: Professional indemnity for feasibility and/or design services

When a design consultant enters into a contract to undertake a design within a certain period, it is obvious that he submits professional indemnity insurance policy for a cover equivalent to the contract amount valid up to the duration of services plus 36 months, as provided in the policy of Ethiopian Insurance Corporation (EIC). The policy being accepted by ERA, currently, provides cover for property damage. "*Impairment of, defect in or damage to the designed object itself due to faulty design or lack of insufficient supervision of construction*" are considered as property damage by the policy. The sufficiency of the policy as related to different scenarios is reviewed as follows:

- The indemnity is limited to contract amount, and therefore, the insurance could not cover damages exceeding the contract amount. Although article 1790(1) entitles recovery of damage, restoration of the product of a design upon failure may exceed the contract amount.
- It is not uncommon that projects designed may not be constructed following the completion of the design mainly because of budgetary constraints or as a matter of priority. The more the construction is delayed the more the period of cover will be elapsed.
- Even if the construction immediately follows the design, most of the main road projects planned to be constructed are long enough that they cannot be completed within three years time after completion of the design, in which the insurance policy (of EIC) is in effect. Currently, there is no practice to renew the insurance policy of the designer beyond the design period and thus, the project will be left with no cover of the liability of the designer.
- Damage may arise from latent defects during service period. There is a possibility that the designer may be liable for the damage arising from professional fault. The professional indemnity insurance policy, because of its limited time span, could not serve the purpose.
- In most cases, in road projects, another supervision consultant may be engaged to supervise a project designed by a design consultant. In the current practice, the supervision consultant is charged with the main duties of design review, which is intended to smooth out deficiencies, if any, in the design document. Although the approach helps to rectify the design, it will create overlap of liabilities which may relieve accountability of the previous designer and thereby the significance of its professional indemnity insurance policy.
- According to article 3039 of the civil code, the contractor is liable, during ten years, for damages due to defect in its execution or to the nature of the soil on which the work has been done. Although the contractor is supposed to carry out soil investigation to satisfy him with the adequacy of the bearing capacity of the soil, the liability vested on the contractor relieves the designer who is primarily responsible for the design. Not only the designer, but the professional indemnity insurance policy, if valid for the period in reference will also be relieved. The contractor on the other hand is not expected to provide professional indemnity insurance policy to cover the risk, but the law held him ultimately liable.

Case 2: Professional indemnity for design review and construction supervision services

In the road sector, in some cases, a design consultant performs a design and then another consultant may supervise the construction. By the time construction begins supervision consultant will be engaged with main duties of design review to ensure its soundness and suitability to field conditions. The supervision consultant, like the design consultant submits professional indemnity insurance before contract award. The professional indemnity insurance or the cover to be submitted is equivalent to the contract amount valid up to the duration of service. The problem here is latent defects that may arise after the duration of services could not be covered by the professional indemnity of the supervision consultant because of the expiry of the policy period.

In both cases, the Informants were asked to respond to the question “Is there experience that design errors and omissions were covered from professional indemnity insurance?” All of them answered “No.”. The reasons include:

- The gap between design and construction period is large, in some cases, and hence the policy period elapses,
- The problem arises after completion of design,
- Inability to explicitly include the type of PII to be submitted,
- Considered as risk of client,
- The trend is to prohibit the consultant from tenders for one or two years

The responses obtained from the Informants also reveal that the professional indemnity insurance is not yet meaningful; rather it is submitted as a matter of formalities.

According to the GDOT (2006) Errors and omissions policy, the consultant should only be held accountable for the cost of the new design; not for additional construction costs resulting from such errors unless E&O are a result of gross negligence or carelessness. If E&O results in additional quantities being added to the project that would have been required any way, and no other quantities, delays, or costs are created, no compensation from the consultant is necessary.

ERA's practice to deal with unforeseen ground conditions is to allocate provisional sum (PS) in the consultancy contract for geotechnical investigation when the site is accessible. The same approach is followed to the Construction contract when the site is not accessible. In both cases ERA cover the cost of investigation from the provisional sum. However, according to article 3039 of the civil code the contractor shall be liable for a period of 10 years for loss or deterioration of the work as is due to a defect in its execution or to the nature of the soil on which the work has been done. Clause 11.1 of the General conditions of contract (ERA, 2002) also charges the contractor with the responsibility to inspect the site before submitting his tender. Nevertheless, clause 12.2 gives a room to reimburse the additional cost resulting from the unforeseen conditions, which in the opinion of the Engineer such conditions could not have been reasonably foreseen by an experienced contractor.

The jurisdiction given to the Engineer by clause 12.2, however, needs baseline records when to accept the contractor claims rather than opinions. This condition, in the opinion of the researcher, presupposes the carrying out of geotechnical investigation by a consultant in the design stage where the site is accessible. The findings of the investigations could form the baseline to demarcate where the risk lies; i.e. risks consistent with or less adverse than the baseline are allocated to the contractor, and those significantly adverse than the baseline are accepted by the client. The Geotechnical Baseline Report (GBR) is such kind of report that aims to establish a contractual understanding of the subsurface site conditions, referred to as a baseline (ASCE 1997). Thus, the inclusion of GBR in a contract and the development of risk sharing packages are amongst the contractual arrangements that need to be considered to minimize the problems of unforeseen geological conditions **(**Hoek and Palmieri, 1998).

Apart from the foregoing limitations, the risk allocation approach of ERA, in general, is in line with qualitative and quantitative risk allocation approach explained in section 2.1.3.2, with the exception of cooperative risk allocation, where both the consultant and client jointly search for an agreement that is mutually acceptable, as in the case of unforeseen ground condition. Qualitative risk allocation approach is to specify obligations of parties in the contract, whereas quantitative approach is to employ a strategy that transfer the risk to insurance (Competitive risk allocation) and jointly share the risk (Cooperative risk allocation).

4.5 Design risk mitigation in Federal Road projects

4.5.1 The practice to mitigate design risks

Apart from defining obligations in contract clauses, to mitigate risks whenever materializes, there are other approaches being followed to minimize design risks. One of the approaches is design review before construction. ERA follows this approach as a means of mitigating design risks, and most of the projects were appraised through this process. The task of design review, in most cases, has two forms; i.e. design review as a first phase followed by construction supervision as second phase, and design review as part of construction supervision services. Therefore, the Request for Proposals (RFP) for such assignment stipulates the following, as primary tasks.

- **For design review as first phase of the assignment**

  " *…. review the detailed engineering design and tender document preparation prepared by a consultant and make any or all amendments required in order for them to assume full responsibility of the design.……* " (RFP for Nehile-Abala road project, Nov. 2007)

- **For design review as part of construction supervision services**

  "*…. satisfy himself with the sufficiency of engineering drawings, plans, technical specifications, design calculation, pertinent reports prepared at design stage – in particular the materials report and sources of material identified. Verify the soundness and sufficiency of detailed engineering design, contract documents, and accuracy of bill of quantities….*" (RFP for Ginir-Imi-Gode road project, Nov. 2007.)

In both cases design consultants are engaged in the works, and the RFPs require a design review report, which is expected to outline the recommendation and appropriate changes if necessary or modification on design standards, design documents, topographic surveying data with the ground condition, the alignment, specification and quantities given by the previous design consultant. The RFP further requires that the key (design) personnel to have a portion of experience on construction projects. Table 9 below shows the requirements of construction experience stipulated in the RFPs for aforementioned road projects.

Table 9: Requirements of construction experience for design review and supervision projects

Position	RFP for Nehile-Abala project	RFP for Ginir-Imi-Gode project
Highway engineer	4 road construction projects	3 years
Pavement/mat'l. Eng	-	2 years
Structural Eng.	2 road construction projects	2 years
Geotechnical Eng.	3 years	2 years

The practice of engaging a design review and/or construction supervision consultant was not new. It has been practiced in the past years as a means to rectify design problems before commencement of construction. The projects selected for the case study exhibits same as shown in Table 10 below.

