A Risk and Cost Management Model for changes during the construction phase of a Civil Engineering Project

by
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ABSTRACT

The construction project environment is dynamic and prone to change. Project change can be defined as any event that alters a project's original scope, execution time or the cost of the works. Improper management of the projects' changes could therefore adversely impact on the actual cost and duration of the project which may lead to project cost overruns and even claims and legal disputes. During the construction phase of a project, change affects every aspect of productivity – the planned schedules and deadlines, work methodology, resource procurement, as well as the budget and thus it could prevent the achievement of the project objectives. A project manager, therefore, wants to limit the number of change to a project.

However, during a construction project there may be quite a number of changes. Managing a construction project is difficult, in that all the relevant information is rarely available at the initial stage of a project to enable one to plan and design the project accurately and make the best possible decisions. As information becomes available during the construction phase of the project, it can lead to various changes. Design errors or variations, unforeseen site conditions and vagueness in the original scope are but some of the reasons for change.

No matter the size of the change, each alteration to the works has a cost, time and risk implication. Due to tight time constraints on most projects, every change requires quick, robust decision making, so as not to delay the project, which therefore results in changes not being comprehensively evaluated. Decisions are often made on intuition or experience, without an assessment of the risks involved or the influence on the cost of the project and without applying well-known project management techniques.

The aim of this research was to determine what a change management process for a civil engineering project should look like, specifically the cost and risk management of changes. It investigated the current state of change management of construction projects in practice, by doing a case study and various interviews with project managers. Based on the findings of the research and the industry requirements, a model was developed for managing the costs and risks of changes. The Model was validated by means of an expert evaluation review.

The change management model developed as part of this thesis can be used to analyse the cost, time and quality impact of the change, and to do a detailed risk assessment. The Model also reviews the proposed change in order to determine whether the change is necessary. It is a generic tool that can be used by engineers and their project team to enhance the management of changes that happens during the construction phase of a project for any civil construction project.

OPSOMMING

Die konstruksie omgewing is dinamies en geneig tot verandering. Projek verandering kan gedefinieer word as enige gebeurtenis wat die projek se aanvanklike omvang verander of lei to verlenging van die tydsduur of vermeerdering van die koste van die projek. Wanbestuur van projek veranderinge kan ‘n nadelige impak op die projek kostes en tydsduur hê wat kan lei tot oorskryding van die begroting en selfs eise en regsdispute. Verandering kan elke aspek van produktiwiteit tydens die konstruksie fase van ‘n projek affekteer. Dit affekteer die beplande skedules, spertye, werk metodologie, hulpbron bestuur, asook die begroting. Dus kan dit verhoed dat die projek doelwitte bereik word. ‘n Projek bestuurder wil daarom die hoeveelheid en omvang van veranderinge beperk.

‘n Konstruksie projek kan egter heelwat veranderinge ondergaan. Om ‘n konstruksie projek te bestuur is moeilik aangesien al die relevante informasie selde beskikbaar is tydens die begin fases van ‘n projek wat nodig is om die beplanning en ontwerp van die projek so akuraat moontlik te doen en die regte besluite te neem. Soos informasie beskikbaar raak tydens die konstruksie fase van die projek, lei dit dikwels to verskeie veranderinge. Ontwerp foute of variasies, onvoorsiene terrein toestande en onduidelikheid oor die projek omvang is van die redes vir veranderinge.

Ongeag die grootte van die verandering het elke wysiging tot die projek ‘n koste, tyd en riskiko implikasie. As gevolge van tydsbeperkinge vereis elke verandering vinnige en kragtige besluitneming om sodoende nie die projek te vertraag nie. Dit lei daartoe dat veranderinge nie omvattend geëvalueer word nie. Besluite word dikwels geneem op intuïsie of ervaring, sonder 'n beoordeling van die risiko's wat betrokke is of die bepaling van die invloed op die koste van die projek, en sonder die toepassing van erkende projek bestuur tegnieke.

Die doel van hierdie navorsing was om vas te stel hoe 'n verandering bestuur proses moet lyk vir ‘n siviele ingenieurswese projek, spesifiek die koste en risiko bestuur van die verandering. Die huidige stand van verandering bestuur van konstruksie projekte in die praktyk is ondersoek deur middel van 'n gevallestudie en verskeie onderhoude met die projek bestuurders. 'n Model is ontwikkel vir die bestuur van die koste en risiko's van veranderinge gebaseer op die bevindinge van die navorsing en ook die vereistes van die bedryf. Die model is getoets met behulp van evaluering deur professionele ingenieurs.

Die verandering bestuur model wat ontwikkel is as deel van hierdie proefskrif kan gebruik word om die koste, tyd en kwaliteit impak van ‘n verandering te analiseer, asook om 'n omvattende risiko assessering te doen. Die model hersien ook die voorgestelde verandering om te bepaal of die verandering nodig is. Dit is 'n generiese hulpmiddel wat deur ingenieurs en hul projek span gebruik kan word vir die bestuur van die veranderinge wat tydens die konstruksie fase van siviele projekte plaasvind.

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1 INTRODUCTION

1.1 BACKGROUND

"And the day came when
the risk to remain tight in a bud
was more painful than
the risk it took to blossom."
Anaïs Nin

One of the primary ways in which modern societies generate new value is through projects that create physical assets, such as factories, commercial buildings, hospitals, schools and highways, which can then be exploited to achieve social and economic ends. Most of these assets are created through construction projects. As the size and complexity of construction projects increase, the necessity for effective project management in order to meet the expectations of time, quality and cost successfully is intensified [1].

However, managing a construction project is difficult because at the initial stage of a project the information required to plan and design the project accurately and make the best possible decisions is rarely available. In the words of Graham M. Winch [1], "management of construction projects is a problem of information, or rather, a problem in the lack of information required for decision making." As information, such as the ground conditions, becomes available during the construction phase of the project, it can lead to various changes.

There are several reasons for project change. Some of them, as defined by C.W Ibbs in his paper on the 'Quantitative impacts of project change' [2], are as follows:

- Design errors or omissions
- Design variations
- Unforeseen site conditions
- Uncertainty due to vagueness in the original scope [3]

During a construction project there may be quite a number of these changes. No matter the size of the change, each alteration to the works has a cost, time and risk implication. Due to tight time constraints on most projects, every change requires quick, robust decision making, so as to not to delay the project, which therefore results in changes not being comprehensively evaluated. Decisions are often made on intuition or experience, without an assessment of the risks involved or the influence on the cost of the project and without applying well-known project management techniques. This is largely due to time constraints [4]. In a recent South African survey it was found that project risk management practices are not yet widely used in South Africa in the engineering and construction environment [5].

Within the engineering and construction environment, changes to the works can have a significant influence on both the cost and risk management of a project. It is therefore no surprise that in his study C.W Ibbs concluded that as the number of changes increases, cost will also increase [2].

Change management, as it is commonly applied in practice, focuses on managing changes in a reactive way. Proactive change management is seldom implemented [2]. A project manager needs to be able to effectively manage the cost and risk impacts of all changes to the scope of the work so as to successfully complete a construction project within the project constraints. To manage projects more effectively, a transformation of the way in which project managers deal with project change is needed, as the epigraph given at the start of this section illustrates. A project manager must understand the implications of changes and manage these changes in such a way that all the project objectives are obtained within time, budget and quality constraints.

For this purpose, a change management model was developed as part of this thesis as a tool that can be used by engineers and their project teams to enhance the management of changes that occurs during the construction phase of a project. It is a generic tool that can be used for any civil construction project that is managed by the engineers on behalf of a client.

To be able to generate an effective and generic cost and risk management model by which changes to the works can be evaluated, the researcher had to understand the environment in which such a model would be applied. This knowledge was gained through the use of two research methods, namely, a case study of a civil engineering construction project, and interviews with project managers within the field of civil engineering. A literature study provided the knowledge on basic project management principles, as well as the applicable values and techniques for change and risk management.

The main purpose of the model is to analyse the impact of the change on cost, time and quality, and to do a detailed risk assessment. The model also reviews the proposed change in order to determine whether it is necessary. Once the change has been found to be appropriate, and its impact has been determined, the change has to be authorised and then recorded for future reference.

The completed model was evaluated by professional engineers in the marketplace, who manages construction projects. They were given a presentation on how the model works and what results it aims to provide the engineer and asked to complete an evaluation form. Their feedback was used to validate the model.

In summary, this thesis sought to determine what a change management process should look like, specifically the cost and risk management of changes. It investigated the current state of change management in practice, by doing a case study and various interviews with project managers. One of the aims of this thesis was to develop a model for managing the costs and risks of changes, based on theoretical and industry requirements. And lastly the thesis evaluated the success of the model in adding value to the change management process.

1.2 The Research Problem

Literature emphasizes the necessity of a systematic change management process; however, it is unclear if this is being applied in practice. The first objective of the thesis, therefore, is to gain a thorough understanding of how change management is being applied in practice, the types of change that must be managed, as well as the impact of the changes on the project. This included the identification of current change management shortcomings, as well as improvements that can be made.

Change management in practice lacks a structured process. Instead, project managers seem to base decision on their experience and engineering intuition, rather than following a systematic approach or thorough impact analysis and risk assessment. This is largely due to time constraints [4]. There is a need for a structured process by which the changes to the works during the construction phase can be evaluated in terms of the cost to the project as well as the associated risk. Project managers cannot make an informed decision regarding the way forward, without knowing what the effect of the change will be on the project. Changes that are mismanaged could affect the project managers' ability to complete a project successfully.

The related research questions that the research will aim to answer are as follows:

- How should changes to the works be managed for construction projects?
- What are cost and risk management?
- How can interviews and case studies be used in research?
- What impact can changes have on a project?
- What are the reasons for changes?
- How are the costs and risks of changes managed in practice by civil consulting engineers?
- What are the current difficulties with cost and risk management of changes?
- Are the current methods of managing changes effective and can they be improved?
- Is there a need for a model by which the effects of changes in terms of cost and risk can be determined?
- If there is, what are the model requirements?
- What would such a model look like and how can it be used?
- Would the model add value to the change management process as part of the project management of a civil construction project?
- Is the model time effective, practical and useful?
- What are the shortcomings of the model?

1.3 The Research Hypothesis

By doing a case study of a construction project as well as various interviews with practicing project managers, an understanding will be gained of the way in which changes are currently managed on construction projects, as well as their potential impact on a project.

Management of changes during the construction phase of a civil engineering project could be improved by the use of a generic change management model. This model should determine the cost and risk impact of the proposed change. This information will enable the project manager to make better informed decisions, so that the project can be completed within the project constraints.

1.4 Word Meanings

'Client' means any person for whom construction work is performed;

'Engineer' is the company or person appointed by the client to design and manage the lifecycle of the project and who has to protect the client's interest. For civil construction projects, the engineer is often the project manager.

'Contractor' means the company or person or partnership whose offer to construct the works has been accepted by or on behalf of the client and who performs construction work; and this includes principal contractors.

'Stakeholder' is any company or person who is part of the creation of the project or who is affected by the project in any way.

'Construction work' means any work in connection with:

(a) the erection, maintenance, alteration, renovation, repair, demolition or dismantling of or addition to a building or any similar structure;

(b) the installation, erection, dismantling or maintenance of a fixed plant where such work includes the risk of a person falling;

(c) the construction, maintenance, demolition or dismantling of any bridge, dam, canal, road, railway, runway, sewer or water reticulation system or any similar civil engineering structure; or

(d) the moving of earth, clearing of land, making of an excavation, piling, or any similar type of work;

'Design' in relation to any structure includes drawings, calculations, design details and specifications.

'Excavation work' means the making of any man-made cavity, trench, pit or depression formed by cutting, digging or scooping.

'User' is used for the person using the change management model that has been developed as part of this thesis.

'*Contingencies*' is the reserve or backup money in the contract used to fund unanticipated changes or risks that materialise. This amount is allocated based on a percentage of the budgeted contract value and is usually in the order of 10%.

2 LITERATURE STUDY

2.1 CHAPTER INTRODUCTION

Construction project environments are dynamic and prone to change. Changes that occur could have a significant impact on the project and its objectives. Change is also unpredictable and therefore project managers need to understand its implications and react appropriately [6].

In order to create a management model by which changes to the works can be assessed and managed, an understanding of project management is necessary. This literature review is about the general principles of project management, but focuses more specifically on the theory and application of change and risk management.

A case study and various interviews with project managers were two of the research methods used for this thesis in order to gather data. Thus, this literature review also looks at the theory and application of these two research methods.

Most of the consulting engineering companies that manage construction projects that were interviewed for this thesis, are ISO 9001:2008 approved. Since the aim of this thesis is to develop a workable model for construction change management, the requirements of that standard also bears relevance to this thesis and are discussed in section 2.2.4.

Chapter Questions

- How should changes to the works be managed for construction projects?
- What impact can changes have on a project?
- What are cost and risk management?
- How can interviews and case studies be used in research?

2.2 Literature Review

2.2.1 Project Management in Construction

2.2.1.1 Introduction

Humankind has been involved in projects since the beginning of recorded history. Construction projects specifically gave mankind notable structures that are monuments to peoples' creativity and intellect. Structures such as the Great Pyramid of Giza, the great wall of China, the Colosseum in Rome, the Golden Gate Bridge, the Taj Mahal and the Burj Khalifa in Dubai, to name but a few, have become architectural landmarks. These projects all came to completion with much planning and organising. As technology advances, projects become increasingly complex and require greater management skills. Project management constantly evolves.

Even though the managing of projects is as ancient as the pyramids, as a distinct discipline it is quite new. It was not until the 1950s that project management tools and techniques were systematically applied to complex engineering projects and project management emerged as a profession. Henry Gantt, after whom the Gantt chart is named, and Henri Fayol, who established the five management functions which form the foundation of the body of knowledge associated with project and programme management, are two of the patriarchs of project management. Other important advances in the modern project management era are that of the "Critical Path Method" (CPM) that was developed by DuPont Corporation in a joint venture with Remington Rand Corporation. The "Program Evaluation and Review Technique" (better known as PERT) was developed by Booz Allen Hamilton as part of the Polaris missile submarine program for the US Navy (in conjunction with the Lockheed Corporation) [7].

Project Management is an ever evolving field which empowers those responsible to be able to complete a project successfully. This section looks at the core principles of project management that are relevant to this thesis.

2.2.1.2 Important Concepts and Definitions

In most handbooks on project management, a project is defined as an activity or a series of activities which has a specific unique objective, with a definite start and end date, limited funding and resources and which involves multiple disciplines within an organisation [8] [9].

Based on the PMBOK® Guide[1], 4th Edition [10], project management can be defined as the knowledge, skills, tools and techniques applied to meet project requirements. It requires the effective management of appropriate processes. A process can be defined as a series of interrelated activities performed in order to meet a specific objective. Each process has its own techniques and tools, and certain inputs and outputs, for achieving the predetermined result. The PMBOK® Guide states that project management involves the five process groups seen in Figure 2.1 [8] [10].

[1] The Project Management Body of Knowledge, PMBOK®, was first published by the Project Management Institute (PMI) in 1987 with the purpose of standardising generally accepted project management information and practices [59].

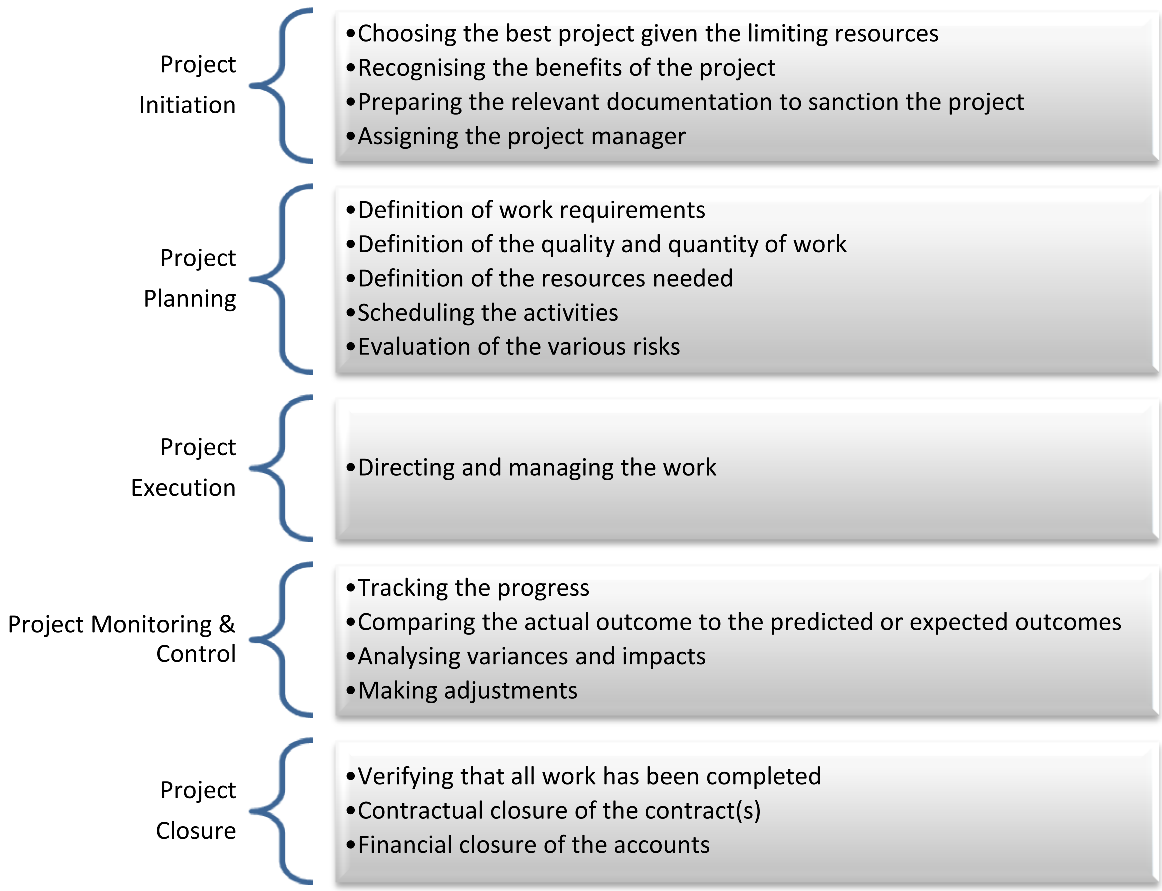

Figure 2.1: Project management process groups

Of the five project management process groups in Figure 2.1, '*project execution*', as well as '*project monitoring and control*' are the two process groups relevant to managing the construction phase of a project. These process groups represent a group of procedures which are executed in order to successfully complete a project.

