CHAPTER (1)

INTRODUCTION

1.1 Introduction

In order to achieve an efficient economic sewage system, optimum time and minimum cost should be met. This target could be obtained by managing any expected risk factors affecting the construction cost and time of these projects. This thesis concerns, with risk factors during sewage project construction phase. Risk factors during this period shall affect the construction cost and time of such a sewerage system. Each item found in this sewerage system is studied according to its risk factors.

Cost overrun together with losing control over sewage construction time is the result of misleading estimation of project cost and time. In order to avoid these, any risk factors which may impact sewage construction time and cost are identified. Risk management process is applied on these risk factors. Risk analysis is followed on case study of sewage project in Egypt and responsive actions are added and analyzed. Analysis results are then compared before and after adding further responsive actions.

1.2 Problem Statement

It is important to use accurate cost estimate and efficient time schedule in the construction of sewage networks projects. Using poor project schedule and cost estimation could lead to sever overrun for projects overall time and cost. For this reason any risk factors which may affect both cost and time of sewage networks projects should be studied. Thus, risk factors must be identified and considered to arrive at a more reliable cost and time. Identified risk factors list reflects the contractor's problems which may appear and have impact on sewage networks during construction.

The analysis of risk factors is useful for the contractor in detecting the degree of both probability and impact of occurrence of these risks. The contractor can concentrate on the most effective risks to be further analyzed. In addition to that, site control is required by the contractor during sewage construction. Any further new risk factors that may impact cost and time of construction activities can be recorded. Neglected risk management during the construction could lead to losing control on sewage networks cost and time during the construction phase.

1.3 Study Objective

This study highlights the importance of obtaining reasonable sewage network construction cost and time. This study objective concentrates on accurately identifying risk factors affecting the construction cost and time of sewage networks projects. By applying risk management analysis, degrees of probability and impact of risks on construction of sewage networks is obtained. Most effective list of risk factors is incorporated into an analysis prediction model and applied on a case study of a sewage project in Egypt. The serious effect of those risk factors impacting the sewage networks cost and time is studied.

Mitigation actions are undertaken on the most effective risk factors by the construction team. In this study analysis is done on the cost and time impact of these risk factors on sewage construction activities. Comparison is made also before and after the implementation of corrective actions. The scope of this study is only confined to the sewage networks construction projects.

1.4 Methodology

The study is conducted through the following sequence:-

1 - **A** literature review is carried out to cover the most important studies in this research area.

2 - **R**isk factors identification process is done. Risk factors which can impact sewage construction cost and time are identified. These risk factors are conducted from the literature.

3 - **Q**ualitative risk analysis process is used to detect those risk factors that have the greatest effect on both cost and time of sewerage system project. Through a questionnaire both probability and impact scales of different risk factors is obtained.

4 - **B**y using a case study of sewage project in Egypt, quantitative risk analysis and Risk response plan processes are studied. Mitigation actions towards the prioritized risk list are given through field questionnaires. Both prioritized risk factors list and mitigation actions are implemented into the risk program. Risk analysis results are compared before and after mitigation actions implementation.

1.5 Thesis Outline

This thesis is a practical application of risk management carried during the construction of sewage networks. It reflects different risk management stages which help in obtaining a successful project. Theses stages include risk identification, qualitative risk analysis, quantitative risk analysis and risk response planning processes. Chapters written in this thesis represent these risk management stages. Throughout this thesis chapters risk factors are identified, analyzed and mitigation actions are placed.

The Literature Review is discussed through Chapter 2. Different papers and studies related to sewage risk management are reviewed. The main objective of this chapter is of twofold. First is to obtain a list of most effective risk factors which might impact the estimated cost and schedule of sewage construction. Second, is to select the best risk management processes strategy which is used in this study.

Chapter3 represents risk identification as the first process of risk management processes. First, risk factors from previous papers and field pilot survey are used in a field survey during the construction of sewage projects. Using risk break down structure, the collected risk factors are categorized before starting a field survey. The target of this survey is to get a list of risk factors which can occur and has impact on project cost and/or time. Most important risk factors are ranked for the most agreed number of personnel. The output of risk identification process is the risk register which is used as an input of the qualitative risk analysis process.

Chapter 4 discusses the qualitative risk analysis process as the second stage of risk management. Risk register obtained from risk identification is used as an input of the qualitative risk analysis process. Questionnaire is used to conduct expert's opinions about degree of both probability of occurrence and impact on time and cost. This survey is carried during sewage networks construction for two case studies. One of which is Cairo Festival City project and the other is Madinaty project. The highest ten risk factors which will be further analyzed quantitatively are obtained. Two risk registers to be made in this chapter for cost and time.

Chapter 5 represents Quantitative risk analysis and risk response plan processes applied on a case study sewage network project. Risk analysis simulation process and response actions taken are to be made. An efficient program tool is used and is called the Pert-Master Primavera risk analysis tool. The distribution histograms and tornado sensitivity charts is represented. The histogram is helpful to the project managers to abstract probabilities to finish the whole works within a certain period and to obtain the date by which the whole works is completed within a proposed probability. A risk analyst will abstract the predecessor which is most driving an activity completion cost or time by viewing the tornado diagram. The probability of occurrence and impact scales of prioritized risk factors are improved in this chapter. These risk factors are transferred to a sewage project. The project team can safely deal at with the construction activities implemented in the projects schedule.

Chapter 6 includes the conclusion obtained from this thesis and the study recommendations. The conclusion includes most important ten risk factors impacting estimated cost and schedule. Best mitigation actions to be taken in order to minimize risk factors impact scales are represented. The possibility of reducing impact scales is reflected through an analysis comparison prior and after mitigations. Through this chapter, the thesis recommendations are discussed. Each risk management stage output is discussed. The benefits to contractors which help in managing sewage risk factors are represented.

CHAPTER (2)

LITERATURE REVIEW

2.1 Introduction

Both risk and uncertainty are common features in most sewage networks projects. Management of sewage, underground or pipe line projects is challenging because of inherent uncertainties. Thus, ignoring these risk and uncertainties and their effect, will cause an impact on both time and cost of a project during the construction phase. The most effective way to deal with uncertainties is to collect supplementary information and knowledge. Many literature has been reviewed which presents and discusses risk management in sewage projects.

The outcome and writers experience is described to present an efficient overview of risk management applied during the project life cycle. The study of risk factors impact on both cost and time during the construction phase is reviewed. It is tended throughout this chapter to investigate the definition of risk, the concept of risk and uncertainty, risk management process, risk management planning, risk identification, risk analysis, risk response planning, risk monitoring and controlling. The previous studies pertaining to risk management in sewage projects is also investigated.

2.2 Definition of Risk

Hayes etal. (1985) describe construction risks characteristics risks and uncertainties as they are associated with specific events or activities that can be individually identified. A risk event implies that there is a range of outcomes of each event and each outcome has a probability of occurrence. Some risks offer only the prospect of adverse (loss) as bankruptcy, war, sea or flood damage; these may be of low or high probability but of high impact. Many common construction risks offer the prospect of either loss or gain as production of labor and plant; these are typically of high probability and may be of low or high impact. Subjective judgment is usually required to calculate the probability of occurrence of specific outcomes of risk event.

Al-Bahar etal. (1990) defined risk as "Exposure to the chance of occurrence of events adversely or favorably affecting project objectives as a consequence of uncertainty". With this definition they characterized risk by the following component, the risk event, what might happen to the determent or in favor of the project. The uncertainty of the event, how likely the event is to occur i.e. the chance of the event occurring. **A Guide to the Project Management Body of Knowledge Book (2008)** defined risk as "Risk is uncertain event or condition that, if it occurs, has an effect on at least one project objective. Objectives can include scope, schedule, cost, and quality. A risk might have one or more causes and, if it occurs, it may have one or more impacts".

Chapman (2003) discusses the meaning of the word risk in detail in the context of project management. They argue that the current risk management processes induces a restricted focus on the management of project uncertainty. The reasons for this is that the word "risk" usually is associated with events rather than more general sources of significant uncertainty and because it often has a threat perspective. Some of the definitions used in the literature are**,** an unwanted event which may occur, the cause of an unwanted event which may occur, the probability of an unwanted event which may occur, the consequence of an adverse event which may occur, the statistical expectation value of an unwanted event which may occur, a measure of variance or distribution. The definitions are used in everyday language and rarely in a technical context. It is also used when the size or seriousness of the risk is to be determined.

2.3 The Concept of Risk and Uncertainty

Management of sewage, underground, or pipeline projects is challenging because of inherent uncertainties. The most effective way to deal with uncertainty is to collect supplementary information and knowledge. **Janak etal. (2007)**.The concept of risk and uncertainty originates from the economic theory of incomplete information. According to **Knight (1921)** "a situation is said to include risk if the randomness facing an economic agent can be expressed in terms of specific numerical probabilities". Many researchers have tried to make the concept of risk as objective as possible. On a fundamental level it is an essentially value-laden concept since risk often takes a "threat perspective". However, risk has a positive side as well, opportunity, which is often ignored. **Hillson (2001)**.

2.4 Risk Management Guidelines and Standards

Project risk management is a particular application of risk management process. However, projects face some specific issues relating to the way they are organized and managed and there are opportunities to develop general risk management principles into more detailed guidance. The most commonly used sources in project risk management are shown below. Each one of these sources has a lot to offer but there are significant differences in their objectives, styles and approaches.

2.4.1 The Australian and New Zealand Standards (AS/NZS 4360)

The **Australian and New Zealand Standard** was first published in 1995 and updated in 1999 and 2004. It is a generic risk management standard that is readily applied to project risk management. It is not confined to projects, and it is just as relevant as to safety, financial or security risk management as to project risk management. It works well at all levels from individual activities to an entire business; in particular it can be used as the basis of an integrated program or business risk management process spanning a portfolio of projects. The main feature of the standard is illustrated in Fig 2.1 **Australian and New Zealand Standards AS/NZS (2004)**.

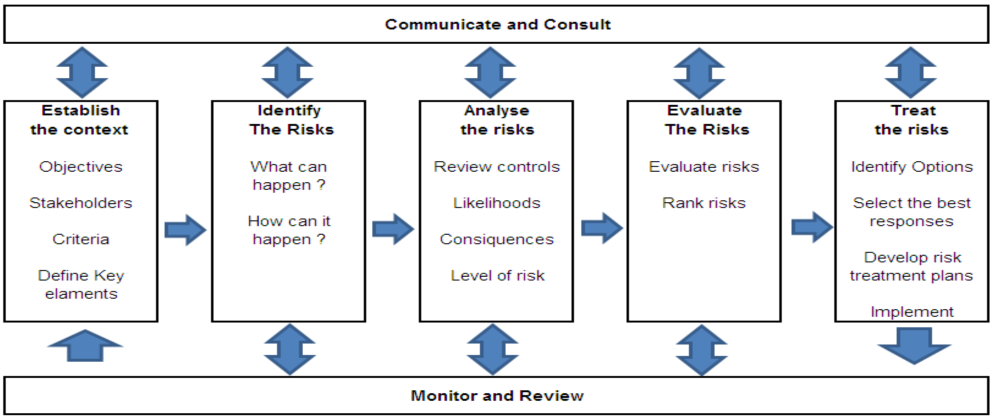

Fig 2.1 Australian and New Zealand main feature standards (2004)

2.4.2 The Project Risk Analysis and Management (PRAM) Guide

The PRAM Guide is a stand-alone project risk management guide. It deliberately separates the risk management process from detailed techniques or methods that might be used to implement various stages in the process. It is written within a project management structure and deals with the process and responsibilities for managing the process. It provides examples of techniques for individual process steps. The team who produced this guide includes practitioners, consultants and academics. The core material is well structured and easy to follow. Fig 2.2 illustrates the key stages and data flows in the **PRAM** Guide process. **Project Risk Analysis and Management (2004)**.

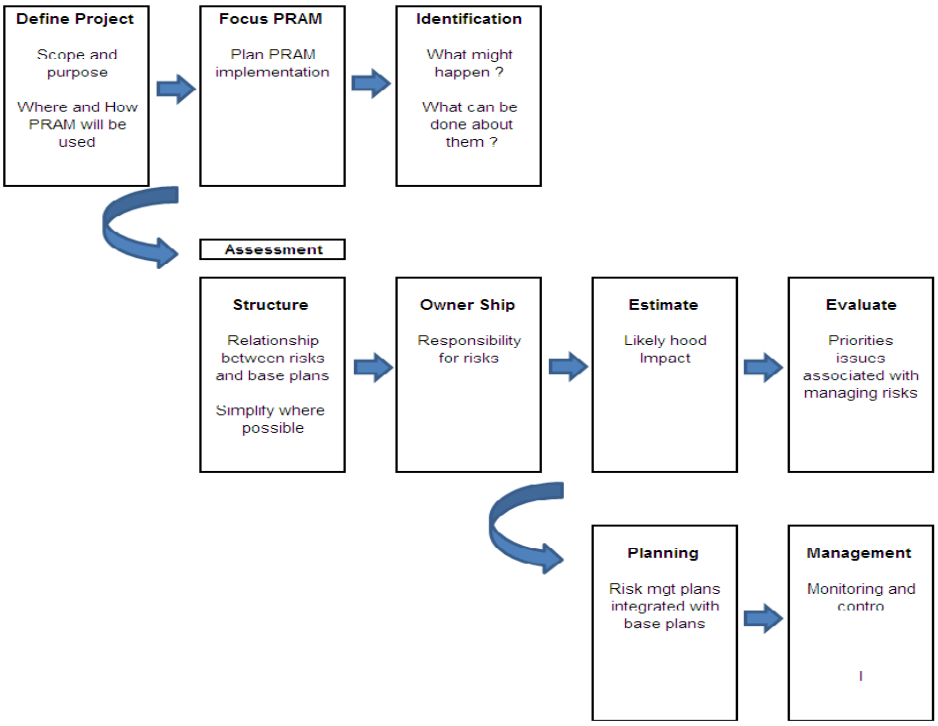

Fig 2.2 key stages and data flows, PRAM Guide process (2004)

2.4.3 The Management of Risk guideline (MOR)

The Management of Risk guideline, known as **MOR**, is written for public sector organizations. It deals with all risks to an organizations success and includes guidance on the risk management process, management structure, roles and responsibilities as well as checklists to assist various stages of the process. It discusses the application of risk management from the strategic level, including corporate governance, through to programs, projects and operations. There is a strong emphasis in the **MOR** guideline on the organizational framework and management structure within which risk management takes place. The guideline touches on culture and other issues relating to the successful implementation in strategic, programs, project and operational con-texts, and from specific tools and methods that might be employed to execute a part of the process. The process flow described in the Management of Risk guideline is illustrated in Fig 2.3 **MOR (2007)**.

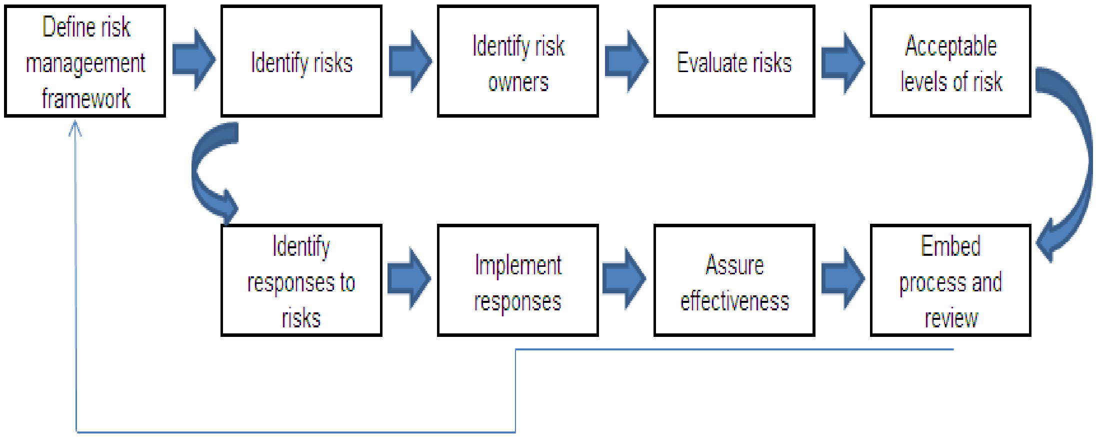

Fig 2.3 Process Flow, MOR (2007)

2.4.4 The Project Management Body of Knowledge (PMBOK)

The Project Management Institute publishes a guide to project management called the **Project Management Body of Knowledge (PMBOK)**. It is structured in a framework of inputs, process and outputs. It deals with management responsibility for the process and links to the wider project management process contained in the rest of the **PMBOK**. The **PMBOK** ranges across qualitative and quantitative risk analysis methods but does not link these together directly. The approach owes a lot to large techno-logically complex project operations. Fig 2.4 illustrates the risk project management overview were different stages of risk management are represented. Starting with the identifying risks process, analyzing risk factors through the analysis process, managing responsive actions towards risk factors and ending by controlling risks factors on construction time and cost of project activities. As most commonly and systematic approach, these risk management processes is used as a guide through this study.

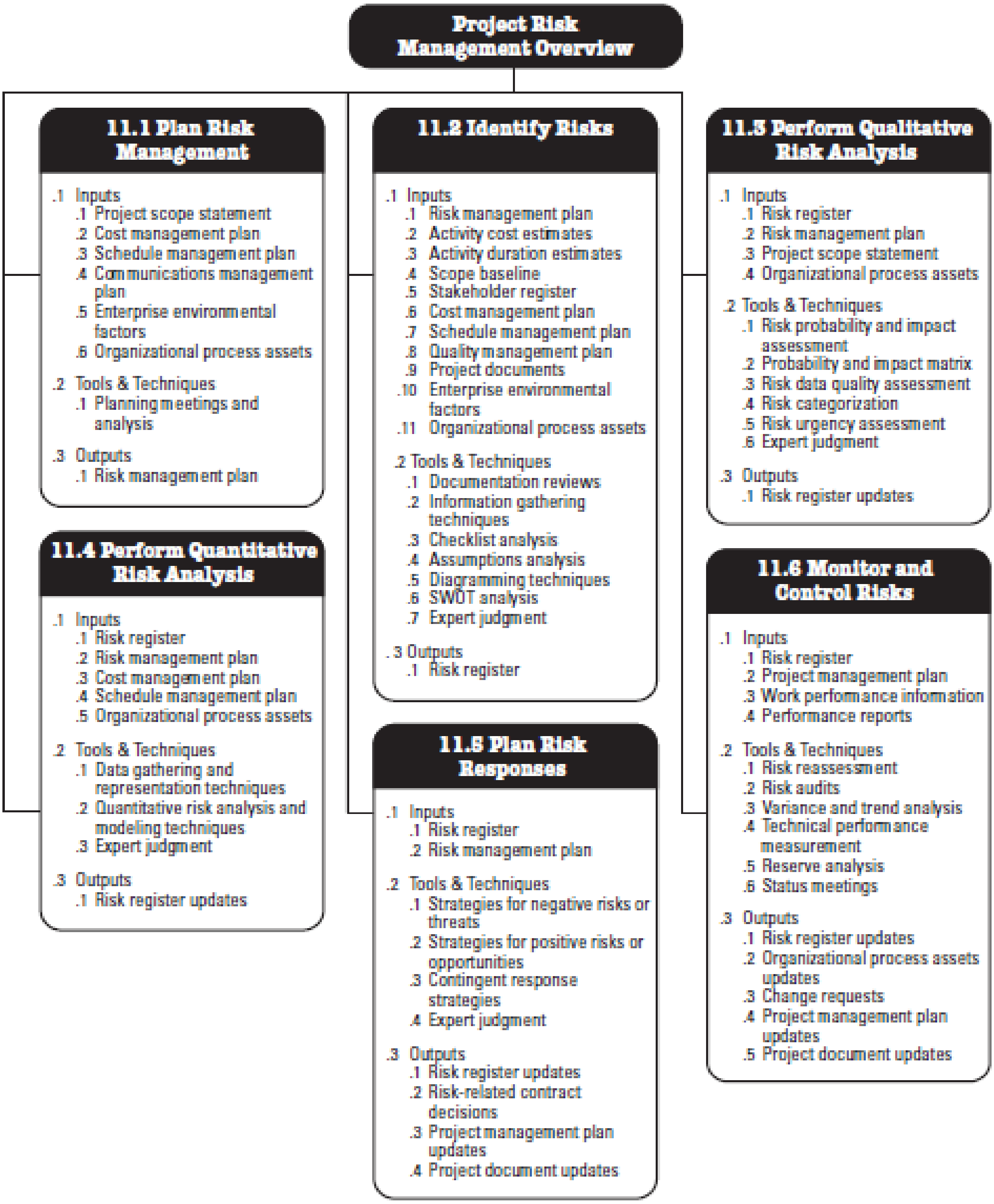

Fig 2.4 Risk Project Management Overview, A Guide to the Project Management Body of Knowledge Book (2008)

2.4.5 Other Project Risk Management Approach

As for the word risk, there exist several definitions of which activities that are included in the risk management process. Fig 2.5 illustrates the risk management process includes risk analysis, risk evaluation and risk reduction/control**.** The risk management process is a process which can be defined as "a systematic application of management policies and procedures in order to analyze, evaluate and mitigate risks"**.** The project risk management includes: Risk identification, risk assessment including risk analysis and evaluation, risk treatment, impact mitigation and probability reduction for analyzed list of risk factors. Review and monitoring during construction of a facility is then followed. **International electro technical commission (1995**).