Table 10: Designers and Reviewers of selected projects

No.	Road project	Designer	Reviewer &/or Supervisor
i	Addis – Jima	Studio Pietrangeli (Italy)	DIWI Consult international GmbH and Tecnica Y Proyectos S.A. Joint Venture in Association with Associated Engineering Consultants
ii	Addis-Mojo-Awassa	Initial design by Transport construction Design Enterprise (TCDE) of Ethiopia. DHV consultants BV of Dutch did the final design	DHV consultants BV of Dutch
iii	Modjo – Awash Arba	Gauff Ingenieure GmbH produced the original design.	Nor Consult made the review and CBI supervised the construction works.
iv	Gewane - Mille	Gauff Ingenieure GmbH	Nor consult performed the design review. Again SHELADIA Associates, inc. in association with Metaferia Consulting Engineers (MCE) carried out a general design review during the mobilization phase of the project.

v	Awash – Hirna	DHV consultants BV of Netherlands	Gauff Engineers of Germany reviewed the design. The Supervision consultant was Consulting Engineering Services (CES) of India in association with DANA consult plc..
vi	Hirna – Kulubi	DHV consultants BV of Netherlands	Scott Wilson Kirkpatrick & Co. Ltd (UK)
vii	Kulubi – Dengego – Dire Dawa and Dengego – Harar	DHV consultants BV of Netherlands	Wilbur Smith Associates Inc. of USA
viii	Tarmaber-Kombolcha	COWI consult of Denmark	Gauff Ingenieure GmbH
ix	Woldia – Alamata	BCEOM	Dar Al Handasah Shair and Partners of Lebanon.
x	Betemariam - Wukro	BCEOM	BCEOM of France

The case study revealed that most of the projects had undergone design review phase by other consultants, and none of them were found to be free of design risks subject to cost and time overruns. This shows that, the design phases by their own were not able to produce constructable designs. The design review phase though minimizes design deficiencies, is additional layer that also add cost and time.

ECEAA (2007) has made the following comments in connection with the design and design review services.

- Design and design review services become obsolete which requires substantial design changes due to topographical and conditions of the project changes,
- Designers knowing these facts provided incomplete design which created tendencies to desperately engage into contracts with low fees without developing any commitment on the services part,
- These situations have also minimized trust of ERA on consultant's services because quality of services became under question, and cost and completion time had exceeded considerably,

- The fact that these situations provided the contractor to be more claim oriented and the client cost oriented, makes consultants to tighten control and in turn created an adversarial relationship between the consultant and the contractor.

The other approach being followed by ERA is design and construction supervision services by consultants. This approach leaves the design risks, if materializes, to the designer himself so that he bears the responsibility to correct his own design deficiencies that may arise during construction phase. The approach, though better than the design review and construction supervision approach, has limitation in such a way that no construction experience is drawn from construction professionals during design. Thus, the designer might not be in a position to see the deficiencies until they are realized, and time may elapse to correct the deficiencies after detection. Therefore, the only difference from the other approach is retaining the designer during construction phase for correction of its design upon failure. ERA also reviews design by its own experts to give feedback to the designer, if there are any corrections to be made before acceptance. However, the final design is released by the consultant incorporating the comment, if any by ERA. In addition, ERA has the intention to introduce performance evaluation system as part of the means to minimize design problems.

4.5.2 Opinions on Constructability concepts

Constructability, which is the optimum use of construction knowledge and experience in planning, design procurement, and field operations to achieve project objectives, is advocated with several research findings. According to ASCE (1991), this approach greatly improve the chances of achieving a better quality project, completed in safe manner, on schedule, for the least cost.

Therefore, the Informants were asked to give their opinions on the concept. And all of them agreed fully with a belief that construction personnel:

- Are the ones who know the site realities (constraint, difficulties, etc),
- Consider the important precautions timely.
- Identify the risks that could be encountered during construction

However, ERA has a practice to include construction experience in addition to design experience in its requirement of key personnel for design review services as mentioned in section 4.5.1. Thus, the Informants were asked to respond to a question whether they get personnel that meet the mix of design and construction experience. Accordingly, 62.5% of the Informants answered “some times”, 12.5 % answered “rarely”, and 25% answered “in most cases”. Two respondent qualified their answers by saying that “even though there are personnel who have the required mix of experience, they are not the ones who does the job except providing CVs for bid evaluation; this happens because of the mismatch between demand and capacity (supply) of personnel with the required mix of experience. As a result, they leave the task to the junior staffs after the contract award, and this situation widened the problems and effects of designs.”

In similar vein there was a question which says “To what extent were you able to minimize design risks by involving personnel with design and construction experience?’’. In this regard 50% of the respondents answered “to some extent”, 25% answered “insignificant”, 12.5% answered “to large extent; if the personnel really involve in the design, which is unlikely as mentioned above”, and 12.5% answered “satisfactorily”. In both cases it can be learnt that a requirement of personnel with the design and construction experience could not fill the gap or improve designs substantially.

In relation to the concept of constructability, Hassun (2005) advocates that constructability reviews of highway projects during design is a primary means of reducing highway project durations, cost overrun, and quality problems. In this connection, the Informants were asked whether they agree with the findings of Hussan, and all agreed fully by reasoning that the review “enable to track possible impediments to be encountered”. Having their agreement with the propositions, they were given the chance to rank the level of importance, and application of some of the design phase constructability concepts modified from Hassun (2005). The responses obtained are tabulated in Table 11 below.

Table 11 Design phase constructability concepts

No.	Constructability concepts	Level of importance			Level of application		
		Very important	Important	Least important	High	Medium	Low
1	Carry out thorough investigation of the site	**6**			**3**	**3**	
2	Design for minimum time below ground	**2**		**1**		**1**	**2**
3	Design for simple assembly		**3**	**1**		**3**	**1**
4	Encourage standardization/repetition	**2**	**4**		**3**	**3**	
5	Design for pre-fabrication, pre-assembly or modularization	**1**	**4**	**1**	**1**	**3**	**2**
6	Analyze accessibility of the job site	**4**	**1**		**2**	**3**	**1**
7	Employ any visualization tools such as 3D CAD to avoid physical interferences	**3**	**2**		**2**	**2**	**1**
8	Investigate any unsuspected, unrealistic or incompatible tolerances	**3**	**2**		**2**	**2**	**1**
9	Investigate the practical sequence of construction	**4**	**2**		**1**	**3**	**1**
10	Plan to avoid damage to work by subsequent operations	**4**	**1**		**1**	**3**	**1**
11	Consider storage requirement at the job site	**2**	**1**	**3**	**1**	**3**	**2**
12	Investigate the impact of design on safety during construction	**3**	**2**			**3**	**1**
13	Design for the skills available	**3**	**2**		**1**	**3**	
14	Consider suitability of designed materials	**4**	**2**		**4**	**3**	
15	Provide detail and clear design information	**6**			**4**	**2**	
16	Consider adverse effects of weather in selecting materials or construction methods	**4**	**2**		**2**	**4**	

The mean score of the responses were further categorized into “high level of importance-high level of application”, “high level of importance-low level of applications”, “Low level of importance-high level of applications”, and “low level of importance-low level of applications” as shown in Figure 10 below.

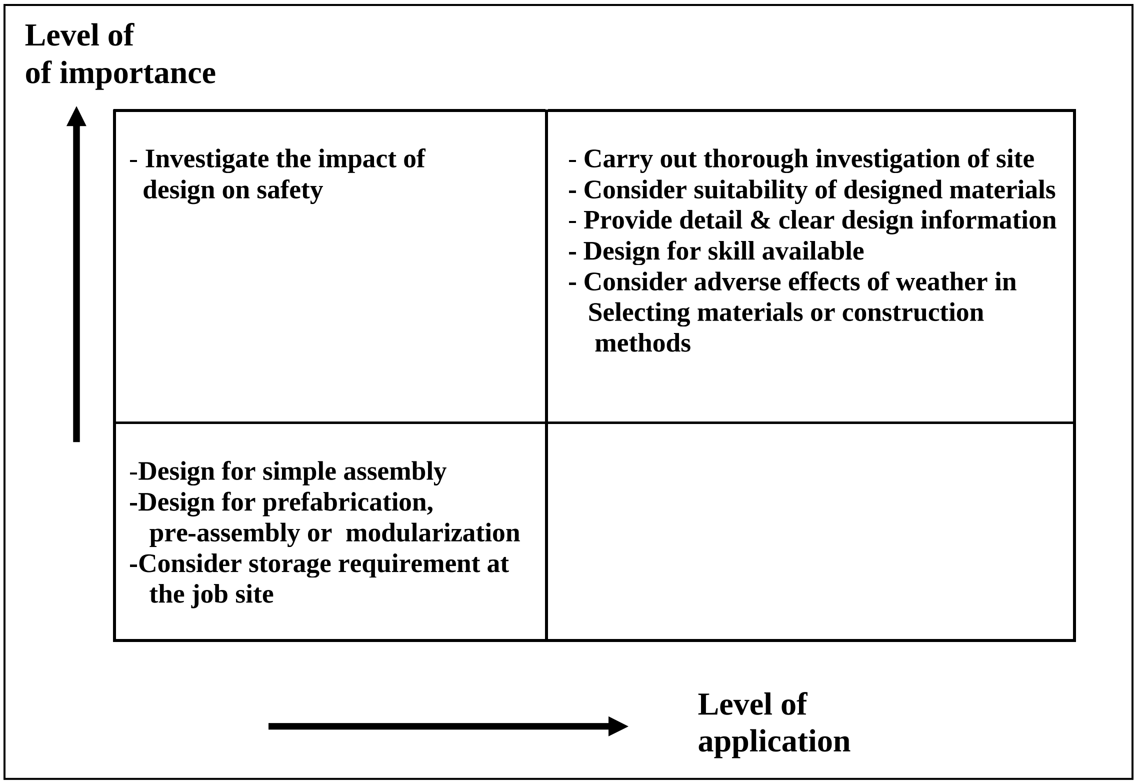

Fig 10: Level of importance & application of Design phase constructability concepts

From the matrix above, it can be learnt that the following design phase constructability concepts are of high level of importance and applications.