The execution process group, as illustrated by Figure 2.2, comprises those processes, as defined in the project management plan, which satisfy the project specification. It involves the coordination of people and resources, as well as the integration of project activities, in order to successfully execute the project and achieve its objectives. The execution phase of a project may involve various changes to activities, such as changes in its duration. Changes may also cause unanticipated risks, which must be analysed and mitigated appropriately. The following project management processes are part of this process group [10]:

- Direct and manage project execution
- Perform quality assurance
- Acquire project team
- Develop project team
- Manage project team
- Distribute Information
- Manage stakeholder expectations
- Conduct Procurements

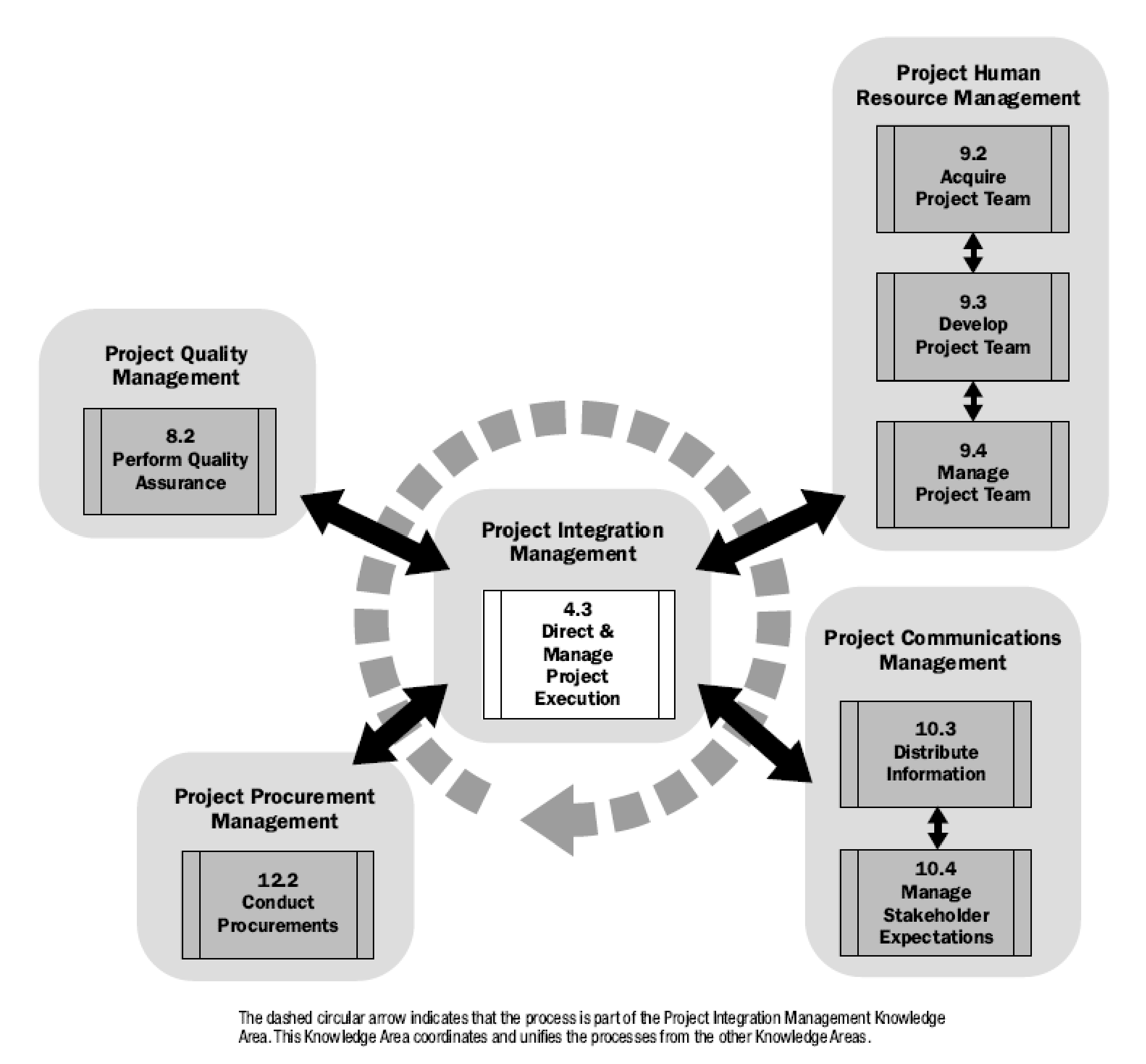

Figure 2.2: Executing process group [10]

The procedures that form part of the monitoring and controlling process group (see Figure 2.3) are necessary in order to monitor, review and regulate the progress and performance of the entire project. Part of the process is to identify any changes required in the project plan and initiate them, but also to identify unintended variances and to control those changes appropriately. Continuous monitoring provides the project team with insight into the health of the project and identifies any areas requiring additional attention. The following project management processes are part of this process group [10]:

- Monitor and control project work
- Perform integrated change control
- Verify scope
- Control scope
- Control schedule
- Control costs
- Perform quality control
- Report performance
- Monitor and control risks

- Administer procurements

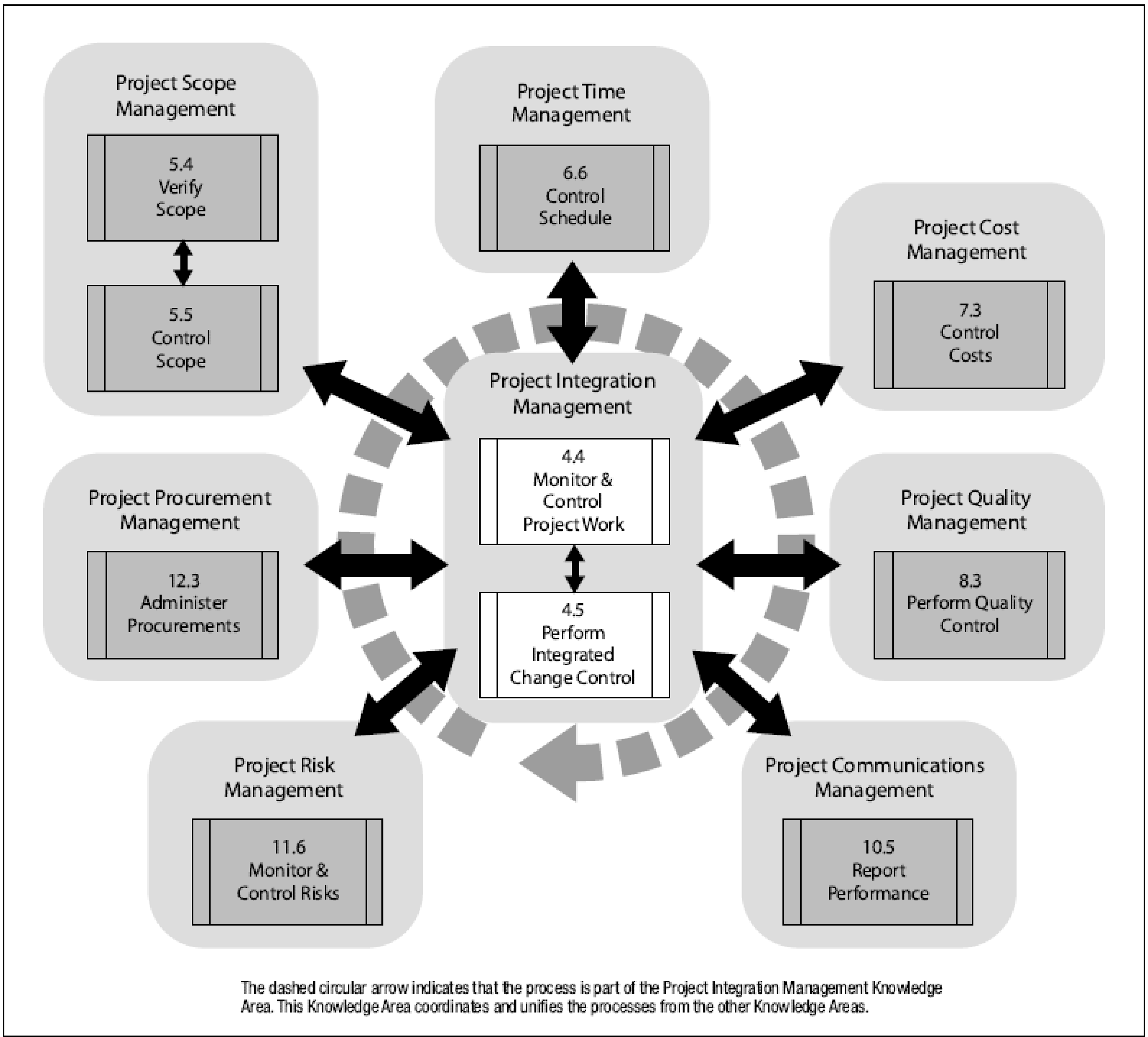

Figure 2.3: Monitoring and controlling process group [10]

The PMBOK® Guide includes the following nine knowledge areas that are expected to be the focus areas of project managers when managing a project [10]:

- Project integration management
- Project scope management
- Project time management
- Project cost management
- Project quality management
- Project human resources management
- Project communications management
- Project risk management
- Project procurement management

Of these nine knowledge areas, project integration, time, cost, quality and risk management all bear relevance to this thesis. Integrated change control is part of the project integration management knowledge area. It is the process of reviewing, approving, documenting and managing all change requests in order to attain the project deliverables. Changes can be requested by any stakeholder and should be recorded in writing and reviewed according to the change management system. The following are important when managing project change [10]:

- All proposed changes should be appropriately analysed.
- A change request has to be either approved or rejected by the predetermined authority.
- The impact of changes on the project should be determined and documented.
- The change should be communicated to all relevant stakeholders.
- Only assessed and approved changes should be incorporated into the project plan and works.
- Change management should be quick and effective, as slow decisions can adversely affect the time, cost or feasibility of the change.
- All approved changes should be monitored and communicated to the project team.

Controlling costs is a process that is part of the cost management knowledge area. The purpose of performing cost control is to monitor the project budget and manage any changes to its baseline, which involves comparing actual spent costs to the works accomplished and identifying any unintended variances [10].

The purpose of understanding the five process groups and each knowledge area, is to effectively manage a project in order to attain the project objectives, which are [8]:

- To complete the project within the allocated timeframe
- To complete the project within the budget allowed for the works
- To complete the project to the required specification and/or quality
- With effective and efficient use of the available resources
- To meet the expectations of the client
- With the minimum or mutually agreed upon scope changes

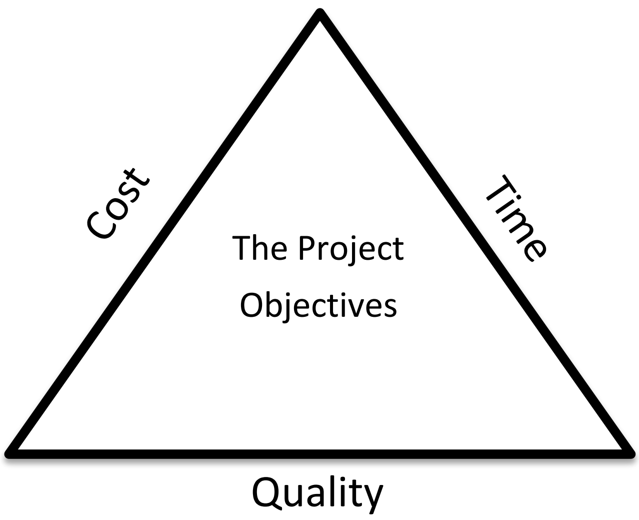

Figure 2.4: The Iron Triangle

The first three objectives on the list given above, namely to finish within the allocated time, cost and quality, are often called the iron triangle, as illustrated by Figure 2.4. As, for example, the cost of a project increases, represented by the length of one side of the triangle, it impacts both the quality and the time constraints of the project. For many years these were the only criteria by which the success of a project was measured [11].

However, all three of these objectives have to be managed within the available resources and to satisfy the customer expectations. Therefore Figure 2.5, which adds these two objectives to the iron triangle, is important to note.

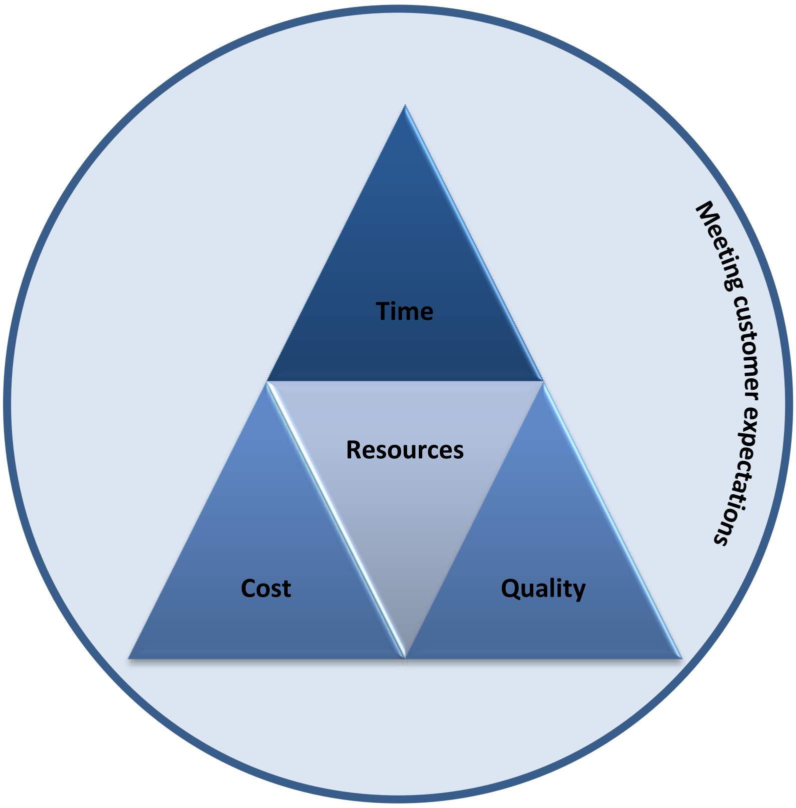

Figure 2.5: Project objectives

If customer expectations are not part of the success measurements of a project, the project may be completed within time and budget and to the correct quality, but with performance gaps. R. Atkinson defined these project performance gaps as a failure to achieve the criteria that customers and users deem as important for project success, and are listed below [11]:

- Failure to achieve the actual project outcome required by the customer
- Failure to achieve the desired project outcome as described by the customer
- Failure to achieve the actual project outcome delivered to the customer
- Failure to achieve the project outcome as perceived by the customer
- Failure to achieve the desired project outcome as perceived by the project team
- Failure to achieve the specific project plan developed by the project team

The last item in the list of project objectives – to complete the project with the least number, or within a mutually agreed upon scope, of changes – is also important. Scope changes to a project have the potential of ruining a project completely. However, changes to the scope of the work, or certain aspects of the work, are inevitable. It is therefore essential that these changes are kept to a minimum. In section 2.2.2 change management is discussed in further detail.

2.2.1.3 Project Stakeholders

On any given project there are various stakeholders. Those that play the most important roles are:

- Client or Project Sponsor
- Project Manager
- Design Team
- The Contractor(s)
- The End User

The project sponsor or client sets the project objectives. A client initiates a project because it would benefit their organization or, in the case of public services, it creates value for the community that it serves. Once the project has been completed, the client assumes ownership of the project outcome and is responsible for the operation and maintenance thereof [46].

Proper and effective project management is essential to the success of any project and thus the choice of project manager is crucial to the project's success. The project manager is responsible for achieving the project objectives set by the client. This requires a lot of planning, the appropriate knowledge, the ability to manage and motivate people and good communication skills [12].

The design team comprises all those involved in the design of the project as well as the monitoring and control of the execution phase. Construction projects usually have a multi-disciplinary design team, as construction involves various disciplines. For example, the project team for the design and construction of a new water treatment plant would consist of some of the following team members:

- Civil Engineer (responsible for the design for the entire infrastructure such as roads, water, wastewater and stormwater pipes etc.)
- Structural Engineer (responsible for the design and specifications of the concrete structures, buildings, tanks etc.)
- Chemical Engineer (responsible for the treatment process design, specification etc.)
- Mechanical Engineer (responsible for the equipment design, specification etc.)
- Electrical Engineer (responsible for the electrical design, specification etc.)
- Environmental Practitioner (responsible for the Environmental Impact Assessment etc.)

The Contractor(s) are those responsible to make the design specifications and drawings a reality. The end user is the one who will eventually use what the rest of the stakeholders have created by means of the project.

It is extremely important for all stakeholders to have the same knowledge and understanding of the project's objectives and its expected outcomes. If this is not the case, a situation might result that resembles the well-known cartoon depicted in Figure 2.6. An effective communication strategy is thus important.

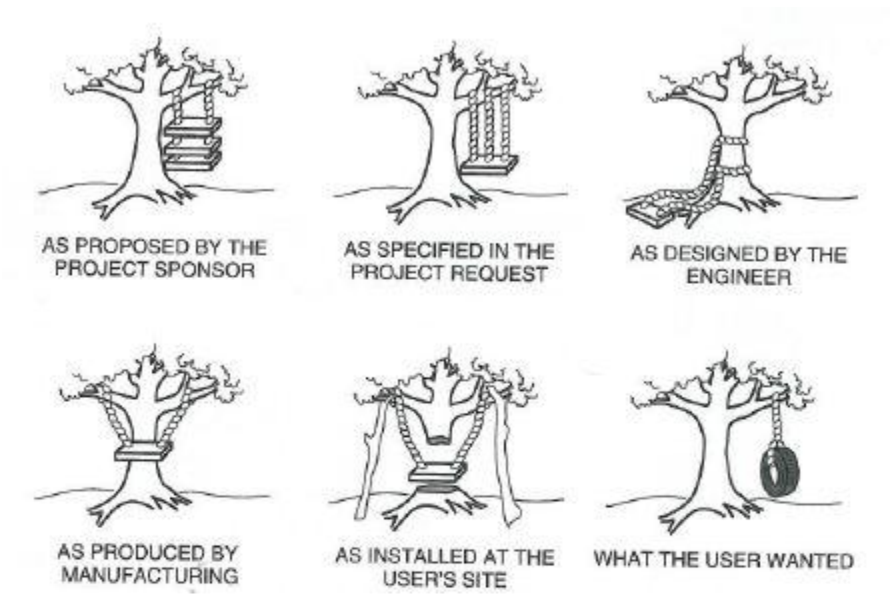

Figure 2.6: A breakdown in communication

2.2.1.4 Project Management Methods and Techniques

2.2.1.4a Project Plan

Planning a project and then executing those plans are the most important responsibilities of a project manager. It is also his responsibility to integrate the various plans of all involved in the project design into an overall project plan that is relevant to the whole team. The purpose of the project plan is to set up policies, procedures and programmes that will enable the project team to achieve the project objectives. For project planning to be successful and effective, it needs to be [8]:

- Systematic
- Disciplined through reviews and controls
- Capable of accepting multifunctional inputs
- Flexible
- An iterative process throughout the project lifecycle

However, it is not possible to prepare a project plan without the appropriate information that needs to be gathered during the project initiation phase. The following information is required [8]:

- The statement of work (SOW)
- The project specifications
- The milestone schedule
- The work breakdown structure (WBS)

A statement of work (SOW) is a clear and narrative description of the work that needs to be done for the project. It should clearly describe the project objectives, give a description of the works that need to be accomplished, clearly indicate any budget constraints, as well as include a schedule and the necessary specifications. A misinterpretation of the SOW very often leads to scope creep. Scope creep is the enlargement of the initial project scope.

The function of a work breakdown structure (WBS) is to stipulate the work necessary to achieve the objectives as stated in the SOW. This is then used for drawing up schedules and allocating responsibilities. It involves the process of structuring of the works into various smaller task and work elements. This is done by sorting the work according to the main work categories, then dividing them into subcategories which, in turn, are then subdivided etc, until the work is broken down into elements that are clearly defined and can be budgeted, scheduled and controlled. The scope and complexity of the work is reduced as the work is broken down level by level. The most common work breakdown structure is the six-level indented structure shown in Table 2.1:

Table 2.1: Levels of the work breakdown structure (WBS)

	Level	Description
Managerial Levels	1	Total Project
	2	Categories
	3	Tasks
Technical Levels	4	Subtask
	5	Work Package
	6	Level of Effort

Once all the relevant information and documentation are available, the project plan can be generated. The project plan must clearly define what needs to be done, the target date and the person responsible for executing the task. The nine major components of the planning phase are as shown in Table 2.2 [8]:

Table 2.2: Nine components of the planning phase

OBJECTIVE: A goal, target or quota to be achieved by a certain time within a certain specification	**PROGRAM:** The strategy or actions that must be followed in order to achieve the objective	**SCHEDULE:** A plan that indicates the various activities with their time and resource allocations
BUDGET: The planned expenditure required to achieve the objectives	**FORECAST:** A projection of the timeline of the project	**ORGANISATION:** The design of the project team and their responsibilities
POLICY: A general guide for decision making and individual actions	**PROCEDURE:** A detailed method for carrying out a policy	**STANDARD:** The acceptable level of performance required

These nine processes are applied to generate a project master plan. The purpose of the project master plan is to guide the project team in the execution of the project. It may be revised when needed and is used to measure progress against in the execution phase of the project. The contents of a project master plan are shown in Table 2.3 [8] [9]:

Table 2.3: Contents of a project master plan

I. Management Summary	• An overview of the project, its objectives, requirements, possible problem areas and contingency plans, as well as a master schedule with major milestones
II. Management and Organization Section	• Key personnel and authority relationships • Team requirements in terms of skills, expertise, and strategies to obtain them • Training and development requirements and plans
III. Technical Section	• Scope of Work • Work Breakdown • Responsibility Assignments • Project Schedules • Budgets • Change Control Plan • Quality and Testing Plan • Risk Management Plan • Health and Safety Plan • Environment Management Plan • Work Review Plan • Documentation • Implimentation

A great illustration of project integration is given in Figure 2.7, which is an example of how all project facets and planning work together.