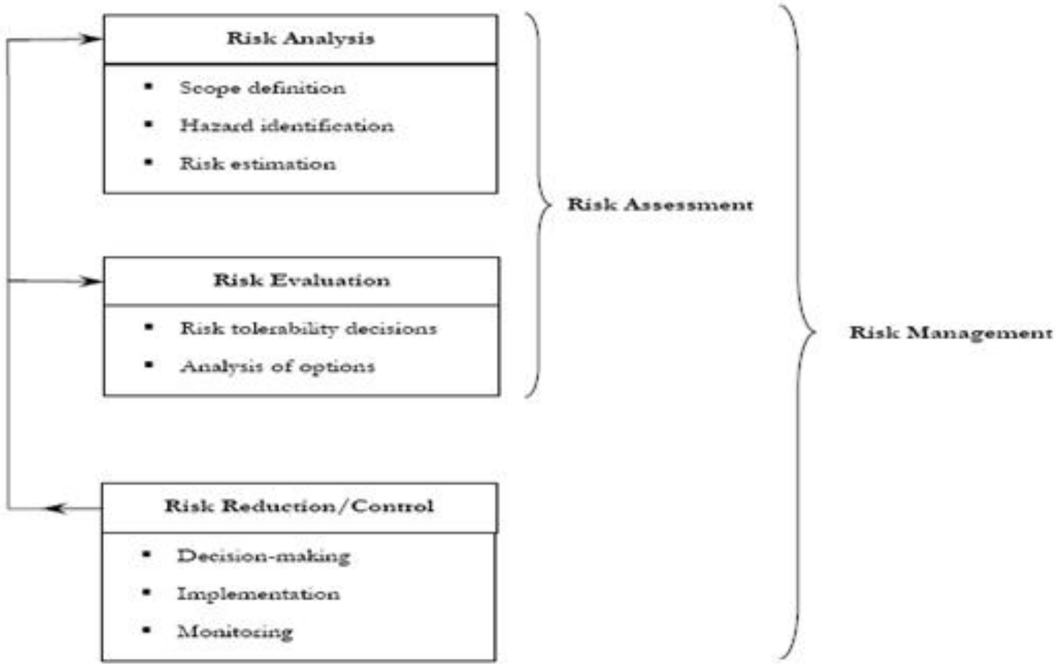

Fig 2.5 Risk analysis and risk activities, Electro Technical Commission (1995)

2.5 Comparison of processes

In order to achieve an efficient Sewage Project Risk Management, a comparison is made between widely used approaches in project risk management. **The Project Management Body of Knowledge (PMBOK) and The Project Risk Analysis and Management (PRAM) Guide** share the following points: They encompass the use of qualitative scales, decision trees; influence diagramming, sensitivity analysis and Monte Carlo Simulations. Risk evaluation is addressed both in terms of individual risks. They are explicitly set in a project management context. **The Management of Risk guideline (MOR)** is, in principle, as generally applicable as **Australian and New Zealand Standards (AS/NZS 4360)** but it is targeted at and described in terms of public sector organizations.

Some analysis techniques are described and there is extensive reference to related publications. Its coverage of analysis methods is as broad as that of **The Project Risk Analysis and Management (PRAM) Guide** and they are dealt with separately from the risk management process, as in the **PRAM Guide** The methods recommended for use at the project level include some that deal with individual risks and others that can be used to understand the aggregate risk to a project as a whole. The overall context of the guide is the organization within which risk management is being applied and the achievement of organizations objectives.

2.6 The Risk Management Process Overview

2.6.1 Introduction

In this research, we have used **The Guide to the Project Management Body of Knowledge Book (2008)** Since it is one of the most widely used approaches of project risk management. It is used as the foundation of our Sewage project risk management**.** The project risk management process carried through this study passes through five main stages as illustrated in Fig 2.6:- Risk Management Planning, Risk Identification, Risk Analysis, Risk Response Plan, Risk Monitoring and Control. The procedures of risk management, time taken within an organization together with choosing the right type of risk management is all taken into consideration with the planning process. Risk factors which can occur and has impact on both time and cost of sewage construction are then identified. By applying qualitative analysis, both probabilities and impact degrees are obtained analyzing risks numerically. Quantitative analysis is followed using the most effective risks list. Responsive actions is given and analyzed. Finally, risk factors are monitored and controlled completing the project risk management process.

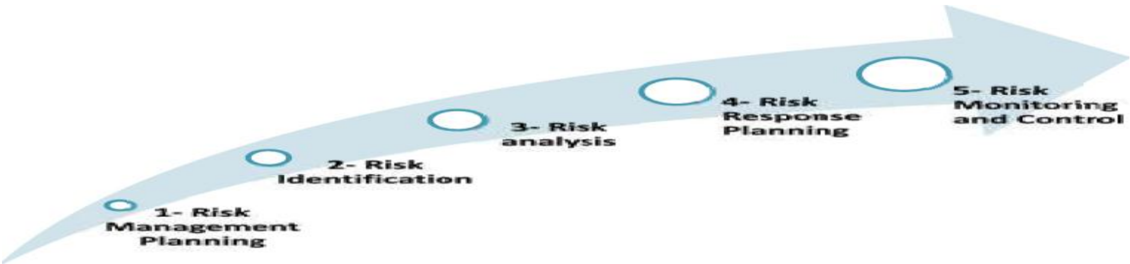

Fig 2.6 The Project Risk Management Process, A Guide to the Project Management Body of Knowledge Book (2008)

2.6.2 Risk Management Planning

Plan risk management is the process of defining how to conduct risk management activities for a project. Careful and explicit planning enhances the probability of success for the five other risk management processes. Planning risk management process is important to ensure that the degree, type, and the visibility of risk management are commensurate with both the risks and the importance of the project to the organization. Planning is also important to provide sufficient resources and time for risk management activities, and to establish an agreed basis for evaluating risk.

The plan management process should begin as a project is conceived and should be completed early during the project planning.

Fig 2.7 **illustrates the risk management planning process.** The first phase in project risk management process is the risk management planning. The project team members carry the process by using inputs of Enterprise Environmental Factors, Organizational Project Assets, Project Scope Statement, and Project Management Plan. Through techniques of Risk Management Planning can be achieved through Planning Meetings and Analysis, the risk management plan is obtained. As part of work plan development, project development team members assign project team members to create a project risk management plan. The assigned project team members begin to create the risk management plan. The risk management plan identifies and establishes in the project plan the activities of risk management for the project. If Value Analysis is made in the project, the Value Analysis team will participates in the risk management study. **A Guide to the Project Management Body of Knowledge Book (2008).**

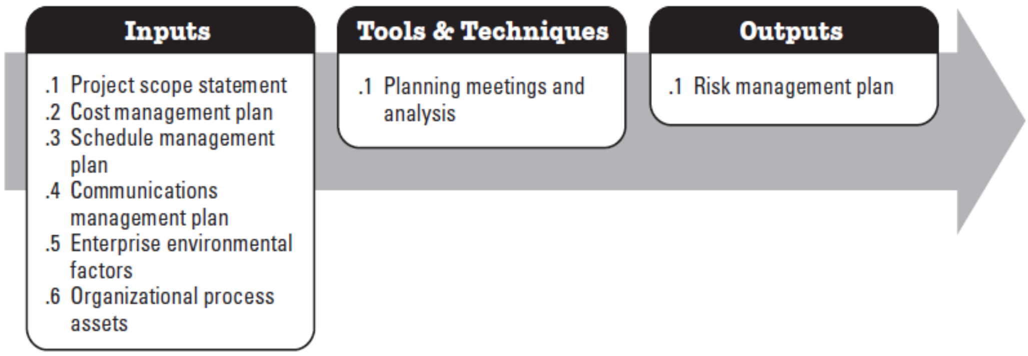

Fig 2.7 Risk Management Planning Process, A Guide to the Project Management Body of Knowledge Book (2008)

2.6.3 Risk identification

Participants in risk identification activities can include the following, project manager, project team members, project team customers, other project manager, stake holders and risk management experts**. A Guide to the Project Management Body of Knowledge Book (2008).** Risk identification is an iterative process because new risks might become known as the project progress through its life cycle. The frequency of iteration and who participates will vary from case to case. The project team should be involved in the process so that they can maintain a sense of ownership and responsibility of the risks and associated.

The risk identification process usually leads to qualitative risk analysis process; alternatively it can lead directly to quantitative risk analysis process**.** The second phase in project risk management process is the risk identification. With the aid of risk categories and risk breakdown structure (RBS – List of risk categories and external sub risk categories) risk factors are structured. **A Guide to the Project Management Body of Knowledge Book (2008).** Fig 2.8 represents inputs including risk factors conducted from papers. Through techniques of documentation reviews, information gathering techniques, A - Brain Storming Sessions, and B - Check list analysis. Risk register is obtained as an output of the risk identification process.

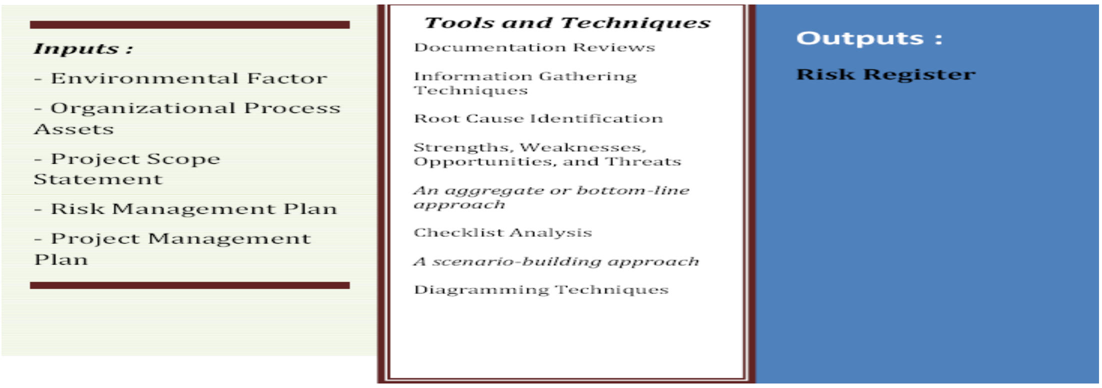

Fig 2.8 Risk Identification Process, A Guide to the Project Management Body of Knowledge Book (2008)

2.6.4 Risk Analysis

The purpose of risk analysis is to measure the impact of the identified risk on a sewage networks project according to the available data. Risk analysis can be performed qualitatively and quantitatively as illustrated in Fig 2.9. **A Guide to the Project Management Body of Knowledge Book (2008).** The objective of this work is to determine and study, classify and categorize, analyze and overview, the main risk analysis and assessment (RAA) methods and techniques by reviewing the scientific literature.

Fig 2.9 Risk Analysis Process. A Guide to the Project Management Body of Knowledge Book (2008)

The objective of this work is to determine and study, classify and categorize, analyze and overview, the main risk analysis and assessment (RAA) methods and techniques by reviewing the scientific literature. According to quantitative techniques, the risk can be considered as a quantity. By which can be estimated and expressed by a mathematical relation, under the help of real accidents data recorded in a work site. The hybrid techniques, present a great complexity due to their ad hoc character that prevents a wide spreading. Fig 2.10 illustrates the classification of the main risk analysis and assessment methodologies. Below, we present an overview of them having in mind this classification. **Marhavilas (2011).**

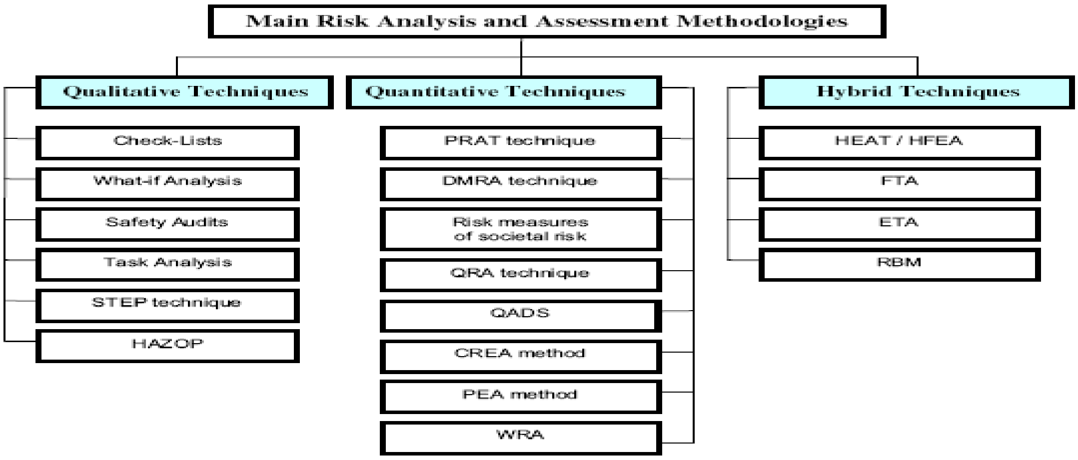

Fig 2.10 Main Risk Analysis Classification Methodologies. Marhavilas (2011).

Risk analysis, is the process of estimating the probability of hazards and the consequences of these. This process is a basis for the decision-making regarding the risks. According to **International electro technical commission(1995**), the risk analysis process can be defined as a "systematic use of available information to identify hazards and to estimate the risk to individuals and populations, property or the environment". Hence the events are in space and time; stochastic processes play an important role.

Methods of risk analysis can roughly be divided into qualitative and quantitative methods depending on their level of precision. The qualitative methods have a descriptive nature and are often used in the purpose to identify those risks that should be further studied with a quantitative method. The quantitative methods aim at estimating both the probability and the consequence of the risks. Examples of qualitative methods used in civil engineering projects are expert analysis, hazard and operability analysis (HAZOP) and What-if analysis

An estimate of the consequences of each risk factor may be also expressed as either low or high or in terms of being insignificant, minor, moderate, major or catastrophic. A risk management matrix can be formed using estimates of likelihood and consequence. For that reason an appropriate structured, powerful and systematically applied qualitatively risk analysis is used**.** Data required for an analysis is identified in Fig 2.11 which is based on **A Guide to the Project Management Body of Knowledge Book (2008)**

Fig2.11 Qualitative Risk Analysis, A Guide to the Project Management Body of Knowledge Book (2008)

2.6.4.1 Qualitative Risk Analysis

The third phase in project risk management process is the risk analysis process; risk is analyzed qualitatively and quantitatively. As illustrated in Fig 2.12, Organizational Project Assets, Project Scope Statements, Risk Management Plan and Risk Register are used as inputs. Through technique of Probability and Impact Matrix, the risk register is updated. An updated risk register include, ranking of priority of project risks, risks grouped by category, lists of risks requiring response in the near term, list of risks for additional analysis and response, watch lists of low priority risks, and trends in qualitative risk analysis results .

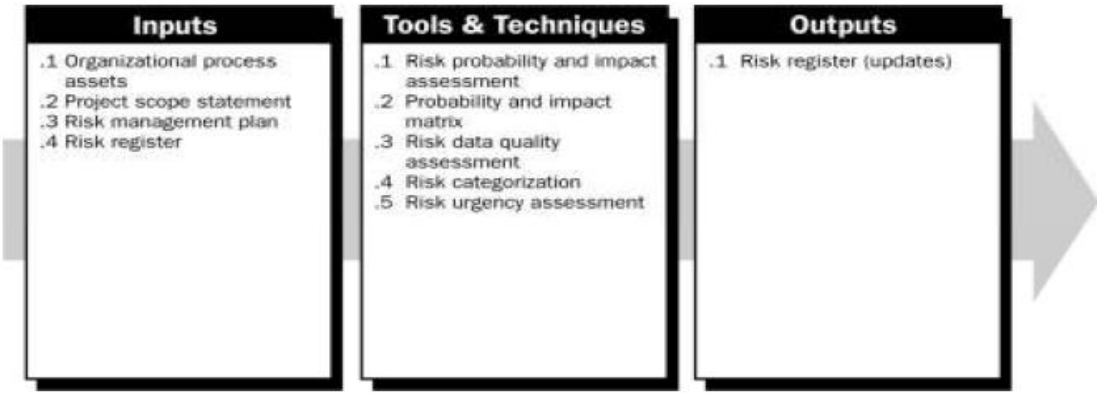

Fig 2.12 Qualitative Risk Analysis Process, A Guide to the Project Management Body of Knowledge Book (2008)

2.6.4.2 Quantitative Risk Analysis

Quantitative analysis is performed on risks which have been prioritized by the qualitative risk analysis process. The quantitative risk analysis process analyses the effect of those risk events and assigns a numerical rating to those risks. It also presents a quantitative approach of making decisions in the presence of uncertainty. Quantitative risk analysis generally follows the qualitative risk analysis process, although experienced risk managers perform it directly after the Risk Identification. In some cases quantitative risk analysis may not be required to develop effective risk response. Availability of time and budget and the need for qualitative or quantitative about risks and impacts will determine which method to use on any particular project.

This process should be repeated after risk response planning, as well as part of risk monitoring and control, to determine if the overall project risk has been satisfactory decreased. Trends indicate the need of more or less risk management action. It is an input to the risk response planning process. Objectives of this process are: Quantify the possible outcomes of the project and their probabilities. Assess the objective of achieving specific project objectives. Identify risks requiring the most attention by quantifying their relative contribution to overall project risk. Identify realistic and achievable costs, schedule or scope targets, given the project risks. Determine the best project management decision when some conditions are uncertain.

As illustrated in Fig 2.13, using organizational process assets, project scope statements, risk management plan, risk register and project management plan as inputs. Techniques of Modeling and Simulation, Sensitivity Analysis, Quantitative Risk Analysis and modeling are used. Risk Register (Updated)is obtained. Updates includes the following main components, A - Probabilistic analysis of the project, B - Probability of achieving cost and time objectives, C - Prioritized list of quantified risks, D - Trends in quantitative risk analysis results.

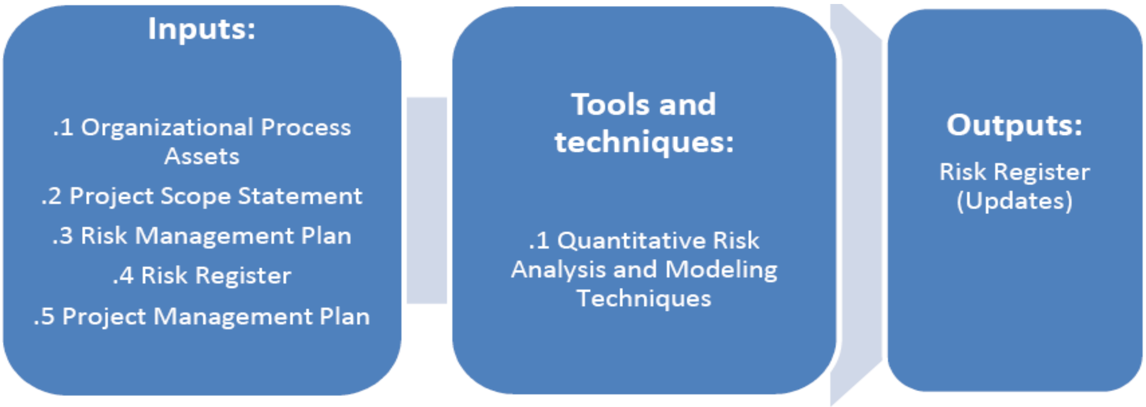

Fig 2.13 Quantitative Risk Analysis Process, A Guide to the Project Management Body of Knowledge Book (2008)

2.6.5 Risk Response Planning

Although some of the individual risk factors may be more significant than the others, the project success usually depends on the combination of all risks, response strategies used to mitigate risks and a company's ability to manage them. **Dikmen etal.(2006).** Risk Response Planning is all about options and actions. It focuses on how to decrease the possibilities of risks from adversely affecting the projects objectives, and how to increase the likely hood of positive risks that can aid the project. Risk Response Planning assigns responsibilities for people and groups close to the risk event. **A Guide to the Project Management Body of Knowledge Book (2008)** Risks would increase or decrease based on the effectiveness of risk response planning.

There are four risk responses:-Avoidance, the project plan is altered to avoid the identified risk. Mitigation, effort is made to reduce the probability, impact, or both of an identified risk in the project before the risk event occurs. Transference, the risk is assigned to a third party, usually for a fee. The risk still exists, but the responsibility is deflected to the third party. Acceptance, the risks are seen as nominal so they are accepted. Risks, regardless of size, that have no other recourse are also accepted. **A Guide to the Project Management Body of Knowledge Book (2008).** The fourth phase in project risk management process is the risk response planning process. As illustrated in Fig 2.14, Risk Management Plan and Risk Register are used as inputs. Using technique of Strategies for negative risks or threats to avoid, transfer or mitigate. Risk register (update), Project management plan (updates) is obtained.