- Carry out thorough investigation of the site,
- Consider suitability of designed materials,
- Provide detail and clear design information,
- Design for skill available, and
- Consider adverse effects of weather in selecting materials or construction methods.

Though the concepts are very general, they give clue where to focus in improving constructability of designs of the road projects under considerations. Nevertheless, all concepts are essential to consider in constructability review of highway projects. In summary, constructability review that involves experienced construction personnel during the design phase is not yet practiced. The research findings, however, promotes the significance of the review in reducing highway project durations, cost overruns and quality problems. On the other hand, the existing practice of design review by design personnel did not ameliorate the problems mentioned above. Therefore, the need to consider constructability review seems to be apparent.

4.6 The project delivery method in use for Federal road projects

The project delivery method widely used by ERA for Federal road projects is the traditional Design-Bid-Build (DBB). Although no detail information was found, about the lessons learned, during this research, Design-Build (DB) was tried long years ago. Currently, there is one DB project, which is underway. In implementing DBB, the Authority, having identified the need for a specific project, procures a consultant to undertake Feasibility study, Environmental impact assessment and/or detail engineering design and tender document preparation through competitive bidding. Sometimes, Environmental impact assessment is included in the tasks of detail engineering design. After completion of this phase, eligible contractors are invited for construction of the project through a process of pre/post qualification, and then the winner of the bid will construct the works.

The methodology for selection of consultants is short listing through Expression of interest (EOI) followed by Quality and Cost Based Selection (QCBS). This selection method involves evaluation of technical proposal on preset criteria, and evaluation and comparison of financial proposal to determine the best evaluated proposal. The weights given to the scores of the technical and financial proposals are usually 80% and 20%, respectively. The consultant who earned the highest combined score will be the winner, if there are no deficiencies in its offer that may change the result. Selection of consultants based on this method takes three to six months on average.

After the design is finalized, depending on the size of the project, requirements of the financer and other relevant criteria, a two stage bidding process is adopted for the selection of contractors for the construction work. Two stage bidding is whereby; at first stage a prequalification application will be solicited from contractors to assess their financial capacity, past experience, equipment, personnel and related matters. To compare financial offers at a second stage a bidding process will be undertaken inviting firms that passed the first stage. Unlike the procedure for selection of consultants which utilizes Quality and Cost based selection, this method uses a pass and fail criterion for the first stage and makes no differentiation in ranking, among the applicants who passed the first stage. The firm who gave the lowest offer will be the winner to be called for negotiation and subsequent award. Selection of contractors based on this method takes about six to twelve months on average. ERA, having completed the foregoing stages, signs separate contracts first with a designer, then with a contractor after the design is completed. Parallel to selection of contractors, selection of supervision consultants will be done for supervision of works. The procedure for selection of supervision consultants is identical with the selection procedure for design consultants. The overall process of selection of contractors and consultants for feasibility study, detailed design and subsequent project implementation takes from nine months up to eighteen months on average.

As explained by CSI (2005) DBB is the required system in most Government contracts as it effectively achieves low price and fair competition. Besides, early completion of design eases planning and facilitates scheduling. The timing also allows the owner to work closely with the designer during the design phase. However, several literatures agree that DBB does not involve experienced construction personnel/contractor input during the design phase, which is believed to off set lack of construction experience by design personnel, or integrate construction knowledge throughout the project.

The findings of this research revealed that design risks contribute to project delays, cost overrun, and poor quality of works. And literatures have proved that these risks are better addressed through constructability review. Constructability review, in turn, requires the involvement of experienced construction personnel or contractor's input during the design phase. However, DBB is characterized by separation of phases of design and construction. Hence, it does not bring the contractor earlier into the process. Becker and Behailu (2006) has also found that DBB, which is currently in place, has contributed to poor design and contract documents which were among the major reasons for cost and time overrun, and poor quality of projects. They have also made the following comments in connection with incentive and innovations.

- ERA during the tender process fixes the contract duration, resulting in no encouragement to contractors for early completion as there is no bonus for early completion. However, if a road can be opened for traffic a certain period earlier than the planned time the benefit gained in doing so might justify the extra costs incurred to finish earlier. For projects procured under DBB, contractors cannot use these methods during construction as there is no mechanism to compensate them. And hence, ERA is not getting the benefit of these alternatives.

- In addition, ERA has published standards and technical specifications that should be used for design and construction of road projects, and contractors and consultants are required to base their work on these standards. However, there is no guarantee that these standards and technical specification are adequate to achieve the required project objective. Besides, contractors may have a different or even better way of doing the work but the system gives no room for these kinds of contractors' experience to be utilized in ERA's projects.

Design-Build, on the other hand, unites the designer and contractor as a single entity to provide the design and construction services. The integration of the services improves constructability of the facility by minimizing design risks. Collaborative efforts of the design and construction personnel as a team help to:

- Improve risk management by reducing design errors and omissions and the resulting impacts on time, cost, and quality since the DB team have no one to blame.
- Better evaluate alternative methods and material options thereby reducing constructability problems by allowing changes to be implemented earlier,
- Overlap design and construction phases which shorten the project duration and avoid design changes resulting from changes in site conditions due to late bidding,
- Improve communication between design and construction personnel which enables integration of design and construction knowledge and experience to produce constructible design.

Moreover, Warne (2005), and Gransberg & Molnaar (2007) concluded that DB is more aligned to reduced time of construction, improved cost control, better quality and overall client satisfaction. Therefore, the suitability of DB for constructability review which minimizes design risks is more apparent than DBB widely used for Federal road projects.

5. Conclusions and Recommendations

The aim of the research, as mentioned in section 1.3 of this thesis, is to enlighten the need for design risk management to enhance achievement of project objectives, thereby contributing to effective implementation of the country's road infrastructure development program. And the main objective was to examine whether design risks are contributory to cost and time overruns, and affect quality objectives of projects, and make recommendations based on the findings. The following conclusions and recommendations are, therefore, presented in line with the specific objectives designed to meet the main objective.

5.1 Conclusions

i. The first specific objective was to assess whether Road project risks are managed with formal Risk management system. The assessment revealed that Road construction risks are not managed with formal risk management system. However, there are routine practices employed to manage risks. The practices include:

   - Reducing scope of the work or allocation of additional budget,
   - Monitoring the works by project engineers and consultants,
   - Acquisition of Performance security & Professional indemnity insurance,
   - Giving timely solution upon occurrence, as much as practicable,
   - Supervision with Quality assurance plan, and
   - Allocation of risks to parties through contract documents.

   These approaches, though contribute to risk management, do not conform to the formal risk management processes which involves risk management planning, identifications, assessment, response planning, and monitoring. It is evident that the Federal road projects are not free of risks which have an impact on time, cost, and quality objectives of the projects. Responding to risks with no structured system does not bring about substantial improvement in managing the risks.

ii. The second specific objective was to find out the sources of risks in road construction projects, and impacts of design risks. The findings obtained has proved that design risks are among the major risks in road construction projects, and has an impact on cost, time and quality of projects. Thus, the findings enlighten the need for design risk management that focuses on risks of high impact-high probability of occurrence, such as omissions of works, incomplete/inadequate survey data, incomplete/inaccurate quantity estimate, incomplete/poor specifications, unforeseen ground condition, and lack of experience of the design team. Submission of quality assurance plan/manual by a consultant as a matter of requirement or design review by the client could not ensure risk free design documents unless a self cleansing quality management system is instituted in the consultant organization.

iii. The third specific objective was to evaluate design risk allocation practices and instruments employed to manage design risks. The results of the evaluation have indicated that Professional indemnity insurance (PII) is submitted by consultants for risks of design errors and omissions, and allocation of provisional sum by ERA for geotechnical investigation to explore ground conditions.

However, the PII is not yet meaningful; rather it is submitted as a matter of formality. Apart from limitations of duration and amount of cover, the policy requires proof of fault for recovery of damages, which sometimes is difficult as indicated by Eileen et al., (2002). Therefore, as he suggested, it is important to allocate risks of design errors and omissions to both the contractor and the design professional where possible. It follows that Design-Build project delivery method that unites both the consultant and contractor needs to be considered to alleviate the problem, not only from PII point of view, but to minimize the risks by optimizing the knowledge and experiences of design and construction personnel. Besides, the applicability of PII policy as related to the nature of risks in road construction projects requires further evaluation in order to make the cover meaningful.