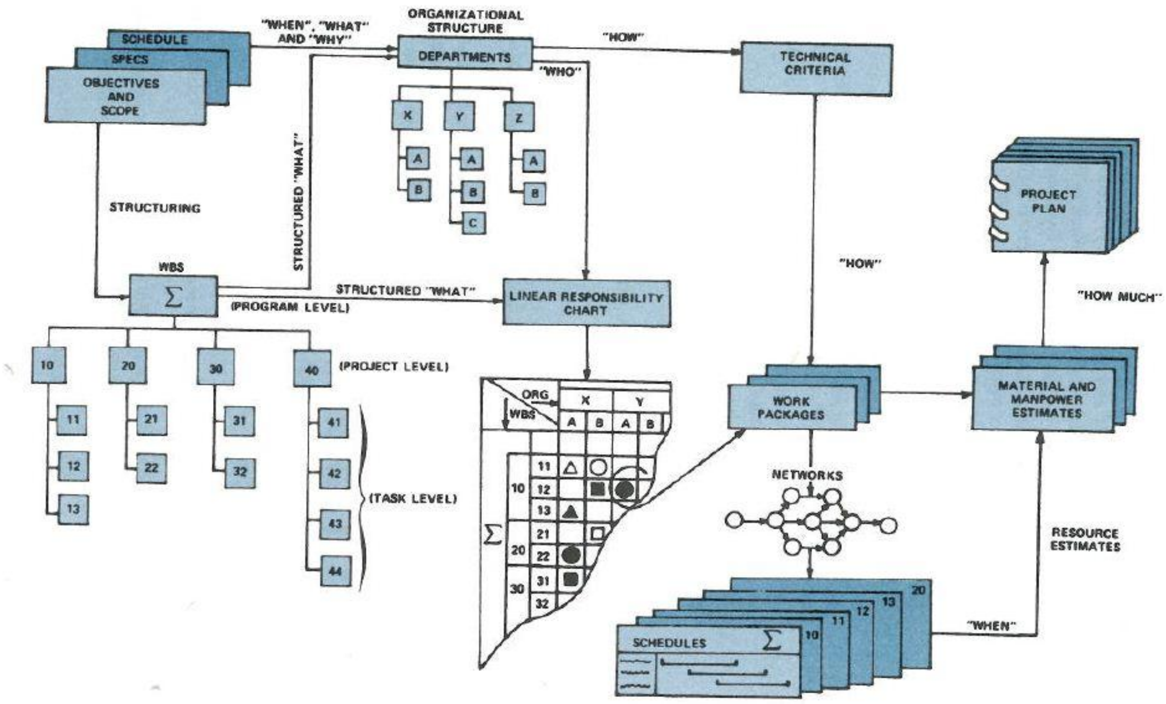

Figure 2.7: Project planning **[8]**

2.2.1.4b Scheduling Techniques

The scheduling of work elements is important in the planning phase of the project, as it is the basis by which the resources are allocated, costs are determined and the project progress is measured. Detailed schedules are then used to manage the total programme throughout the project lifecycle and to assist the project manager in decision making by providing a basis for obtaining the necessary facts and information. The most common techniques used are [8]:

- Gantt or bar charts
- CPM (Critical Path Method)
- PERT (Program Evaluation and Review Technique)
- Milestone charts
- PDM (Precedence Diagramming Method, IBM Co., 1964)
- GERT (Graphical Evaluation and Review Technique)
- Monte Carlo Analysis

A Gantt chart (or bar chart) is the simplest and most commonly used scheduling technique. It was developed by Henry L. Gantt during the First World War as a method for depicting project progress for the U.S. Army. It is a method by which the duration of each of the activities of the work breakdown structure (WBS) is plotted according to the preceding activities. Once the base programme is established, the progress of the project can be measured against it. Gantt charts can also be used for resource planning and budgeting. The Gantt chart, however, does not indicate the interrelationships between activities [9].

The WBS is at the core of most scheduling techniques. The WBS identifies the various tasks that need to be performed for the project to progress. These tasks have dependencies upon one another. Certain tasks have to be completed before other can start, and these are called an activity's predecessors. To be able to cope with the complexities of these dependencies, the critical path method (CPM) was developed. CPM was developed by the DuPont Company in conjunction with Remington Rand and Mauchy Associates in 1957 as part of a plant construction project. It differs from PERT in that it gives greater emphasis to cost than PERT, and it has a more deterministic approach. CPM uses only one time estimate per activity and there is no allowance for uncertainty [9] [1].

The critical path is the longest path through the task network and determines the duration of the project. It is also the shortest amount of time necessary to complete the project. Since there is only one path through the network that is the longest, all other paths must be either similar in duration or shorter. Some activities can therefore commence later than planned, and still finish before being required by subsequent activities. The time difference between the scheduled completion date and the latest date it can be completed to meet the critical path requirement, is known as the slack time of an activity. Slack time can therefore be defined as the difference between the latest allowable date (late start [T_{LS}] or late finish [T_{LF}]) and the earliest expected date (early start [T_{ES}] or early finish [T_{EF}]) that an event can take place, without extending the project's completion date, see equation 2.1. If an activity is moved by more than its available slack, that will affect the critical path and thus extend the project completion date.

$$\text{Slack time} = T_{LS} - T_{ES} = T_{LF} - T_{EF} \qquad (2.1)$$

The CPM makes the following assumptions [9]:

- The time taken to perform an activity is dependent on the amount of effort or resources applied, and is thus variable.
- The estimated time for completing an activity can be reduced by additional resources such as labour, equipment or cost.

PERT was developed by the US Navy, in association with Booz-Allen Hamilton and Lockheed Co. in 1958 because they were concerned by the performance trends on large military development programmes. PERT and CPM are commonly used network methods for project planning and scheduling, and are both critical path orientated methods that compute the expected project duration, early and late times, and slack [9].

PERT is often used in projects where there is uncertainty associated with the nature and duration of activities. PERT uses three activity duration time estimates - *optimistic* (*a*), *most likely* (*m*) and *pessimistic* (*b*) – which forms a beta distribution. Based on the distribution it is possible to determine the *expected time* (t_e), as well as the *variance* (*V*) of each activity using the following formulas [9]:

$$t_e = \frac{a+4m+b}{6} \quad (2.2)$$

$$V = \left(\frac{b-a}{6}\right)^2 \quad (2.3)$$

The expected duration of the project (T_e) can then be determined by adding the individual expected times (t_e) of the activities on the critical path (*CP*). Similarly the variance in the project duration (V_P) can be determined by the sum of all the variances of the critical path activities [9]:

$$T_e = \sum_{CP} t_e \quad (2.4)$$

$$V_P = \sum_{CP} V \quad (2.5)$$

To determine the probability of meeting the project's target completion date (T_s), assuming that the expected completion date (T_e) is different, equation 2.6 can be used. The distribution of project durations is approximated based on the bell shaped normal distribution, from which the z values for equation 2.6 can be interpolated, see Figure 2.8.

$$z = \frac{T_s - T_e}{\sqrt{V_P}} \quad (2.6)$$

PERT statistical procedures have been criticized for producing results that are overly optimistic. This is also based on the assumption that an activity's optimistic, most likely, and pessimistic time, can be accurately estimated. But without proper historical data, these values are just guesses which reflect the estimator's biases. Another criticism of PERT is that it assumes that activities are independent of each other. The duration of an activity can be influenced by the availability of resources or workers morale, to name but two factors. And, lastly, looking only at the critical path can be misleading. The near-critical paths must also be considered and analysed [9].

Z	Probability of Completing Project by T_s*
3.0	.999
2.8	.997
2.6	.995
2.4	.992
2.2	.986
2.0	.977
1.8	.964
1.6	.945
1.4	.919
1.2	.885
1.0	.841
.8	.788
.6	.726
.4	.655
.2	.579
0.0	.500
−.2	.421
−.4	.345
−.6	.274
−.8	.212
−1.0	.159
−1.2	.115
−1.4	.081
−1.6	.055
−1.8	.036
−2.0	.023
−2.2	.014
−2.4	.008
−2.6	.005
−2.8	.003
−3.0	.001

*Based on the area under a standard normal curve

Figure 2.8: Z values for normal distribution **[9]**

When an activity is performed under normal conditions it is assumed to have a normal time (T_n) and a normal cost (C_n). When all available resources and the maximum effort are applied to reduce the duration of the activity, the activity is said to be crashed. A crashed activity will have the shortest duration (crash time, T_c) but at a much greater cost (crash cost, C_c) to the project. The cost slope represents the time-cost relationship, which is an indication of how much an activity can be shortened and what the direct cost impact thereof will be. This relationship is not necessarily linear but, to simplify the calculations, it is assumed to be linear and thus has the following formula [9]:

$$\boldsymbol{cost\ slope} = \frac{C_c - C_n}{T_c - T_n} \qquad (2.7)$$

The cost slope is a representation of direct costs. Indirect costs, such as administration costs, usually reduce as project duration shortens. This also has to be taken into account when analysing the total project cost. Another restriction to crashing a project may be the availability of resources. Most resources are finite or even scarce, and thus work should be scheduled taking these limitations into account. Constraint resources could therefore dictate the activity path and override the critical path; this is called the "*critical chain*" by Goldratt [9].

The graphical evaluation and review technique (GERT) is quite similar to PERT, but it allows for looping and branching of activities as well as multiple project end results. CPM and PERT are limiting in that they require that [8] [9]:

- the immediate predecessor activities must be completed for a new activity to start;
- an activity can't be repeated;
- the activity time is restricted to a Beta distribution for PERT and a single estimate for CPM;
- the critical path is always considered to be the longest path, even if changes can affect this assumption.

The GERT technique overcomes these limitations mainly by the use of complex nodes. A node in PERT represents the start or finish of an activity with the assumption that the immediate predecessor has been completed. GERT uses probabilistic and branching nodes which indicate the number of activities leading to them which have to be completed, as well as the potential multiple branching paths that can emanate from them [8] [9].

The Monte Carlo analysis is a method by which each variable or sensitivity parameter can be tested for various scenarios and probability distributions. Near critical paths can easily become critical, and the Monte Carlo computer simulation takes this into account by randomly selecting times for the activities from various probability distributions and then determining the critical path. This is repeated numerous times to generate a distribution of project durations. Due to the vast number of possible outcomes that is being considered, as well as other paths that might become critical, this procedure provides more realistic answers [9] [13].

2.2.1.5 Quality Management

Quality management is the ability to manage the project in order to achieve the predetermined objectives, requirements and specifications, while determining possible errors that may occur and taking precautions to prevent them. This is commonly done by implementing a quality management plan that stipulates the measures and procedures necessary to obtain the quality requirements as defined by the project management plan. The purpose of quality control is the anticipation of possible errors or to determine why requirements or conditions are not being met, to eliminate the sources of the errors and to prevent them from occurring in the future [8] [9].

ISO 9000 series is a quality system standard applicable to any product, service or process worldwide. Many engineering consulting companies are ISO 9001:2008 accredited, so as to assure their customers that their work is managed by an audited quality management system which entails a continuous cycle of planning, controlling and documenting of the quality management system. ISO 9000, as well as ISO 31000, is further discussed in section 2.2.4 [8] [14].

2.2.1.5a Quality Management Concepts

There are six basic quality management concepts which are important for any quality management system. The quality management system requires the following [8]:

- A policy
- Objectives
- Quality assurance
- Quality control

- An audit
- A program plan

A company should develop a quality management policy which clearly states general quality objectives and standards for all projects and appoint a person to be responsible for the policy and how it will be measured and audited. Each project must have a project quality plan, which is a document that states the project's specific quality objectives, a breakdown of these objectives into a work breakdown structure (WBS) and the delegation of responsibility for the objectives to the team members. The WBS must be adequately detailed to define the actions required to achieve the overall quality goals. The quality objectives should be clearly defined, obtainable and measurable.

Quality assurance and control is the collective term for the activities, techniques and processes established by management to measure and ensure that the quality related objectives are being attained. It also entails the continuous improvement of the system. A quality audit is done to evaluate the performance of the project in achieving the quality objectives [8].

2.2.1.5b Quality Control Tools

Quality control tools are used for identification and analysis of quality management problems. The following tools will be discussed [8]:

- Data tables
- Cause-and-effect Analysis
- Histogram
- Pareto Analysis
- Scatter Diagrams
- Trend Analysis
- Control Charts

Data tables are an identification technique which makes use of forms designed for collecting data in a way that simplifies review and the analysis thereof. Once a problem is identified, its cause can be determined by a cause-and-effect analysis that uses the fishbone diagramming technique (see Figure 2.9). This entails the following steps [8]:

1. Identifying the problem (using methods such as Pareto analysis, histograms, brainstorming and control charts).
2. Selecting an interdisciplinary brainstorming team.
3. Drawing a problem box (containing the problem statement being evaluated) and a prime arrow.
4. Specifying the major categories contributing to the problem.
5. Identifying the causes of the defect contributing to each category (using either the random, systematic or process analysis method).
6. Identifying corrective actions.

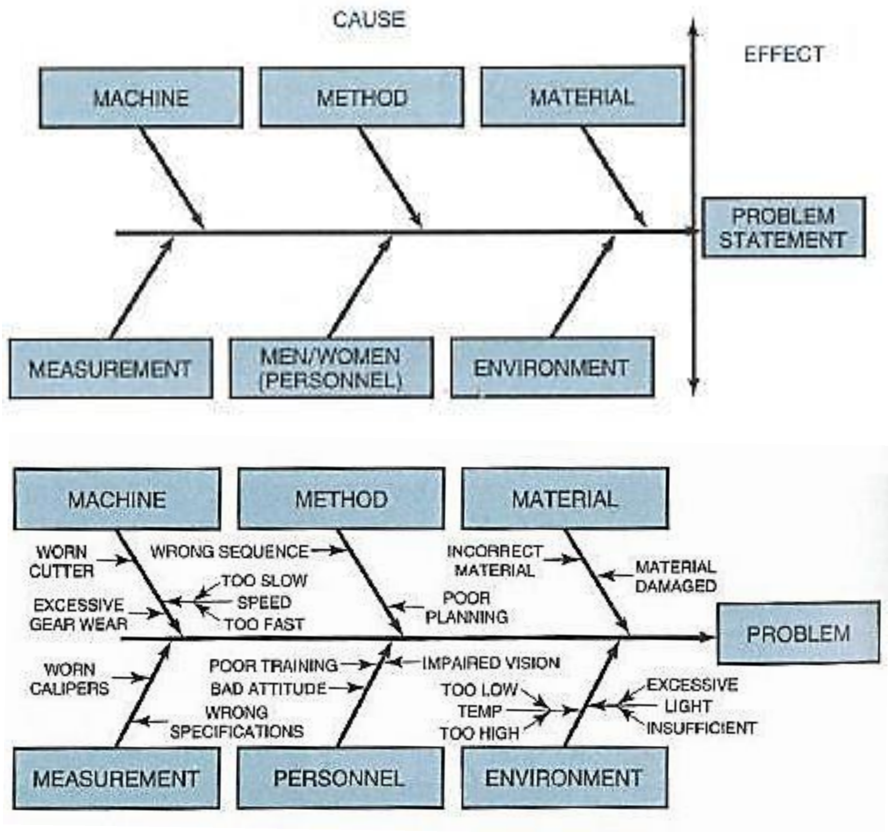

Figure 2.9: Cause-and-effect diagram

Histograms are used to graphically view the data distribution of attributes or variables for a single point in time for a better understanding of their relative values. A Pareto Analysis is a special type of histogram that can assist in identifying and prioritising problem areas by quantifying and displaying the frequency of certain occurrences relevant to the quality control on a graph. It also identifies the most significant value based on frequency.

Scatter diagrams are another method of graphically portraying quality control data. They make use of a dependent and an independent variable, and can indicate various correlations. To determine which equation best fits a scatter plot, a trend analysis is done. This is a means of explaining the relationships of the data and what these reveal. It is also an ideal method for forecasting. Most of the methods already mentioned have the function of helping in the understanding, identifying and analysing of existing problems. Control charts differ from them in that their function is a more preventative one.

2.2.1.6 The Project Life Cycle

A project is defined as a temporary endeavour with a series of activities undertaken to create a unique product. It has specific objectives with a definite start and end date, limiting funding and resources and it often involves multiple disciplines within an organisation [8] [9] [10]. Although each project is unique and varies in size and complexity, all projects have the same life cycle [10]:

- Starting the project
- Organizing, planning and preparation
- Carrying out the project work (construction phase)

- Close down of the project

The relationship of project resource requirements (such as cost and staff) with time is shown in Figure 2.10 which clearly indicates that the greatest resource requirement is during the execution phase of a project.

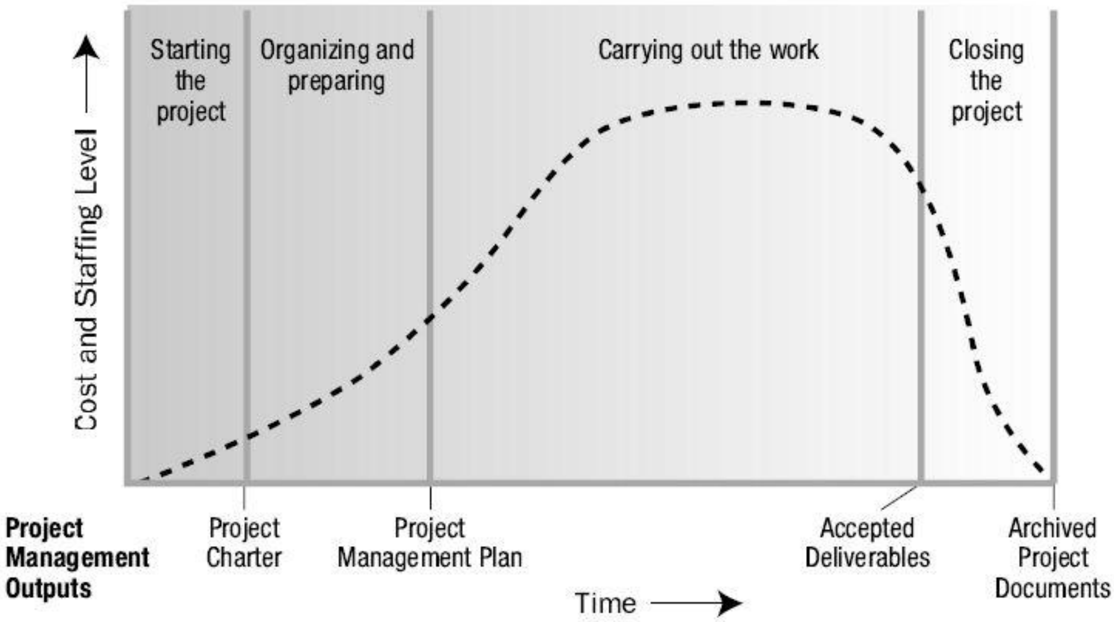

Figure 2.10: Typical cost and staffing levels across the project life cycle **[10]**

Another well-known graph of the influence of various factors on the project life cycle is Figure 2.11. It indicates the relationship of stakeholder influence, risk and uncertainty against project time, as well as the cost of changes in relation to project time. This graph illustrates that the cost impact of changes becomes greater as the project progresses in time. Inversely, the influence of project stakeholders, uncertainty and risk, reduces with time as the unknowns become fewer and the objectives are more clearly defined.