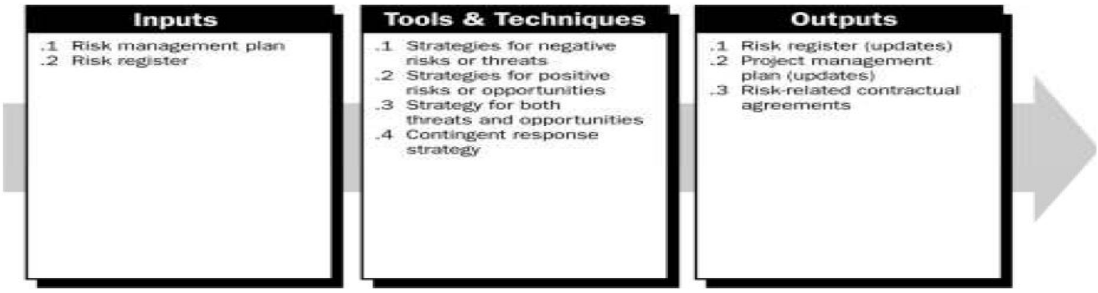

Fig 2.14 Risk Response Plan. A Guide to the Project Management Body of Knowledge Book (2008)

2.6.6 Risk Monitoring And Control

Planned risk responses that are included in the risk management plan are executed during the life cycle of the project. But the project work should be continuously monitored for new and changing risks. Risk monitoring and control is the process of identifying, analyzing, and planning for new arising risk. This process also keeps tracking the identified risks and those on the watch list. In addition to that, reanalyzing existing risks, monitoring trigger conditions for contingency plans and monitoring residual risks and reviewing the execution of risk responses are performed**. A Guide to the Project Management Body of Knowledge Book (2008)**

The risk monitoring and control process applies techniques, such as variance and trend analysis. These techniques require the use of performance data generated during the project execution. Risk monitoring and control as well as the other risk management processes, is an ongoing process for the life of the project. Other purpose of risk monitoring and control are to determine if risk as assessed has changed from its prior state, with analysis of trends. Proper risk management policies and procedures are being followed. Contingency reserves of cost or schedule should be modified in line with the risks of project. Risk monitoring and control can involve choosing alternative strategies, executing contingency or fallback plan, taking corrective actions, and modifying the project management plan. **A Guide to the Project Management Body of Knowledge Book (2008)**

The risk response owner reports directly to the project manager on the effectiveness of the plan, any unanticipated effects, and any midcourse correction needed to handle the risk appropriately. Risk monitoring and control includes also updating the organizational process assets, including project lessons learned databases and risk management templates for the benefit of future projects. **A Guide to the Project Management Body of Knowledge Book (2008).** The fifth phase in project risk management process is the risk monitoring and control process. As illustrated in Fig 2.15**,** risk management plan, risk register, work performance Information, and performance reports are used as inputs. Through technique of risk reassessment, risk audits, technical performance measurement, reserve analysis, status meeting. risk register updates, requested changes, recommended corrective actions, recommended preventive actions, organizational project assets, project management plan, and key responsibilities are obtained as output of the risk control process.

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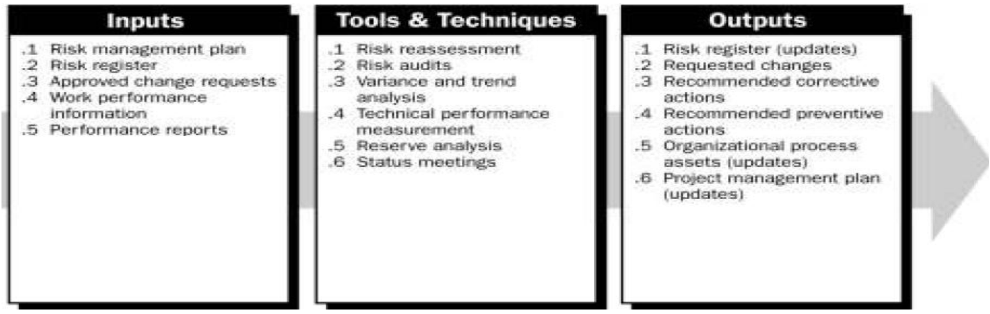


Fig 2.15 Risk Monitoring and Control. A Guide to the Project Management Body of Knowledge Book (2008)

2.7- Previous Studies

Benedettia etal. (2007), In order to comply with the Water Framework Directive's requirement to reveal the major pressures and impacts on the receiving water at river basin level, the merits of a methodology that combines substance flow analysis and mass balances were evaluated with the aid of a case study. The river basin analysis consisted of the analysis of all individual municipal sewer catchments constituting the basin on a yearly time scale, and included the description of the main sewers and waste water treatment plants and their performance in environmental and economic terms. A wide set of indicators was evaluated. Uncertainties and information gaps arising from the study are described. The choice of the geographic scale seems a key factor in the evaluation. The case study indicates that such an evaluation is of great value for decision-makers in the perspective of the Water Framework Directive implementation, to highlight situations of weak or strong performance and to pinpoint information gaps requiring further research in order to take more informed decisions, to identify the main pressures on the environment and to plan more cost-effective measures.

Darsono etal. (2006), Attempts at implementing real-time control systems as a cost-effective means of minimizing the pollution impacts of untreated combined sewer overflows have largely been unstained due to the complexity of the real-time control problem. Optimal real-time regulation of flows and in-line storage in combined sewer systems is challenging due to the need for complex optimization models integrated with urban storm water runoff prediction and fully dynamic routing of sewer flows within 5e15 min computational time increments. A neural-optimal control algorithm is presented that fully incorporates the complexities of dynamic, unsteady hydraulic modeling of combined sewer system flows and optimal coordinated, system-wide regulation of in-line storage. The neural-optimal control module is based on a recurrent Jordan neural network architecture that is trained using optimal policies produced by a dynamic optimal control module. The neural-optimal control algorithm is demonstrated in a simulated real-time control experiment for the King County combined sewer system, Seattle, Washington, USA. The algorithm exhibits an effective adaptive learning capability that results in near-optimal performance of the control system while satisfying the time constraints of real-time implementation.

Gilchrist etal. (2004), Communities that surround an operating construction site often find themselves subjected to negative impacts such as annoyances and economic losses. The latter often called ‘‘social costs’’, refer to the monetary equivalent of consumed resources, loss of income and loss of enjoyment experienced by parties not engaged in the contractual agreement, solely due to a construction process. Social costs take many forms including loss of revenue, productivity and time, consumption of non-renewable resources and accelerated deterioration of secondary roads. Social costs, while widely acknowledged, are rarely considered in the design, planning or bid evaluation phases of construction projects in North America. This is attributed to the difficulty associated with quantifying social costs using standard estimating methods and the fact that these costs are borne by the community rather than the contractual parties. This paper outlines 22 sources of social costs associated with construction projects in urban environments. The concept of ‘social indicators’ is introduced as a mean to link adverse impacts generated by construction activities and valuation methods. Seven methodologies developed in the fields of economics and actuary is presented and their suitability for quantifying specific classes of social costs associated with construction projects is investigated. The capacity of current bid evaluation methods to account for social costs is also examined. It is concluded that a methodical approach for the incorporation of social costs in the bid evaluation process is a key step towards a more sustainable-oriented construction industry.

Kolsky etal. (2002), this paper describes conceptual and practical aspects of urban storm drainage performance indicators, based on the authors experience in developing countries, particularly India. The paper begins by presenting a general framework of objectives and performance indicators as logical intermediate steps between values and the decisions taken to reflect them. The paper then considers practical approaches to performance and indicator measurement, based on field experience in India. General conclusions about drainage performance indicators are then presented, stressing the challenge of finding indicators which are (1) valid indicators of performance, (2) relatively easy to measure, and (3) helpful to the decision-maker.

Martin etal. (2006), Multi-criteria analysis methods have been used over the past decade for resolving environmental issues. This paper deals with the application of a multi-criteria analysis (MCA) approach to urban storm water drainage management. Storm water source control has become a popular alternative solution for managing storm water in urban areas. Source control constitutes one variant of best management practices (BMPs) that can be evaluated with respect to various criteria, including: hydraulic efficiency, pollution retention, environmental impact, operation and maintenance, economic investment, and social and sustainable urban living. A French survey was undertaken to assess the performance of different BMPs at the national scale; results highlight the main reasons justifying the use of BMPs. These reasons are primarily related to flood prevention, which far outweighs the economic incentives. Moreover, hydraulic and technical aspects are most frequently noted by users, whereas operation and maintenance aspects are often seen as obstacles to application of these techniques. The survey results, completed by a literature review and expert statements, have been used to establish a matrix of alternatives for multi-criteria analysis. The analysis results obtained allow ranking the various alternatives from best to worst, taking into account the different strategies adopted by the decision-makers involved. The development of a multi-criteria approach could, in the future, serve as a supporting decision-aid tool, whose purpose would be to guide users in their choice of storm water source solution.

Ming etal. (2010), Closed circuit television (CCTV) has been applied in many developing or developed counties for sewer inspection due to its low setup cost and technical requirement. Several automated diagnosis systems of sewer pipe defects had been developed to assist the technicians in interpreting or classifying sewer pipe defects. However, many researchers pointed out that good image quality is the prerequisite for accurate interpretation and diagnosis of CCTV inspection but has not a proper evaluation approach. In this paper, a CCTV image quality index considering both of the luminance distortion and the contrast distortion of a CCTV image compared by reference images is proposed and was applied to assess the image quality of the CCTV images shot for a sewer house-connection project. The experimental result indicates that rather than luminance contrast plays a more important role in the CCTV image quality that can be effectively improved by contrast enhancement. Since CCTV image quality can hardly distinguished by human eyes, the proposed image quality index can provide helpful information to efficiently assist the on-site technicians in precisely shooting better CCTV images for the pipe defection.

Mansouri etal. (2010), this research is an effort to develop a Risk Management-based Decision Analysis (RMDA) framework based on the common fundamental elements that define the nature of resilience in Port Sewage Systems (PIS). While developing a systematic process for making strategic and investment decisions, RMDA guides the decision-makers to identify, analyze, and prioritize risks involved in PIS operations; to define ways for risk mitigation, plan for contingencies, and devise mechanisms for continuously monitoring and controlling risk factors and threats to the system; and to value the adopted resilience investment plans and strategies. Our suggested RMDA framework is a policy making tool that utilizes a Decision Tree Analysis (DTA) methodology for assessing the cost-effectiveness of the devised strategies.

Marhavilas etal. (2011), the objective of this work is to determine and study, analyze and elaborate, classify and categorize the main risk analysis and risk-assessment methods and techniques by reviewing the scientific literature. The paper consists of two parts: a) the investigation, presentation and elaboration of the main risk assessment methodologies and b) the statistical analysis, classification, and comparative study of the corresponding scientific papers published by six representative scientific journals of Elsevier, B.V. covering the decade 2000-2009. The scientific literature reviewing showed that the risk analysis and assessment techniques are classified into three main categories: (a) the qualitative, (b) the quantitative, and (c) the hybrid techniques (qualitative quantitative, semi-quantitative).

The qualitative techniques are based both on analytical estimation processes, and on the safety managers engineer ability. According to quantitative techniques, the risk can be considered as a quantity. Risk can be estimated and expressed by a mathematical relation, under the help of real accidents' data recorded in a work site. The hybrid techniques, present a great complexity due to their ad hoc character that prevents a wide spreading. The statistical analysis shows that the quantitative methods present the highest relative frequency (65.63%) while the qualitative a lower one (27.68%). Furthermore the hybrid methods remain constantly at a very low level (6.70%) during the entire processing period.

Norman etal.(2010), Most African cities lack piped sewerage networks; where such networks exist; they typically serve only wealthy districts and are grossly dysfunctional. So can low-cost sewage networks be appropriate; or would efforts be better directed at non-piped sanitation solutions such as latrines and septic tanks. The recently terminated PAQPUD project was a World Bank-financed sanitation intervention in Dakar (Senegal), including about 14 million US$ for provision of settled sewerage networks in 11 low-income districts of the city; this is the first large-scale implementation of low-cost sewerage in sub-Saharan Africa. This article reports an independent evaluation of project outcome carried out in 2009, including the results of householder surveys in 3 of the 5 districts in which the system became operational. Various aspects of the project are laudable models of development project implementation, including the specific targeting of low-income districts, and the effective involvement of local community organizations in project implementation; furthermore, in the operational districts, reasonably high coverage levels were achieved, and beneficiary householders generally showed high satisfaction.

Reilly etal. (1996).The rationale for specifying and/or electing to use trenchless construction techniques rather than trenched methods is based upon a combination of construction, service and economic factors. With trenchless technology, as with all other forms of construction, the benefits of the proposed technique must be balanced out against the risks which the technology entails. In this paper a variety of techniques are described for assessing risk in the context of trenchless construction as well as managing the identified risks in a cost-effective manner. Suggestions are made for establishing contingency arrangements in the event of failure. Some general aspects of the techniques/suggestions described are illustrated using brief case histories.

Pollardetal. (2004), the provision of wholesome, affordable and safe drinking water that has the trust of customers is the goal of the international water utility sector. Risk management, in terms of protecting the public health from pathogenic and chemical hazards has driven and continues to drive developments within the sector. In common with much of industry, the water sector is formalizing and making explicit approaches to risk management and decision-making that has formerly been implicit. Here, we review the risk management frameworks and risk analysis tools and techniques used within the water sector, considering their application at the strategic, program and operational levels of decision-making. Our analysis extends the application beyond that of public health to issues of financial risk management, reliability and risk-based maintenance and the application of business risk maturity models.

Ruwanpura etal. (2007), Simulation is an efficient and cost-effective tool for decision-making and analyzing real-world systems and repetitive construction processes. Tunneling and trenchless construction processes are excellent candidates for the utilization of computer simulation due to their repetitive nature. This paper presents six simulation tools that have been developed over the last five years and implemented to plan and manage a range of several applications in underground sewage construction. The purpose of the tools, modeling framework, modeling logic, inputs, and outputs for tunneling, soil type prediction, sewer condition forecasting, pipeline routing, horizontal directional drilling, and trenchless pipe replacement are presented. The successful development and implementation of the tools presented in this paper further illustrate the usefulness of employing simulation for pre-planning and decision-making to reduce uncertainty inherent in construction projects involving underground sewage systems.

Technologies used provide many benefits in terms of cost, time, quality, and expected service life. However, the safety aspects of these techniques have not been discussed and documented in detail probably due to the complexity and the lack of safety standards and specifications directly associated with the techniques. This paper discusses the application of a risk assessment framework to assess potential safety issues of currently available trenchless technologies for culvert rehabilitation. The findings of the study will provide additional information to improve the decision making process in selecting and planning culvert rehabilitation projects.

Weng etal. (2011), In order to develop a sound material-cycle society, cost-effective municipal solid waste (MSW) management systems are required for the municipalities in the context of the integrated accounting system for MSW management. Firstly, this paper attempts to establish an integrated cost–benefit analysis (CBA) framework for evaluating the effectiveness of MSW management systems. In this paper, detailed cost/ benefit items due to waste problems are particularly clarified. The stakeholders of MSW management systems, including the decision-makers of the municipalities and the citizens, are expected to reconsider the waste problems in depth and thus take wise actions with the aid of the proposed CBA framework. Secondly, focusing on the financial cost, this study develops a generalized methodology to evaluate the financial cost-effectiveness of MSW management systems, simultaneously considering the treatment technological levels and policy effects. The impacts of the influencing factors on the annual total and average financial MSW operation and maintenance (O&M) costs are analyzed in the Taiwanese case study with a demonstrative short-term future projection of the financial costs under scenario analysis. The established methodology would contribute to the evaluation of the current policy measures and to the modification of the policy design for the municipalities.

2.8 Summary

In this Literature Review, project risk management is carried on a sewage networks project, risk management is used as a systematic process for planning, identifying, analyzing, responding to, and monitoring uncertain events in a sewage project during its construction. The objective of our study is to reduce the number of surprise events, minimize consequences of adverse events, and maximize the result of positive events, this can be done through the project risk management process by which risk is planned, identified, analyzed, responded to, and controlled.

The first phase in risk management process is the risk management planning, were project team members carry the process, by using inputs of Enterprise Environmental Factors, Organizational Project Assets, Project Scope Statement, Project Management Plan, and through techniques of Risk Management Planning which can be achieved through Planning Meetings and Analysis, the risk management plan is obtained. Risk management process second stage is risk identification. By the aid of risk categories and risk breakdown structure (RBS – List of risk categories and external sub risk categories), inputs including Risk Factors Conducted From Papers, and through techniques of, documentation reviews and information gathering techniques the risk register is obtained as an output of this process.

The third phase in project risk management process is the risk analysis process, were risk is analyzed qualitatively and quantitatively. During qualitative analysis, Organizational Project Assets, Project Scope Statements, Risk Management Plan, and Risk Register are used as inputs, and through technique of Probability and Impact Matrix, the risk register is updated. An updated risk register include, ranking of priority of project risks , risks grouped by category, lists of risks requiring response in the near term, list of risks for additional analysis and response, watch lists of low priority risks, and trends in qualitative risk analysis results. For quantitative analysis, using Organizational Process Assets, Project Scope Statements, Risk Management Plan, Risk Register, Project Management Plan as inputs, and through techniques of Modeling and Simulation, Sensitivity Analysis, Quantitative Risk Analysis and modeling techniques, Risk Register (Updated) is obtained. Updates includes the following main components, A - Probabilistic analysis of the project, B - Probability of achieving cost and time objectives, C - Prioritized list of quantified risks, D - Trends in quantitative risk analysis results.

The fourth phase in project risk management process is the risk response planning process, using Risk Management Plan, Risk Register, as inputs, and through technique of Strategies for negative risks or threats A – Avoid , B – Transfer and C – Mitigate, Risk register (updates), Project management plan (updates) is obtained. The fifth phase in project risk management process is the risk monitoring and control process, using Risk Management Plan, Risk Register, Work Performance Information, and Performance Reports, as inputs, and through technique of Risk Reassessment, Risk Audits, Technical Performance Measurement the control process can be carried by the project team.

CHAPTER (3)

RISK IDENTIFICATION

3.1 Introduction

This research is a risk management approach applied during construction of a complete sewage networks project. This chapter represents the risk identification process as the first phase of risk management processes. Risk identification process done in this thesis is based on project management body of knowledge book. This process is considered as an iterative process. New risks may be known as the project progress through its life cycle. The frequency of iteration and who participates will vary from case to case.

This process alternatively leads to risk analysis processes, where risk factors are analyzed qualitatively and quantitatively. It is important to examine and identify project specific potential hazards. This may be done by reducing them to a detailed level, thus permits an evaluator to understand the significance of any risk and identify its origins and causes.

3.2 Methodology

As illustrated in Fig 3.1, risk factors collected from both literature relative to study and interviews on site are used as an input of this process. Through check list technique using conducted risk factors, risk register results as an output of risk identification process. **A Guide to the Project Management Body of Knowledge Book (2008).** The input of this process is data collected concerning identification and description of various risk factors affecting contractors during construction. These data is gathered from literature reviews in addition to other risk factors which affect time and cost of constructing a sewage networks. Risk factors conducted from literature is tabulated. Risk break down structure, paper name as well as paper publisher is clearly identified.

Fig 3.1 Risk Identification Process, A Guide to the Project Management Body of Knowledge Book (2008)

In order to perform the technique of checklist analysis, risk factors collected are first categorized according to their risk break down structure. Each risk category represents a list of risk factors which has an impact on cost and/or time of sewage networks construction. Risk categories include technical risks, project management risks, financial risks, environmental risks, organizational risks and external risks. Each risk category is given a code. Consequently risk factors are coded based on these categories. Thus risk factors are tabulated according to their **Risk Break Down Structure (RBS)**.

Risk factors and their categories are so formulated into a questionnaire. Such questionnaire is used in a survey among different parties' professionals. These professionals represent different contractors and consultants during construction of sewage networks. Questionnaires distributed consist of all conducted risk factors as well as their risk break down structure. Participant's opinion that agrees or disagrees that this risk will affect cost and/or time of sewage networks construction is taken. In addition to that, project party responsible for risk occurrence and project objective affected either cost or time is also conducted.