The risks of unforeseen conditions during the design and/or construction are dealt with allocation of provisional sum by ERA, while the ultimate liability for such loss or deterioration of the work due to a defect in its execution or to the nature of the soil on which the work has been done lies on the contractor. Nevertheless, Clause 11.1 of the General conditions of contract (ERA, 2002) charges the contractor with the responsibility to inspect the site before submitting his tender, and clause 12.2 gives a room to reimburse the additional cost resulting from the unforeseen conditions, which in the opinion of the Engineer such conditions could not have been reasonably foreseen by an experienced contractor.

The jurisdiction given to the Engineer by clause 12.2, however, needs baseline records when to accept the contractor claims rather than opinions. This condition, in the opinion of the researcher, presupposes the carrying out of geotechnical investigation by a consultant in the design stage where the site is accessible. The findings of the investigations could form the baseline to demarcate where the risk lies; i.e risks consistent with or less adverse than the baseline are allocated to the contractor, and those significantly adverse than the baseline are accepted by the client.

iv. The fourth specific objective was to assess the existing practices of design risk reduction/mitigation. The assessment revealed that design review, and design and construction supervision by consultants are the mechanisms currently in place to mitigate design risks. However, literatures have proved that these risks are better addressed through constructability review. Constructability review, in turn, requires the involvement of experienced construction personnel or contractor’s input during the design phase. However, DBB which is currently in place is characterized by separation of phases of design and construction. Hence, it does not bring the contractor earlier into the process.

5.2 Recommendations

i) Formal Risk management system needs to be established at ERA level to minimize the risks.

ii) Consultants' need to establish certified quality management system in accordance with ISO 9000 standards, which requires regular evaluation of the system for continual improvement, and this, has to be a requirement of eligibility for providing consultancy services.

iii) A study of guideline which determine the amount and duration of cover depending on assessment of typical risks is recommended to alleviate the shortcomings of the insurance cover. In addition, it is recommended to introduce a Geotechnical Baseline Report (GBR) which establishes a contractual understanding of the subsurface site conditions referred as a baseline.

iv) Constructability review need to be introduced to minimize road construction project risks in general, and design risks in particular, and Design-Build project delivery system is recommended to better realize constructability review. Since local capacity of contractors is limited, for sometime, to engage in such undertaking, a form of either Designer-led, or Contractor-led Design-Builder or Joint venture is recommended to apply the project delivery method.

References

Abdou O.A. (1996) Managing Construction Risks, Journal of Architectural Engineering, 2(1), 3-10.

Abrahmson, M: Contractual Risks in Tunneling: How they should be Shared, Tunnels and Tunneling, November, pp. 587-598, 1973.

Adam, S. (1989). Practical Buildability**.** The Construction Industry Research and Information Association, London.

Akinsola, A. O., Potts, K.F., Ndekugri, I. and Harris, F.C. (1997). Identification and Evaluation of Factors Influencing Variations on Building Projects. International Journal of Project Management, Vol. 18: 51-59.

Akintoye, A. S., & MacLeod, M. J. (1997). Risk analysis and Management in Construction. International Journal of Project Management, 15(1), 31.

Akintoye, A. S., & MacLeod, M. J. (1997). Risk analysis and Management in Construction. International Journal of Project Management, 15(1), 31.

Anderson, S.D., and Fisher, D.J. (1997a) “Constructability review process for transportation facilities.” National Cooperative Highway Research Program, Rep. No. 390, National Academy Press. Washington. D.C.

Anderson, S. D., and Fisher, D.J. (1997b). “Constructability review process for transportation facilities-workbook”. National Cooperative Highway Research Program, Rep. 391, National Academy Press, Washington, D.C.

Anderson. S.D., and Fischer, et al. (1999). “Constructability issues for highway projects” Journal of Management Engineering 15(3): 60-68

Andi (2006). The importance and allocation of risks in Indonesian construction Projects. Construction Management and Economics, 24, 69-80

Angelo, W., and Rubin, D. (2001) “School Officials Learn Lesson in Managing Booming Work.” Engineering News Reconrd, 27 (7), 47-48

Al-Bahar, J.F., and Crandall, K. C., Systematic Risk Management Approach for Construction Project, Journal of Construction Engineering and Management, Vol. 116, No. 3, 1990, pp. 533-546.

Al-Bahar, J. F. and Crandull, K.C. Systematic Risk Management Approach for Construction projects, Journal of Construction Engineering and Management, Vol. 106. No. 3. September, 533-546, 1990

Aleshin, A: Risk Management of International Projects in Russia, International Journal of Project Management 19, 207-222, 2001.

APM, Project Management Body of Knowledge, Fourth Edition, Edited by Dixon, M, Association for Project Management, UK, 2000.

Austin, S.A., Baldwin A.N. Li, B. and Waskett, P. (2000). Improving Building Design through Integrated Planning and Control. Engineering, Construction and Architectural Management, Vol. 1.9, No. 3, pp 249-258.

Australian Procurement and Construction Council Inc (2004), professional indemnity in the building and construction industry

Baker, S., Ponniah, D. & Smith, S. (1998) Techniques for the analysis to risks in major projects. The journal of the Operational Research Society, 49(6), 567-572.

Baldwin, A. N., Austin, S.A., Hassan, T.M. and Thorp, A. (1999). Modeling information Flow during Conceptual and Schematic Stages of Building Design, Construction Management Economics, Vol. 17, pp 155-167.

Barber, R.B. (2005) Understanding internally generated risks in projects. International Journal of Project Management, 23 (8), 584-590.

Barber, P., Graves, A., Hall, M., Sheath, D., Tomkins, C. (2000), "Quality failure costs in civil engineering projects", International Journal of Quality & Reliability Management, Vol. 17 No.4/5, pp.479-92.

Baxendale, A.T. and Schofield, T.J. (1996). Planning and Progressing Project Variations in Langford and Retik. The Organization and Management of Construction: Shaping theory and practice, Vol. 2, E & FNSPON, UK.

Becker H. J. and Behailu D.D. (2006). Public Private Partnership in Road Projects in Ethiopia. Fachgebiet Integrierte Verkehrsplanung, Technische Universität Berlin Institut für Land- und Seeverkehr, Berlin

Boyce, W.J. (1991). Design for Constructability. Hydrocarbon Processing. 73(12): 81

Bramble, B.B. and Cipollini, M.D. (1995). Resolution of Disputes to Avoid Construction Claims. Transportation Research Board, National Research Council. Washington D.C. USA.

Bubshait, A. A., Al-Said, F.A. and Abolnour, M.M. (1998). Design Fee versus Design Deficiency. Journal of Architectural Engineering, ASCE, Vol. 4, No. 2 pp 44-46.

Burati, J. L., Farrington, J.J. and Led, W.B. (1992). Causes of Quality Deviation in Design and Constrution. Journal of Construction Engineering and Management, ASCE, Vol. 118, No. 1, pp 34-49.

Caldwell, J.A., Hagen, T.D. (1994), "Engineering consultants implement TQM", Quality Progress, Vol. 27 No.1, pp.57-63.

Carter, R. L. and Doherty, N. A, Handbook of Risk Management, Khrwer-Harrap Handbooks, London, 1974.

Chan, d. W. M. and Kunaraswamy, M. M, Modeling and predicting construction durations in Hong Kong Public Housing. Construction Management and Economics, Fol. 17, No. 3, May, pp.351-362, 1999

Chapman, c., Project risk analysis and management – PRAM the generic process, International Journal of Project Management, 1997, Vol. 15, No. 5, pp. 273-281 .

Chapman, C. & Ward, S. (2002) Managing project risk and uncertainty: a constructively simple approach to decision making, Chichester, Wiley.

Chapman, C. & Wards, S. (2004). Why risk efficiency is key aspect of best practice projects. International Journal of Project Management, 22 (8), 619-632.

Chini, A.R., Valdez, H.E. (2003), "ISO 9000 and the US construction industry", Journal of Management in Engineering, Vol. 19 No.2, pp.69-77.

CII (1986). Constructability – A Primer. Publication 3-1 Austin, Texas: Construction Industry Institute.

CIRIA (1983). Buildability: An Assessment. Special Publication 26: CIRIA

CIRIA (1987), Quality Assurance in Construction: The Present Position, Special Publication 49, CIRIA Press, London.

CII (1992). Constructability Implementation Guide, Special Publication. Austin, Texas: Construction Industry Institute.

Clamp H and Cox S (1998) “which Contract: Choosing Appropriate Building contract: RIBA Pub. London

Construction Industry Institute Australia (CII Australia) (1996) Constructability Manual. CII Australia.

Construction Industry Institute (CII) 1987a) Guidelines for Implementing a Constructability Program. CII, Austin, Texas.