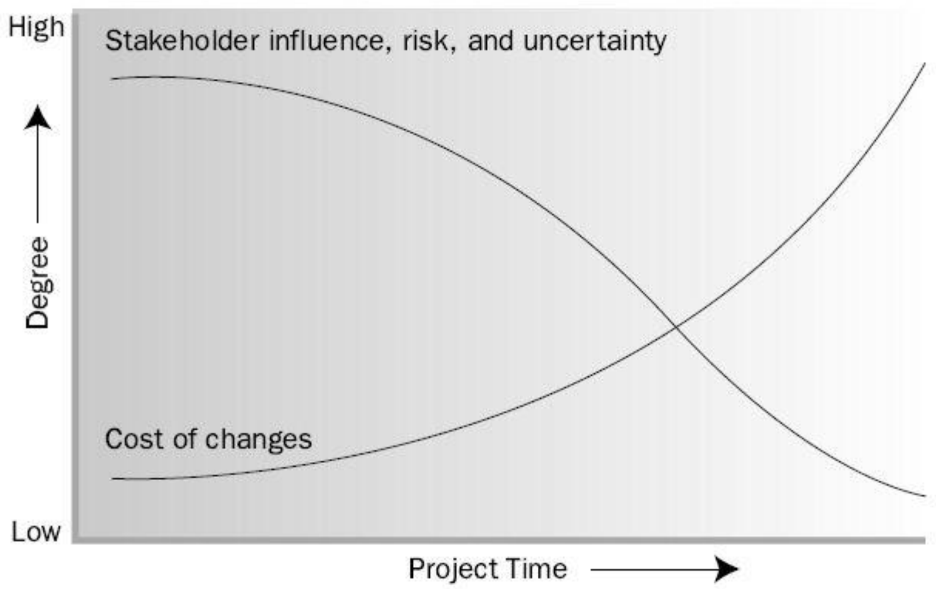

Figure 2.11: Impact of variables based on project time **[10]**

2.2.1.7 General Project Problems

2.2.1.7a Design problems

In the words of Graham M. Winch [1], "the management of construction projects is a problem in information, or rather, a problem in the lack of information required for decision making. Decision-making in construction is, therefore, about robust decisions, rather than optimal decisions." As information, such as the ground conditions, become available during the construction phase of the project, it can lead to various changes.

2.2.1.7b Changes to the project

A project seldom goes according to plan. Due to planning oversights, new opportunities, changes to the client's requirements, or even unanticipated circumstances or events, changes are made to the project. Changes to the project could involve changes or modifications to the main design, the project resources, as well as cost, time or quality trade-offs in order to accommodate the change. These changes could therefore adversely impact on the actual cost and duration of the project [9].

Over and above the cost and time consequences, changes can also affect stakeholder relationships and team morale. The uncertainties associated with change are often the result of iterative cycles or further changes due to unanticipated side effects of a current change during the construction process [15]. It is thus imperative to understand change, the types of change, its impact on the project and how to analyse, manage and control it. The following section deals specifically with project change management on construction projects.

2.2.2 Project Change Management

2.2.2.1 Introduction

Project change can be defined as any event that alters the projects' original scope, execution time or the cost of the works. Improper management of the projects' changes could have an immense financial impact which may lead to project cost overruns or even claims and legal disputes. During the construction phase of a project, change affects every aspect of productivity, the planned schedules and deadlines, work methodology, resource procurement, as well as the budget, and thus it could result in the project objectives not being achieved. The purpose of project change management, therefore, is to insure that changes are carefully reviewed and their impact is properly assessed in order to ensure the success of the project [9] [2].

There are various methods and models that could be used to manage uncertainty in a project. Risk management, which focuses on identification, analysis and mitigation of risks, is an example of one such method. Invariably, any construction project will experience change, and change is coupled with uncertainty. It is also important to note that change and quality cannot be dealt with separately; both affect the project's performance and customer satisfaction [15]. Project managers often use contingencies and construction buffers as the only mechanism for dealing with unexpected change. By fully understanding the implications of the change, project managers are able to manage it more effectively [6].

Change management, therefore, has various components. Firstly, to understand the change and the need for the change; secondly to assess the implications of the change on the overall project and all project objectives (such as duration, quality and cost); thirdly to assess the risks linked to the change and mitigate them; to do configuration management in order to ensure that the change is communicated to all the relevant parties involved and lastly, to manage the change and its impact effectively.

2.2.2.2 Types of Change and their Reasons

Change can be categorised into two groups: unintended changes and intended (also called managerial) changes. Unintended changes occur without the intervention of managerial actions and are in most cases the result of low quality work, poor work conditions, external scope changes or even upstream hidden changes. Managerial changes are those changes that are assessed, approved and implemented by the project manager. The rest of this section discusses the various types of managerial changes that occur on construction projects [16].

In the construction industry there is an ever increasing demand for faster development time of projects. This leads to the requirement of concurrent design and construction projects, or projects where construction starts when the design is approximately 40 – 50% complete. This used to be the exception, but has become the norm. However, this means that there is an increased amount of uncertainty and complexity to the project and that certain decisions are based on assumptions, due to lack of information. This could lead to a chain of wrong decisions and rework, and it could make the project difficult to control [15]. I.A. Motawa et al. [3], in their study on proactively determining the risk of change on construction projects, also confirm this in stating that changes in construction projects often result from uncertainty, due to inaccurate and vague project information at the early stages of a project. Another reason for change is the actual scope of the work being increased. Additional work is often added to the project scope in order to deal with design errors and changes [15].

According to a study done by Charles Leonard published in 1988 [17] the major causes of change are design errors and omissions (65%); design changes (30%) and unforeseen conditions (5%). Love et al. [5] did a case study on a residential construction project of two six-storey residential apartment blocks, containing a total of 43 units, in order to better understand change and rework in construction project management. Their findings on the various types of changes and its impact on the project are further discussed below.

Table 2.4: The impact of changes on a project **[6]**

Reason for Change	No. of events		Non-productive time		Total Cost ($)		Mean cost per event ($)	% of Contract Value
	Number	% of total	Days	% of total	Cost ($)	% of total		
Client changes	49	18%	10	26%	105 620.00	13%	2 155.00	0.96
User changes	132	48%	14	36%	235 440.00	29%	78.00	2.14
Design omissions	83	30%	13	33%	265 980.00	33%	3 205.00	2.43
Local Authorities (Rates/Taxes/Fees)	5	2%	2	5%	146 080.00	18%	29 216.00	1.33
Extension of Time (Claims)	6	2%	0	0%	53 240.00	7%	8 873.00	0.49
TOTALS	**275**		**39**		**806 360.00**		**43 527.00**	**7.35**

Table 2.4 indicates that the most common changes were those made by the User (48%). These changes resulted in the greatest loss of productivity (36% of all time lost) and had the second highest impact on the budget (2.14% of the contract value). Design omissions were responsible for 30% of all changes, 33% of all lost time on the project and a total of $265,980 additional cost to the project (2.43% of the contract value). Other causes of change were client changes and changes due to the requirements of the local authority.

Change could also result in rework. Construction deals with the physical manifestation of a design, and thus rework usually entails the demolition or modification of existing structures. For this reason, rework is perceived to have a greater impact on construction performance than change. When project managers are under time or resource constraints, they would rather avoid rework by modifying the design and specifications. However, change may have a greater impact on the works than rework [16].

In the case study mentioned previously done by Love et al. [6], it was found that construction errors, omissions or damage was responsible for the greatest number of rework items (57% of all rework items). This resulted in 40% of all non-productive time due to rework (28 days), but its cost impact was a mere 7% of all the cost allocated to rework, a total of 0.206% of the contract value. In comparison, design changes, together with construction changes, caused 36% of all rework items. This resulted in 22 non-productive days (32% of the total) and it had the greatest cost impact on the project (74% of all cost allocated to rework and 2.33% of the contract value). Design and construction changes therefore had the greatest cost impact, as well as a substantial time impact on the project. Table 2.5 shows the causes of rework and its cost to the project.

Table 2.5: The impact of rework on a project **[6]**

Reason for Rework	No. of events		Non-productive time		Total Cost ($)		Mean cost per event ($)	% of Contract Value
	Number	% of Total	Days	% of Total	Cost ($)	% of Total		
Design change	65	30%	20	29%	182 893.00	53%	2 814.00	1.67
Design error	12	6%	13	19%	59 233.00	17%	4 936.00	0.55
Design omission	2	1%	7	10%	6 837.00	2%	3 419.00	0.06
Construction change	14	6%	2	3%	72 979.00	21%	5 213.00	0.66
Construction error	120	55%	14	20%	19 514.00	6%	163.00	0.17
Construction omission	2	1%	0	0%	760.00	0%	380.00	0.006
Construction damage	3	1%	14	20%	3 288.00	1%	1 096.00	0.03
TOTAL	**218**		**70**		**345 504.00**		**1 584.88**	**3.15**

It is also noteworthy that intended changes, once implemented, often trigger subsequent changes in other tasks [16].

2.2.2.3 The Impact of Project Change

The case study done by Love et al. [6], mentioned in the previous section, indicates that the changes and rework had a combined 10.5% cost impact on the project and resulted in 109 non-productive days. The value spent on changes is more than double the amount spent on rework. There is thus no doubt that change can have a tremendous impact on a construction project. The case study therefore made the following findings:

- Change can have a significant cost and time impact on a construction project.
- Change has a greater impact than rework.

A study on the impact of project change conducted by Professor C.W. Ibbs from the University of California at Berkley [2] had the following findings:

- As the amount of change increases, the cost will also increase.
- As change increases on a project, productivity decreases.
- Change that occurs during the construction phase of a project has a more disruptive impact on the project than change that occurs during the design phase of a project.
- A project that has a large amount of change would have a less efficient implementation of that change.

As stated in the previous section, projects with concurrent design and construction are complex and have an increased amount of uncertainty. One incorrect assumption or wrong decision could affect various project activities, because construction activities are highly interrelated with significant procedural and physical constraints [15].

Change, in most cases, also increases the scope of work. To quantify the effects of change is difficult and, therefore, it frequently leads to disputes between contractors and clients [18]. It is therefore important for a project manager to be able to respond promptly to change, to consider the impact and risks of the change using relevant techniques, as well as experience, and then derive a method of dealing with the change in the best way possible.

2.2.2.4 Project Change Management Methods

It is essential that a proper change management system or methodology is implemented and used by the project team. The purpose of such a system is to ensure that change is properly managed, that it is authorised by the relevant parties and communicated to those in the project team that need to know about it. Communication about change is extremely important, especially on a project with large, multi-disciplinary teams, to ensure that the whole team is in agreement.

The change management framework has two components: a scope management process and the claim and change management process. Scope management is necessary in order to ensure that the given scope of work is the same as the one specified in the drawings and specifications, so as to limit possible changes to the scope that will impact on the project. One purpose of change management is to decide whether a requested change order should be accepted or rejected and to determine the impact on the project and manage its execution [15].

According to John M. Nicholas in his book on project management for business and engineering [9], and Love et al. [6] a change management system must consist of the following:

- **Change Identification:** Identify the changes as they occur.
- **Impact Assessment:** Determine the consequences of the change in terms of its impact on the budget, the project duration, quality and other tasks.
- **Change Analysis:** Do an analysis of the change, its alternative options and its impact on the resources and duties of the project team.
- **Go / No go:** The stage gate review of the change (when the change is accepted or rejected) can be made once the impact of the change is clear.
- **Approval and propagation:** A pre-specified request and approval process for all changes is required.
- **Communication Strategy:** There must be a clear coordinating and communication strategy in place which clarifies the following: The management hierarchy and the person responsible for making decisions and determining specific milestones; how and to whom changes must be communicated; and how change should be recorded.
- **Control:** Lastly, it is important to implement continuous control measurements throughout the project process to ensure that the new activities meet planned requirements in terms of cost, time, quality and safety. Thus a summary of all changes that have been made and their impact on the project should be reviewed and reported regularly (e.g. monthly) to identify any deviations.
- **Handling of Disputes:** A policy for resolving disputes or conflict that may arise due to change is necessary.

Two change management models suggested in literature, which were found to be useful, are explained below:

2.2.2.4a Generic change process model

I.A. Motawa et al [18] developed a generic change process model (Figure 2.12) for managing the complete process of change, as well as the key decisions required to implement that change. The model is based on various change management models in the literature, as well as experience gained from a number of case studies. It comprises four sections: Start up, identification and evaluation, approval and propagation and post change.

The purpose of the "Start up" process is to define a set of proactive requirements essential for effectively and readily responding to change and to facilitate contingency plans if required. The purpose of the change identification phase is to determine causes, types and effects of change. This phase has to identify and analyse how the change affects the project tasks, processes and its overall objectives. The analysis of the change has to determine all other options available, their implications and whether the change should be implemented or not. The third phase of the model is the approval and propagation phase where the client needs to review potential changes against the project baseline to decide on a change option. Once the change is made, there may be disputes about it which would thus require mitigation and an investigation of direct and indirect causes of change. This is part of the final phase of the model [18].

The change management process as given in Figure 2.12, developed by I.A. Motawa et al [18], also provides for iterative cycles resulting from latent or unanticipated changes or decisions that have to be reconsidered. If changes were rejected due to the availability of better options, for example, the rejected change may either become a permanently rejected change or it can be designated as a latent change in terms of its potential for reconsideration later in the process, as shown in Figure 2.12.

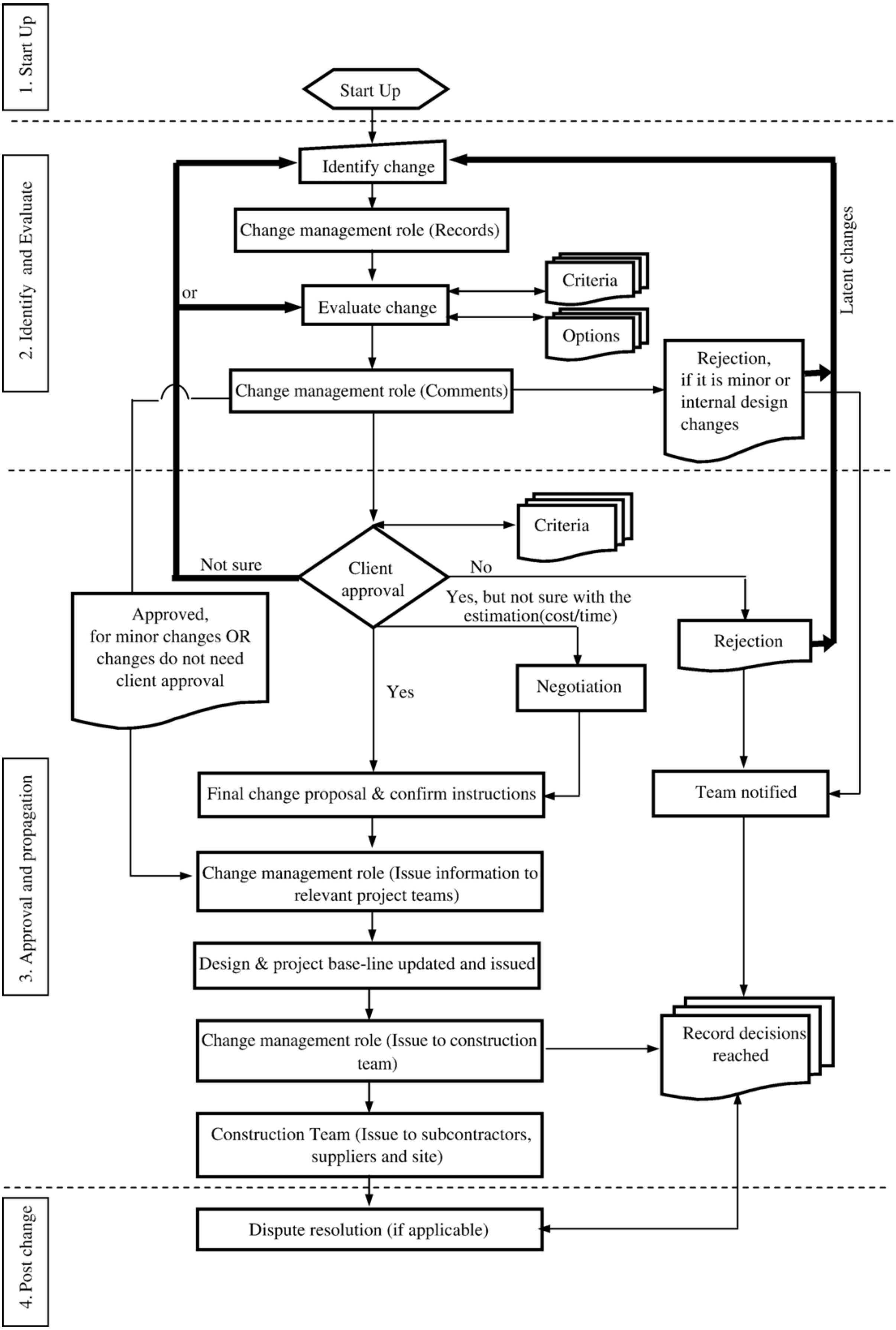

Figure 2.12: Generic change process model **[18]**

2.2.2.4b The generic construction process model

Lee et al. [15], developed a dynamic construction process model using system dynamics. The purpose of this model is to capture and manage the dynamic impacts of errors and changes on construction performance. Errors and changes cannot be treated as constant events, because they usually occur as iterative cycles and have a complex interrelationship of activities. Thus, one change action may lead to another if there are any unanticipated side effects due to the change. To address this problem, the model presents a framework for quality and change management by which the generation of iterative cycles can be identified and managed. Before considering the complete model, it is important to understand how changes behave internally within a single activity. Figure 2.13 gives the internal quality and change management framework of the model. Note that work is performed based on a given work scope which is executed during either the design or construction phase of the project [15].

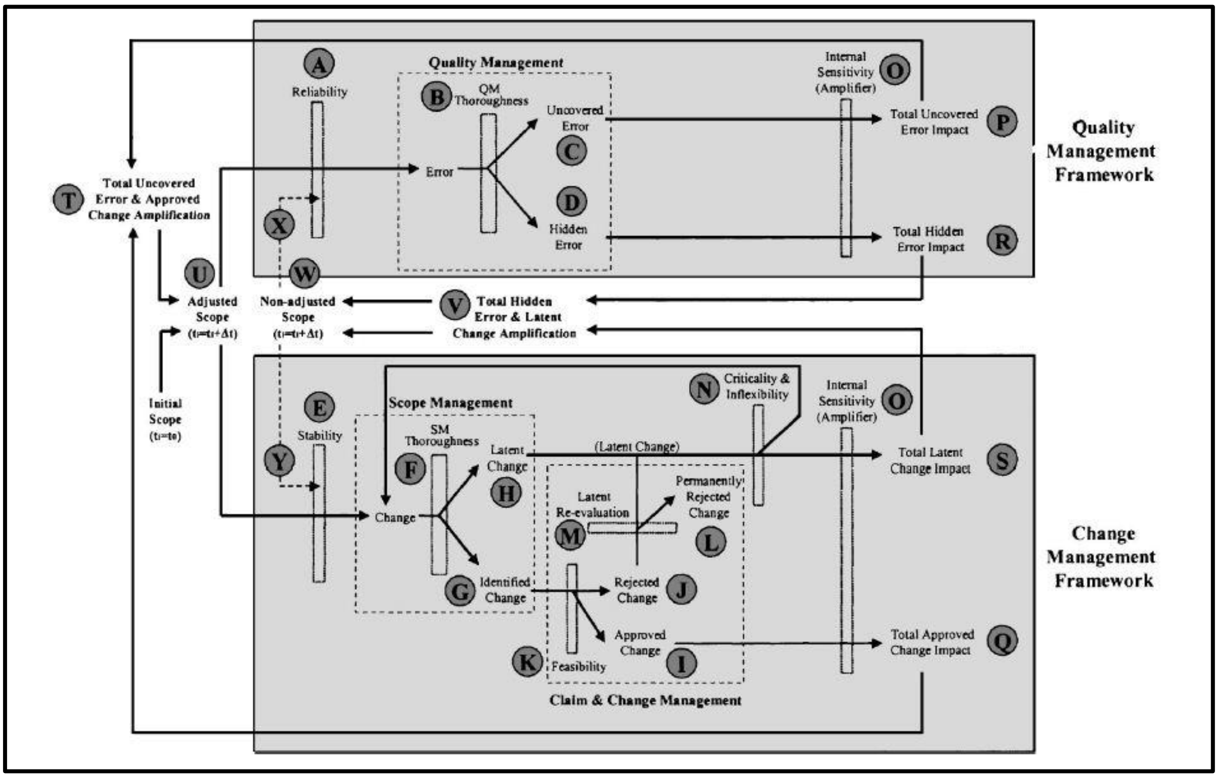

Figure 2.13: Internal quality and change management framework **[15]**

The internal quality and change management framework, as given in Figure 2.13, can be extended to also include the effects of the quality and change management process from one activity to other interrelated activities, as shown in Figure 2.14, for the full project network. This is possible as changes (or errors) that occur on a certain activity may also affect adjacent activities due to their corresponding sensitivity to change. Therefore change management is an iterative process, due to the external sensitivity to change and its effects that exists among all the activities of the project.