3.3 Risk Identification Input

3.3.1 Risk Breakdown Structure

Risk Breakdown Structure will provide means for the project manager and risk manager to organize the risks being addressed or tracked. Just as the **project management institute (PMI)** defines the work break down structure as a "deliverable-oriented grouping of project elements that organizes and defines the total work scope of the project". The **Risk Break down Structure (RBS)** is considered as a "hierarchically organized depiction of the identified project risks arranged by risk category." The Project Management Institute **(PMI)** has a team of working on a Practice Standard for Risk Management. This team has identified one very good tool i.e. the risk breakdown structure **(RBS)**. The **RBS** will help the risk management team to understand, and therefore will identify and assess risk. **A Guide to the Project Management Body of Knowledge Book (2008).**

Risk categories provides a structure that ensures comprehensive process of systematically identifying risks to a consistent level of detail and contributes to the effectiveness and quality of risk process identification. As illustrated in Fig 3.2 an organization may use a previously prepared categorization framework which may take the form of a simple list of categories or may be structured into a **risk break down structure (RBS)**. The **RBS** is a hierarch racy organized depiction of the identified project risks arranged by risk category and sub category. **A Guide to the Project Management Body of Knowledge Book (2008).**

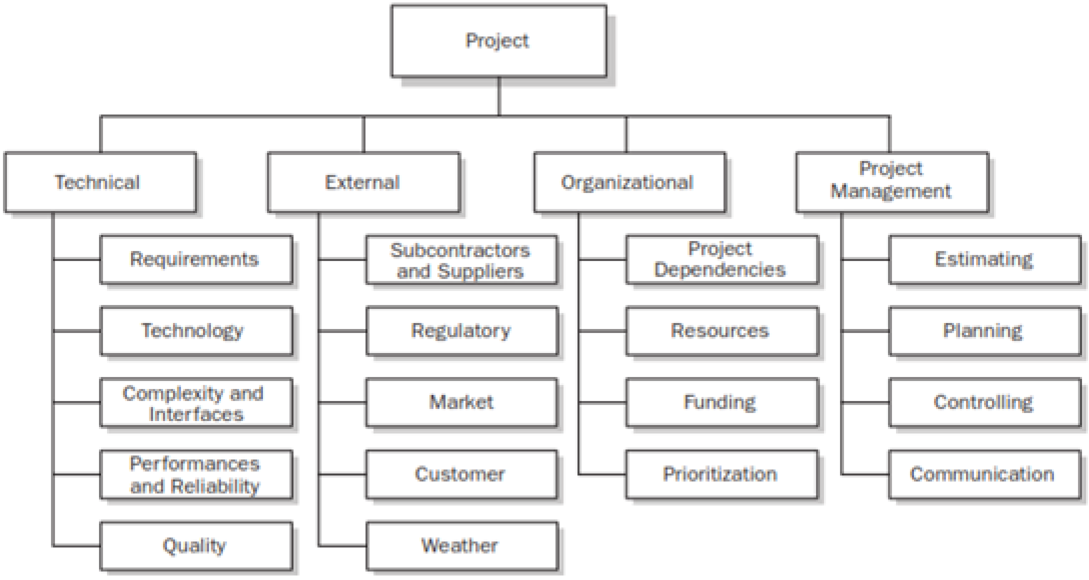


Fig 3.2 Risk Break Down Structure levels, A Guide to the Project Management Body of Knowledge Book (2008)

Thus **risk break down structure (RBS)** which is used in this study collecting risk factors as illustrated in Fig 3.3. There are six risk categories called technical risks, project management risks, financial risks, environmental risks and external risks. Collected risk factors are further classified based on these risk categories. Thus questionnaires are distributed among professionals based on this **R.B.S**.

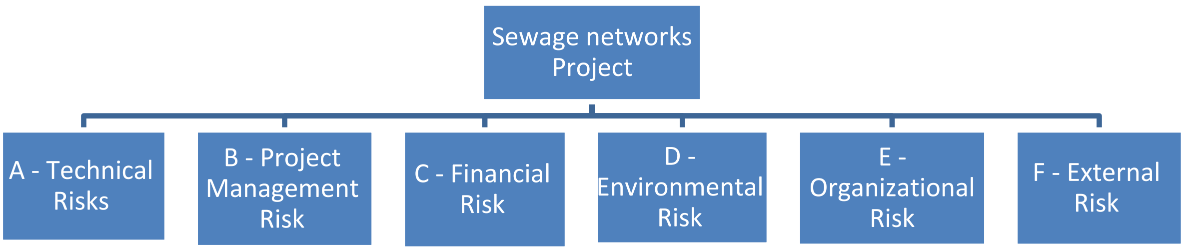


Fig 3.3 Risk Break Down Structure used in this study

3.3.2 Gathering data from the literature

The first step to perform the risk identification process is to gather risk factors from previous papers. The result of literature review relative to this study is illustrated in Table 3.1. The Table represents total of eighty risk factors which can affect sewage network projects cost and time. Data includes reviewed paper title, paper publisher, risk factors conducted and there corresponding categorized groups. Furthermore, these eighty risk factors conducted together with other risk factors added using a pilot survey is surveyed to agree on the most effective of them in the risk identification stage.

Table 3.1 Data Collected from Literature Review

Paper Title	Paper Author	Risk Category	Risk Factor
Risk Factors affecting management and maintenance cost of urban sewage	Makarand etal. (2001)	Project Management	Management Focus
		Organizational Risks	Communication
		Technical Risks	Technology Changes
			Productivity
			Material Selection
			Quality Control
The Structural Condition Of Rigid Sewer	Daviesetal. (2001)	Technical Risks	Sewer Location
			Sewer Material
			Soil Corrosively
			Sewer Size
			Soil Fracture Potential
			Sewer Pipe Length
Productivity And Efficiency In The Water Industry	Abbot etal. (2009)	Technical Risks	Productivity measures

Cont. Table 3.1 Data Collected from Literature Review

Paper Title	Paper Author	Risk Category	Risk Factor
Developing a Risk Assessment For Public Project China	Xu etal.(2010).	Financial Risks	Interest rate fluctuation
			Conflicting contract
			Change in market demand
			insufficient finance
			operation cost overrun
			Florien exchange fluctuation
			Inflation
			Project operation changes
			Price Change.
		External Risks	Poor public decision making process
			Government corruption
			Inadequate Law
			Delay in project approval and permits
			Inadequate competition to tender.
			Third party delay / violation
			Legislation change

Cont. Table 3.1 Data Collected from Literature Review

Paper Title	Paper Author	Risk Category	Risk Factor
Developing a Risk Assessment For Public Project China	Xu etal.(2010).	External Risks	Change In tax Regulation
			Political public opposition
			Unforeseen weather geotechnical condition
		Technical Risks	Supervision system
			Market Competition
			Material non availability
			Labor non availability
			Using unproven technology
		Organization Risks	Organization and coordination risk
Using fuzzy risk assessment to rate cost overrun risk for international construction projects	Dikmen etal. (2006).	Technical Risks	Vagueness of construction technical methods
			Complexity (Technical and Managerial)
			Poor planning design errors
			Inexperience of client
			Attitude of client
			Unavailability of subcontractors
			Poor performance of subcontractors

Cont. Table 3.1 Data Collected from Literature Review

Paper Title	Paper Author	Risk Category	Risk Factor
Using fuzzy risk assessment to rate cost overrun risk for international construction projects	Dikmen etal. (2006).	Financial Risks	Unavailability of funds
			Delay in payments
Application of financial engineering into the Egyptian construction industry using simulation models for portfolio risk assessment	Hamdi (2002).	Financial Risks	Cash flow problems during construction
			Financing and Payments of completed works
			Delay in contractor payment by owner
			Change orders
		Technical Risks	Labor productivity
			Design change by owners
			Shortage of construction materials
			Unforeseen ground conditions
			Owner slow Decision
			Owner interference

Cont. Table 3.1 Data Collected from Literature Review

Paper Title	Paper Author	Risk Category	Risk Factor
Application of financial engineering into the Egyptian construction industry using simulation models for portfolio risk assessment	Hamdi (2002).	Technical Risks	material management problems by contractor
			Poor site management
			Inadequate contractor experience
			Uncooperative owner
			Subcontractor and nominated suppliers
			Designer slow response
			Subcontractor schedule improper planning
			Lack of personnel training
			Contractor unrealistic duration
			Changes in design drawings during construction
			Changes in shop drawings during construction
			Delay in approval and preparation of shop drawings

Cont. Table 3.1 Data Collected from Literature Review

Paper Title	Paper Author	Risk Category	Risk Factor
Application of financial engineering into the Egyptian construction industry using simulation models for portfolio risk assessment	Hamdi (2002).	Technical Risks	Incomplete contractors method of statement
			Design errors by A/E firms
			Problem in imported material
			Shortage of site workers
			Complicated inspection procedures used on site used by the consultant engineer
			Unqualified subcontractor
			Delay in preparation of schedule of work ,
			Design change by the owner
			Changes in specifications made by the consultant firm
		Organizational Risks	Contractor Internal coordination deficiencies
			Excessive burecracy by owner organization

3.4 Questionnaire Survey

3.4.1 Methodology

Questionnaires are used in three risk management processes through the theses**.** They are used as a technique for the risk identification process. The objective is to obtain an agreed list of fifty risk factors which can affect sewage objectives cost and time. This agreed list will be conducted from a checklist of hundred and fifty seven risk factors collected from literature and pilot survey. Were eighty of these risk factors were previously obtained from the literature. The questionnaire consists of an introduction and two parts. The introduction gives a description of the survey, its purpose and objectives. Thus the participant is asked to give his opinion whether he/she agrees about the risk. Also, they are allowed to state whether the risk factor lead to another risk and mention the project party responsible for this risk factor. The first part of the questionnaire is related to general information about the participant and his job description. The respondents are requested to answer information classifying their classification and their experience in constructing sewage networks. The second part of the questionnaire will include a list of risk factors affecting the time and cost of construction of sewage networks.

Questionnaires are used in the qualitative risk analysis stage. Using the agreed list of fifty risk factors obtained from the risk identification stage the risk factors are prioritized. A list of the most effective ten risk factors on project objectives cost and time is conducted. The questionnaire consists of two parts. An interview is made giving a description about the survey, its purpose and objectives. Thus the participant is asked to give his opinion about the probability of occurrence of the risk factor. In addition to that professionals were asked to suggest an impact degree of this risk factor on cost and time of sewage networks construction. The first part of the questionnaire is related to general information about the participant and his job description. The respondents were requested to answer information using their experience in constructing sewage networks. The second part of the questionnaire includes a list of risk factors and their relative degree of both probability of occurrence and impact on project objectives.

Through a Case Study of a sewage network project, questionnaires were used. Participants were asked to add their opinions on different mitigations to be taken towards the prioritized ten risk factors. Mitigation action will then decrease the probability and impact scales suggested in the qualitative phase. The analysis of prioritized list of ten risk factors can be then done before and after applying mitigation actions. Questionnaire samples used for the three risk management processes are represented in the appendix at the end of this thesis.

3.4.2 Sample Size

The survey sample is distributed through two sewage networks projects in Egypt during their construction phase. Random number is used to choose participants and thus the sampling method is random sampling. The sample size to conduct this study is determined from the following formula**. Shash.etal. (1993)**.

n = n' / (1 + n'/N).

Where: n= sample size; N= size of population for two sewage projects in Egypt; n'= sample size for non-finite population (S^2/V^2); v= the standard error of sampling distribution (taken 0.05) and S= the maximum standard population in the distribution elements. For a total error of 0.1 at confidence level of 95 %, $S^2 = P * (1 – P) = 0.5 * 0.5 = 0.25$. P = the proportion of population elements that belongs to a defined class, the maximum value is chosen at P = 0.5. According to the professional participants in two sewage projects in Egypt, population size of 70 personnel is used (N=70). It was not possible for political reasons in Egypt to get more than seventy as a population size. The size of sampling is calculated by substituting into the above formula in order to obtain the minimum sample personnel size. The sample size for non-finite population n'= (S^2/ V^2) = ($0.25/0.05^2$) = 100 Substituting into the formula to get the sample size.

n = n'/(1+n'/N) = 100/ (1+100/70) = 42 personnel.

3.4.3 Sampling Approach

The questionnaire is asked to be answered by professionals during the construction of sewage networks. Professionals will include project managers, assistant resident engineers and site engineers on site. The questionnaire is distributed on a sample of 70 personnel as size of population in all surveys. A total of 50 respondents answered the questionnaire. This response rate is due to the positive administration of the questionnaire.

3.4.4 Risk Identification Check List Technique

Sample of distributed checklist is shown in Table 3.2. The Table includes hundred fifty seven risk factors and their corresponding categories. In the literature review eighty risk factors was concluded and additional seventy seven risk factors were added through a pilot survey. The objective of this checklist is to obtain the most effective fifty risk factors to be analysed qualitatively. Each risk category is given a code by which risk factors are sorted according to their RBS. The codes used in this paper are as follows: A- Technical Risks, B- Project management risks, C- Financial risks, D- Environmental risks, E- Organizational risks and F- External Risks. The evaluation column reflects opinion whatever the participant agrees or disagree. A risk factor can occur during construction of sewage networks. Does it leads to a risk column reflects the severity of risk in case it occurs. The end right comments column allows the participant to add further information. Such information may include the party responsible for this risk factor and objective affected whether its cost and/or time.

Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
A	Technical quality performance risk	√	Yes	
A1	Technology changes	√	Yes	
A2	Poor Water Insulation Application on Site	√	Yes	
A3	Delay in Material Approval	√	Yes	
A4	Late Delivery of Material to Site	√	Yes	
A5	Inefficient Quality control	√	Yes	
A6	Incorrect Sewer location during construction	√	Yes	
A7	Poorly Installed Sewers	√	Yes	
A8	Shortage of construction equipment’s	√	Yes	
A9	Unsuitable Soil Filled Around Sewers	√	Yes	
A10	Wrongly Installed Sewer size	√	Yes	
A11	Delivery Problems in Sewer pipe length and Short Pieces	√	Yes	
A12	Inadequate quality check contractor and consultant	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
A13	Using unproven technology during construction	√	Yes	
A14	Complexity in constructing works	√	Yes	
A15	Lack of personnel training	√	Yes	
A16	Poor subcontractors performance	√	Yes	
A17	Shortage of construction materials	√	Yes	
A18	Inadequate contractors experience	√	Yes	
A19	Unqualified labours	√	Yes	
A20	Unqualified subcontractors	√	Yes	
A21	Safety Environmental analysis incomplete	√	Yes	
A22	Unexpected geotechnical issues	√	Yes	
A23	Change requests because of errors	√	Yes	
A24	Inaccurate assumptions on technical issues in planning stage	√	Yes	
A25	Surveys late and/or surveys in error	√	Yes	
A26	Structural designs incomplete or in error	√	Yes	
A27	Hazardous waste site analysis incomplete or in error	√	Yes	
A28	Consultant design not up to department standards	√	Yes	
A29	Inadequate design/design uncertainty for interchanges	√	Yes	
A30	Inaccurate contract time estimates	√	Yes	
A31	Contractor Permit work windows delays	√	Yes	
A32	Unavailable Equipment’s	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
A33	Unqualified Surveyors	√	Yes	
B	External risks			
B1	Misleading Management Focus	√	Yes	
B2	Lack of communication between contractors	√	Yes	
B3	Inadequate supervision system	√	Yes	
B4	Poor Equipment's Productivity and Efficiency measures	√	Yes	
B5	Low subcontractor performance	√	Yes	
B6	Lack of communication between subcontractors	√	Yes	
B7	Poor site management in the contractors organization	√	Yes	
B8	Unavailability of subcontractors	√	Yes	
B9	Lack of construction management	√	Yes	
B10	Poor planning errors	√	Yes	
B11	Contractor managerial complexity	√	Yes	
B12	Inefficient equipment management	√	Yes	
B13	Labour no availability	√	Yes	
B14	Low equipment productivity	√	Yes	
B15	Material no availability	√	Yes	
B16	Subcontractors and nominated suppliers	√	Yes	
B17	Increase in design errors	√	Yes	
B18	Poor contract management	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
B19	Low labour productivity	√	Yes	
B20	Contractor material management problem	√	Yes	
B21	Deficiencies in contractors organization	√	Yes	
B22	Poor schedule of subcontractors	√	Yes	
B23	Coordination deficiency by the contractor	√	Yes	
B24	Owner poor contract management	√	Yes	
C	Financial Risks			
C1	Funds unavailability	√	Yes	
C2	Interest rate fluctuation	√	Yes	
C3	Public credit	√	Yes	
C4	Inflation	√	Yes	
C5	Material price changes	√	Yes	
C6	Expense payment	√	Yes	
C7	Legislation change	√	Yes	
C8	Land Acquisition	√	Yes	
C9	Change order	√	Yes	
C10	Payments delay of completed work	√	Yes	
C11	Force majeure	√	Yes	
C12	Cash flow problems during construction	√	Yes	
C13	Market conditions	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
C14	Labour disruptions	√	Yes	
C15	Owner Financing problems	√	Yes	
D	Environmental Risks			
D1	Permits or agency actions delayed or take longer than expected	√	Yes	
D2	New information required for permits	√	Yes	
D3	Environmental regulations change	√	Yes	
D4	Water quality regulation changes	√	Yes	
D5	Reviewing agency requires higher-level review than assumed	√	Yes	
D6	Historic site, endangered species, or wetlands present	√	Yes	
D7	Environmental impact statement (EIS) required	√	Yes	
D8	Controversy on environmental grounds expected	√	Yes	
D9	Environmental analysis on new alignments required	√	Yes	
D10	Project in an area of high sensitivity for palaeontology	√	Yes	
D11	Project on a Scenic Highway	√	Yes	
D12	Project near a Wild and Scenic River	√	Yes	
D13	Project in a floodplain or a regulatory floodway	√	Yes	
D14	Negative community impacts expected	√	Yes	
D15	Hazardous waste preliminary site investigation required	√	Yes	
D16	Pressure to compress the environmental schedule	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
D17	Geotechnical conditions	√	Yes	
E	Management Risks			
E1	Inexperienced staff assigned	√	Yes	
E2	Losing critical staff at crucial point of the project	√	Yes	
E3	Insufficient time to plan	√	Yes	
E4	Unanticipated project manager workload	√	Yes	
E5	Internal red tape causes delay getting approvals, decisions	√	Yes	
E6	Functional units not available or overloaded	√	Yes	
E7	Lack of understanding of complex internal funding procedures	√	Yes	
E8	Not enough time to plan	√	Yes	
E9	Priorities change on existing program	√	Yes	
E10	New priority project inserted into program	√	Yes	
E11	Inconsistent Project Objectives Management Risks	√	Yes	
E12	Project purpose and need are poorly defined	√	Yes	
E13	Project scope definition is poor or incomplete	√	Yes	
E14	Project scope, schedule, objectives and deliverables are not clearly defined	√	Yes	
E15	No control over staff priorities	√	Yes	
E16	Consultant or contractor delays	√	Yes	
E17	Estimating and/or scheduling errors	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
E18	Unplanned work that must be accommodated	√	Yes	
E19	Communication breakdown with project team	√	Yes	
E20	Pressure to deliver project on an accelerated schedule	√	Yes	
E21	Lack of coordination/communication	√	Yes	
E22	Lack of upper management support	√	Yes	
E23	Change in key staffing throughout the project	√	Yes	
E24	Inexperienced workforce/inadequate staff/resource availability	√	Yes	
E25	Local agency issues	√	Yes	
E26	Public awareness/support	√	Yes	
F	External Risks			
F1	Inadequate law	√	Yes	
F2	Government corruption	√	Yes	
F3	Delay in project approval and permits	√	Yes	
F4	Third party delay / violation	√	Yes	
F5	Change in tax regulations	√	Yes	
F6	Political public opposition	√	Yes	
F7	Unforeseen whether condition	√	Yes	
F8	Unforeseen geotechnical condition	√	Yes	
F9	Inexperience of client	√	Yes	
F10	Client attitude	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
F11	Unforeseen construction conditions	√	Yes	
F12	Delay in sewer system permit approval	√	Yes	
F13	Owner slow decision	√	Yes	
F14	Owner interference	√	Yes	
F15	Uncooperative owner	√	Yes	
F16	Designer slow response	√	Yes	
F17	Contractors relation with subcontractor schedule	√	Yes	
F18	Unrealistic duration of the sewage networks project	√	Yes	
F19	Changes in the drawings	√	Yes	
F20	Law regulation changes	√	Yes	
F21	Preparation and approval of design drawings	√	Yes	
F22	Incomplete A/E documents	√	Yes	
F23	Design errors by A/E firms	√	Yes	
F24	Inspection procedures carried on site	√	Yes	
F25	excessive burecracy in owner organization	√	Yes	
F26	Contractor delay in preparing work schedule	√	Yes	
F27	Specifications changed by the A/E	√	Yes	
F28	Delay in preparation of shop drawing	√	Yes	
F29	Delay in the approval of shop drawing by A/E	√	Yes	
F30	Delay in material supply delivery	√	Yes	

Cont. Table 3.2 Sample of distributed questionnaire

Code	Risk Factors	Evaluation (√/x)	Does it lead to a risk ?	Comment
F31	Delay in material supply manufacturing	√	Yes	
F32	Landowners unwilling to sell	√	Yes	
F33	Priorities change on existing program	√	Yes	
F34	Inconsistent cost, time, scope, and quality objectives	√	Yes	
F35	Local communities pose objections	√	Yes	
F36	Funding changes for fiscal year	√	Yes	
F37	Political factors change	√	Yes	
F38	Stakeholders request late changes	√	Yes	
F39	New stakeholders emerge and demand new work	√	Yes	
F40	stakeholders request additional needs	√	Yes	
F41	Threat of lawsuits	√	Yes	
F42	Stakeholders choose time and/or cost over quality	√	Yes	

Checklists are distributed among different professional project parties. A total number of forty eight participants will give their opinion responses towards the listed risk factors. Out of hundred and fifty seven risk factors, the most agreed risks by participants are those which is further preceded in the risk management process. Table 3.3 consists of each risk factor and its corresponding code, these risk codes is related to the risk category and its risk break down structure. The table represents the total number of agreed participants, as well as the risk factor agreed percentage. Risk factors percentages are ranked in a descending order choosing 50 risks which have the highest effect on sewage network projects cost and time.