Cooper, K.G. (1993). “The change cycle: Benchmarks for the project manager.” Project Management J., 24(1), 17-22.

CSI (The Construction Specifications Institute), (2005). Project Resource Manual –CSI Manual of Practice. Fifth Edition. New York: McGraw-Hill.

Culp, G., Smith, A., Abbott, J. (1993), "Implementation of TQM in consulting engineering firm", Journal of Management in Engineering, Vol. 9 No.4, pp.340-66.

Dar Al-Handasah (2004). Draft completion report of Woldiya-Adigrat Road upgrading project, Contract 1, Wodiya-Alamata

Day, R.L. (1984), "Modeling choices among alternative responses to dissatisfaction", in Perreault, W.D. (Eds), Advances in Consumer Research, Association for Consumer Research, Atlanta, GA, pp.496-9.

Deming, W.E. (1982), Quality, Productivity, and Competitive Position, Massachusetts Institute of Technology (MIT), Cambridge, MA,

Design Build Institute of America, An Introduction to Design-Build (DBIA 1994)

Diekmann, J. E. and Nelson, M.P. (1992). Super Change: Expert System for Analysis of Change Claims. Journal of Construction Engineering and Management, ASCE, Vol. 111, No. 1, pp 74-81

Dougalas. P, (2006), Constructability problems are endemic in the design-bid-build delivery system, vol 17, No 4, WWW.folklaw.com

Duncan, W. R: A. Guide to the Project Management Body of Knowledge, Project Management Institute, 1996.

Dissanayaka, S.M., Kumaraswamy, M.M., Karim, K., Marosszeky, M. (2001), "Evaluating outcomes from ISO 9000-certified quality systems for Hong Kong constructors", Total Quality Management, Vol. 12 No.1, pp.29-40.

Duncan, J.M., Thorpe, B., Summer, P. (1990), Quality Assurance in Construction, Gower, Aldershot.

Eldin, N.N. (1996). Constructability Improvements of Project Designs. Journal of Construction Engineering and Management. ASCE. 114(4): 631-639.

Ellis, R.D., Kumar, A., and Ahmed, Q. A. (1992). “Life Cycle reconstruct ability.” Rep. No. FL/DOT/RMC/99700-7557-119, Florida Department of Transportation

Emmitt, S. (2001). Observing the Act of Specifications. Design Studies, ASCE Vol. 22, No. 5, and pp397-408.

Essex, R.J. (1996) Means of Avoiding and Resolving Disputes during Construction. Tunneling and Underground Space Technology, Vol. 11, pp27-31, Tallahassee, Fla.

Ethiopian consulting engineers and architects association (2007). Critical constraints and proposal intervention

Ethiopian Roads Authority (2002). Standard bidding documents for Roadwork contracts

Ethiopian Roads Authority (2005). DCI: How is it performing over the RSDP period; Paper prepared for mid term review of RSDP, Planning & programming Division of ERA.

Ethiopian Roads Authority (2007). Road Sector Development Program III (2007-2010)

Ethiopian Roads Authority (2007). Request for proposal (RFP) for consultancy services for construction supervision of Ginir-Imi-Gode Road project, Contract 4, Lab-Gode

Ethiopian Roads Authority (2007). Request for proposal (RFP) for consultancy services for Design review and construction supervision of Yalo-Nehile-Ab ala, Contract 2, Nehile-Ab ala Road project.

Federal Construction Council (1993). Consulting Committee on Contract Management, Technical Report No. 74. Managing Changes in the Construction Process. National Academy Press. Washington D.C. USA.

Ficher, Tatum. (1997). Characteristics of Design Relevant Constructability Knowledge Journal of construction Engineering and Management, ASCE, Vol. 123, No. 3,253-255

Finke, M.R. (1998). A Better Way to estimate and Mitigate Disruption. Journal of Construction Engineering and Management, ASCE, VOL. 124, No. 6, pp490-497.

Fisher, D.J., and Rajan, N. (1996). “Automated Constructability Analysis 122(1), 36-43

Fisk, R. E: Construction Project Administration, 5ed, Prentice-Hall Inc, Upper Saddle River, New Jersey, 1997.

Flanagan, R., & Norman, G. (1993). Risk Management and construction. Oxford: Blackwell Scientific Publications.

Flanagan, R. and Norman, G., Risk Management and Construction, Blackwell Scientific, Oxford, UK, 1993.

Flood, R.L. (1993), Beyond TQM, John Wiley & Sons, Chichester, .

Flyvbjerg, Bent, Mette S. Holm, and S. Buhl. (2002). “Underestimating Costs in Public Works Projects,” Journal of American Planning Association, Vol. 68, No. 3, 279-295

Ford David N., and Sterman, J. D. (2003). “The Liar’s club: Concealing rework in concurrent development.” Concurrent Eng. Res. Appl., 111(3). 211-219.

Forguson, I. (1989). Buildability in Practice. London: Mitchell's Professional Library.

Ganah, A., Anumba, C. and Bouchlaghem, No. (2000). The Use of Visualization of Communicate Information to Construction Sites. ARCOM 16 th. Annual Conference. 6-8 September. Glasgow Caledonian University, UK: 833-842

Goetsch, D.L., Davis, S.B. (2002), Understanding and implementing ISO 9000:2000, 2nd ed., Prentice-Hall, Upper Saddle River, NJ.

Griffith, A and Sidwell, T. (1995). Constructability in Building and Engineering Projects. London: Mac Millan Press Ltd.

Lu Youjie, (2001) Risk Management for Large-scale Infrastructure Projects in China, Department of Construction Management Tsinghua University, Beijing

Hartman, F. and Soelgrove, P: Risk Allocation in Lump-Sum Contracts: Concept of Latent Dispute, Journal of Construction Engineering and Management, Vol. 122, No. 3, September, pp. 291-296, 1996.

Harris, F., McCaffer, R. & Edum-Fotwe, F. (2006) Modern construction management, Oxford, Blackwell.

Harthy and Amur salim (2006) , The consultancy fee for structural design changes of Reinforced concrete building in Oman, Faculty of civil engineering university

Hattan, D.E., Lalani, N. (1997), "Selecting the right consultant team", Institute of Transportation Engineering Journal, Vol. 67 No.9, pp.40-6.

Henry, E. (2000), "Quality management standardization in the French construction industry: singularities and internationalization prospects", Construction Management and Economics, Vol. 18 pp.667-77.

Hertz, D.B., and Thomas, H. (1983). "Risk Analysis and its Applications." Wiley, New York, 1-5.

Hibbered, P. R. (1982). Building Contract: variations. MSc Thesis. The Victoria University of Manchester, Manchester, UK

Hill, N., Self, B., Roche, G. (2002), Customer Satisfaction Measurement for ISO 9000:2000, Butterworth-Heinemann, Oxford,

Hugo, F., O' Connor, J.T. and Ward, W.V. (1990). Highway Constructability Guide. Research Project 3-6-88-1149. Centre for Transport Research. University of Texas

Hugo, F., O' Connor, J. T. and Ward W.V. (1990). "Highway constructability guide investigation of highway project constructability improvement." Research Project No. 3-6-88-1149, The Center for Transportation Research, The University of Texas at Austin.

Jaafari, A. (2001) Management of Risks, Uncertainties and opportunities on projects: time for a fundamental shift. International Journal of Project Management, 19(2), 89-101.

Jaafari, A. (2001). Management of risks, Uncertainties and opportunities on projects: Time for a fundamental shift. International Journal of Project Management, 19(2), 89-101

Jergeas, G.F. and Hartman, F.T. (1994). Contractors' Construction –Claims Avoidance. Journal of Construction Engineering and Management, ASCE, Vol. 120 No. 3, pp553-561

Jensen, T. (1994), "ISO 9001 in consulting engineering", Structural Engineering International, Vol. 1 pp.51-3.

Jergeas, P.E., John Vander Put. (2001). Benefits of Constructability on Construction Projects. Journal of Construction Engineering and Management, ASCE, Vol. 127, No. 4, 281-290

Kahkonen, K. (2007) Quantities risk management for construction – model of elements for workable solutions. 4th Nordic Conference on Construction Economics and Organization. Lulea, Sweden

Kelvin, Y. (1996). Project Control: Cos/Schedule/Progress Management. Cost Engineering, Vol. 38, UK

Kerzner, H., (2003) Project Management: A Systems Approach to Planning Scheduling and Controlling Wiley

Kirby, J. G., Furry, D.A. and Hiks, D.K. (1988). Improvements in Design Review Management. Journal of Construction Engineering and Management, ASCE, Vol. 114, No. 1, pp69-82

Kraig L. (2006). An Analysis of Constructability Strategies in Project Delivery:
Making Infrastructure Construction Sustainable in Copán Ruinas, Honduras, MSc thesis, Michigan technological university

Landin, A. (2000), "ISO 9001 within the Swedish construction sector", Construction Management and Economics, Vol. 18 No.6, pp.509-18.