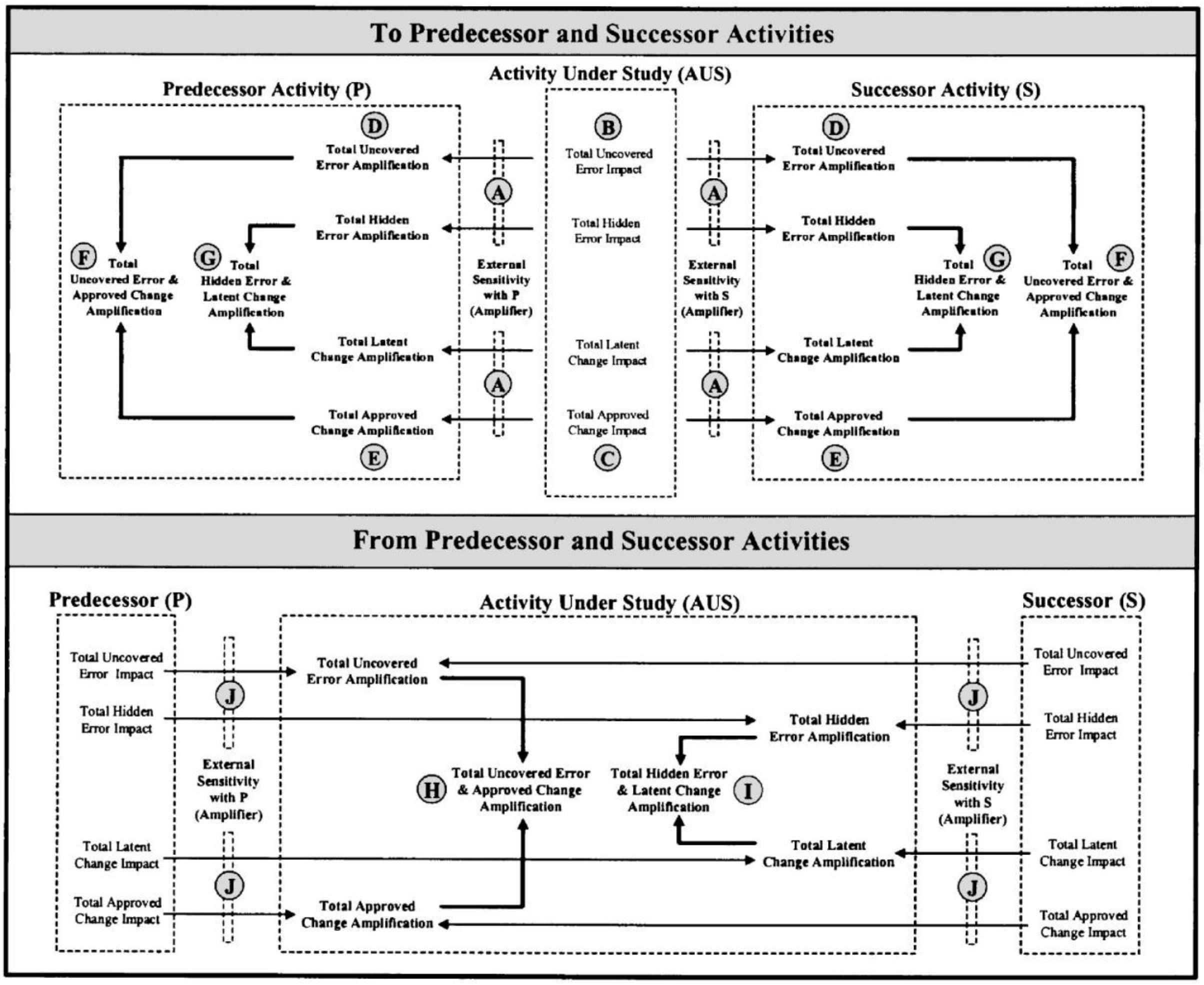

Figure 2.14: External quality and change management framework [15]

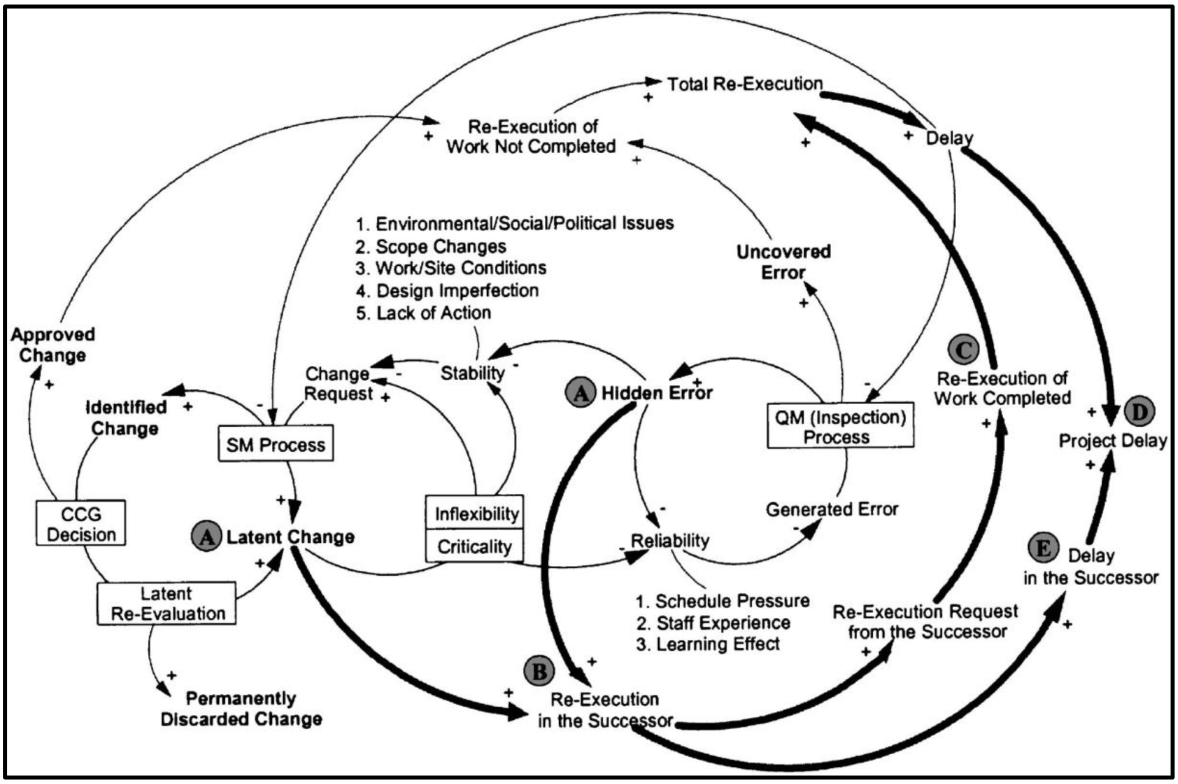

Figure 2.15: Feedback processes on quality and change management process **[15]**

The dynamic assumptions on which the model was built are summarised in Figure 2.15. The loop diagram (given in Figure 2.15) indicates how the related variables can be interlinked. To explain the relationship logic of the diagram the following example will be used: A hidden error or latent change (both of the A's in Figure 2.15) would result in the re-examination of the work to be done in the successor activity (B in Figure 2.15). This may then lead to the re-execution of the completed predecessor activity (C in Figure 2.15) which could thus result in a project delay (D in Figure 2.15), as well as the delay of the successor activity (E in Figure 2.15) [15].

The dynamic construction model, which forms part of the overall model, has five subcomponents: project scope, the project target (i.e. schedule, cost, and quality), resource acquisition and allocation process (design and construction), and the project performance. The role of the model is to identify when any one of the subcomponents is different from expectations, which would indicate a change. A project has an initial scope, resources and base line schedule. During the construction phase the performance of the project is measured against the base line schedule, scope and resources. Should the monitored performance be different from the expected performance it would affect all three of these variables. For example, should the scope of work increase due to changes made during the construction, additional resources would be required or the schedule would need to be extended to include the new works. These changes might trigger other changes due to the interdependencies of activities. It is therefore an iterative process [15].

The generic construction process model structure shown in Figure 2.16 is developed based on the dynamic assumptions shown in Figure 2.15 and the dynamic construction project model explained in the previous paragraph. A stock and flow structure which characterizes the state of the system generates the information and represents the generic process of design and construction. It explicitly addresses the following: the dynamic and complex cycles, such as iterative cycles, caused by error and change, their settlement through requests for information (RFI), the change decision process and an increased amount of work. The model was tested and found to produce sound behaviour in project performance to represent the impacts of errors and changes [15].

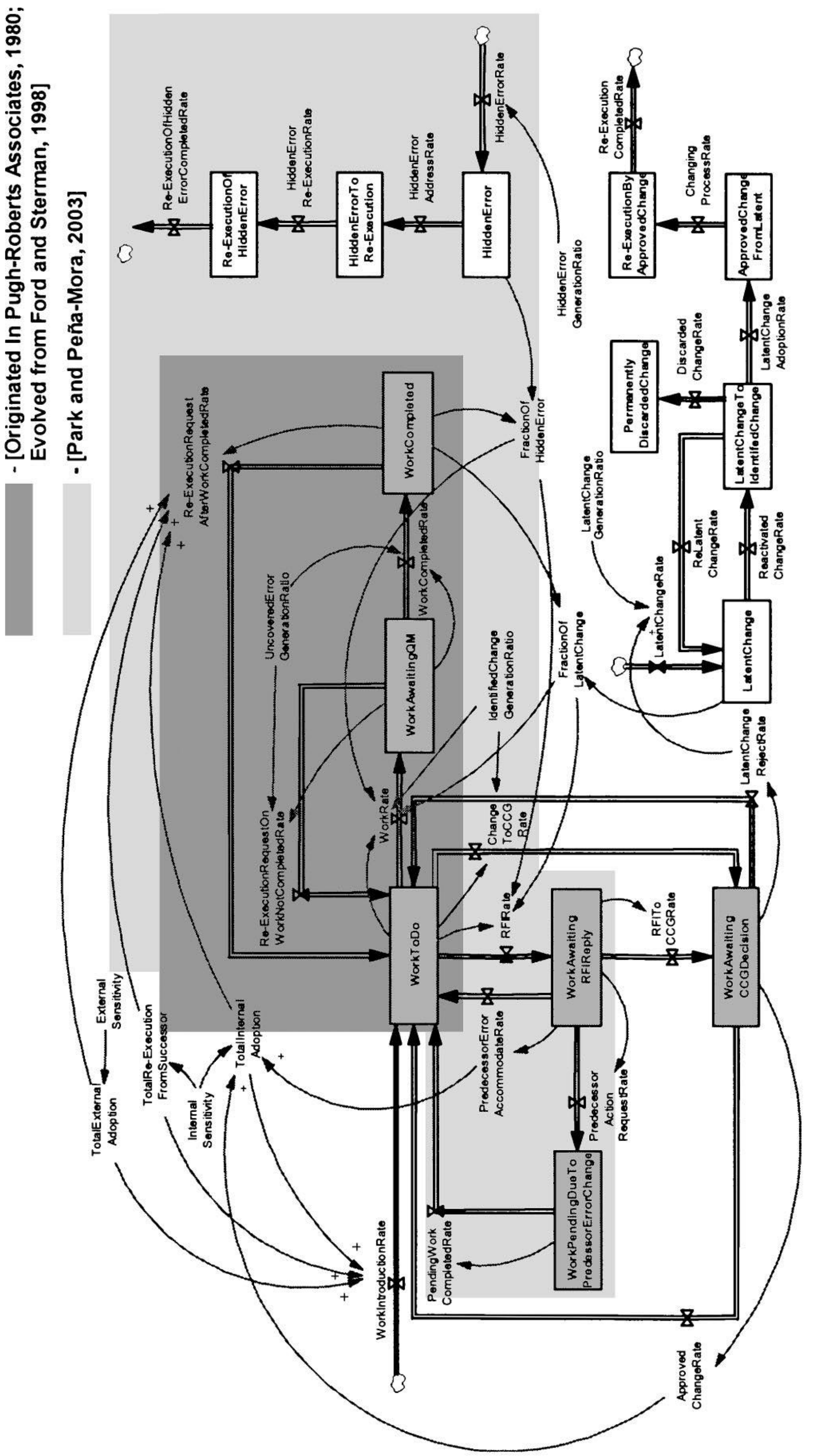

Figure 2.16: Generic construction process model [15]

2.2.2.4c Critique on the existing models

Both the generic change process model developed by I.A. Motawa et al [18], as well as the dynamic construction process model developed by Lee et al. [15], are change management models that would be useful to the industry and would enable project managers to manage change more effectively and make better decisions. However, they are both quite complex and difficult to implement easily. They also require a fair amount of input and thus could be time consuming. Engineers prefer to utilise a change management system that is simple and time effective.

2.2.3 Risk Management

2.2.3.1 Introduction

A project's success is measured by the achievement of the three objectives that all projects share – to be completed within the allocated time, budget and quality requirements that were agreed upon at the inception of the project. However, changes that occur in the project environment are the main obstacles that prevent projects from achieving these three goals. The larger and longer the duration of the project, the more uncertainties and risks there are and, therefore, the harder it becomes to achieve the project outcomes [19]. Risk management is about dealing with those risks. Although it is not possible to eliminate them altogether, they can be reduced [9]. This includes planning for the risks that might occur, identifying and analysing them and, lastly, managing the risks in such a way that the project objectives are still achieved [8].

Right from the start it must be understood that risk management is not just one tick box on the project managers list of to-dos, it should be incorporated as part of the lifecycle management of a project, from inception to close-down. Apart from it being integrated into every aspect of project management, risk management must be proactive rather than, as it is unfortunately often applied in practice, reactive. Thus risk management should be understood in its entirety.

2.2.3.2 Risk Concepts

Most project management handbooks define risk as a measure of the probability and the impact of not achieving a particular project goal. Risk is therefore a function of probability and impact.

$$\mathbf{Risk} = \mathbf{f}\ \mathbf{probability},\ \mathbf{impact} \qquad (2.8)$$

This, however, is not always easy to evaluate, as the probabilities and consequences of any particular occurrence cannot be measured accurately. They can only be estimated by statistical analysis, experience and judgement or other methods that will be discussed later [8].

G.M. Winch [1] defined uncertainty as the absence of information required for a decision that must be taken at a point in time. Any project has elements that are certain, that which is uncertain, as well as risks. Risk and uncertainty both deal with a lack of knowledge of a future event, but risk incorporates the probability of such an occurrence, as well as an estimated impact [8]. Other risk factors include the size and complexity of a project, the construction period, its location, the uniqueness of the project and the experience of the project team [19]. For the purpose of this thesis, we will focus only on risk.

Another important element of risk is its cause. The source of a potential danger is referred to as a hazard. The impact of hazards can be reduced by prior knowledge of them and safeguards that are put in place to overcome them. Thus risk is also a function of a hazard and the safeguard against it [8].

$$\mathbf{Risk} = \mathbf{f}\ \mathbf{hazard},\ \mathbf{safeguard} \qquad (2.9)$$

2.2.3.3 Risk Management Planning

In the words of Charles Tremper: "The first step in the risk management process is to acknowledge the reality of risk. Denial is a common tactic that substitutes deliberate ignorance for thoughtful planning."

Planning is the first step in risk management. This is where a strategy for the risk management of the whole project is determined and set up in such a way that it can be applied throughout the lifecycle of the project. A risk management plan (RPM) (which is the output of this phase and, important to note, not the process itself) must be a comprehensive outline of how risk management will be applied throughout the project and should be well documented. This document must be clear on the methods that will be used in each phase, the resources required, the assigned responsibilities, as well as the report and communication strategy that will be implemented throughout the lifecycle of the project [8]. However, it is important to know that risk management is an iterative process (see Figure 2.17) and that, although there is a good plan in place, each phase of risk management feeds into the RMP and can modify it.

Figure 2.17: Risk management process

2.2.3.4 Risk Identification

After a risk management plan has been prepared, the next phase is to identify the risks to the project. This phase is extremely important for risk management, because only those risks that are identified will be analysed and mitigated against. The output of the risk identification phase is a risk register (see Figure 2.17), which is a comprehensive list of all the risks that could have an impact on the project objectives. Thus the sources of risk must be identified and the appropriate techniques must be applied to identify the risks to the project.

2.2.3.4a Risk Identification Approach

Firstly, the project manager must identify the sources of risk. There are various ways in which this can be approached. Risks can be identified by type, or according to the lifecycle phase, or can be approached based on programme elements, processes and requirements. Each of these approaches may fail to illuminate all the serious risks. Thus it is better to incorporate more than one approach in the risk identification strategy.

The most commonly used risk types can be arranged in three levels: macro, meso and micro. The macro level comprises risks that emerge from external events that influence the project. Meso level risks are those that occur and impact the project internally. Micro level risks emerge from the relationships between the various stakeholders in a project [20]. For construction projects the risk types are typically depicted as follows, but they may vary from project to project:

Macro level

- External risks (such as political and legal risks)
- Financial and Economic risks
- Acts of God (normal and abnormal calamities)
- Contractual risks
- Environmental risks

Meso level

- Technical risks
- Design risks
- Construction risks
- Schedule risks
- Cost risks
- Quality risks
- Health and Safety risks
- Geological risks

Micro level

- Organisational risks
- Interface and communication risks
- Contract relationship risks
- Liability risks

As stated previously, risks can be identified per project phase. The risks associated with the approval, preliminary planning and design, detailed design, execution (which would be the construction phase of a civil engineering construction project) and closure phases of a project, should be identified. Most literature agrees that as the project progresses through these phases, risk decreases and the monetary value at stake increases. Figure 2.18 is a good illustration of the different risks that are relevant to each phase of a project.

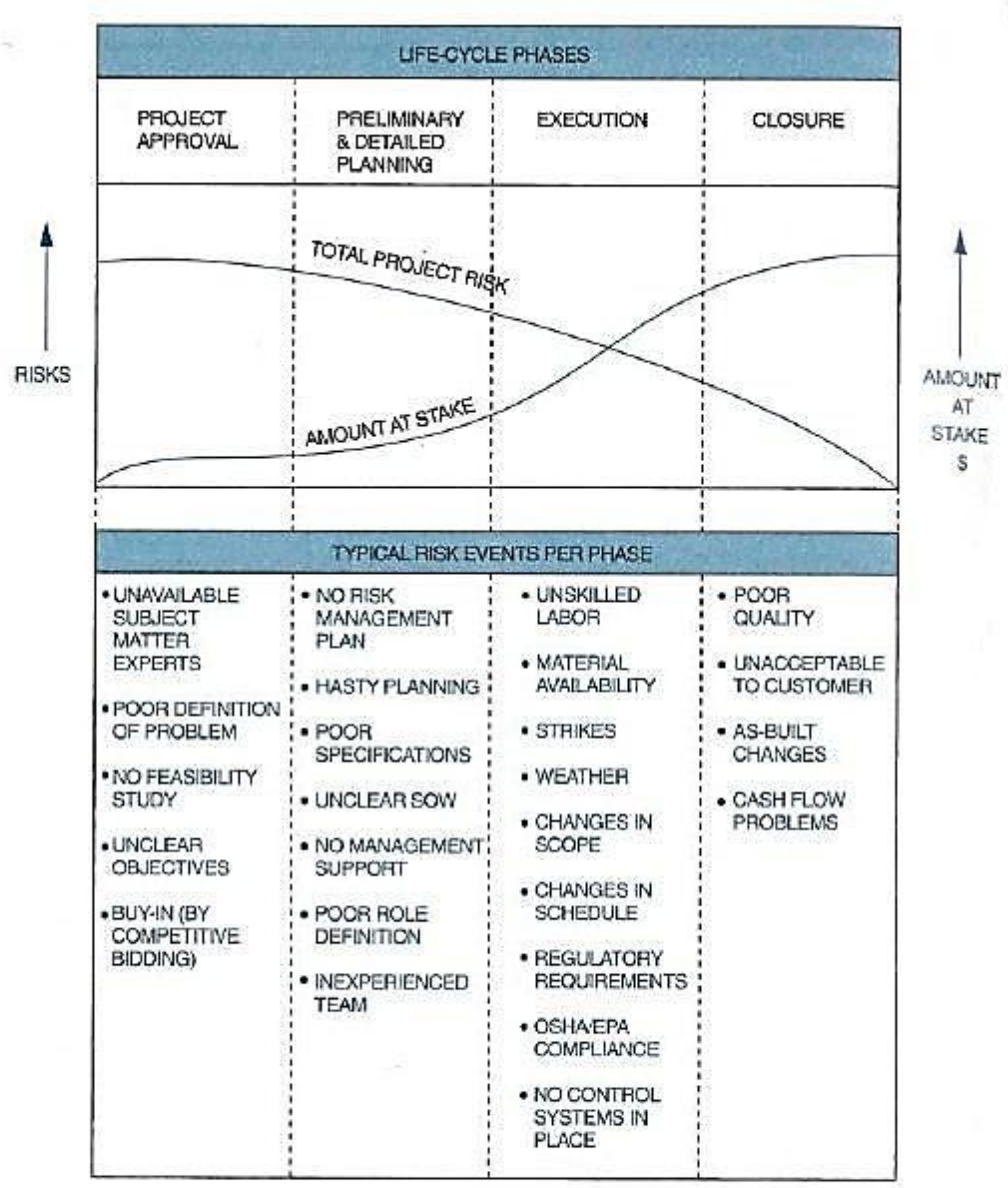

Figure 2.18: Life-cycle risks

Risks can also be identified by breaking down the programme elements, processes and requirements. This, however, will differ according to the phase of the project that is under examination. This approach is thus very similar to the previous one discussed. The programme elements are investigated based on the project's work breakdown structure (WBS), which can be grouped according to the different levels (refer back to Table 2.1) in order to make the analysis easier [8]. Typically, the top level risks resides in the WBS levels 1 to 2 and medium level risks in WBS levels 3-6. Depending on the project size, it may be essential to evaluate even the low level risks in WBS levels greater than 6 [8]. The process approach is similar to that of the categorizing of risks according to their type. Only here it is about evaluating the different processes involved in the project, such as design, testing, etc. The aim of the requirement approach is to determine which of the project requirements poses a risk to the project that is unlikely to be met.