Table 3.3 Risk Identification Survey Results

Code	Risk Factors	Total No. agreed	Agreed %
A6	Incorrect Sewer location during construction	43	89.6
A3	Delay in Material Approval	42	87.5
A4	Late Delivery of Material to Site	41	85.4
A5	Inefficient Quality control	41	85.4
A7	Poorly Installed Sewers	41	85.4
A10	Wrongly Installed Sewer size	41	85.4
A11	Delivery Problems in Sewer pipe length and Short Pieces	41	85.4
A1	Technology changes	40	83.3
A9	Unsuitable Soil Filled Around Sewers	40	83.3
B3	Inadequate supervision system	40	83.3
B5	Low subcontractor performance	40	83.3
A2	Poor Water Insulation Application on Site	39	81.3
A8	Shortage of construction equipment’s	39	81.3
A16	Poor subcontractors performance	39	81.3
A17	Shortage of construction materials	39	81.3
B2	Lack of communication between contractors	39	81.3
B4	Poor equipment’s Productivity and Efficiency measures	39	81.3
B12	Inefficient equipment management	39	81.3
B7	Poor site management in the contractors organization	38	79.2
B10	Poor planning errors	38	79.2
A12	Inadequate quality check from contractor and consultant	37	77.1

Cont. Table 3.3 Risk Identification Survey Results

Code	Risk Factors	Total No. agreed	Agreed %
A13	Using unproven technology during construction	37	77.1
A18	Inadequate contractors experience	37	77.1
A19	Unqualified labours	37	77.1
B1	Misleading Management Focus	37	77.1
B6	Lack of communication between subcontractors	37	77.1
B8	Unavailability of subcontractors	37	77.1
B9	Lack of construction management	37	77.1
B14	Low equipment productivity	37	77.1
C12	Cash flow problems during construction	36	75
B15	Material no availability	35	72.9
C15	Owner Financing problems	35	72.9
A14	Complexity in constructing works	34	70.8
A15	Lack of personnel training	34	70.8
A20	Unqualified subcontractors	34	70.8
A24	Inaccurate assumptions on technical issues in planning stage	34	70.8
A25	Surveys late and/or surveys in error	34	70.8
B13	Labour no availability	34	70.8
B17	Increase in design errors	34	70.8
C10	Payments delay of completed work	34	70.8
E1	Inexperienced staff assigned	34	70.8

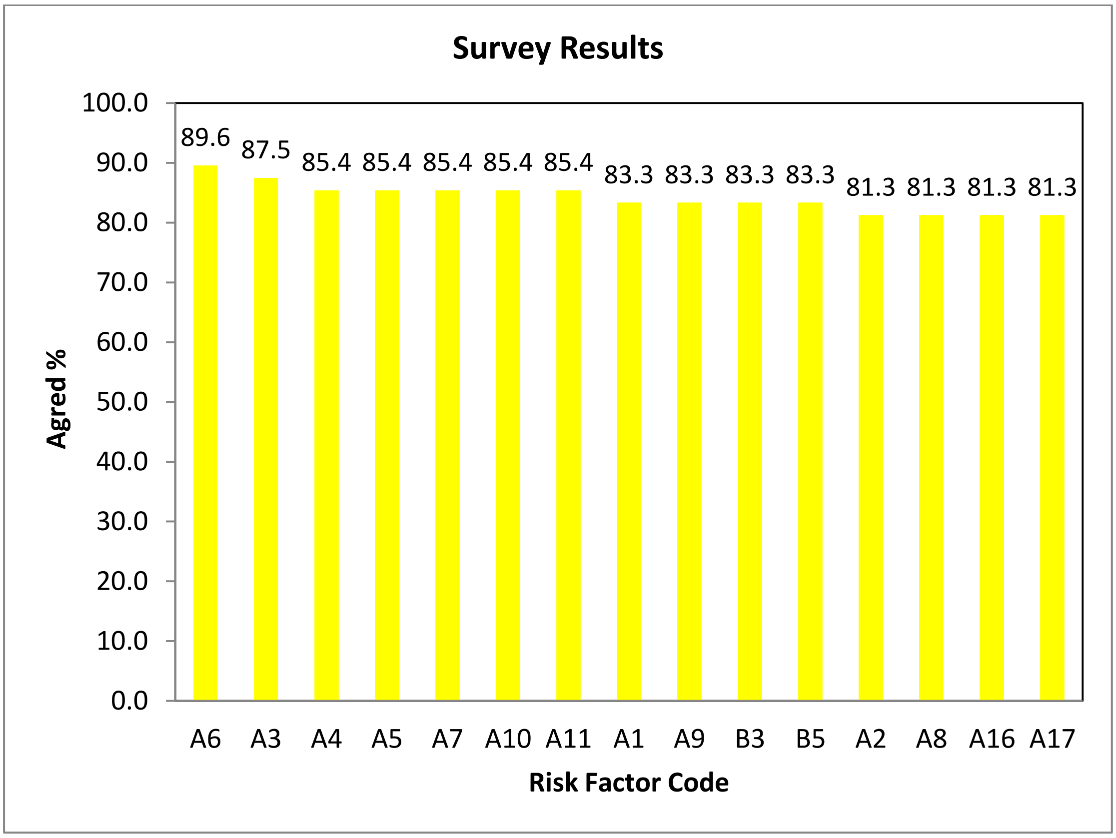
Cont. Table 3.3 Risk Identification Survey Results

Code	Risk Factors	Total No. agreed	Agreed %
F5	Change in tax regulations	34	70.8
A23	Change requests because of errors	33	68.8
A26	Structural designs incomplete or in error	33	68.8
B20	Contractor material management problem	33	68.8
C5	Material price changes	33	68.8
C11	Force majeure	33	68.8
C13	Market conditions	33	68.8
E2	Losing critical staff at crucial point of the project	33	68.8
F3	Delay in project approval and permits	33	68.8
F19	Changes in the drawings	33	68.8
A22	Unexpected geotechnical issues	32	66.7
B16	Subcontractors and nominated suppliers	32	66.7
C6	Expense payment	32	66.7
C14	Labour disruptions	32	66.7
D2	New information required for permits	32	66.7
E3	Insufficient time to plan	32	66.7
E13	Project scope definition is poor or incomplete	32	66.7
E15	No control over staff priorities	32	66.7
F8	Unforeseen geotechnical condition	32	66.7
A21	Safety Environmental analysis incomplete or in error	31	64.6

Cont. Table 3.3 Risk Identification Survey Results

Code	Risk Factors	Total No. agreed	Agreed %
B18	Poor contract management	31	64.6
D1	Permits or agency actions delayed or take longer than expected	31	64.6
E14	Project scope, schedule, objectives and deliverables are not clearly defined	31	64.6
F4	Third party delay / violation	31	64.6
F6	Political public opposition	31	64.6
F7	Unforeseen weather condition	31	64.6
F9	Inexperience of client	31	64.6
F10	Client attitude	31	64.6
F20	Law regulation changes	31	64.6
F22	Incomplete A/E documents	31	64.6

Survey results are also represented in the form of a bar chart. Most agreed percentage of all participants is represented graphically. 50% of the Risk factors sharing highest agreed percentage of 50% or more are most important. Fig 3.4 represents risk factors codes based on their risk break down structure on the x-axis, and corresponding agreed percentage for all projects participants on the y-axis, thus results of checklist analysis technique are clearly representable to be registered. The highest 10 percentage will represent the most important risk factors. These factors are further implemented into the qualitative risk analysis stage to be analyzed.



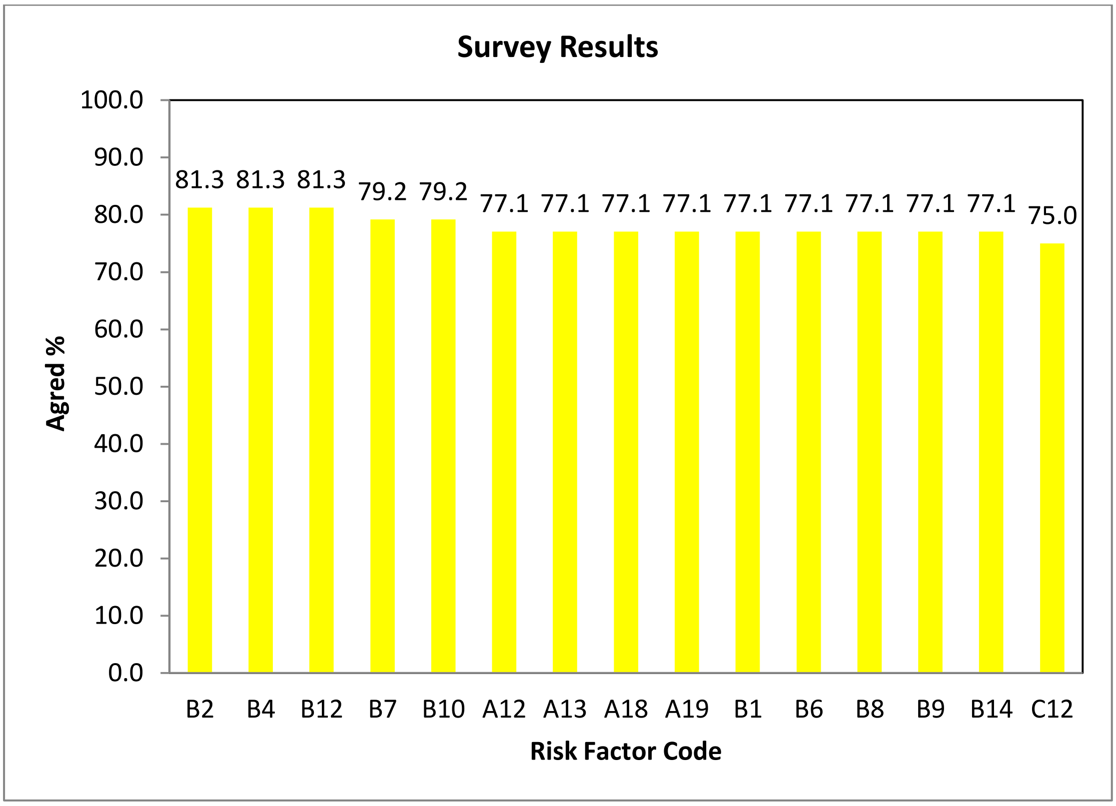
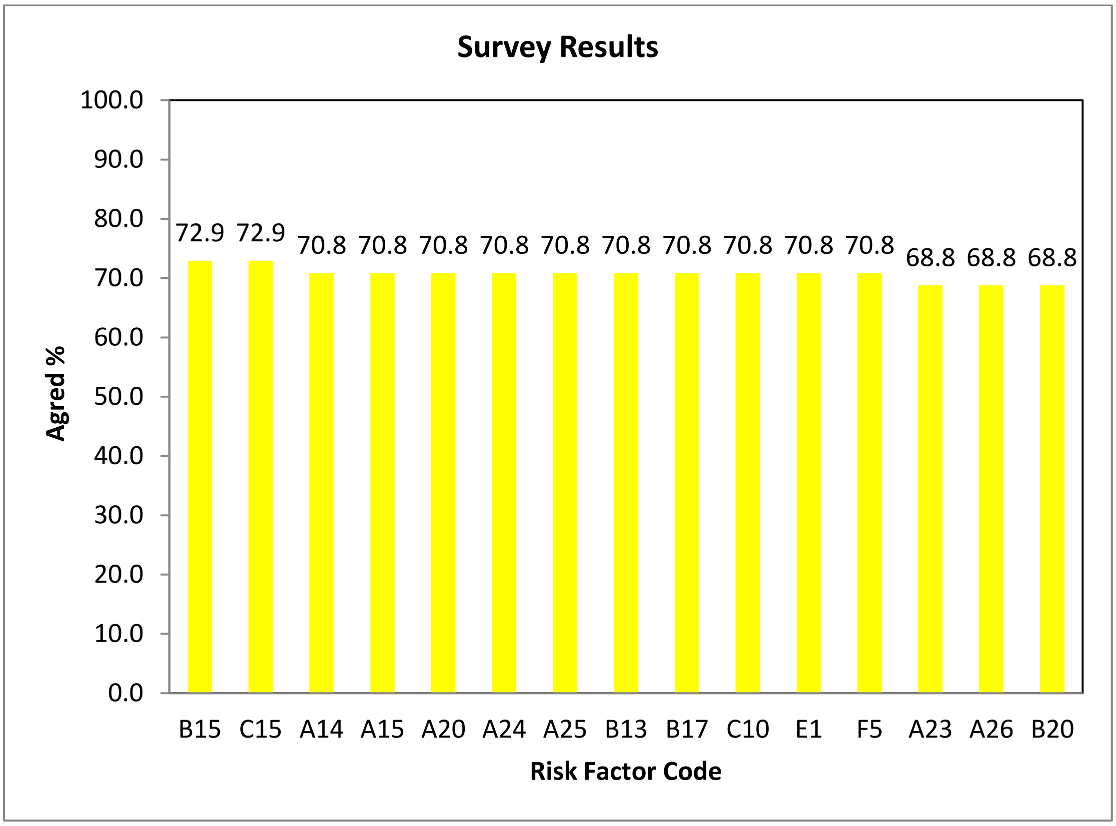
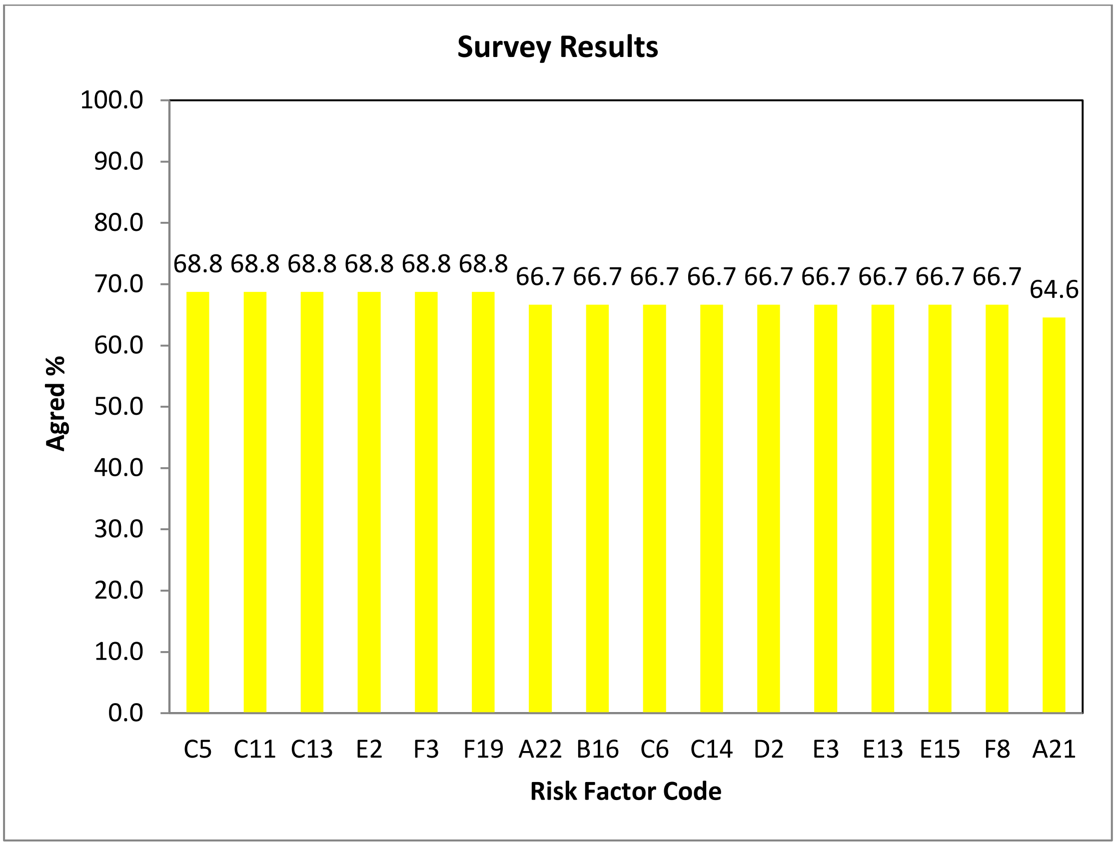
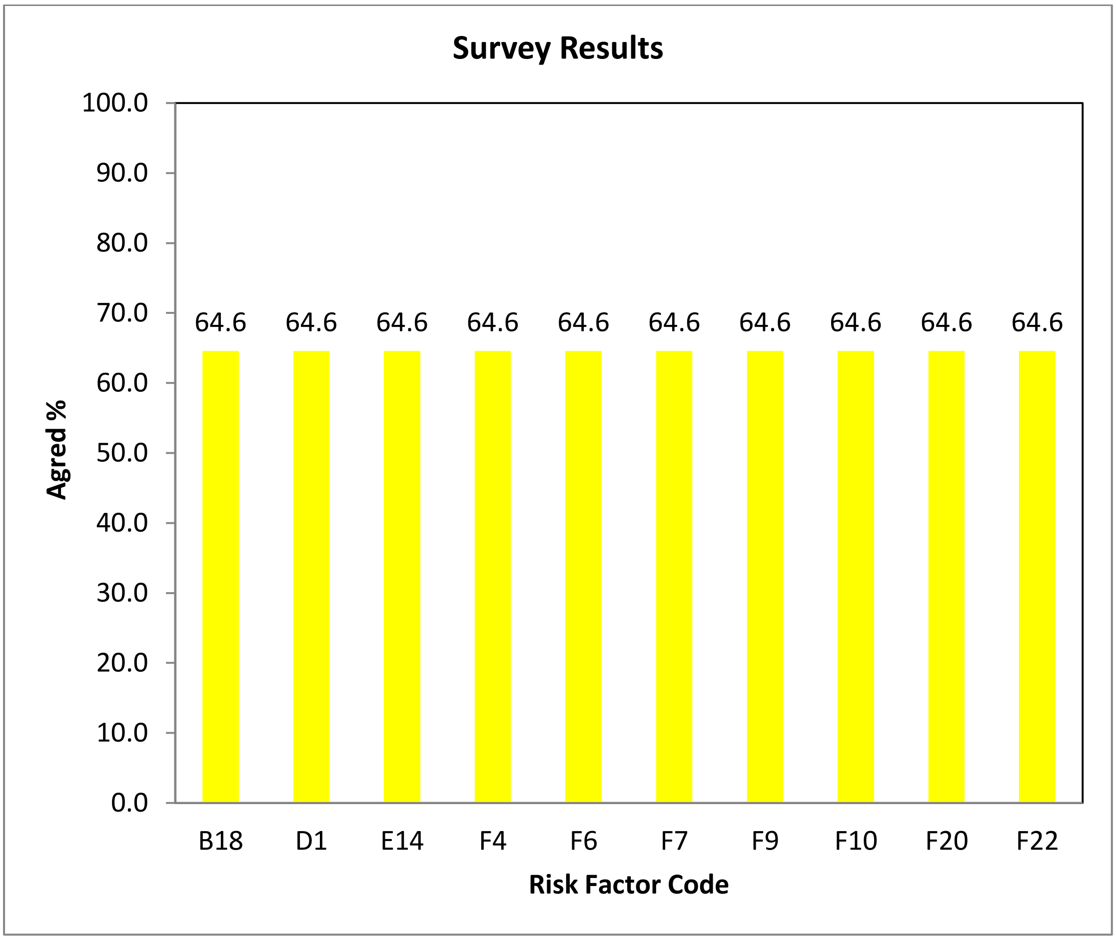


Fig 3.4 Survey Results Bar Chart





Cont. Bar Chart Fig 3.4 Survey Results



Cont. Bar Chart Fig 3.4 Survey Results

3.5 Risk Identification Output

The primary output from risk identification process is the initial entries into the risk register. The risk register ultimately contains the outcomes of the other risk processes as they are conducted, resulting in an increase in the level and the type of information contained in the risk register. Table 3.4 represents the risk register by which each risk factor and its corresponding code. Risk factors are considered to be threats as shown after agreed by sewage network projects expert participants. Each categorized group is also indicated corresponding to each risk factor. Later on, this risk register as an output of risk identification process is used as an input into risk analysis phase.