Langford, D.A., EI-Tigani, H., Marosszeky, M. (2000), "Does quality assurance deliver higher -productivity?" Construction management and Economics, Vol. 18No. 7, pp.775-82

Latham, M. (1994), Constructing the Team, HMSO, London.

Latham, Sir, M, (1994) Constructing the team: final report joint review of procurement & contractual arrangements in the UK construction industry.

Leonard, C. A. Fazio, P. and Moselhi, O. (1988). Construction Productivity: Major Causes of Impact. AACE Transactions, New York, NY. PpD10.1-D10.7

Lewis R. McClain (2007), Design-build interoperability and conceptual design and development of a design-build management control system, MSc Thesis, Building Construction and Integrated Facility Management, Georgia Institute of Technology

Limam, M. (1995). “Constructability review process framework for transportation facilities.” MSc thesis, Texas A&M University, College Station, Tex.

Love, Peter E.D., Irani, Zahir, Edwards, David G. (November, 2004). “A Rework Reduction Model for Construction Projects.” IEEE Transactions on Engineering Management. Vol. 51, No.4

Love, P.E.D., Gunasekaran, A., Li, H. (1998), “improving the competitiveness of manufacturing companies through continuous incremental change”, TQM Magazine, Vol. 10 No.3 pp177-85

Lutz, J.D., Hancher, D.H. and East, E.W. (1990). Framework for Design Quality-Review Data-Base System. Journal of Management in Engineering ASCE, Vol. 6, No. 3, pp 296-311

Lyons, T., & Skitmore, M. (2004). Project risk management the Queensland engineering construction industry: A survey. International journal of project management (22), 51-61

Macdonald, C. C: Allocation of Risk in Major Infrastructure Projects – Why do we get it so wrong? The International Construction Law Review, Vol. 18, Part 2, April, pp. 345-352, 2001.

Madelsohn, M. (1997). The Constructability Review Process: A Constructor’s perspective. Journal of Management in Engineering. ASCE. 13(3): 17-19

May Associates (2005). Dispute and claim resolution study of EDF funded road projects in Ethiopia, Final report, Delegation of the European commission in Ethiopia, Addis Ababa

Mbachu, J.I.C. & Vinasithamby, K. (2005) Sources of risks in construction project development: an exploratory study. IN A.C., S. (Ed.) Research Week International Conference. Australia, Queensland University of Technology

McDermott, P. and Dpdd. K/ (1984). The Sources, Causes and Effects of Variations on Building Contracts. Final Report of a Study Supported by Science and Engineering Research Council, Construction Study Unit, Brunel University, Uxbridge, UK.

Mokhtar, A. H. M. (2002). Coordination and Customizing Design Information through the Internet. Engineering Construction and Architectural Management, Vol. 9, No. 3 pp222-231

Molenaar, K.R. (2005) “Programmatic cost risk analysis for highway megaprojects “journal of Construction Engineering and Management 131(3). 343.53.

Mulholland, b. and Christian, J. (1999) Risk Assessment in Construction Schedule, Journal of Construction Engineering and Management, Vol. 125, No. 1, January February, pp 8-15.

Murphy, R.J. (2002), Implementing an ISO 9001:2000 Based Quality Management System: Including Safety and Environmental Considerations, ABS Consulting Press, Rockville, MD.

National Audit Office Department of Transport (1992). Contracting for roads.

New South Wales Construction Agency Coordination Committee (2004), Insurance for Government Construction Projects Guidelines, NSW Department of Commerce

Nima, A.N. (2001). Constructability in the Malaysian Construction Industry, Faculty of Engineering, UPM, PhD. Thesis.

Nima, Mohd R. Kadir, S. Jaafar. (2004). Constructability Concepts in Kuala Selangor Cable-Stayed bridge In Malaysia. Journal of Construction Engineering and Management, ASCE, Vol. 130, No.3, 315-321.

Nijkamp, P. and B. Ubbels (1999) "How reliable are estimates of infrastructure costs

Niwa K: Knowledge-Based Risk Management in Engineering A case Study in Human-Computer Cooperative Systems, John Wiley * Sons, Inc, Canada, 1989.

O'Connor.J.T.F. Hugo, et al. (1991) "Improving highway specifications for constructability, "Journal of Construction Engineering and Management 117(2): 242. 258.

Ofori, G., Gang, G. (2001), "ISO 9000 certification of Singapore construction enterprises: its costs and benefits and its role in the development of the industry", Engineering, Construction and Architectural Management, Vol. 8 No.2, pp.145-57.

Ogunlana, S. O., Promkuntong, K. and Jearkjirm, V. (1996). Construction delays in a Fast – Growing Economy: Comparing Thailand with other Economies. International Journal of Project Management, Vol. 14, No. 1, pp37-45

Papagecorge, T.E.: Risk Management for Building Professionals, R.S. Means Company Inc, US, 1988.

PBL (1987). The Swedish Planning and Building Act.

Perry, J.H. and Hayes, R.W. (1985) Risk and Its Management in Construction Projects, Proceedings of the Institution of Civil Engineering, Part I, 78, 499-521

Perry, J. G. and Hayes, R.W. Construction Projects-Know the Risks, CME, Charted Mechanical Engineer, London, Vol. 32, No. 2, February, pp. 42-45, 1985.

Pipattanapiwong, J, Multi-party Risk Management Process (MRMP) for a Construction Project Financed by an International Lender, Master Thesis No. ST-00-43, Asian Institute of Technology, 2000.

PMBOK.(2000). A guide to the project management body to knowledge. Newton Square Project Management Institute.

PMI (2000) A guide to the project management body of knowledge, Newton Square, Project Management Institute.

Pocock, J. B., Liu, L. Y. and Kim, M. K. (1997). Impact of Management Approach on Project Interaction and Performance. Journal of Construction Engineering and Management, ASCE, Vol. 123, No. 4, pp411-418

Public Procurement Agency (2006). Standard RFP for the procurement of consultancy services

Public Procurement Agency (1997EC). Public procurement guideline of the Federal Government of Ethiopia

Rosli Mohamad Zin (2004). Constructability Improvement of Project Design, Dept of Civil Engineering, UTM, Johor, PH.D. Thesis.

Russell, J.S., and Anderson, S.D. (2000). “Construction Engineering and Management research program.” Rep. No. 10-58, National Cooperative Highway Research Program.

Russell, J.S. and Gugel, J.G. (1993). Comparison of Two Corporate Constructability Program. Journal of Construction Engineering and Management. ASCE. 119(4): 771-785.

Russell, J.S., and Swiggum, K.E. (1994).” Investigation of constructability concepts and tools for highway construction.” Rep. No. W1/SPR-05-94, Wisconsin Department of Transportation.

Shammas-Toma, M., Seymour, D.E., Clark L. (1996), “The effectiveness of formal quality management system in achieving the required cover in reinforced concrete”, Construction management and Economics, Vol No. 4, pp. 353-64

Shehu.Z and Sommerville, J.(2006) ,Real time risk management approach to construction projects , Glasgow Calonian university , Glasgow , United Kingdom

Smith, N.J., (1999). Managing Risk in Construction Projects, Blackwell Science, UK.

Smith, N. J., Tony, M. & Jobling, P. (2006) Managing risk in construction Projects, Blackwell Publishing.

Simu K. (2006) Risk Management in small construction projects. Department of Civil, Mining and Environmental Engineering. Lulea, Lulea University of Technology.

S. Thomas Ng, Performance of engineering consultants in ISO 9000-based quality management systems implementation, Department of Civil Engineering, The University of Hong Kong, Hong Kong, Vol. 12, No. 6, pp. 519-532, 2005

Tah, J. H. M., & Carr, V. (2001). Knowledge based approach to construction project risk management. Journal of computing in civil engineering, 15(3), 170-177.

Tan, R.R., Lu, Y.G. (1995), "On the quality of construction engineering design projects: criteria and impacting factors", International Journal of Quality & Reliability Management, Vol. 12 No.5, pp.18-37.

Tang, S.L., Kam, C.W. (1999), "A survey of ISO 9001 implementation in engineering consultancies in Hong Kong", International Journal of Quality & Reliability Management, Vol. 16 No.6, pp.562-74.

Tang, W., Qiang, M., Duffield, C., Young, D.M. & Lu, Y. (2007) Risk management the Chinese construction industry. Journal of construction engineering and management, 133 (12).

Tasmania (2002) PM007 Project Risk Register, Template and Guide. URL {Accessed 12th September, 2004} http://www.projectmanagement.tas.gov.au/tools/proformas/pm007 riskregistery 1.0.htm

Thomas, H. R., Korte, Q. c., Sanvido, V.E. and Prfitt, M. K. (1999). Conceptual Model or Measuring Productivity of Design and Engineering. Journal of Architectural engineering, ASCE, Vol. 5, No. 1, pp 1-7

Thompson, P. and Perry, J., Engineering Construction Risks: A Guide to project Risk Analysis and Risk Management, Thomas Telford, London, 1992.