2.2.3.4b Risk Identification Methods

Once the approach of risk identification has been established, there are various methods that can be used to identify the individual risks. Those that were thought to be useful to this research are listed below and briefly discussed:

- Experience
- Brainstorming
- Risks checklists
- Cause-and-effect diagram/Fishbone diagram
- Nominal group technique
- Delphi technique
- Recording experience and evaluations of past projects in a '*lessons learned*' file
- Analysis of available documentation and records
- Physical inspections
- Hazard and operability studies
- Fault trees

As GM Winch [1] puts it, even though risk identification is critical to risk management, this phase is often done in a non-formal way, such as relying on the experience and knowledge of older hands or organising brainstorming sessions. In his book on risk management in the construction industry, L Edwards [21] confirms that the most common form of risk identification in the construction industry is some form of committee brainstorming session. This is often as far as risk identification goes in most consulting engineering firms. Experience and brainstorming sessions are both very valuable identification methods, but are limited to the knowledge and experience of those members involved and thus may be incomplete. A recent study on the influence of experience on project risk identification performance conclusively found that to rely solely on project management experience is inadequate for identification of project risk [22]. However, it did find that when the information search style is being applied, the level of education and the risk management training of the project manager significantly impact the identification phase.

Other than experience and brainstorming, risk checklists and interview sessions have been found to be the most commonly used risk identification methods [22]. A risk checklist is a compilation of all the risks that have been identified on previous projects of a similar nature, and it is examined and updated with every new project. Most risk checklists categorise risk according to their sources. This depends on the risk identification approach that is taken, as discussed previously. A risk checklist can be very valuable for repetitive types of activity, but can be a hindrance for unique activities, as it constrains the creativity of those involved [23].

Diagramming techniques, such as the cause-and-effect diagram illustrated in Figure 2.19, are used to uncover those risks that are not always obvious. This section will elaborate on this concept which was briefly touched on in section 2.2.1.5b. Cause-and-effect diagrams are also known as fishbone diagrams (because they are drawn to resemble the skeleton of a fish) or Ishikawa diagrams, as they were invented by Kaoru Ishikawa. The purpose of a cause-and-effect diagram is to identify all the potential causes and the relevant factors responsible for a certain event, effect or risk. It is, thus, also an indication of the risk symptoms and their warning signs. These are visible signs that a risk has materialised and should be taken as triggers for the contingency plans to be set into motion.

The identified causes are grouped together under major categories used to identify all potential sources of variation. The typical categories used are: *people*, *methods*, *machines*, *materials*, *measurements* and *environment*. Figure 2.9, in section 2.2.1.5b, is an example of such a cause-and-effect analysis. However, the user should choose categories most relevant for the application. In most cases the causes that are identified are arranged according to their level of importance or detail, thus creating a hierarchy of relationships and events that is very helpful for identifying the root causes of a problem. It is also helpful for identifying areas of concern and comparing the relative importance of different causes. Figure 2.19 is an example of a cause and effect diagram taken from JM Nicolas' book on project management [9] [24] [25] [26].

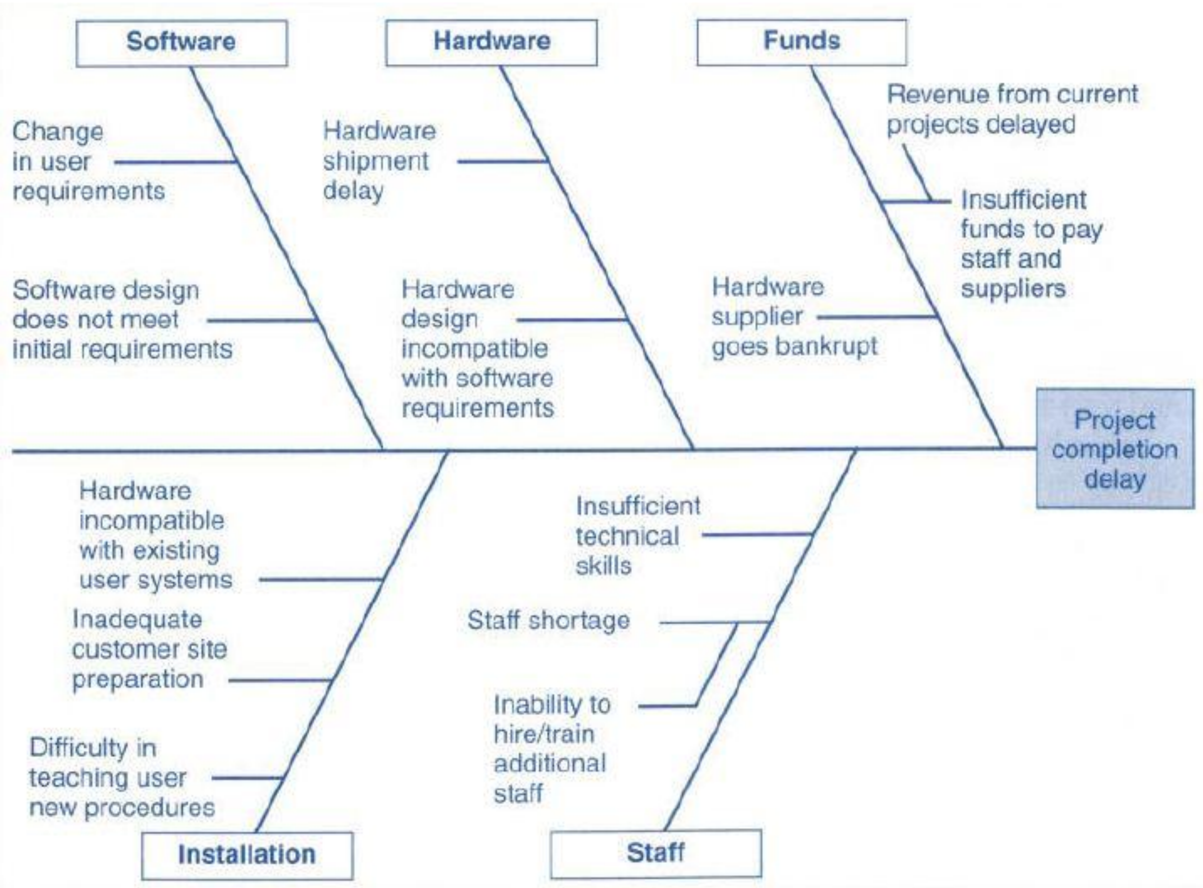

Figure 2.19: Cause-and-effect diagram

The nominal group technique (NGT) and the Delphi technique are both helpful group techniques for risk identification. The NGT was developed by Delbecq in 1968 and was derived from social-psychological studies of decision conferences, management-science studies and social work studies [23]. The method entails convening a panel of seven to ten people, most likely those in the project team and other colleagues with relevant experience. Each member of the group is then asked to individually generate a list of risks without discussing them with anyone. All the ideas are then listed on a board or flip chart. Then the group discusses each one of the risks that was listed. Each panellist then gets the opportunity to prioritise the risks. All the panellists' scores are then collected and combined to form a group ranking of each risk.

The Delphi technique involves convening a panel of experts from within and outside of the company. Each panellist is then asked to make an individual and anonymous prediction or comment on a particular topic through carefully designed consecutive questionnaires. Each expert receives the combined feedback of the entire panel and is then asked to make new predictions. The process is repeated until the results stabilise, usually within two or three iterations [23].

Recording experience and evaluations of past projects in a 'lessons learned' file, as well as an analysis of available documentation and records, are both very useful techniques of risk identification. Even physical inspections of the potential construction site, for construction projects, would most likely be helpful in identifying potential project risks.

Hazard and operability (HAZOP) studies are used for "the systematic analysis of the individual parts of a process in detail", as Leslie Edwards explain in his book on practical risk management [21]. This is a qualitative analysis method that looks into the fundamental parts of the processes of the project under evaluation. The purpose of this detailed study is to identify the following:

- The purpose of the specific process, part or item
- Possible deviation from intentions
- Possible causes of deviations
- The consequences of deviations

A flow chart of the processes, parts or items in the system is drawn up to ensure that every part of this complicated system is thoroughly investigated. This process enables the project team to do an extensive identification of all the possible risks involved, which can then be analysed. However it does take an immense amount of time. It might require the simplification of some processes in order to assist the analysis, which could mean that some risks might be overlooked [21].

The fault tree analysis (FTA), which was originally developed by H.A. Watson in 1962 at Bell Laboratories, is a systematic analysis that determines possible hazards and their potential impact on the project. It can identify risks in detail, whilst also being able to indicate the magnitude of the impact they could have. FTA uses a tree-notation where the top node represents the hazard under investigation, from where the analysis works backwards to determine what could cause such an event. The branches of the tree represent all the possible events that could lead to the initial hazard and the leaf nodes represent the causes of those events (see Figure 2.20).

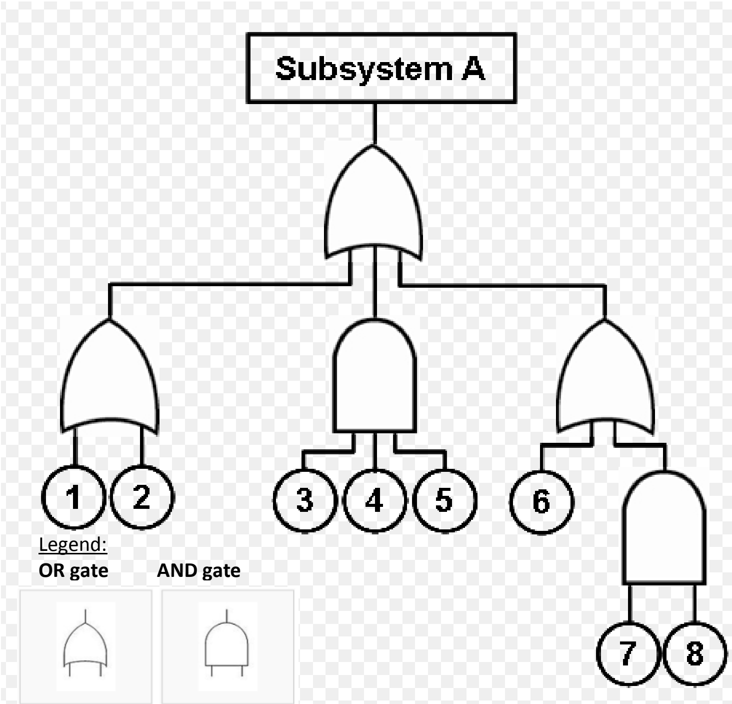

Figure 2.20: Example of a Fault Tree Analysis **[29]**

Each 'leaf' node is assigned a probability as well as either an "and' or an "or" gate between individual 'leaf' nodes. This gives a diagrammatic view of how combined individual events could cause a hazard to materialise. It also allows for the quantification of the overall probability of the combination of events to occur. The probabilities of 'leaf' nodes linked by "and" gates should be multiplied and those with "or" gates should be added, but to determine the node probabilities is often quite difficult. The advantages of FTA is that it can describe a complicated system or process in a very structured way, which makes it easier to understand and evaluate. It is a good way to identify potential risks and can also be used to determine how sensitive the main risk event is to certain minor events or items. Thus it could also be used to mitigate those risks. The disadvantages however, are that it takes a lot of time to do the analysis, and that it is dependent on the accuracy of the probabilities of the 'leaf'-nodes [21] [27] [28] [29].

Once the risks have been identified, they are documented and categorised in a risk register. The risk register is therefore the output of the risk identification phase of risk management.

2.2.3.5 Risk Analysis

Once the risk register has been developed, each risk event has to be analysed. The purpose of the analysis is to determine the probability of the risk and the impact it could have on the project. The output of this phase of risk management is the risk rating, which is based on the risk probability and the size of the impact it would have on the project (see equation 2.8). The risks are then given a risk level based on their risk rating, which is used in the mitigation phase of risk management. Risk varies inversely with knowledge and thus the better a risk is understood, the better it can be mitigated.

2.2.3.5a Risk Probability

To determine the probability of an event, it is necessary to gather as much information as possible. The probability can either be expressed as a numerical value between 1.0 (represents certainty) and 0 (represents impossibility), or it can be expressed in a qualitative manner such as high, medium or low. Here it is important to note that subjective probability statements can have significantly different meanings to different people. It is therefore advisable that whichever scale is used, this should be discussed by the panel analysing the risks and their definitions should be agreed upon before they are applied [8] [9].

2.2.3.5b Risk Impact

The risk impact is the consequence of a hazard materialising. When a risk becomes reality, there can be various types of consequence, such as an impact on the project schedule, time or budget. There could even be environmental or health and safety consequences. There might be an impact on confidence in the company's brand name. Whatever the consequences may be, they must be determined, evaluated and given a rating, such as low, medium or high. Once again, this is a subjective value that needs to be discussed and clarified by the team involved [9].

2.2.3.5c Risk Analysis Methods

There are various methods by which risks can be analysed. Some methods are useful for both risk identification and analysis, such as the Delphi technique, fault tree analysis and brainstorming sessions. All of which were discussed in the previous section. It is not always possible to clearly determine the probability factors needed to determine the risk rating, thus subjective judgement is needed to assign a relative rating. Risk analysis methods can thus be divided into qualitative and quantitative methods of analysis. A list of risk analysis methods and a brief discussion thereof follows [8] [9].

- Risk Mapping Matrix
- Scenario Analysis
- Sensitivity Analysis
- Decision Tree Analysis
- Monte Carlo

2.2.3.5d Risk Mapping Matrix

Harold Kerzner [8] and John M. Nicholas [9], in their respective books on project management, have two different methods of risk analysis when there is more than one probability or impact scale involved. Their methods differ in how the risk likelihood and risk impact variables are determined. Kerzner and Nicholas both use a qualitative scale for determining the probability and likelihood of a risk, which can then be used in a risk mapping matrix. Nicolas, however, uses numerical values to represent the qualitative ratings in order to calculate the eventual risk consequence rating (RCR).

In the case of more than one probability or impact scale being considered, Kerzner conservatively picks the maximum result of each category. This method is not perfect, but it prevents the risk being diluted when added to or averaged out between various categories. The researcher chose to use Kerzner's method in the theory application discussed later in the thesis, as it is the most conservative [8].

Nicholas, on the other hand calculates a composite factor for both the likelihood and the impact of a risk. When a project has multiple, independent risk sources, they can be expressed as a single composite likelihood factor (CLF) and composite impact factor (CIF). Both these factors are calculated as a weighted average, with W_i and V_i having a value between 0 and 1. [9]

$$\mathbf{CLF} = {}_{\mathbf{i=0,j=0}}^{\mathbf{i=n,j=n}}(\mathbf{W_i})(\mathbf{L_j}) \qquad (2.10)$$

$$\text{where} \quad {}_{i=0}^{i=n} W_i = 1 \qquad (2.11)$$

$$\mathbf{CIF} = {}_{\mathbf{i=0,j=0}}^{\mathbf{i=n,j=n}}(\mathbf{V_i})(\mathbf{I_j}) \qquad (2.12)$$

$$\text{where} \quad {}_{i=0}^{i=n} V_i = 1 \qquad (2.13)$$

Once both factors have been determined, the risk rating (RR) can be determined, by which the seriousness of the risk to the project is measured. Generally a RR of higher than 0.7 would represent a high-risk project and value lower than 0.2 would represent a low-risk project [9].

$$\mathbf{RCR} = \mathbf{CLF} + \mathbf{CIF} - \quad \mathbf{CLF} \quad \mathbf{CIF} \qquad (2.14)$$

Risk mapping matrices are used to determine the risk level of an item by taking the probability of its occurrence and the impact thereof into account. The matrix should be an nxn matrix where 'n' is the number of the ordinary scale levels (e.g. A to E) being applied. The matrix area is then divided into areas that represent the risk level. In most cases three risk levels are used to indicate low, medium and high risk items [8].

Definition	Scale Level
Basic principles observed	E
Concept design analyzed for performance	D
Breadboard or brassboard validation in relevant environment	C
Prototype passes performance tests	B
Item deployed and operational	A

Figure 2.21: Example of a probability scale **[8]**

C_C	C_S	C_T	Scale Level
≥10%	Can't achieve key team or major program milestone	Unacceptable	E
7–<10%	Major slip in key milestone or critical path impacted	Acceptable; no remaining margin	D
5–<7%	Minor slip in key milestones, not able to meet need date	Acceptable with significant reduction in margin	C
<5%	Additional resources required, able to meet need date	Acceptable with some reduction in margin	B
Minimal or no impact	Minimal or no impact	Minimal or no impact	A

Figure 2.22: Example of an impact scale for three sources of occurrence (Cost, Schedule and Technical) **[8]**

As an example, consider a single probability (P) scale (Figure 2.21) and three impact scales (Figure 2.22) for cost (C_C), schedule (C_S) and technical (C_T) consequences. These are used to populate the 5x5 risk mapping matrix (Figure 2.23). In the risk matrix, probability and impact is rated on a scale of A to E, representing values of *low*, *medium low*, *medium*, *medium high* and *high* respectively. It is best to link each of these scale levels with a clear definition so as to avoid ambiguity and incorrect input. In the risk matrix the letters "L", "M" and "H" stands for *low*, *medium* and *high* respectively [8].

For this example, let's say the resulting values for an item under review were found to be: P=C; C_C=C; C_S=B and C_T=D. Given this information and the risk mapping matrix (Figure 2.23), the risk levels derived for the cost, schedule and technical categories are found to be *medium*, *low* and *medium* respectively (see red circles in Figure 2.23). Taking the maximum of the three risk scores yields an overall *medium* risk level for the item [8].

Consequence → Higher

Probability → Higher

	A	B	C	D	E
E	M	M	H	H	H
D	L	M	M	H	H
C	L	L	M	M	H
B	L	L	L	M	M
A	L	L	L	L	M

Figure 2.23: Example of a 5x5 risk mapping matrix [8]

2.2.3.5e Other Risk Analysis Methods

Scenario analysis is a method used to analyse possible risk events by considering alternative outcomes (scenarios). This is useful for perceiving possible future outcomes of events, as well as the development paths that could lead to those outcomes. Thus the triggers for certain risk scenarios can be identified and monitored as part of the mitigation phase of risk management. By discussing various scenarios, the project management team can combine them to form a pessimistic, most likely and optimistic scenario. Experience has shown that three scenarios are appropriate for further analysis [30].