Table 3.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
A6	T	Incorrect Sewer location during construction	Technical Risks
A3	T	Delay in Material Approval	Technical Risks
A4	T	Late Delivery of Material to Site	Technical Risks
A5	T	Inefficient Quality control	Technical Risks
A7	T	Poorly Installed Sewers	Technical Risks
A10	T	Wrongly Installed Sewer size	Technical Risks
A11	T	Delivery Problems in Sewer pipe length and Short Pieces	Technical Risks
A1	T	Technology changes	Technical Risks
A9	T	Unsuitable Soil Filled Around Sewers	Technical Risks
B3	T	Inadequate supervision system	Project Management Risk
B5	T	Low subcontractor performance	Project Management Risk
A2	T	Poor Water Insulation Application on Site	Technical Risks
A8	T	Shortage of construction equipment’s	Technical Risks
A16	T	Poor subcontractors performance	Technical Risks

Cont. Table 3.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
A17	T	Shortage of construction materials	Technical Risks
B2	T	Lack of communication between contractors	Project Management Risk
B4	T	Poor equipment's Productivity and Efficiency measures	Project Management Risk
B12	T	Inefficient equipment management	Project Management Risk
B7	T	Poor site management in the contractors organization	Project Management Risk
B10	T	Poor planning errors	Project Management Risk
A12	T	Inadequate quality check from contractor and consultant	Technical Risks
A13	T	Using unproven technology during construction	Technical Risks
A18	T	Inadequate contractors experience	Technical Risks
A19	T	Unqualified labours	Technical Risks
B1	T	Misleading Management Focus	Project Management Risk
B6	T	Lack of communication between subcontractors	Project Management Risk
B8	T	Unavailability of subcontractors	Project Management Risk
B9	T	Lack of construction management	Project Management Risk
B14	T	Low equipment productivity	Project Management Risk
C12	T	Cash flow problems during construction	Financial Risks
B15	T	Material no availability	Project Management Risk
C15	T	Owner Financing problems	Financial Risks
A14	T	Complexity in constructing works	Technical Risks
A15	T	Lack of personnel training	Technical Risks

Cont. Table 3.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
A20	T	Unqualified subcontractors	Technical Risks
A24	T	Inaccurate assumptions on technical issues in planning stage	Technical Risks
A25	T	Surveys late and/or surveys in error	Technical Risks
B13	T	Labour no availability	Project Management Risk
B17	T	Increase in design errors	Project Management Risk
C10	T	Payments delay of completed work	Financial Risks
E1	T	Inexperienced staff assigned	Environmental Risks
F5	T	Change in tax regulations	Organizational Risks
A23	T	Change requests because of errors	Technical Risks
A26	T	Structural designs incomplete or in error	Technical Risks
B20	T	Contractor material management problem	Project Management Risk
C5	T	Material price changes	Financial Risks
C11	T	Force majeure	Financial Risks
C13	T	Market conditions	Financial Risks
E2	T	Losing critical staff at crucial point of the project	Environmental Risks
F3	T	Delay in project approval and permits	Organizational Risks
F19	T	Changes in the drawings	Organizational Risks
A22	T	Unexpected geotechnical issues	Technical Risks
B16	T	Subcontractors and nominated suppliers	Project Management Risk
C6	T	Expense payment	Financial Risks

Cont. Table 3.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
C14	T	Labour disruptions	Financial Risks
D2	T	New information required for permits	External Risks
E3	T	Insufficient time to plan	Environmental Risks
E13	T	Project scope definition is poor or incomplete	Environmental Risks
E15	T	No control over staff priorities	Environmental Risks
F8	T	Unforeseen geotechnical condition	Organizational Risks
A21	T	Safety Environmental analysis incomplete or in error	Technical Risks
B18	T	Poor contract management	Project Management Risk
D1	T	Permits or agency actions delayed or take longer than expected	External Risks
E14	T	Project scope, schedule, objectives and deliverables are not clearly defined	Environmental Risks
F4	T	Third party delay / violation	Organizational Risks
F6	T	Political public opposition	Organizational Risks
F7	T	Unforeseen weather condition	Organizational Risks
F9	T	Inexperience of client	Organizational Risks
F10	T	Client attitude	Organizational Risks
F20	T	Law regulation changes	Organizational Risks
F22	T	Incomplete A/E documents	Organizational Risks

3.6 Conclusion:

This chapter represents the first step of the risk management process which is the risk identification. Total of eighty risk factors are obtained from the literature review. These risk factors in addition to risk factors added from a pilot survey represent a list of hundred and fifty seven risk factors. These risk factors are surveyed to conduct the most agreed 50 risk factors.

The survey results represent the percentage of the total number of participants who chose this risk factor. Furthermore risk factors are ranked where most important risks are identified. This score percentage is represented in a group of bar charts to reflect risk factors conducted from checklists ranked in a descending order. The output of risk identification process is the risk register.

Risk register clearly reflects the results obtained from these checklists. These results include all approved risk factors and their corresponding group category arranged according to the risk breakdown structure. These risk factors are coded according to their category. Furthermore risk register is used as the input of the second process in risk management which is qualitative risk analysis process.

CHAPTER (4)

QUALITATIVE RISK ANALYSIS

4.1 Introduction

4.1.1 Qualitative Risk Analysis Process

Qualitative Risk Analysis Process is carried using risk register obtained from risk identification process. Furthermore the data collected is formulated to develop and design a comprehensive questionnaire that covers the required information for the analysis. This questionnaire is used as the process of estimating the probability of risks occurrence and their consequences on both time and cost of sewage networks. Updated risk register is thus obtained for risks which are further analyzed quantitatively. **A Guide to the Project Management Body of Knowledge Book (2008).** The risk analysis process can be defined as a "systematic use of available information to identify hazards and to estimate the risk to individuals and populations, property or the environment". **International Electric Commission IEC (1995)**.

4.1.2 Risk Assessment Categories

Qualitative risk assessment separates risks into categories for better project management. Table 4.1 reflects risk ratings and implications. **Hewlett et al. (2004)**.High risk, are resolved in the baseline plan. The best managers are assigned. Additional resources are applied. With some of these risks, project scoping may be considered. Moderate risk can be addressed with plans that balance the cost of risk management with the risk-adjusted impact on the project. Contingency plans may be applied to these risks. Low risks may often be left to the project team for further address.

Table 4.1 Risk Ratings and Implications, Hewlett el al. (2004)

Risk Rating	Stop Light Condition	Risk Management Implication
High Risk	Red	Resolve or mitigate in Baseline Plan
Moderate Risk	Yellow	Mitigate or develop Contingency Plan
Low Risk	Green	Leave resolution to project team

Risk assessment takes into account both the likelihood of a risk occurring and its impact on project objectives if it does occur. There are several ways to measure the likelihood and impact of a risk event. The best approach scales to these two characteristics between 0.0 and 1.0. Likelihood is usually measured between 0.0 (no likelihood) and 1.0 (certainty). While this seems to be natural, questions can be developed that lead to answers that indicate the level of likelihood. One example of some questions to determine the likelihood of technical risk is shown in Table 4.2 below**. Hewlett el al. (2004)**.

Table 4.2 LikelyHood of Project Risk Factors. Hewlett el al. (2004).

Likelihood of Technology Risk	
Description to Technology	**Likelihood Rating**
Scientific research required	.9
Concept design formulated	.8
Concept design tested - bench scale	.7
Critical functions / characteristics demonstrated	.6
Process passed performance test at pilot scale	.4
Full-scale prototype passed performance test	.3
More than one full scale facility operational	.1

The impact of a risk, if occurs, is to jeopardize the project's ability to succeed as one of its objectives. Typical objectives include cost, schedule and performance. It is not entirely usual to judge these impacts on a scale of 0.0 to 1.0, so some questions and their associated ratings is developed. **A Guide to the Project Management Body of Knowledge Book (2008).** Table 4.3 is an example of definitions of negative impacts that may be used in evaluating risk impacts related to two project objectives. Cost and Time of sewage networks construction are the two objectives in this study.

Table 4.3 Impact on Cost and Time Ratings, A Guide to the Project Management Body of Knowledge Book (2008)

Defined Conditions for impact scales of a risk on major project objectives					
Project Objectives	Very Low /0.10	Low / 0.3	Moderate /0.5	High / 0.70	Very High / 0.90
Cost	Insignificant Cost Increase	< 10% Cost Increase	10-20% Cost Increase	20-40% Cost Increase	>40% cost increase
Time	Insignificant Time Increase	< 10% Time Increase	5-10% Time Increase	10-20% Time Increase	>20% time increase

4.2 Methodology

Fig 4.1 illustrates the project risk qualitative analysis process. In order to perform risk qualitative analysis, risk register obtained from risk identification process is used as an input. Techniques of expert judgment and probability impact matrix are used. Questionnaires are used in order to conduct both probability of occurrence and impact on project objectives cost and time. Finally risk register is updated as an output of risk qualitative analysis process. **A Guide to the Project Management Body of Knowledge Book (2008).**

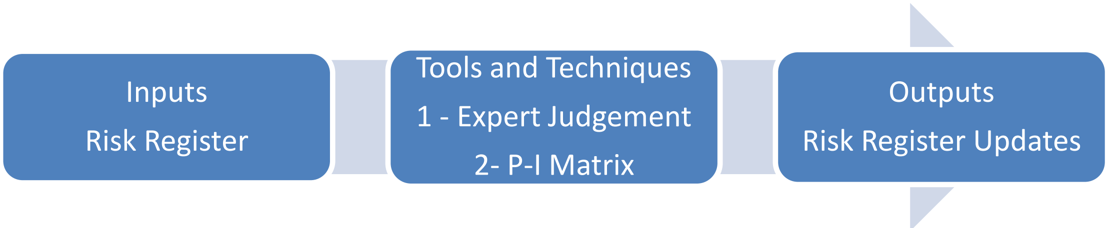


Fig 4.1 Qualitative Risk Analysis Process, A Guide to the Project Management Body of Knowledge Book (2008)

4.3 Risk Qualitative Analysis Input

Table 4.4 represents the risk register through which each risk factor and its corresponding code is identified whether it is an **opportunity or a threat (O/T)**. Each categorized group is also indicated corresponding to each risk factor. Later on this risk register as an output of risk identification process is used as an input into the qualitative risk analysis phase.

Table 4.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
A6	T	Incorrect Sewer location during construction	Technical Risks
A3	T	Delay in Material Approval	Technical Risks
A4	T	Late Delivery of Material to Site	Technical Risks
A5	T	Inefficient Quality control	Technical Risks
A7	T	Poorly Installed Sewers	Technical Risks
A10	T	Wrongly Installed Sewer size	Technical Risks
A11	T	Delivery Problems in Sewer pipe length and Short Pieces	Technical Risks
A1	T	Technology changes	Technical Risks

Cont. Table 4.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
A9	T	Unsuitable Soil Filled Around Sewers	Technical Risks
B3	T	Inadequate supervision system	Project Management Risk
B5	T	Low subcontractor performance	Project Management Risk
A2	T	Poor Water Insulation Application on Site	Technical Risks
A8	T	Shortage of construction equipment’s	Technical Risks
A16	T	Poor subcontractors performance	Technical Risks
A17	T	Shortage of construction materials	Technical Risks
B2	T	Lack of communication between contractors	Project Management Risk
B4	T	Poor equipment’s Productivity and Efficiency measures	Project Management Risk
B12	T	Inefficient equipment management	Project Management Risk
B7	T	Poor site management in the contractors organization	Project Management Risk
B10	T	Poor planning errors	Project Management Risk
A12	T	Inadequate quality check from contractor and consultant	Technical Risks
A13	T	Using unproven technology during construction	Technical Risks
A18	T	Inadequate contractors experience	Technical Risks
A19	T	Unqualified labours	Technical Risks
B1	T	Misleading Management Focus	Project Management Risk
B6	T	Lack of communication between subcontractors	Project Management Risk
B8	T	Unavailability of subcontractors	Project Management Risk
B9	T	Lack of construction management	Project Management Risk
B14	T	Low equipment productivity	Project Management Risk
C12	T	Cash flow problems during construction	Financial Risks

Cont. Table 4.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
B15	T	Material no availability	Project Management Risk
C15	T	Owner Financing problems	Financial Risks
A14	T	Complexity in constructing works	Technical Risks
A15	T	Lack of personnel training	Technical Risks
A20	T	Unqualified subcontractors	Technical Risks
A24	T	Inaccurate assumptions on technical issues in planning stage	Technical Risks
A25	T	Surveys late and/or surveys in error	Technical Risks
B13	T	Labour no availability	Project Management Risk
B17	T	Increase in design errors	Project Management Risk
C10	T	Payments delay of completed work	Financial Risks
E1	T	Inexperienced staff assigned	Environmental Risks
F5	T	Change in tax regulations	Organizational Risks
A23	T	Change requests because of errors	Technical Risks
A26	T	Structural designs incomplete or in error	Technical Risks
B20	T	Contractor material management problem	Project Management Risk
C5	T	Material price changes	Financial Risks
C11	T	Force majeure	Financial Risks
C13	T	Market conditions	Financial Risks
E2	T	Losing critical staff at crucial point of the project	Environmental Risks
F3	T	Delay in project approval and permits	Organizational Risks
F19	T	Changes in the drawings	Organizational Risks
A22	T	Unexpected geotechnical issues	Technical Risks
B16	T	Subcontractors and nominated suppliers	Project Management Risk

Cont. Table 4.4 Risk Register

Risk code	O/T	Risk Title	Risk Category
C6	T	Expense payment	Financial Risks
C14	T	Labour disruptions	Financial Risks
D2	T	New information required for permits	External Risks
E3	T	Insufficient time to plan	Environmental Risks
E13	T	Project scope definition is poor or incomplete	Environmental Risks
E15	T	No control over staff priorities	Environmental Risks
F8	T	Unforeseen geotechnical condition	Organizational Risks
A21	T	Safety Environmental analysis incomplete or in error	Technical Risks
B18	T	Poor contract management	Project Management Risk
D1	T	Permits or agency actions delayed or take longer than expected	External Risks
E14	T	Project scope, schedule, objectives and deliverables are not clearly defined	Environmental Risks
F4	T	Third party delay / violation	Organizational Risks
F6	T	Political public opposition	Organizational Risks
F7	T	Unforeseen weather condition	Organizational Risks
F9	T	Inexperience of client	Organizational Risks
F10	T	Client attitude	Organizational Risks
F20	T	Law regulation changes	Organizational Risks
F22	T	Incomplete A/E documents	Organizational Risks

4.4 Risk Qualitative Analysis Techniques

4.4.1 Probability-Impact Matrix (P-I matrix)

Probability and impact of a risk is combined in a **P-I matrix** to rank the risks into classes. There are several ways to do this, but one common approach is the one suggested by **Harold. etal. (1998)** and used by project offices in several government agencies and corporations. It is shown below, with red, yellow and green designations of high, moderate and low risks. After identifying sources of risk, consider using numerical values for scaling. This requires definitions for each of the values. When establishing scales, the whole range from greater than 0 to less than 1 is used. If a numeric scaling be done, use qualitative measures such as low, medium or high. These may be refined further by adding very low (below low) and very high (above high). These measurements must be well specified in words. **Harold etal. (1998)**. Fig 4.2 a illustrates the product of probability of occurrence and impact on cost gives the risk score, Fig 4.2 b classifies the risk score could be either high, moderate or low risks from 0 .5-1 is high, 0.1-0.5 moderate and <0.1 low.

Likelihood		Impact on Cost				
		Very Low	Low	Moderate	High	Very High
		0.1	0.3	0.5	0.7	0.9
Very High	0.9	0.090	0.270	0.450	0.630	0.810
High	0.7	0.070	0.210	0.350	0.490	0.630
Moderate	0.5	0.050	0.150	0.250	0.350	0.450
Low	0.3	0.030	0.090	0.150	0.210	0.270
Very Low	0.1	0.010	0.030	0.050	0.070	0.090

Fig 4.2 a Risk Score in P-I Matrix, Harold (1998).

Likelihood		Impact on Cost				
		Very Low	Low	Moderate	High	Very High
		0.1	0.3	0.5	0.7	0.9
Very High	0.9	Low	Moderate	High	High	High
High	0.7	Low	Moderate	Moderate	High	High
Moderate	0.5	Low	Low	Moderate	Moderate	High
Low	0.3	Low	Low	Low	Moderate	Moderate
Very Low	0.1	Low	Low	Low	Low	Low

Fig 4.2 b Classifying Risks in P-I Matrix, Harold (1998).

4.4.2 Impact on Cost

First objective in this study is cost of construction of a sewage networks, both probability of occurrence degree for risk factors and its impact if it appears during construction are conducted from these questionnaires. Table 4.5 indicates each risk factor, their codes, probability of risk occurrence and impact on cost degree if the risk occurs. Probability and Impact can vary from one risk another. The degree of a risk factor is numerically represented as: Very high–0.9, High–0.7, Moderate– 0.5, Low-0.3 and Very low–0.1. **A Guide to the Project Management Body of Knowledge Book (2008).** Each degree indicated the total number of participants who chose this degree. The total probability and total impact at the end of each risk factor represents the cumulative product of both degree and total number of participants who chose this degree.

Table 4.5 Probability and Impact on Cost Conducted from Questionnaires

Code	Risk Factors	Probability of Occurrence						Impact on Cost					
		Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
A	Technical Risks												
A3	Delay in material approval		17	18	10	3	48		17	17	11	3	48
A4	Late delivery of material to site	1	13	20	9	5	48		15	13	13	7	48
A6	Incorrect sewer location during construction		14	18	12	4	48	1	17	17	9	4	48
A2	Poor water insulation application		16	16	12	4	48		16	16	10	6	48
A5	Inefficient quality control		15	21	9	3	48		17	15	10	6	48
A7	Poorly installed sewers		13	19	12	4	48		18	15	8	7	48

Cont. Table 4.5 Probability and Impact on Cost Conducted from Questionnaires

Code	Risk Factors	Probability of Occurrence						Impact on Cost					
		Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
A10	Wrongly installed sewer size		12	19	7	10	48		14	18	10	6	48
A11	Delivery problems in pipe lengths		15	15	9	9	48		12	18	8	10	48
A12	Inadequate quality check form contractor and consultant		14	15	11	8	48		13	19	10	6	48
A13	Using unproven technology during construction	1	15	15	11	6	48		12	19	8	9	48
A17	Shortage of construction materials		14	19	9	6	48		13	19	10	6	48
A1	Construction method changes		13	17	12	6	48		13	18	11	6	48
A8	Shortage of construction equipment's		12	18	10	8	48	1	16	17	9	5	48
A9	Unsuitable soil placed surrounding sewers		15	15	12	6	48	1	13	20	10	4	48
A16	Poor subcontractors performance		15	17	12	4	48		13	19	12	4	48
A14	Complexity in constructing works		15	15	12	6	48		12	21	11	4	48
A18	Inadequate contractors experience		16	17	10	5	48	1	15	18	9	5	48
A19	Unqualified labours		13	19	10	6	48		15	17	13	3	48
A25	Surveys errors		14	18	11	5	48		15	17	12	4	48

Cont. Table 4.5 Probability and Impact on Cost Conducted from Questionnaires

Code	Risk Factors	Probability of Occurrence						Impact on Cost					
		Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
A26	Structure design incomplete or in error		12	18	13	5	48		13	19	12	4	48
A22	Unexpected geotechnical issues		15	19	8	6	48		15	17	10	6	48
A23	Change Inspection requests because of errors		15	22	9	2	48		15	16	12	5	48
A24	Inaccurate assumptions on technical issues during planning stage		14	20	10	4	48		16	19	10	3	48
B	Project Management Risk												
B1	Misleading management focus	1	17	19	6	5	48		11	19	14	4	48
B2	Lack of communication between contractors		15	18	12	3	48		11	22	9	6	48
B3	Inadequate supervision system		16	19	10	3	48		12	18	12	6	48
B4	Poor equipment’s productivity and efficiency measures		19	18	7	4	48		15	22	7	4	48
B5	Low subcontractor performance	1	15	21	9	2	48		12	21	12	3	48
B7	Poor site management in the contractors organization	1	14	22	9	2	48		15	17	11	5	48
B10	Poor planning errors	1	16	20	9	2	48		16	16	11	5	48

Cont. Table 4.5 Probability and Impact on Cost Conducted from Questionnaires

Code	Risk Factors	Probability of Occurrence						Impact on Cost					
		Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
B6	Lack of communication between subcontractors		15	18	11	4	48		17	16	12	3	48
B8	Unavailability of subcontractors		14	17	12	5	48		16	18	10	4	48
B9	Lack of construction management		15	19	11	3	48		14	18	13	3	48
B17	Increase in design errors		14	18	11	5	48		13	19	12	4	48
B11	Contractor managerial complexity	1	12	19	11	5	48		14	18	11	5	48
B12	Inefficient equipment management	1	14	19	9	5	48		16	16	12	4	48
B14	Low equipment productivity		14	19	11	4	48		16	16	14	2	48
B15	Material no availability		14	21	11	2	48		14	18	12	4	48
B19	Low labor productivity		13	18	13	4	48		13	21	10	4	48
B20	Contractor material management problem		14	17	12	5	48		14	18	11	5	48
C	Financial Risk												
C1	Funds unavailability	1	16	18	9	4	48	1	15	19	9	4	48
C6	Expense Payment	1	17	16	10	4	48		13	19	11	5	48