Turner, J.R. (1992) The handbook of project based management: improving processes for achieving your strategic objectives, New York, McGraw-Hill.

Tweeds (1996) Laxton's Guide to Risk Analysis and Management, Tweeds Chartered Quantity Surveyors, Cost Engineers and Construction Economists (Eds), Oxford.

Uher, T.E. & Toakley, A.R. (1999). Risk management in the conceptual phase of a project international Journal of Project Management, 17(3), 161.

Vaughan, E. J: Risk Management, John Wiley & Sons, Inc., US, 1997.

Ward, A., Liker, J., Cristiano, J., and Sobek, D. (1995). "The second Toyota Paradox: how delaying decisions can make better cars faster." Sloan Manage. Rev., 36(3), 43-61.

Ward. S.C. and Chapman C.B. (1995) Risk-Management perspectives on the project lifecycle. International Journal of Project Management, 13(3), 145-149.

Wideman, R. M.: Project & Program Risk Management: A Guide to Managing Project Risks and Opportunities, Project Management Institute, 1992.

Wilson, R.L. (1982). Prevention and Resolution of Construction Claims. Journal of Construction Division Vol. 108, No. CO3 pp390-405

Wood, G.D. & Ellis, R.S.T. (2003) Risk management practices of leading UK cost consultants. Engineering, construction, and architectural management, 10 (4), 254-62.

Works Bureau (2001), Quality Management System Certification of Consultants and Contractors for Public Works Administered by the Works Group of Departments, Works Bureau Technical Circular No. 13/2001, HKSAR Government, Hong Kong, .

World Bank (1994) World development report 1994 infrastructure for development Oxford.

Yamaguchi H, Uher, T.E. and Runeson, G: Risk Allocation in PFI Projects, Proceedings of the 17th Association of Researchers in Construction Management (ARCOM) annual conference, September, 2001, University of Salford, UK, pp: 885-894.

Yogeswaran, K. (1998). Sources, causes and Minimization of Contractual Claims in Civil Engineering Projects in Hong Kong. PhD Thesis, The University of Hong Kong Hong Kong.

Zhi, H., Risk Management for Overseas Construction Projects, International Journal of Project Management , Vol. 13, No. 4, pp. 231-237, 1995.

Zhi, H. (1995) Risk management for overseas construction projects. International Journal of Project Management, 13 (4), 231-237.

Appendix

Interview schedule

Introduction

This interview schedule is prepared to obtain information from key informants with semi-structured questions. The information is required for the academic research entitled "Design risk management practices in Federal road projects", which is being conducted as partial fulfillment of MSc in construction technology and management. The main objective of the research is to examine whether design risks contribute to cost and time overruns, and affect quality objectives of projects, and make recommendations based on the findings.

The schedule consists of six sections with a total of 27 questions. Section 1 contains general questions about the informant. Section 2 assesses the current practices of Risk management in Road construction projects at Federal level. Section 3 examines the sources of risks in road construction projects, and design risks in particular. Section 4 investigates the existing practices of design risk allocations, and the instruments employed to manage the risks. Section 5 assesses the existing practices to reduce design risks, and explores the opinions of informants on constructability concepts and alternative project delivery methods. Section 6 is left for general comments on the research.

Your response, in this regard, is highly valuable and contributory to the outcome of the research. All feedback will be kept strictly confidential, and utilized for this academic research only.

Thank you,

Getachew Tsegaye

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Addis Ababa

1. General profile of the respondent

1.1 Name: …………………………………………………….

1.2 Position: ……………………………………………………..

1.3 Organization: ……………………………………………………..

1.4 Address: ……………………………………………………….

1.5 Educational status?

☐ BSc ☐ MSc

☐ Others; please specify……………………………….

1.6 What is your field of specialization?

☐ Civil engineering ☐ Transportation engineering

☐ Highway engineering ☐ Geotechnical engineering

☐ Others, please specify…………………………………….

1.7 How long have yow worked in the Road sector?

☐ 0 – 5 years ☐ 6 – 10 years

☐ 11 – 15 years ☐ More than 15 years

2. Risk management

Several literatures define Project risk as the chance of certain occurrences adversely affecting project objectives such as cost, time, and quality. Risk management is defined as systematic approach for identifying, evaluating, and responding to risks encountered in a project. It follows that dealing with risk involves planning for risk, assessing risk issues, developing risk handling strategies, and monitoring risks to determine how they have changed. The following questions are, therefore, intended to assess the current practice of Risk management of Road construction projects at Federal level.

2.1 Do you have a **formal risk management system** consisting of the foregoing processes?

☐ Yes ☐ No

2.2 Do you, as a Client, require a **risk management plan** for projects as part of Consultants' services?

☐ Yes ☐ No

2.3 If you have a formal risk management system, what **methods/tools** do you use to plan, identify, assess, respond, and monitor project risks?

a) Risk identification

…………………………………………………………………………………….

…………………………………………………………………………………….

b) Risk assessment/analysis

…………………………………………………………………………………….

…………………………………………………………………………………….

c) Risk response planning

…………………………………………………………………………………….

…………………………………………………………………………………….

d) Risk monitoring

…………………………………………………………………………………….

…………………………………………………………………………………….

2.4 If you conduct a formal risk assessment,

a) What **types of risks** do you concentrate on? ……………………………………

…………………………………………………………………………………….

……………………………………………………………………………………..

b) How do you **manage** it?

☐ By designating risk management officer

☐ By designating risk management team

☐ Other arrangement, please describe ………………………………….

....

…………………………………………………………………...

2.5 If you don't have a formal risk management system,

a) Would you like to share **your experience on how you deal with risks** that may have an impact on cost, time, and quality of a project?

……………………………………………………………………………………….

……………………………………………………………………………………….

b) What are the **main impediments** to establish/practice the system?

……………………………………………………………………………………….

……………………………………………………………………………………….

3. Risks in road construction projects

This section is intended to investigate the **sources of risks in road construction projects, and design risks in particular**, and evaluate their impact on time, cost, and quality objectives of road projects.

3.1 Sources of risks

3.1.1 From your experience in the sector, what are the sources of risks in road construction projects? Identify from the list and rank them in order of probability of occurrence and severity of impact? You can add, if any.

Sources of risks	Probability of occurrence			Impact								
				Time			Cost			Quality		
	High	moderate	Low	High	moderate	Low	High	moderate	Low	High	moderate	Low
Planning and selection risks • Inadequate project planning • Inefficient project delivery system • Inappropriate contract award process, • etc												

Financial risks • Funding risks • Currency fluctuation • Insolvency/Bankruptcy of major participant • etc												
Design risks • See example from next table												
Construction risks • Differing site condition • Unidentified utilities • etc												
External risks • Price escalation • Objection by local communities • Labor shortage or strike • etc												
Environmental risks • Incomplete Environmental analysis • Historic site, endangered species • etc												
Contractual risks • Ambiguities in contract formation process • Liquidated, consequential, and Punitive damages clauses • etc												
Project management risks • Lack of coordination/ communication • Inefficient dispute resolution procedures • etc												
Force majeure risks • Severe weather • etc												
Other, please describe												

Sources of risks modified from Hassan (2005), Caltrans (2007)

3.2 Design risks

Based on your experience, would you please rank the following design risks in terms of probability of occurrence and severity of impact on time, cost, & quality? You can add, if any.

Design risks	Probability of occurrence			Impact								
				Time			Cost			Quality		
	High	moderate	Low	High	moderate	Low	High	moderate	Low	High	moderate	Low
Changes in scope of work/Clients new requirement												
Unclear scope of work												
Unforeseen design exceptions												
Unexpected sub-surface conditions/Inadequate geo-technical information												
Design error and/or omissions												
• Inaccurate assumptions on technical issues												
• Incomplete/inadequate survey data												
• Inadequate hydrological/ hydraulic study												
• Incomplete or poor specifications												
• Design not up to standards (non conformance to codes and standards)												
• Incomplete/inaccurate quantity estimates												
• Inaccurate cost estimate												
• Emphasis on meeting schedules & increased production volume (tight schedule)												
• Lengthy project development period (change in site conditions due to late bidding)												

• Lack of coordination among design members' disciplines												
• Lack of experience of the design team												
Other; Please describe												

4. Design risk allocation

Risk allocation is the apportionments of risks to those project/contracting parties who can best manage them. This holds true for design risks. For the purpose of the research, design risks are categorized into "**Design errors and omissions**" and "**Unexpected sub-surface conditions/Inadequate geo-technical information**" assuming that scope changes made by the client are managed by planned choice to bear the consequences. Thus, the following questions are meant to assess the existing practices of design risk allocations, and the instruments employed to manage the risks.