The purpose of a sensitivity analysis (also known as a "what-if" analysis) is to determine how the change of a major variable affects the project. It thus determines the projects sensitivity to change. To be able to do this analysis, the variables must be quantifiable. Because it is used as a risk assessment tool, the probability of the change in the variable also needs to be taken into account. Typically, only adverse changes are considered in sensitivity analysis. A sensitivity analysis is extremely helpful in identifying key variables that could have an impact on the project's objectives, as well as to assess what the impact would be when the variables change dramatically. It is also helpful in identifying risk response actions that could lessen the impact of changes in these variables on the project [31]. An example of how the variables can be quantified, is assessing the financial impact of an event on the project by using the NPV (net present value) based on an optimistic, most likely and pessimistic approach for the sensitivity analysis [8]. A sensitivity analysis can be very useful when there are limited resources for risk mitigation, as it can determine which variables could have the biggest impact on the project objectives [32].

Decision tree analysis is similar to that of fault tree analysis (discussed in the previous section), in that it is a graphical illustration of alternative choices and their possible consequences, which is useful for making decisions. Figure 2.24 below is an example of a decision tree analysis used to determine whether a business should develop a new product or consolidate. The probabilities of each option, the cost and time associated with them and the resources required, could all be illustrated to indicate the risks involved in each choice. This analysis enables the risk management team to obtain a clear picture of how certain options or choices could impact the project [33] [34] [35].

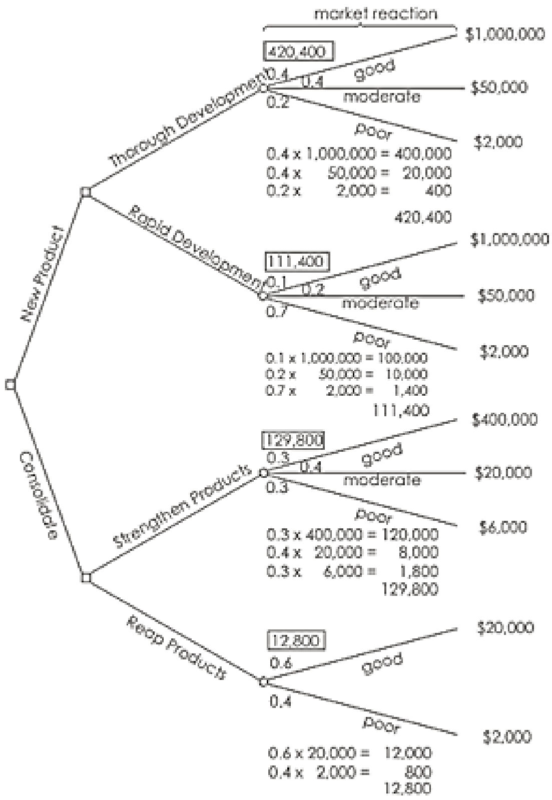

Figure 2.24: Example of a Decision Tree Analysis **[34]**

Monte Carlo Risk Analyses, developed by John von Neumann, Stanislaw Ulam and Nicholas Metropolis in the 1940s, is a method that uses a series of probability distributions for potential risks (such as cost, time and quality risks), that is repeatedly sampled randomly to compute a result. The purpose is to model the variables and use multiple random sampling to simulate all the possible values such a variable can have, because of the uncertainty of the input value. The accuracy of the analysis depends on the correctness of the model that will be analysed. A Monte Carlo analysis generally has the following steps [36]:

a) Define the domain of possible inputs;
b) Generate random inputs from a probability distribution over the domain;
c) Perform a deterministic computation on the inputs
d) Aggregate the results.

It is critical that the input values are totally random, evenly distributed across the domain and as many as possible, as that will improve the approximation [36]. As explained by Touran and Wiser [37], if the project cost estimate were to be analysed with a Monte Carlo simulation, every cost component with a high potential for variability is modelled as a random variable. Then an appropriate computer program is used to generate random numbers, based on the assumed statistical distributions for various cost components. These numbers, as well as the constant cost items that have fairly accurate estimates which are not expected to show great variations, are then compiled into a cost estimate. This is an iterative process that eventually shows a distribution of the projected project cost which can be used to determine the probabilities for finishing within or outside the estimated costs [37].

2.2.3.6 Risk Response Planning and Managing

"*Unmanaged or unmitigated risks are one of the primary causes of project failure*" [38]. Thus, after the risk register has been compiled, the risks have been analysed and given a risk rating according to which they can be categorised and prioritised, a risk response plan must be made. A risk response plan is a section of the risk management plan. By looking again at Figure 2.17, it should be clear that risk management is an iterative process of constant identification, analysis and mitigation.

The risk response plan should identify the methods and techniques by which the risks will be managed, the people responsible for the risks and the resources that might be required to handle each risk should it materialise. The main objective of this phase of risk management is to reduce risk factors to more acceptable levels [8].

There are four ways to respond to risks. They are listed and briefly defined below [9]:

- *Transfer:* The risk is transferred partly or completely to another stakeholder.
- *Avoidance:* Risks could be avoided or reduced if the project is altered in certain ways.
- *Control:* Most of the time a risk cannot be avoided, but it can be reduced and / or controlled by certain measures and contingency plans.
- *Acceptance:* This is when the project manager chooses to do nothing about the risk, as the benefit of any other form of response is far less than the resources required to implement it. It is advisable to have a contingency plan for these risks as well.

It is necessary to identify suitable metrics or triggers, as part of the risk response plan, to enable the project manager to monitor risks and know when to implement the contingency plans [8].

2.2.3.7 Risk and Change

There is an interdependency between risk management and change management; both form part of project management. Every risk management strategy might result in changes to the project which, again, could result in additional risk. They go hand in hand and thus certain companies integrate them into one methodology. Changes that are not managed result in more time and money being required for risk management, which then would be more like crisis management. Managed changes, in comparison, require fewer resources [8].

2.2.4 International Organization for Standardization (ISO)

2.2.4.1 Introduction

The International Organization for Standardization (ISO), based in Geneva, Switzerland, which is a consortium of approximately 162 of the world's industrial nations, is the world's largest developer and publisher of International Standards. It is a non-governmental organization that develops new international standards required by specific sectors and stakeholders, suitable for implementation on a broad basis. Standards are developed through technical committees, comprising industrial, technical and business experts and often assisted by representatives of government agencies, testing laboratories, consumer associations, non-governmental organizations and academic circles.

Most of the consulting engineering companies that manage construction projects are ISO 9001:2008 certified. Since the aim of this thesis is to develop a workable model for construction change management, the requirements of that standard also bear relevance to this thesis and are discussed in this section. In this section, the ISO 9001:2008 requirements in terms of change, cost and risk management are investigated, along with the ISO standard for risk management (ISO 31000:2009).

2.2.4.2 ISO 9001:2008 (Quality Management Systems – Requirements)

The purpose of being an ISO 9001:2008 approved company is to ensure that the company is able to provide its clients with products that meet their requirements. The International Standard (ISO 9001:2008) promotes the adoption of a process approach to quality management. By stating this they refer to a system of various processes within an organisation that ensures that the product meets the specifications and that client requirements are met. These processes interact with each other and have to be managed effectively in order to attain this goal, as shown in Figure 2.25.

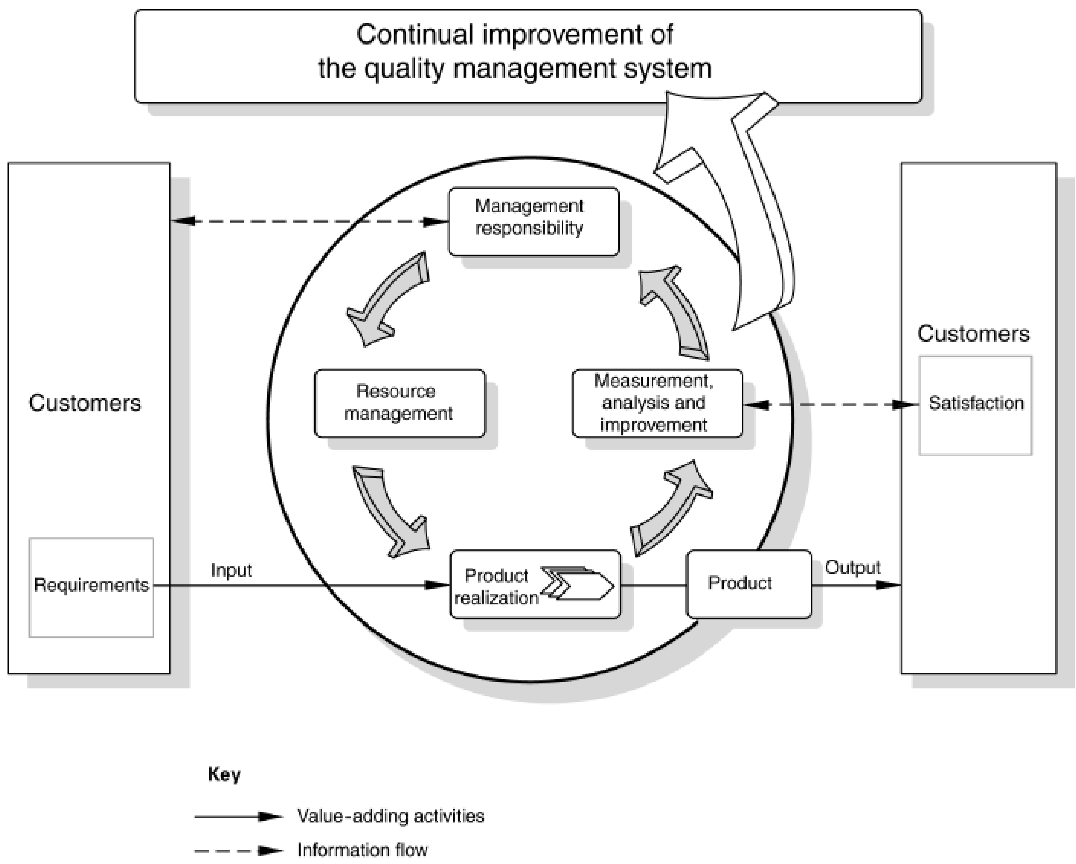

Figure 2.25: Model of a process-based quality management system **[40]**

The International Standard gives various requirements for the quality management system. Those that are important to the change management model of this thesis, are discussed below.

The organisation applying the ISO standard has to determine the processes needed for the quality management system, how and in which sequence they are applied. The interaction between various processes, as well as the criteria and methods by which the efficiency of these processes will be monitored, analysed and improved, must be clearly defined. The documentation for the quality management system should include the following [40]:

- Documented statements of a quality policy and quality objectives
- Quality Manual
- Documented procedures and records required by this International Standard
- Documents/records that show the effective planning, operation and control of processes

A control procedure must be in place for all documents required by the quality control system to ensure that these documents are properly reviewed, updated and issued correctly.

To enable the organization to meet the client specifications, the organization will have to do the following [40]:

- Plan and develop the processes necessary to meet the client specifications.
- Determine the requirements related to the product – those stated by the client, those not stated by the client but essential to make the product work, as well as the relevant statutory and regulatory requirements.
- Review requirements and ensure that they are clearly defined and understood.
- All changes to the scope of the work must be well communicated to the relevant parties and all documentation and designs must be amended to reflect this.
- An effective communication strategy must be put in place.
- The design and development of the product must be well managed.

The managing of the design and development of the product is crucial for achieving the requirements of the product. This requires the following [40]:

- Planning and control of the design and development of the product. The organization must plan how they will review, verify and validate the design at the predetermined design stages, as well as assign the responsibilities therefor.
- All inputs and outputs used for the design must be well recorded.
- Review of the design and development and identification of any problems and setting in place of the necessary steps to rectify the problems.
- Verification of the design and development to ensure that the design meets the requirements.
- Validation of the products ability to meet the requirements.
- Control of design and development changes. All changes must be identified and well recorded.

Regarding the management of changes to a project, ISO 9001:2008, paragraph 7.3.7 [40] states the following: *"The changes shall be* ***reviewed, verified and validated****, as appropriate,* ***and approved before implementation****. The review of design and development changes shall* ***include evaluation of the effect of the changes on constituent parts and product already delivered****. Records of the results of the review of changes and any necessary actions shall be maintained."*

2.2.4.3 ISO 31000:2009 (Risk Management – Principles and guidelines)

The international standard on risk management aims to make risk management more effective by integrating it into the organization's overall governance, strategy and planning, management, reporting process, policies, values and culture. It provides a generic approach that can be applied to various forms of risk within any scope and context which is systematic, transparent and credible [41].

The international standard for risk management (ISO 31000:2009), when managed and implemented correctly, could benefit an organization tremendously. Some of these advantages are listed below [41]:

- It increases the likelihood of achieving the objectives
- It encourages proactive management
- It highlights the need to identify and treat risks in all facets of the organization
- It improves stakeholder confidence and trust
- It establishes a reliable basis for decision making and planning
- It improves operational effectiveness and efficiency
- It minimises losses
- It improves incident management

Figure 2.26 illustrates the way in which risk management principles, framework and processes are related according to the international standard for risk management (ISO 31000:2009).

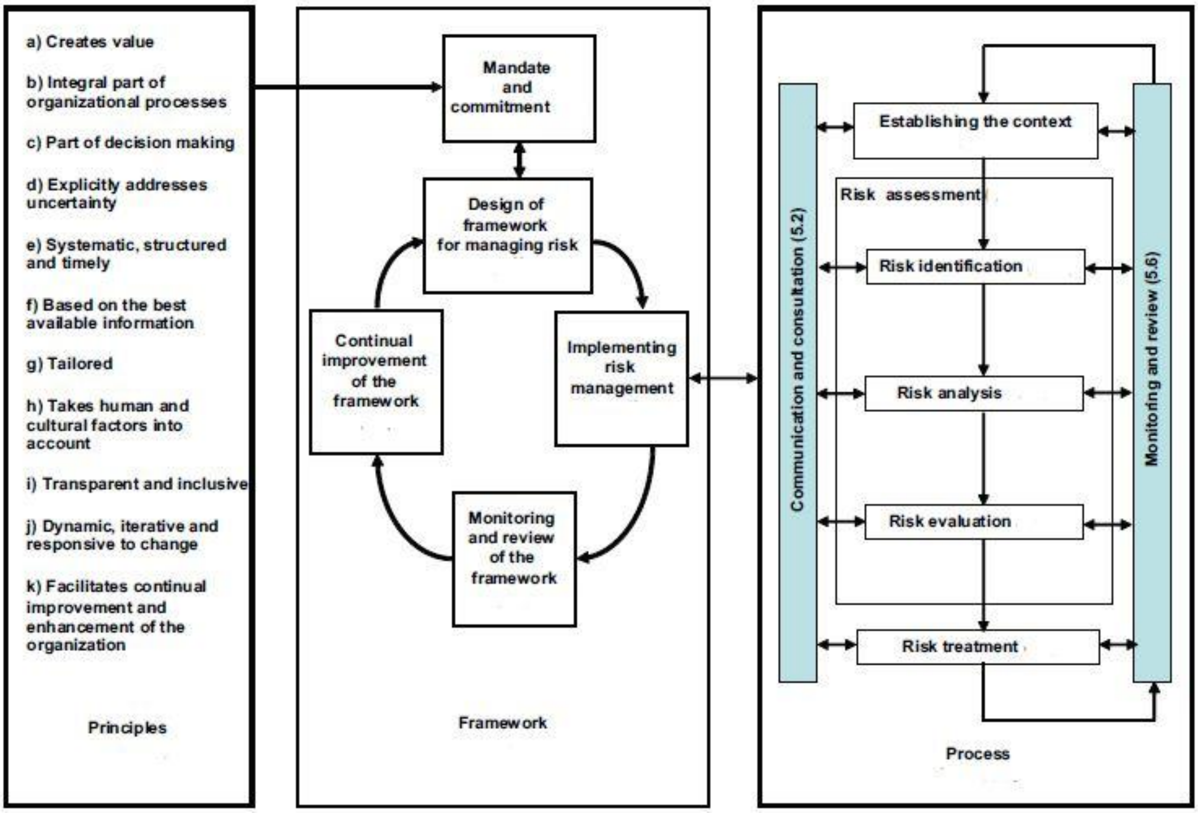

Figure 2.26: Relationship between the risk management principles, framework and process **[41]**

The risk management process, according to the international standard, is very similar to that mentioned in the literature review. It involves an identification phase, a risk analysis phase and a risk evaluation phase, all as part of the overall risk assessment. Once the risk has been identified and analysed, a mitigation process is decided on. With every phase there should be communication and consultation with the relevant stakeholders. Each phase must be monitored and reviewed. This is an integral part of risk management and can take place periodically or on an *ad hoc* basis. The purpose of the monitoring and review is to ensure that the controls put in place are effective. Part of the process is to analyse what happened and learn lessons from events, even near-misses, as well as all changes, successes and failures. Detecting any changes to the context that could influence the risk might lead to a revision of the risk treatment allocated to that risk [41].

2.2.5 Case Studies

2.2.5.1 Introduction

Case studies as a research methodology, work best when a researcher want to investigate an issue in depth, and within the complexities of real life situations [42]. The objective is to gain a thorough understanding of a given situation or system, as in the case of social studies with culture and behaviour. A case study is thus a research strategy that focuses on a comprehensive understanding of the dynamics present within a single setting [43].

2.2.5.2 Selection of a Case

All the major researchers in the field of case study research, including Yin, Stake, Feagin and others, are in agreement that a case study should not be viewed as sampling research. However, they all emphasize the importance of critically selecting cases in such a manner that yields the greatest gain of knowledge and understanding in the shortest period of time. Here it is important that the objective of the study is clear, to ensure that the choices made are appropriate [44].

Descombe [42] lists the following as criteria for selecting a case:

- The case should have the relevant attributes based on the research problem being investigated.
- The case should be a fair and typical illustration of the real life situation being investigated.
- The boundaries of the case should be clearly defined.
- The case should be an independent entity.

2.2.5.3 The value of Case Studies

The value and use of case studies as a research method is disputed in literature. Some are of the opinion that you cannot generalize from a single case and that case studies have a bias towards verification. However, in his paper "*Five misunderstandings about case-study research*" (2006), Bent Flyvbjerg [45] set about to prove the value of case studies as a research method and clear up these common misunderstandings about the application thereof.

He argues that it is not always the number of cases that validates research but rather the characteristics of the case and how well the case is chosen. Carefully chosen experiments, cases, and experience were also critical to the development of the physics of Newton, Einstein, and Bohr, just as the case study occupied a central place in the works of Darwin, Marx, and Freud. Yin adds to this in that he states that single cases are very valuable for confirming or challenging a theory, or to represent a unique or extreme case [46]. An in depth study of a single situation regularly produces more discoveries and a better understanding of the work than statistics applied to large groups. Tellis [44] also mentions the value of single-case studies. He states that they are ideal for "revelatory cases where an observer may have access to a phenomenon that was previously inaccessible". Flyvbjerg thus concludes that it is possible to generalise based on a single case and that case study research is an important scientific method which can be used either to enrich other research or on its own [45].

On the issue of a case studies' alleged bias towards verification, Flyvbjerg makes a few points worth noting. Firstly, that this is an important issue which all researchers should be aware of and do their best to avoid. Also, that subjectivism and bias toward verification applies to all methods, not just to the case study. All researchers have preconceived ideas, assumptions and concepts with which they approach their research. Flyvbjerg concludes that "case studies contain no greater bias toward verification of the researcher's preconceived notions than other methods of inquiry. On the contrary, experience indicates that the case study contains a greater bias toward falsification of preconceived notions than toward verification" [45].

Yin [46] responded to this criticism of the case study as a research methodology in a different way. He suggested three remedies to eliminate the potential criticism regarding investigator subjectivity. He suggested the use of various sources of evidence, so that the researcher ensures the establishment of a chain of evidence and that the case study report should be reviewed by the key informants of the research [46].

2.2.5.4 Conducting a Case Study

Most experts agree that one of the first steps in conducting case study research, before starting with the data collection, is to set up a case study protocol. This protocol should determine how the case study will be conducted, set out the procedures and general rules. This is critical for a study of multiple cases, and desirable for a single-case study [44].

When conducting a case study as part of research, there are five important aspects which form part of the research design, as identified by Yin [46]. Firstly, a case study is built around the initial research question(s), these are typically "why" or "how". The second aspect is the study's theoretical propositions and the third the unit of analysis. Fourth is the logic that links the data to the propositions. And last, the criteria by which the findings of the study will be interpreted. The researcher must be able to create a framework of how the data is to be collected and how the conclusions that will be drawn will be linked back to the initial research questions.