Cont. Table 4.5 Probability and Impact on Cost Conducted from Questionnaires

Code	Risk Factors	Probability of Occurrence						Impact on Cost					
		Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
C7	Legislation change		11	22	11	4	48		14	19	11	4	48
C8	Land Acquisition	1	14	19	11	3	48	1	14	19	10	4	48
C10	Payment delay of completed work		13	22	9	4	48		18	16	10	4	48
D	Environmental Risk												
D1	Permits delayed		15	20	8	5	48		17	18	8	5	48
D2	New information required for permits	1	14	19	10	4	48		16	17	10	5	48
F	External Risk												
F3	Delay in shop drawing approval	1	15	22	7	3	48		14	18	13	3	48
F4	Third party delay approval		17	18	8	5	48		15	21	9	4	48
F5	Change in tax regulations		13	22	9	4	48		18	17	9	4	48

4.4.3 Risk Score Method for Ranking Risk Factors

Statistical analysis is carried, showing risk priority and ranking according to different contractors and consultants. Ranking these risk factors for all personnel projects is based on risk score method. Risk Score is calculated as the product of the average probability and average impact. The total number of participants agreed at a certain scale is indicated below the probability and impact scales. Table 4.6 represents ranking risk factors in a descending order according to their calculated risk score. **A Guide to the Project Management Body of Knowledge Book (2008).**

Table 4.6 Ranked Risk Factors for Cost, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability Of Occurrence						Impact on Cost						Risk Score
		V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Prob (%)	V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Imp (%)	
B4	Poor equipment's productivity and efficiency measures		19	18	7	4	0.46		15	22	7	4	0.50	0.232
F3	Delay in shop drawing approval	1	15	22	7	3	0.47		14	18	13	3	0.48	0.224
B10	Poor planning errors	1	16	20	9	2	0.46		16	16	11	5	0.48	0.221
C1	Funds unavailability	1	16	18	9	4	0.44	1	15	19	9	4	0.50	0.220
A3	Delay in material approval		17	18	10	3	0.44		17	17	11	3	0.50	0.218
B5	Low subcontractor performance	1	15	21	9	2	0.46		12	21	12	3	0.48	0.217
F4	Third party delay approval		17	18	8	5	0.44		15	21	8	4	0.50	0.216
B7	Poor site management in the contractors organization	1	14	22	9	2	0.45		15	17	11	5	0.48	0.215
D1	Permits delayed		15	20	8	5	0.43		17	18	8	5	0.50	0.212
F5	Change in tax regulations		13	22	9	4	0.42		18	17	9	4	0.50	0.211
B1	Misleading management focus	1	17	19	6	5	0.46		11	19	14	4	0.45	0.211
A23	Change Inspection requests because of errors		15	22	9	2	0.45		15	16	12	5	0.47	0.211
A5	Inefficient quality control		15	21	9	3	0.44		17	15	10	6	0.48	0.210

Cont. Table 4.6 Ranked Risk Factors for Cost, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability Of Occurrence						Impact on Cost						Risk Score
		V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Prob (%)	V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Imp (%)	
C10	Payment delay of completed work		13	22	9	4	0.42		18	16	10	4	0.50	0.210
C8	Land Acquisition	1	14	19	11	3	0.42	1	14	19	10	4	0.49	0.207
A24	Inaccurate assumptions on technical issues during planning stage		14	20	10	4	0.41		16	19	10	3	0.50	0.207
B12	Inefficient equipment management	1	14	19	9	5	0.42		16	16	12	4	0.48	0.204
D2	New information required for permits	1	14	19	10	4	0.42		16	17	10	5	0.48	0.204
C6	Expense Payment	1	17	16	10	4	0.43		13	19	11	5	0.47	0.202
A18	Inadequate contractors experience		16	17	10	5	0.41	1	15	18	9	5	0.49	0.202
B6	Lack of communication between subcontractors		15	18	11	4	0.41		17	16	12	3	0.50	0.202
B15	Material no availability		14	21	11	2	0.42		14	18	12	4	0.48	0.201
B9	Lack of construction management		15	19	11	3	0.42		14	18	13	3	0.48	0.200
A6	Incorrect sewer location during construction		14	18	12	4	0.39	1	17	17	9	4	0.51	0.199
B14	Low equipment productivity		14	19	11	4	0.40		16	16	14	2	0.49	0.198
A22	Unexpected geotechnical issues		15	19	8	6	0.42		15	17	10	6	0.47	0.196

Cont. Table 4.6 Ranked Risk Factors for Cost, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability Of Occurrence						Impact on Cost						Risk Score
		V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Prob (%)	V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Imp (%)	
B3	Inadequate supervision system		16	19	10	3	0.43		12	18	12	6	0.45	0.194
A2	Poor water insulation application		16	16	12	4	0.40		16	16	10	6	0.48	0.190
A25	Surveys errors		14	18	11	5	0.39		15	17	12	4	0.48	0.188
B8	Unavailability of subcontractors		14	17	12	5	0.38		16	18	10	4	0.49	0.188
A4	Late delivery of material to site	1	13	20	9	5	0.42		15	13	13	7	0.45	0.188
A19	Unqualified labours		13	19	10	6	0.39		15	17	13	3	0.48	0.188
A7	Poorly installed sewers		13	19	12	4	0.39		18	15	8	7	0.48	0.188
C7	Legislation change		11	22	11	4	0.39		14	19	11	4	0.48	0.187
A16	Poor subcontractors performance		15	17	12	4	0.40		13	19	12	4	0.47	0.187
B2	Lack of communication between contractors		15	18	12	3	0.41		11	22	9	6	0.46	0.186
A17	Shortage of construction materials		14	19	9	6	0.40		13	19	10	6	0.46	0.186
B17	Increase in design errors		14	18	11	5	0.39		13	19	12	4	0.47	0.185
B11	Contractor managerial complexity	1	12	19	11	5	0.39		14	18	11	5	0.47	0.185

Cont. Table 4.6 Ranked Risk Factors for Cost, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability Of Occurrence						Impact on Cost						Risk Score
		V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Prob (%)	V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Imp (%)	
A9	Unsuitable soil placed surrounding sewers		15	15	12	6	0.38	1	13	20	10	4	0.49	0.183
B19	Low labor productivity		13	18	13	4	0.38		13	21	10	4	0.48	0.181
A8	Shortage of construction equipment's		12	18	10	8	0.36	1	16	17	9	5	0.50	0.180
B20	Contractor material management problem		14	17	12	5	0.38		14	18	11	5	0.47	0.180
A14	Complexity in constructing works		15	15	12	6	0.38		12	21	11	4	0.47	0.177
A10	Wrongly installed sewer size		12	19	7	10	0.37		14	18	10	6	0.47	0.174
A13	Using unproven technology during construction	1	15	15	11	6	0.39		12	19	8	9	0.44	0.174
A26	Structure design incomplete or in error		12	18	13	5	0.36		13	19	12	4	0.47	0.171
A1	Construction method changes		13	17	12	6	0.37		13	18	11	6	0.46	0.168
A12	Inadequate quality check form contractor and consultant		14	15	11	8	0.36		13	19	10	6	0.46	0.167
A11	Delivery problems in pipe lengths		15	15	9	9	0.38		12	18	8	10	0.43	0.163

4.4.4 Prioritizing Risk Factors

Table 4.7 represents the highest 10 risk factors reflects the highest risk factors probability to occur which has greatest impact on cost. Risk factors represented in Table 4.7 are the most important risk factors which might occur. Thus they have a high impact on cost. Each risk factor is further analyzed quantitatively and responses towards them shall be monitored in order to be controlled during construction.

Table 4.7 Prioritizing Risk Factors for cost

Code	Risk Factors	Probability Of Occurrence						Impact on Cost						Risk Score
		V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Prob (%)	V.H 90%	H 70%	M 50%	L 30%	V.L 10%	Avrg Imp (%)	
B4	Poor equipment’s productivity and efficiency measures		19	18	7	4	0.46		15	22	7	4	0.50	0.232
F3	Delay in shop drawing approval	1	15	22	7	3	0.47		14	18	13	3	0.48	0.224
B10	Poor planning errors	1	16	20	9	2	0.46		16	16	11	5	0.48	0.221
C1	Funds unavailability	1	16	18	9	4	0.44	1	15	19	9	4	0.50	0.220
A3	Delay in material approval		17	18	10	3	0.44		17	17	11	3	0.50	0.218
B5	Low subcontractor performance	1	15	21	9	2	0.46		12	21	12	3	0.48	0.217
F4	Third party delay approval		17	18	8	5	0.44		15	21	8	4	0.50	0.216
B7	Poor site management in the contractors organization	1	14	22	9	2	0.45		15	17	11	5	0.48	0.215
D1	Permits delayed		15	20	8	5	0.43		17	18	8	5	0.50	0.212
F5	Change in tax regulations		13	22	9	4	0.42		18	17	9	4	0.50	0.211

4.4.5 Locating Priority Area

Fig 4.3 illustrates results concerned with risk factors of highest risk score is represented on a bar chart locating area of highest priority used in this study. The chart represents risk factors and their codes on the y-axis against risk score on the x-axis. Risk score method used will depend on multiplying the expected probabilities and impacts of each risk factor. The previously identified list of 50 risk factors is ranked. The highest list of 10 risk factors is obtained and illustrated in Fig 4.3. These factors are the most probably to occur and will have the greatest impact on sewage network projects cost.

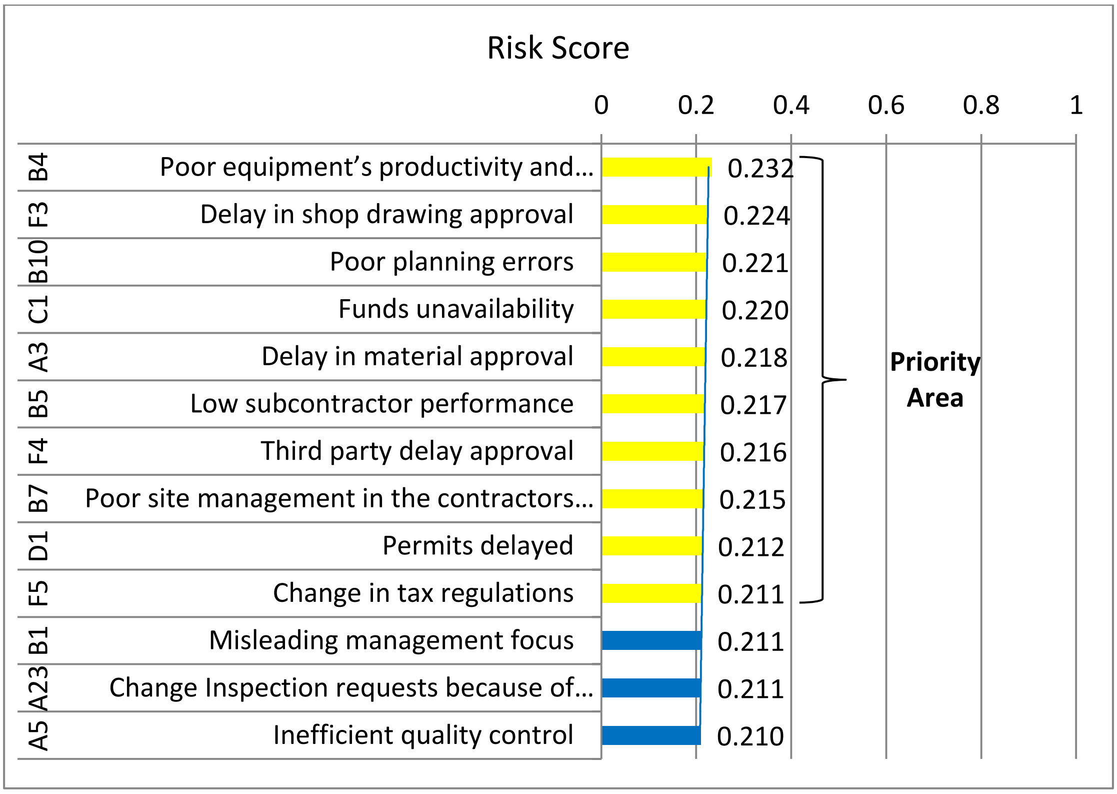


Fig 4.3 Locating Priority Area for Cost Objective

4.4.6 Impact on Time

Second objective in this study is time of construction of sewage networks. Both probability of occurrence degree for risk factors and its impact if it appears during construction is conducted from these questionnaires. Table 4.8 indicates each risk factor, their codes, probability of risk occurrence and impact on time degree if the risk occurs. Probability and Impact can vary from one risk another. The degree of a risk factor is numerically represented as, Very high–0.9, High–0.7, Moderate –0.5, Low–0.3 and Very low–0.1. **A Guide to the Project Management Body of Knowledge Book (2008).** Under each degree indicated the total number of participants who chose this degree. The total probability and total impact at the end of each risk factor represents the cumulative product of both the degree and the total number of participants who chose this degree.

Table 4.8 Probability and Impact Conducted from Questionnaires for time.

Code	Risk Factors	Probability of Occurrence						Impact on Time					
		Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
A	Technical Risks												
A3	Delay in material approval		17	18	10	3	48	1	22	16	6	3	48
A4	Late delivery of material to site	1	13	20	9	5	48	1	14	20	9	4	48
A6	Incorrect sewer location during construction		14	18	12	4	48	1	17	17	11	2	48
A2	Poor water insulation application		16	16	12	4	48		13	20	11	4	48
A5	Inefficient quality control		15	21	9	3	48		17	19	8	4	48
A7	Poorly installed sewers		13	19	12	4	48		13	21	8	6	48
A10	Wrongly installed sewer size		12	19	7	10	48		17	17	9	5	48
A11	Delivery problems in pipe lengths		15	15	9	9	48	1	12	19	11	5	48
A12	Inadequate quality check form contractor and consultant		14	15	11	8	48		13	20	11	4	48
A13	Using unproven technology during construction	1	15	15	11	6	48		10	22	11	5	48

Cont. Table 4.8 Probability & Impact Conducted from Questionnaires for Time

Code	Risk Factors	Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
		Probability of Occurrence						Impact on Tme					
A17	Shortage of construction materials		14	19	9	6	48	1	13	21	10	3	48
A1	Construction method changes		13	17	12	6	48	1	11	20	11	5	48
A8	Shortage of construction equipment’s		12	18	10	8	48	1	15	18	10	4	48
A9	Unsuitable soil placed surrounding sewers		15	15	12	6	48	1	12	19	9	7	48
A16	Poor subcontractors performance		15	17	12	4	48	1	15	21	7	4	48
A14	Complexity in constructing works		15	15	12	6	48	1	13	20	7	7	48
A18	Inadequate contractors experience		16	17	10	5	48		14	19	10	5	48
A19	Unqualified labours		13	19	10	6	48		12	17	14	5	48
A25	Surveys errors		14	18	11	5	48	1	13	23	9	2	48
A26	Structure design incomplete or in error		12	18	13	5	48	1	15	18	10	4	48
A22	Unexpected geotechnical issues		15	19	8	6	48		13	21	9	5	48
A23	Change Inspection requests because of errors		15	22	9	2	48	1	12	21	11	3	48

Cont. Table 4.8 Probability & Impact Conducted from Questionnaires for Time

Code	Risk Factors	Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
		Probability of Occurrence						Impact on Tme					
A24	Inaccurate assumptions on technical issues during planning stage		14	20	10	4	48		14	22	9	3	48
B	Project Management Risk												
B1	Misleading management focus	1	17	19	6	5	48	1	18	17	8	4	48
B2	Lack of communication between contractors		15	18	12	3	48	1	16	16	12	3	48
B3	Inadequate supervision system		16	19	10	3	48		16	20	9	3	48
B4	Poor equipment's productivity and efficiency measures		19	18	7	4	48	3	14	22	7	2	48
B5	Low subcontractor performance	1	15	21	9	2	48	2	17	15	12	2	48
B7	Poor site management in the contractors organization	1	14	22	9	2	48	3	16	19	8	2	48
B10	Poor planning errors	1	16	20	9	2	48	2	15	21	8	2	48
B6	Lack of communication between subcontractors		15	18	11	4	48	2	12	22	10	2	48
B8	Unavailability of subcontractors		14	17	12	5	48	3	13	22	8	2	48
B9	Lack of construction management		15	19	11	3	48	6	17	15	8	2	48

Cont. Table 4.8 Probability & Impact Conducted from Questionnaires for Time

Code	Risk Factors	Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
		Probability of Occurrence						Impact on Tme					
B17	Increase in design errors		14	18	11	5	48	3	16	20	7	2	48
B11	Contractor managerial complexity	1	12	19	11	5	48	1	14	21	10	2	48
B12	Inefficient equipment management	1	14	19	9	5	48		19	18	8	3	48
B14	Low equipment productivity		14	19	11	4	48		17	21	8	2	48
B15	Material no availability		14	21	11	2	48	2	18	15	11	2	48
B19	Low labor productivity		13	18	13	4	48	1	20	16	9	2	48
B20	Contractor material management problem		14	17	12	5	48	2	15	17	12	2	48
C	Financial Risk												
C1	Funds unavailability	1	16	18	9	4	48	1	17	21	7	2	48
C6	Expense Payment	1	17	16	10	4	48		16	20	10	2	48
C7	Legislation change		11	22	11	4	48		18	18	10	2	48
C8	Land Acquisition	1	14	19	11	3	48	1	16	20	8	3	48
C10	Payment delay of completed work		13	22	9	4	48	2	14	18	12	2	48

Cont. Table 4.8 Probability & Impact Conducted from Questionnaires for Time

Code	Risk Factors	Very High	High	Mod.	Low	Very Low	Total	Very High	High	Mod.	Low	Very Low	Total
		Probability of Occurrence						Impact on Tme					
D	Environmental Risk												
D1	Permits delayed		15	20	8	5	48	3	18	16	9	2	48
D2	New information required for permits	1	14	19	10	4	48	3	17	17	9	2	48
F	External Risk												
F3	Delay in shop drawing approval	1	15	22	7	3	48	5	17	16	8	2	48
F4	Third party delay approval		17	18	8	5	48	3	16	17	9	3	48
F5	Change in tax regulations		13	22	9	4	48	3	17	17	8	3	48

4.4.6.1 Risk Score Method for Ranking Risk Factors

Risk Score is so calculated for these risk factors, and is used for ranking them in a descending order see table 4.8.Risk Score is calculated as the product of the average probability and average impact. The average value is calculated by multiplying the total number of participants obtained and the scale percentage. This is done for calculating the average probability and average impact values. Table 4.9 represents ranking risk factors in a descending order. The total number of participants agreed at a certain scale is indicated below together with both the probability and impact scales. **A Guide to the Project Management Body of Knowledge Book (2008).**

Table 4.9 Ranking Risk Factors in Descending Order for Time, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability of Occurrence						Impact on Time						Risk Score
		Very High	High	Mod.	Low	Very Low	AvrgProb (%)	Very High	High	Mod	Low	Very Low	Avrg Imp (%)	
F3	Delay in shop drawing approval	1	15	22	7	3	0.46	5	17	16	8	2	0.56	0.26
B4	Poor equipment’s productivity and efficiency measures		19	18	7	4	0.46	3	14	22	7	2	0.53	0.24
B7	Poor site management in the contractors organization	1	14	22	9	2	0.45	3	16	19	8	2	0.54	0.24
B10	Poor planning errors	1	16	20	9	2	0.46	2	15	21	8	2	0.52	0.24
B1	Misleading management focus	1	17	19	6	5	0.46	1	18	17	8	4	0.51	0.24
A3	Delay in material approval		17	18	10	3	0.43	1	22	16	6	3	0.55	0.23
B9	Lack of construction management		15	19	11	3	0.41	6	17	15	8	2	0.57	0.23
B5	Low subcontractor performance	1	15	21	9	2	0.45	2	17	15	12	2	0.52	0.23
C1	Funds unavailability	1	16	18	9	4	0.44	1	17	21	7	2	0.53	0.23
D1	Permits delayed		15	20	8	5	0.42	3	18	16	9	2	0.54	0.23
F4	Third party delay approval		17	18	8	5	0.43	3	16	17	9	3	0.52	0.23
D2	New information required for permits	1	14	19	10	4	0.42	3	17	17	9	2	0.54	0.22
F5	Change in tax regulations		13	22	9	4	0.41	3	17	17	8	3	0.53	0.22