4.1 In your practices, **to whom do you assign these two categories of risks**?

a) Design errors and omissions
- ☐ Consultants
- ☐ Client
- ☐ Both, Client & Consultant
- ☐ Other, describe ……………………

b) Unexpected sub-surface conditions/ Inadequate geo-technical information
- ☐ Consultants
- ☐ Client
- ☐ Both, Client & Consultant
- ☐ Other; describe …………………….

……………………………………….

4.2 What **instruments** do you employ to manage the design risks?

a) Design errors and omissions

☐ Submission of Professional indemnity insurance (PI) by the consultant

☐ Other, please describe …………………………………………..

b) Unexpected sub-surface conditions/inadequate geo-technical information

☐ Allocating provisional sum in the contract

☐ It is contractor's risk

☐ Other, please describe……………………………………………

4.3 What are the practices in submission of **PI I policy**

a) By international consultants

- Period of liability ……………………………………………………
- Max. amount of liability………………………………………………..
- Renewal of policy ……………………………………………………
- Other practices different from local consultants, please describe ……….. ……………………………………………………………………………. …………………………………………………………………………….

b) By local consultants

- Period of liability ……………………………………………………
- Max. Amount of liability………………………………………………..
- Renewal of policy ……………………………………………………
- Other practices, please describe ………………………………………. ……………………………………………………………………………. …………………………………………………………………………….

4.4 Is there experience that **design errors and omissions** were recovered from Professional indemnity insurance?

☐ Yes ☐ No ☐ Partially

- If yes, could you mention the risks that were recovered fully or partially?

  ………………………………………………………………………………………

  ………………………………………………………………………………………

- If No, what do you think are the reasons?

  ☐ Considered as risk of client

  ☐ Expiry of defect liability period

  ☐ Failure to lodge claim

  ☐ Difficulty to prove the fault

  ☐ Other, please describe …………………………………………………

  ……………………………………………………………………………..

- What were the factors that contributed to the reason you have cited above?

  ………………………………………………………………………………………

  ………………………………………………………………………………………

4.5 What were your experiences in managing risks that occurred, if any, from **unexpected sub-surface conditions/Inadequate geo-technical information**? Please describe the risk, and the measures taken to recover the damage.

……………………………………………………………………………………..

……………………………………………………………………………………..

………………………………………………………………………………………

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………………………………………………………………………………………

4.6 In practice, design risks may materialize during construction and/or service period. However, the period of liability of the consultant specified in the contract is the duration of services. Besides, the maximum amount of liability is also the service contract amount. The

PI insurance policy required by the contract complies with these requirements. Therefore, how does **damages arising from latent defects**, if any, recovered if the insurance cover is limited to the duration of the services?

…………………………………………………………………………………………….

…………………………………………………………………………………………….

4.7 There is a practice that contract for design services is executed by a consultant, and after sometime, another supervision consultant is engaged to supervise the works. In this case, the supervision consultant is charged with design review and then supervision of the works. Apart from change in site conditions, such **overlapping responsibility** may relieve the previous designer from professional liability, if any. What are the reasons to compromise such limitations?

…………………………………………………………………………………………….

……………………………………………………………………………………………..

5. Design risk reduction

Design risk reduction or mitigation implies a reduction in the probability and/or impact of an adverse risk event to an acceptable threshold (Caltrans, 2007). This section focuses on assessing the existing practices to reduce design risks, and explores the opinions of informants on constructability concepts and alternative project delivery methods.

5.1 What are your **practices to reduce/minimize design risks**?

- ☐ Design review by consultant as sole task
- ☐ Design review by construction supervision consultant as part of its duties
- ☐ Carry out design and supervision by same consultant
- ☐ By all approaches/except, if any, ………………………………………………..
- ☐ Other, please describe ………………………………………………………..

5.2 Would you please describe the reasons to follow the selected approach?

…. ……………………………………………………………………………………...

…………………………………………………………………………………………….

5.3 Opinions on Constructability concepts

Constructability has been defined as the **optimum use of construction knowledge and experience** in planning, design, procurement, and field operations to achieve overall project objectives (CII, 1987).

5.3.1 Do you agree that experienced **construction personnel should be involved** in planning, design, procurement, and field operations to achieve overall project objectives?

☐ Agree, because …………………………………………………………………
…………………………………………………………………….

☐ Disagree, because …………………………………………………………….
…………………………………………………………………….

☐ Partially agree, because ……………………………………………………..
………………………………………………………...
…………………………………………………………

☐ Other opinion ………………………………………………………………….
……………………………………………………………………..
……………………………………………………………………..

5.3.2 The Request for proposal (RFP) of the Ethiopian Roads Authority (ERA) requires construction experience for key-design personnel.

a) Do you get personnel that meet the required mix of design and construction experience?

☐ Always ☐ In most cases ☐ Sometimes ☐ Rarely

☐ Other, please state ……………………………………………………..

b) To what extent were you able to minimize design risks by involving personnel with design and construction experience?

☐ Satisfactorily ☐ To large extent ☐ To some extent ☐ Insignificant

☐ Other, please state ………………………………………………………….

5.3.3 The integration of experienced construction personnel into the earliest stages of project planning as full-fledged members of the project team will greatly improve the chances of achieving a better quality project, completed in safe manner, on schedule, for the least cost ” (ASCE 1991). Further Hussan (2005) argue that **Constructability reviews** of highway projects during design is a primary means of reducing highway project durations, cost overrun, and quality problems.

a) Do you agree?

☐ Agree, because ……………………………………………………………………
……………………………………………………………………….
……………………………………………………………………….

☐ Disagree, because ………………………………………………………………….
………………………………………………………………….
………………………………………………………………….

☐ Partially agree, because ………………………………………………………….
…… ……………………………………………………………...
……..…………………………………………………………

☐ Other opinion …………………………………………………………………….
……………………………………………………………………..
……………………………………………………………………..

5.3.4 Would you please rank the level of importance and applications of the following design phase constructability concepts?

No.	Constructability concepts	Level of importance			Level of application		
		Very important	Important	Least important	High	Medium	Low
1	Carry out thorough investigation of the site						
2	Design for minimum time below ground						
3	Design for simple assembly						
4	Encourage standardization/repetition						
5	Design for pre-fabrication, pre-assembly or modularization						
6	Analyze accessibility of the job site						
7	Employ any visualization tools such as 3D CAD to avoid physical interferences						
8	Investigate any unsuspected, unrealistic or incompatible tolerances						
9	Investigate the practical sequence of construction						
10	Plan to avoid damage to work by subsequent operations						
11	Consider storage requirement at the job site						
12	Investigate the impact of design on safety during construction						
13	Design for the skills available						
14	Consider suitability of designed materials						
15	Provide detail and clear design information						
16	Consider adverse effects of weather in selecting materials or construction methods						

Adapted from Hassan (2005)

5.4. Project delivery method

Koppinent and Lahdenpera (2004) define project delivery method as a system for organizing and financing design, construction, operations, and maintenance activities that facilitates the delivery of services. The most common methods are Design-Bid-Build, Design-Build, and Construction Manager @ risk. The following questions explore the features of existing project delivery methods for Federal road projects.

5.4.1 What type of project delivery methods does your firm practices? ………………….

……………………………………………………………………………………….

5.4.2 What are the most common procurement processes that you follow?

a) For consultancy services: ……………………………………………………….

………………………………………………………………………………..

b) For construction/works: ………………………………………………………….

….…………………………………………………………………………………

5.4.3 Do you outsource procurement functions? ☐ Yes ☐ No

5.4.4 What are the reasons to outsource? ....

………………………………………………………………………………

……………………………………………………………………………………….

5.4.5 How long will it take to select consultants to award a contract, i.e. the whole process?

……………………………………………………………………….................

………………………………………………………………………………..

5.4.6 How long will it take to select contractors to award a contract, i.e. the whole process?

……………………………………………………………………….................

………………………………………………………………………………..

5.4.7 From your experience, in what type of project delivery method design risks are better minimized?

☐ Design-Bid-Build

☐ Design-Build

☐ Construction Manager @ risk

☐ Other; please specify ………………………………………………..

5.4.8 Does your firm have experience in either of the last three project delivery methods?

☐Yes ☐ No

a) If yes, which method? ………………………………………………………….

b) What were your firm's experiences on the method you have cited?

- From the point of design risk reduction/ management?

…………………………………. ………………………………………….

- Why is it discarded from use? ………………………………………………

  ……………………………………………………………………………..

  ………………………………………………………………………………

- Any other comment on project delivery method …………………………….

  ……………………………………………………………………………..

  ……………………………………………………………………………..

6. General comment on the research

…………………………………………………………………………………

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…………………………………………………………………………………

Thank you,