Cont. Table 4.9 Ranking Risk Factors in Descending Order for Time, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability of Occurrence						Impact on Time						Risk Score
		Very High	High	Mod.	Low	Very Low	AvrgP rob (%)	Very High	High	Mod	Low	Very Low	Avrg Imp (%)	
B15	Material no availability		14	21	11	2	0.42	2	18	15	11	2	0.52	0.22
A5	Inefficient quality control		15	21	9	3	0.43		17	19	8	4	0.50	0.22
C6	Expense Payment	1	17	16	10	4	0.43		16	20	10	2	0.50	0.22
B12	Inefficient equipment management	1	14	19	9	5	0.42		19	18	8	3	0.52	0.21
A23	Change Inspection requests because of errors		15	22	9	2	0.44	1	12	21	11	3	0.48	0.21
C8	Land Acquisition	1	14	19	11	3	0.42	1	16	20	8	3	0.51	0.21
B3	Inadequate supervision system		16	19	10	3	0.43		16	20	9	3	0.50	0.21
B17	Increase in design errors		14	18	11	5	0.39	3	16	20	7	2	0.54	0.21
C10	Payment delay of completed work		13	22	9	4	0.41	2	14	18	12	2	0.50	0.21
B14	Low equipment productivity		14	19	11	4	0.40		17	21	8	2	0.52	0.20
A4	Late delivery of material to site	1	13	20	9	5	0.41	1	14	20	9	4	0.49	0.20
B6	Lack of communication between subcontractors		15	18	11	4	0.40	2	12	22	10	2	0.50	0.20

Cont. Table 4.9 Ranking Risk Factors in Descending Order for Time, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability of Occurrence						Impact on Time						Risk Score
		Very High	High	Mod.	Low	Very Low	AvrgProb (%)	Very High	High	Mod	Low	Very Low	Avrg Imp (%)	
A24	Inaccurate assumptions on technical issues during planning stage		14	20	10	4	0.41		14	22	9	3	0.49	0.20
B2	Lack of communication between contractors		15	18	12	3	0.40	1	16	16	12	3	0.5	0.20
B19	Low labor productivity		13	18	13	4	0.37	1	20	16	9	2	0.53	0.20
A6	Incorrect sewer location during construction		14	18	12	4	0.39	1	17	17	11	2	0.51	0.20
B8	Unavailability of subcontractors		14	17	12	5	0.38	3	13	22	8	2	0.52	0.20
C7	Legislation change		11	22	11	4	0.39		18	18	10	2	0.51	0.20
A16	Poor subcontractors performance		15	17	12	4	0.39	1	15	21	7	4	0.50	0.20
A17	Shortage of construction materials		14	19	9	6	0.40	1	13	21	10	3	0.49	0.19
A25	Surveys errors		14	18	11	5	0.39	1	13	23	9	2	0.50	0.19
B11	Contractor managerial complexity	1	12	19	11	5	0.39	1	14	21	10	2	0.50	0.19
A22	Unexpected geotechnical issues		15	19	8	6	0.41		13	21	9	5	0.47	0.19
B20	Contractor material management problem		14	17	12	5	0.38	2	15	17	12	2	0.51	0.19

Cont. Table 4.9 Ranking Risk Factors in Descending Order for Time, A Guide to the Project Management Body of Knowledge Book (2008)

Code	Risk Factors	Probability of Occurrence						Impact on Time						Risk Score
		Very High	High	Mod.	Low	Very Low	AvrgP rob (%)	Very High	High	Mod	Low	Very Low	Avrg Imp (%)	
A18	Inadequate contractors experience		16	17	10	5	0.41		14	19	10	5	0.47	0.19
A2	Poor water insulation application		16	16	12	4	0.40		13	20	11	4	0.47	0.19
A10	Wrongly installed sewer size		12	19	7	10	0.37		17	17	9	5	0.49	0.18
A7	Poorly installed sewers		13	19	12	4	0.38		13	21	8	6	0.47	0.18
A8	Shortage of construction equipment's		12	18	10	8	0.36	1	15	18	10	4	0.49	0.18
A26	Structure design incomplete or in error		12	18	13	5	0.36	1	15	18	10	4	0.49	0.18
A13	Using unproven technology during construction	1	15	15	11	6	0.39		10	22	11	5	0.45	0.17
A14	Complexity in constructing works		15	15	12	6	0.37	1	13	20	7	7	0.47	0.17
A11	Delivery problems in pipe lengths		15	15	9	9	0.37	1	12	19	11	5	0.47	0.17
A19	Unqualified labours		13	19	10	6	0.38		12	17	14	5	0.45	0.17
A9	Unsuitable soil placed surrounding sewers		15	15	12	6	0.37	1	12	19	9	7	0.46	0.17
A12	Inadequate quality check form contractor and consultant		14	15	11	8	0.36		13	20	11	4	0.47	0.17
A1	Construction method changes		13	17	12	6	0.36	1	11	20	11	5	0.46	0.17

4.4.6.2 Prioritizing Risk Factors

Table 4.10 represents the highest 10 risk factors reflecting the highest risk factors probability to occur which will have the greatest impact on time. Each risk factor is further analyzed quantitatively and responses towards them are monitored in order to be controlled during construction. Ranking is made according to the risk score method. Risk score is calculated as the product of the average probability and the average impact on time objective.

Table 4.10 Prioritized Risk Factors for Time

Code	Risk Factors	Probability of Occurrence						Impact on Time						Risk Score
		Very High	High	Mod.	Low	Very Low	AvrgProb (%)	Very High	High	Mod	Low	Very Low	Avrg Imp (%)	
F3	Delay in shop drawing approval	1	15	22	7	3	0.46	5	17	16	8	2	0.56	0.26
B4	Poor equipment’s productivity and efficiency measures		19	18	7	4	0.46	3	14	22	7	2	0.53	0.24
B7	Poor site management in the contractors organization	1	14	22	9	2	0.45	3	16	19	8	2	0.54	0.24
B10	Poor planning errors	1	16	20	9	2	0.46	2	15	21	8	2	0.52	0.24
B1	Misleading management focus	1	17	19	6	5	0.46	1	18	17	8	4	0.51	0.24
A3	Delay in material approval		17	18	10	3	0.43	1	22	16	6	3	0.55	0.23
B9	Lack of construction management		15	19	11	3	0.41	6	17	15	8	2	0.57	0.23
B5	Low subcontractor performance	1	15	21	9	2	0.45	2	17	15	12	2	0.52	0.23
C1	Funds unavailability	1	16	18	9	4	0.44	1	17	21	7	2	0.53	0.23
D1	Permits delayed		15	20	8	5	0.42	3	18	16	9	2	0.54	0.23

4.4.6.3 Locating Priority Area

Fig 4.4 illustrates results concerned with risk factors of highest risk score which is represented on a bar chart locating area of highest priority used in this study. The chart represents risk factors and their codes on the y-axis against risk score on the x-axis. Risk score method used depends on multiplying the expected probabilities and impacts of each risk factor. The previously identified list of 50 risk factors is ranked. The highest list of 10 risk factors is obtained and is illustrated in Fig 4.4. These factors is the most probably to occur and will have the greatest impact on sewage network projects time objective.

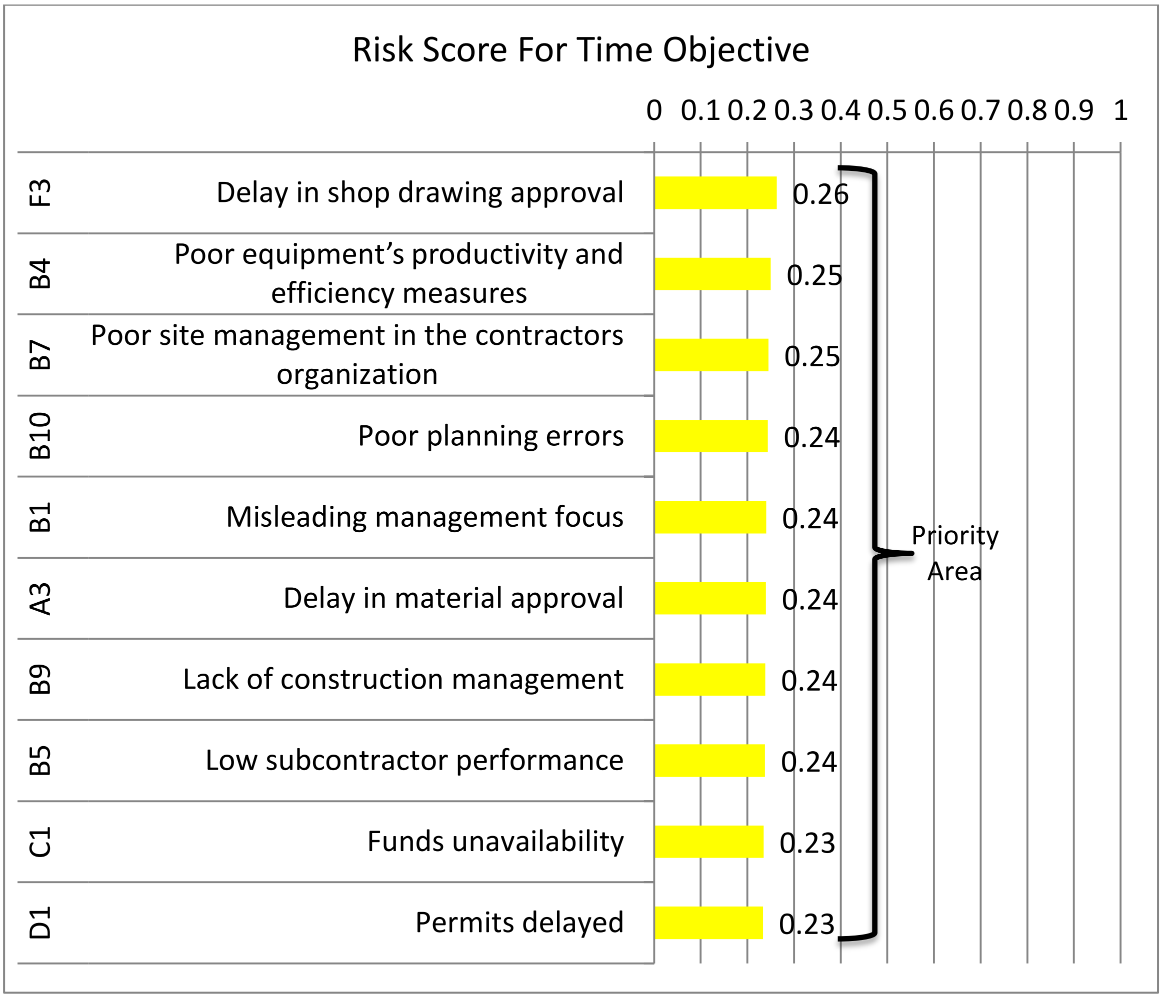


Fig 4.4 Locating Priority Area for Time Objective

4.5 Risk Qualitative Analysis Output

The Risk Register will start during the risk identification stage. The Risk Register is updated with information from Qualitative Risk Analysis stage. Thus an updated risk register is included in the project documents. The updated risk register will include risk factors, risk code and whether risk is an **opportunity or a threat (O/T)**. It also will reflect professionals opinions conducted during this stage about both probability and impact scales of risks. Furthermore, risk score calculated will represent the base which is used for ranking risk factors. The product of probability and impact percentages in table 4.11a and table 4.11b represent the risk score used for ranking the most important factors which is further analyzed in the risk analysis stage. Below represented Table 4.11 a register for cost and Table 4.11 b register for time.

Table 4.11 a Updated Risk Register for Cost.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
B4	T	Poor equipment’s productivity and efficiency measures	Project Management Risk	0.46	0.50	0.232
F3	T	Delay in shop drawing approval	Organizational Risks	0.47	0.48	0.224
B10	T	Poor planning errors	Project Management Risk	0.46	0.48	0.221
C1	T	Funds unavailability	Financial Risks	0.44	0.50	0.220
A3	T	Delay in material approval	Technical Risks	0.44	0.50	0.218
B5	T	Low subcontractor performance	Project Management Risk	0.46	0.48	0.217
F4	T	Third party delay approval	Organizational Risks	0.44	0.50	0.216
B7	T	Poor site management in the contractors organization	Project Management Risk	0.45	0.48	0.215
D1	T	Permits delayed	External Risks	0.43	0.50	0.212
F5	T	Change in tax regulations	Organizational Risks	0.42	0.50	0.211

Cont. Table 4.11 a Updated Risk Register for Cost.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
B1	T	Misleading management focus	Project Management Risk	0.46	0.45	0.211
A23	T	Change Inspection requests because of errors	Technical Risks	0.45	0.47	0.211
A5	T	Inefficient quality control	Technical Risks	0.44	0.48	0.210
C10	T	Payment delay of completed work	Financial Risks	0.42	0.50	0.210
C8	T	Land Acquisition	Financial Risks	0.42	0.49	0.207
A24	T	Inaccurate assumptions on technical issues during planning stage	Technical Risks	0.41	0.50	0.207
B12	T	Inefficient equipment management	Project Management Risk	0.42	0.48	0.204
D2	T	New information required for permits	External Risks	0.42	0.48	0.204
C6	T	Expense Payment	Financial Risks	0.43	0.47	0.202
A18	T	Inadequate contractors experience	Technical Risks	0.41	0.49	0.202
B6	T	Lack of communication between subcontractors	Project Management Risk	0.41	0.50	0.202
B15	T	Material no availability	Project Management Risk	0.42	0.48	0.201
B9	T	Lack of construction management	Project Management Risk	0.42	0.48	0.200
A6	T	Incorrect sewer location during construction	Technical Risks	0.39	0.51	0.199

Cont. Table 4.11 a Updated Risk Register for Cost.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
B14	T	Low equipment productivity	Project Management Risk	0.40	0.49	0.198
A22	T	Unexpected geotechnical issues	Technical Risks	0.42	0.47	0.196
B3	T	Inadequate supervision system	Project Management Risk	0.43	0.45	0.194
A2	T	Poor water insulation application	Technical Risks	0.40	0.48	0.190
A25	T	Surveys errors	Technical Risks	0.39	0.48	0.188
B8	T	Unavailability of subcontractors	Project Management Risk	0.38	0.49	0.188
A4	T	Late delivery of material to site	Technical Risks	0.42	0.45	0.188
A19	T	Unqualified labours	Technical Risks	0.39	0.48	0.188
A7	T	Poorly installed sewers	Technical Risks	0.39	0.48	0.188
C7	T	Legislation change	Financial Risks	0.39	0.48	0.187
A16	T	Poor subcontractors performance	Technical Risks	0.40	0.47	0.187
B2	T	Lack of communication between contractors	Project Management Risk	0.41	0.46	0.186
A17	T	Shortage of construction materials	Technical Risks	0.40	0.46	0.186
B17	T	Increase in design errors	Project Management Risk	0.39	0.47	0.185

Cont. Table 4.11 a Updated Risk Register for Cost.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
B11	T	Contractor managerial complexity	Project Management Risk	0.39	0.47	0.185
A9	T	Unsuitable soil placed surrounding sewers	Technical Risks	0.38	0.49	0.183
B19	T	Low labor productivity	Project Management Risk	0.38	0.48	0.181
A8	T	Shortage of construction equipment's	Technical Risks	0.36	0.50	0.180
B20	T	Contractor material management problem	Project Management Risk	0.38	0.47	0.180
A14	T	Complexity in constructing works	Technical Risks	0.38	0.47	0.177
A10	T	Wrongly installed sewer size	Technical Risks	0.37	0.47	0.174
A13	T	Using unproven technology during construction	Technical Risks	0.39	0.44	0.174
A26	T	Structure design incomplete or in error	Technical Risks	0.36	0.47	0.171
A1	T	Construction method changes	Technical Risks	0.37	0.46	0.168
A12	T	Inadequate quality check form contractor and consultant	Technical Risks	0.36	0.46	0.167
A11	T	Delivery problems in pipe lengths	Technical Risks	0.38	0.43	0.163

Table 4.11 b Updated Risk Register for Time.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
F3	T	Delay in shop drawing approval	Organizational Risks	0.46	0.56	0.26
B4	T	Poor equipment's productivity and efficiency measures	Project Management Risk	0.46	0.53	0.24
B7	T	Poor site management in the contractors organization	Project Management Risk	0.45	0.54	0.24
B10	T	Poor planning errors	Project Management Risk	0.46	0.52	0.24
B1	T	Misleading management focus	Project Management Risk	0.46	0.51	0.24
A3	T	Delay in material approval	Technical Risks	0.43	0.55	0.23
B9	T	Lack of construction management	Project Management Risk	0.41	0.57	0.23
B5	T	Low subcontractor performance	Project Management Risk	0.45	0.52	0.23
C1	T	Funds unavailability	Financial Risks	0.44	0.53	0.23
D1	T	Permits delayed	External Risks	0.42	0.54	0.23
F4	T	Third party delay approval	Organizational Risks	0.43	0.52	0.23
D2	T	New information required for permits	External Risks	0.42	0.54	0.22
F5	T	Change in tax regulations	Organizational Risks	0.41	0.53	0.22
B15	T	Material no availability	Project Management Risk	0.42	0.52	0.22

Cont. Table 4.11 b Updated Risk Register for Time.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
A5	T	Inefficient quality control	Technical Risks	0.43	0.50	0.22
C6	T	Expense Payment	Financial Risks	0.43	0.50	0.22
B12	T	Inefficient equipment management	Project Management Risk	0.42	0.52	0.21
A23	T	Change Inspection requests because of errors	Technical Risks	0.44	0.48	0.21
C8	T	Land Acquisition	Financial Risks	0.42	0.51	0.21
B3	T	Inadequate supervision system	Project Management Risk	0.43	0.50	0.21
B17	T	Increase in design errors	Project Management Risk	0.39	0.54	0.21
C10	T	Payment delay of completed work	Financial Risks	0.41	0.50	0.21
B14	T	Low equipment productivity	Project Management Risk	0.40	0.52	0.20
A4	T	Late delivery of material to site	Technical Risks	0.41	0.49	0.20
B6	T	Lack of communication between subcontractors	Project Management Risk	0.40	0.50	0.20
A24	T	Inaccurate assumptions on technical issues during planning stage	Technical Risks	0.41	0.49	0.20
B2	T	Lack of communication between contractors	Project Management Risk	0.40	0.5	0.20

Cont. Table 4.11 b Updated Risk Register for Time.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
B19	T	Low labor productivity	Project Management Risk	0.37	0.53	0.20
A6	T	Incorrect sewer location during construction	Technical Risks	0.39	0.51	0.20
B8	T	Unavailability of subcontractors	Project Management Risk	0.38	0.52	0.20
C7	T	Legislation change	Financial Risks	0.39	0.51	0.20
A16	T	Poor subcontractors performance	Technical Risks	0.39	0.50	0.20
A17	T	Shortage of construction materials	Technical Risks	0.40	0.49	0.19
A25	T	Surveys errors	Technical Risks	0.39	0.50	0.19
B11	T	Contractor managerial complexity	Project Management Risk	0.39	0.50	0.19
A22	T	Unexpected geotechnical issues	Technical Risks	0.41	0.47	0.19
B20	T	Contractor material management problem	Project Management Risk	0.38	0.51	0.19
A18	T	Inadequate contractors experience	Technical Risks	0.41	0.47	0.19
A2	T	Poor water insulation application	Technical Risks	0.40	0.47	0.19
A10	T	Wrongly installed sewer size	Technical Risks	0.37	0.49	0.18

Cont. Table 4.11 b Updated Risk Register for Time.

Risk ID	T/O	Risk Title	Risk Category	Probability (%)	Impact (%)	Risk Score
A7	T	Poorly installed sewers	Technical Risks	0.38	0.47	0.18
A8	T	Shortage of construction equipment's	Technical Risks	0.36	0.49	0.18
A26	T	Structure design incomplete or in error	Technical Risks	0.36	0.49	0.18
A13	T	Using unproven technology during construction	Technical Risks	0.39	0.45	0.17
A14	T	Complexity in constructing works	Technical Risks	0.37	0.47	0.17
A11	T	Delivery problems in pipe lengths	Technical Risks	0.37	0.47	0.17
A19	T	Unqualified labours	Technical Risks	0.38	0.45	0.17
A9	T	Unsuitable soil placed surrounding sewers	Technical Risks	0.37	0.46	0.17
A12	T	Inadequate quality check form contractor and consultant	Technical Risks	0.36	0.47	0.17
A1	T	Construction method changes	Technical Risks	0.36	0.46	0.17

4.6 Conclusion:-

This chapter represents the second stage of risk management which is the qualitative risk analysis process. The output of risk identification process is the risk register which includes identified risk factors and their categorized group. Furthermore risk register is used as an input of qualitative risk analysis process. Technique of checklist analysis is carried through a site survey. This survey is carried during sewage networks construction for two case studies. Questionnaire is used to conduct expert's opinions about degree of both probability of occurrence and impact on time and/or cost.

Results of this survey are represented in different forms through this chapter. First the total number of participants for each degree of importance for both probability and impact is conducted. Risk factors are then ranked according to their risk score in a descending order. The aim of the rank is to obtain the most important risk factors which are further analyzed quantitatively. Risk score is the product of average probability and impact. Results are represented on a bar chart, were the highest 10 risk factors are obtained. Most important risk factors affecting sewage networks construction are thus obtained which has impact on cost and time of project.

The output of this process is an updated risk register. It concludes the qualitative risk process in a simple format. Risk factors probability of occurrence, Impact on cost and/or time and describing risk as either threat or an opportunity is clearly represented in this updated risk register. Two Risk registers are made in this chapter for cost and for time as the two project objectives studied in this thesis. Furthermore these updated risk registers are analyzed quantitatively using a case study of a sewage network project in Egypt and mitigations are added.