2.2.5.5 Analysing data

The analysis of the case study should clearly show that it depends on all the relevant evidence; that all conflicting interpretations were considered; that the major issues of the research are addressed by the analysis; and that any relevant previous experience is brought to the study [46]. When analysing a case study, several techniques can be used. Some of the critical features of a case study analysis, as identified in the papers by Eisenhardt [43] and Yin [46], are stated in the following paragraph.

One technique is to develop a detailed case study description. The analysis is then built around the general characteristics of the case. A second method used for analysis is pattern-matching. When multiple cases are used, the researcher should look for cross-case patterns, the similarities and differences between them. Another way is to compare empirically based patterns with predicted ones.

- Comparing the expected outcomes: Was the initially predicted outcome found and is there an absence of conflicting results?
- Rival explanations: The presence of certain explanations can exclude others. A researcher should never ignore the conflicting findings, because that reduces confidence in the findings.

Another technique is explanation building. This consists of systematically comparing the data from the case study with the initial hypothesis and then deriving a theory based on the evidence from the study. The analysis is then the result of a series of iterations. It can also be a comparison of the emerging theory or hypothesis with existing literature, determining the similarities and contradictions. If there is conflicting literature, this presents an opportunity for new ideas, as it forces the researcher to relook at the data more creatively. The result can be greater insight into the developing theory and the conflicting literature, as well as a sharpening of the limits to which the main research may be generalised. Lastly, a case study can be analysed by time-series analysis. This involves asking "how" and "why" questions about relationships and changes in events over time.

2.2.5.6 Advantages of Case Studies

There are several advantages to using case studies as a research methodology, such as the following [42]:

- This is a research method that can deal with the intricacies and subtleties of complex situations
- It integrates several sources of data into the research
- The researcher does not have to impose any controls
- It is also relevant for theory-building and theory-testing

2.2.5.7 Disadvantages of Case Studies

The disadvantages to using case studies as a research method are as follows [42]:

- The perceived lack of credibility of generalizations made from the findings
- It can be difficult to define the boundaries of the study
- Case studies are often reliant on permission from external people, which can ruin the research if that permission is withheld or withdrawn.
- Case studies may also be hindered by restricted access to documents, people or settings due to confidentiality requirement.

2.2.6 Interviews

2.2.6.1 Introduction

Interviews are a data collecting method that is best used when the aim of the research is to gain insight into things such as people's opinions, feelings and experiences [42]. When the researcher needs only to gather information on simple and uncontroversial matters, surveys are a much more relevant and cost effective method.

2.2.6.2 The types of Interviews

There are various types of research interviews, however only two are relevant for this study: structured and semi-structured interviews. Structured interviews are in many ways similar to a questionnaire, with the only exception being that they are conducted face-to-face with a respondent. The researcher sets up a list of questions with limited-option responses. This method of doing interviews has the advantage of 'standardization' and that the data can be fairly easily analysed. Semi-structured interviews also have a pre-determined list of questions, but allow the respondents more freedom in their answers. One of the goals of this method of interviewing is to give the respondent the opportunity to elaborate on points of interest and give their opinions.

Interviews can also be done in different formats. The most common form is the one-on-one personal interview. This form of interviewing is easy to arrange, all the answers given in the interview comes from one source. Another advantage is that it is easier to control and to transcribe afterwards. For these reasons only one-on-one personal interviews were conducted for this thesis [42].

2.2.6.3 The Interviewer Effect

Research on interviewing has proven quite conclusively that the way in which people respond is dependent on what their perception is of the person who is interviewing them [42]. Particularly things such as the sex, age and race of the interviewer can have an impact on the way people respond to questions. Thus the research data will most probably be affected in one way or another by the personal identity of the interviewer. The measure of impact is also dependent on the nature of the topic under discussion. The more sensitive the questions, the more important the perception of the researcher's identity will be. There is, however, little that can be done to eliminate the interviewer effect.

Literature mainly advises researchers to be aware of the interviewer effect, to be professional and to remain neutral and non-committal in their presentation.

2.2.6.4 Planning and Preparation for interviews

It is vital for the success of this research method that the researcher should properly plan and prepare for the interviews. Some of these preparations, as listed by Descombe [42], are discussed in this paragraph. It is essential that the researcher develops questions with the end goal in mind. It is also beneficial to take the future analysis requirements into account when setting up the questions. A researcher needs to be well informed on the subject on which he or she will be interviewing other people.

The sample size of a group of interviewees is usually much smaller than that of a survey, and thus the respondents are generally selected for what they can contribute to the research in terms of experience and education. It all depends on what the aim of the research is. Should the researcher want to produce results that are generalizable, it would be better to choose a representative sample of people to interview. If the aim is to thoroughly uncover a particular subject, it would be better to interview key role players in that specific field. It is also necessary that the researcher gain approval for the study from the relevant authorities.

2.2.6.5 The validity of Interview Data

How do you know if the respondent is telling the truth? This is a vital question for a researcher using interviews to gather data on a certain subject. Here the subject plays an important role. If the interview is regarding information of a factual nature, which is the case in this research, the researcher can check whether the information is broadly corroborated by other people and sources. Some of the ways to ensure the validity of the data are as follows [42]:

- Comparing the data with other sources of information on the topic, such as documents, observations or even other interviews to see if there is some level of consistency.
- Where possible, the researcher should go back to the interviewee with the transcript, in order to check that the facts are accurate.
- Look for themes in the transcripts. A recurrent theme in interviews indicates that the issue/idea is shared among a broader group, and thus has more validity than one single opinion.

2.2.6.6 Advantages and Disadvantages of Interviews

As with all research methods, there are various advantages and disadvantages of using this method. The main advantages of interviews are as follows [42]:

- Interview data on a subject is comprehensive and detailed.
- Interviews can give great insight into a subject
- Interviews require little in terms of resources
- Interviews are flexible and allow for the development of an idea or thought, which is not possible with surveys.

Some of the disadvantages of interviews, as stated by Discombe [42] are as follows:

- Data analysis is difficult and can be time consuming.
- The impact of the interviewer is difficult to determine, also consistency and objectivity are harder to achieve which, in turn, has an effect on the reliability of the data.

2.3 CHAPTER CONCLUSION

The aim of this chapter was to understand project change, the impact it can have on a project and how it should be managed in practice. Several articles, books and webpages on the subject of project change were studies and discussed in this chapter. Specific focus was given to the subjects of cost and risk management, as they are the focus of the study.

The literature shows that change can have a great impact on a project's objectives and, therefore, effective change management is crucial to successfully manage a project. The core values of change management, which should be incorporated into the change management model, are as follows:

- Changes should be identified
- All change requests should be reviewed
- The impact of the changes should be analysed
- Changes should be authorised
- Changes should be communicated to project team
- Changes should be documented
- Implementation of changes should be monitored

In order to analyse the impact of project change, the effect of the change on the project budget, schedule, quality and its potential risks should be evaluated. This is important, as these are the critical success parameters of a project. The International Organization for Standardization's standard for quality management (ISO 9001:2008), requires that the evaluation of the effect of the change on the overall project be part of the change review process and, along with any necessary action, has to be documented and kept for record purposes.

The literature shows that risk management is a vitally important aspect of change management. There is an interdependency between risk management and change management. Every risk management strategy might result in changes to the project which, again, could result in additional risk. Changes that are not managed require more time and money for risk management, which then would be more like crisis management. Managed changes, in comparison, require fewer resources. These aspects should be kept in mind when designing the model [8].

3 METHODOLOGY

3.1 CHAPTER INTRODUCTION

As in business, research requires a strategy or action plan designed to achieve the desired objectives. A strategy requires [42]:

- An overview of the whole project as the basis for deciding how to approach the research (a research paradigm)
- A carefully constructed plan of action (research design)
- A specific goal which is to be achieved and which is clearly identified (research problem or hypotheses)

This chapter documents the design and methodology followed for the research and the model development. It starts with an explanation of the background that led to the study and the objectives of the thesis. The chapter concludes with the formation of the research hypothesis.

Chapter Questions

- Why was this research initiated?
- What is the aim of this thesis?
- How will the research be conducted in order to achieve the research objectives?
- What is the research hypothesis?

3.2 Research Design

3.2.1 Research Paradigm

The research paradigm is a summary of the applicable facts and findings of the literature review. This information forms the foundation of the thesis and is summarised in this section.

Project management can be defined as the application of knowledge, skills, tools and techniques to project activities to meet project requirements. It requires the effective management of appropriate processes. However, a project seldom goes according to plan. Due to planning oversights, new opportunities, changes to the client's requirements, or even unanticipated circumstances, changes are made to the project. Project change can be defined as any event that alters the project's original scope, execution time or the cost of the works. Improper management of the project's changes could have an immense financial impact, which may lead to project cost overruns and even claims or legal disputes.

During the construction phase of a project, change affects every aspect of productivity – the planned schedules and deadlines, work methodology, resource procurement, as well as the budget and this could prevent achieving the project objectives. The purpose of project change management, therefore, is to ensure that changes are carefully reviewed and that their impact is properly assessed, in order to ensure the success of the project [8] [9] [2] [10].

The literature study discussed in the previous chapter aimed to answer various questions in order to understand the research paradigm of this thesis. These questions are:

- Why do changes occur and what impact can they have on a project?
- How should changes to the works be managed for construction projects?
- What is cost and risk management?
- Which management methods are relevant?
- How can interviews and case studies be used in research?

3.2.1.1 Why do changes occur and what impact can they have on a project?

In the literature review three case studies which is conducted with the aim of determining the reasons for changes, and their impact, are cited. They are the studies by Charles Leonard [17]; Love et al. [6], and I.A. Motawa et al [3]. Combined, they highlighted the following reasons for change during the construction phase of a civil project:

- Design errors and omissions
- Design changes
- Unforeseen conditions
- Inaccurate or vague project information at the initial stages of the project
- Scope creep
- Client requirements change
- Extension of time
- Requirements by regulatory authorities
- Rework due to construction errors, omissions, damage etc.
- New opportunities

Effective change management is a crucial component of successfully managing a project. The case study done by Love et al. [6] found that changes and rework had a combined 10.5% cost impact on the project and resulted in 109 non-productive days. There is thus no doubt that change can have a significant impact on a construction project. In his study on the impact of change, Professor C.W. Ibbs from the University of California at Berkeley, had similar findings [2]. They are as follows:

- As change increases on a project, productivity decreases.
- Change that occurs during the construction phase of a project has a more disruptive impact on the project than change that occurs during the design phase of a project.
- A project that has a large amount of change would have a less efficient implementation of that change.

3.2.1.2 How should changes to the works be managed for construction projects?

The following points are the essential phases of a comprehensive change management system [9] [6] [10]:

- Identification of all changes
- Review of all change requests
- Impact analysis of the changes
- Authorisation of the proposed changes
- Communication of the changes to the project team
- Documenting the changes
- Implementation of changes to be controlled and monitored

The purpose of the impact analysis is to determine the consequences of the change. Any analysis of the impact of change has to look at the impact of that change on cost, schedule, quality and risk, as well as its impact on the rest of the project. These components are the critical project success parameters. As part of the change analysis, all available alternative options should be investigated along with the impact of the change on the resources and duties of the project team. Once the project manager has reviewed the change and its impact, it can be determined whether to proceed with the change or not.

Changes can be requested by any stakeholder and should be recorded in writing and reviewed according to the change management system. Only assessed and approved changes should be incorporated into the project plan and works, and their impact assessment should be documented and kept for record purposes. However, it is essential that change management should be quick and effective, as slow decisions can adversely affect the time, cost or feasibility of the change.

Change management also requires a clear communication strategy which explicitly clarifies: the management hierarchy and the person responsible for making decisions and setting milestones; how and to whom changes must be communicated; and how change should be recorded. As part of the communication strategy, a policy for resolving disputes or conflict that may arise due to change, is also necessary.

The International Organization for Standardization’s standard for Quality Management (ISO 9001:2008), which is used by most civil engineering consulting firms, requires that all changes be reviewed, verified and validated, before being implemented. An evaluation of the effect of the change on the overall project is required to be part of the review process and has to be documented and kept for record purposes, along with any necessary actions.

Lastly, it is important to implement continuous control measurements throughout the project process to ensure that the new activities meet planned requirements in terms of cost, time, quality and safety. Thus a summary of all changes that were made and their impact on the project should be reviewed and reported regularly (e.g. monthly) to identify any deviations.

3.2.1.3 What is cost and risk management? Which management methods are relevant to this thesis?

Managing the cost, duration and risks of a project is critical, as a lack of control in these areas could have a major impact on the project's outcome. The purpose of performing cost control is to monitor the project budget and manage any changes to its baseline. This involves comparing actual spent costs to the accomplished works and identifying any unintended variances [10].

The duration of a project is managed based on a project programme. The most common scheduling technique used in construction is that of creating a detailed work breakdown structure of all items of work, which is then scheduled according to the critical path method to form the project programme. Gantt charts are used to represent it graphically.

Risk is a function of an event's probability of occurrence and its potential impact. To manage a project's risks, the following five processes are important:

- Risk Planning
- Risk Identification
- Risk Analysis
- Risk Response
- Monitoring and Control

There are various methods that can be used to identify risks. Those that were thought to be useful to this research are:

- Experience
- Brainstorming with colleagues or hired specialists
- Risks checklists
- Cause-and-effect diagrams

Once the risks have been identified and a risk register has been developed, each risk event has to be analysed. The purpose of the analysis is to determine what the probability of the risk is and the impact it could have on the project. The output of this phase of risk management is the risk rating, which is used to determine the risk response. There are four ways to respond to risks. The manager can either: transfer the risk to another stakeholder; avoid the risk by altering the project; control the risk with certain measures and contingency plans; or accept the risk and do nothing.

3.2.1.4 How can interviews and case studies be used in research?

As a research methodology, case studies work best when a researcher wants to investigate an issue in depth and within the complexities of real life situations [42]. The objective is to gain a thorough understanding of a given situation. A case study is thus a research strategy that focuses on a comprehensive understanding of the dynamics present within a single setting [43]. It integrates several sources of data into the research and the researcher does not have to impose any controls.

Interviews are a data collecting method that is best used when the aim of the research is to gain insight into things such as people's opinions, feelings and experiences [42]. Semi-structured interviews have a pre-determined list of questions, but allow the respondents more freedom in their answers. One of the goals of this method of interviewing is to give the respondent the opportunity to elaborate on points of interest and give their opinions.

3.2.2 Research Problem

Literature emphasizes the necessity of a systematic change management process, however, it is unclear if this is being applied in practice. Therefore a thorough understanding of how change management is being applied in practice, the type of changes that must be managed as well as the impact of the changes on the project, is necessary. This includes the identification of current change management short-comings as well as improvements that can be made.

Project managers seem to base important project decisions on experience and engineering intuition, rather than following a systematic approach or conducting a thorough impact analysis or risk assessment. This is largely due to time constraints [4]. There is a need for a structured process by which the changes to the works during the construction phase can be evaluated in terms of the cost to the project as well as the risk associated with it. This process must be time effective. Project managers cannot make an informed decision regarding the way forward, without knowing the effect of the change on the project. Changes that are mismanaged could affect the project managers' ability of completing a project successfully.

3.2.3 Research Objective

The research has mainly two objectives. Firstly to conduct a case study of a construction project as well as various interviews with practicing project managers, in order to gain an understanding of the current way in which changes are managed on construction projects as well as their potential impact on a project.

The second aim of this thesis is to create an effective and generic model by which changes to the works during the construction phase can be evaluated in terms of their cost to the project as well as the risk associated with them. This model should guide project managers through a systematic and time effective process for managing changes. This will enable project managers to make better informed decisions regarding the way forward so that projects can be completed within their project constraints.

3.2.4 Research Design

The thesis is divided into six phases (see Figure 3.1), of which the purpose of the first three is data collection by means of various research methods. The data is then reviewed and used to generate a model and lastly the model has to be validated. The research methods used in this thesis are as follows:

- Literature review on how to conduct a case study and on interview research
- Case study
- Interviews
- Literature study on project, risk, and change management

Figure 3.1: Research design

The aim of the literature study is to identify the principles and techniques applicable to risk and cost management that could be useful to the change management model, as well as how research methods such as the case study and interviews are applied. Phases 2 and 3 (the case study and interview research) are the data collection phases of the thesis.

To be able to generate an effective and generic cost and risk management model by which changes to the works can be evaluated, the researcher has to understand the environment in which such a model will be applied. Thus the research design entails a case study on the cost management of a large multidisciplinary construction project. It also includes research by means of several interviews on both cost and risk management of changes. The purpose of the case study is to determine the impact that changes to works have on a project, especially in terms of cost management and the ways in which current project managers err in their management of these changes. Interviews with project managers within the construction field will clarify what is happening in practice in terms of cost and risk management and will inform the researcher of what is required of a change management model.

3.3 Research Hypothesis

By doing a case study of a construction project as well as various interviews with practicing project managers, an understanding will be gained of the current way in which changes are managed on construction projects as well as their potential impact on a project.

Management of changes during the construction phase of a civil engineering project could be improved by the use of a generic change management model specifically developed to determine the cost and risk impact of the proposed change. This would enable the project manager to make better informed decisions so that the project can be completed within the project constraints.

3.4 Chapter Conclusion

In this chapter the background and motivation for the initiation of the research, together with the identified research problem, was discussed. The chapter also documents the research design and methodology followed for developing the change management model, believed to be the solution to the identified research problem.

4 MODEL DEVELOPMENT

4.1 CHAPTER INTRODUCTION

A change management model was developed as part of this thesis as a tool that can be used by engineers and their project team to enhance the management of changes that happen during the construction phase of a project. It is a generic tool that can be used for any civil construction project that is managed by the engineers on behalf of their client.

In order to develop a model that could be used in practice to manage the impact of changes in terms of their risks and costs, the researcher had to first gain a thorough understanding of the subject at hand. The researcher used two methods of data collection, namely, a case study of a civil engineering construction project as well as interviews with project managers within the field of engineering. This was done in order to be able to understand how cost and risk management of changes is applied in practice. In this chapter the data collected and the results of the research will be discussed in detail.

The purpose of the case study was to analyse a real construction project and to determine how the project finances were managed, the reasoning behind this, its effectiveness, and its shortcomings. The interviews conducted with project managers within the field, showed the researcher how cost, risk and change management are being applied in practice. The data collected by these two methods was used to understand the status quo of cost and risk management in practice. Furthermore, the data was used to determine what the practical requirements for cost and risk management of changes are, in order to determine the requirements for the model.

Once the data had been collected and analysed and the model requirements had been determined, the research model was developed.

Chapter Questions

- How great is the impact of changes on a project?
- What are the reasons for changes?
- How are the costs and risks of changes managed in practice by civil consulting engineers?
- What are the current difficulties with cost and risk management of changes?
- Is there a need for a model by which the effects of changes in terms of cost and risk can be determined?
- If there is, what are the model requirements?
- What would such a model look like and how can it be used?

4.2 Data Collection & Analysis

4.2.1 Case Study

4.2.1.1 Introduction

A case study of a construction project that the researcher had prior exposure to was conducted as part of the research for this thesis. The purpose of the case study was to determine the effect of changes that occur in practice during the construction stage of a project. The focus was to determine what the reasons for the changes were, how they were assessed and managed, and more specifically, what their cost impact was. Each change was reviewed and analysed. The necessary information was provided by the consulting engineers who designed and managed the project on behalf of their client. For the purpose of confidentiality, all names of the stakeholders involved in the project have been omitted from this thesis.

4.2.1.2 Project Overview

The project under review is the construction of a multi-million rand integrated waste management facility for a metropolitan municipality, which required a multi-disciplinary project team. The project was designed and managed by civil and structural consulting engineers in joint venture with mechanical and electrical consulting engineers. The project director of the civil and structural consulting engineers firm was the project manager of the development appointed by the client.

The client required that the facility be modern and mechanized so as to efficiently and cost-effectively transfer municipal general solid waste and to recover recyclable waste materials. The design required a 100 tonnes per day materials recovery facility (MRF) and a 1000 tonnes per day refuse transfer station (RTS). The facility also had to make provision for container handling operations, garden refuse chipping facilities, a domestic recycling centre, a workshop, as well as several minor buildings. The works also included the upgrade of a provincial road adjacent to the site.

The design of a facility of this nature involves several aspects of engineering such as roads, structures, municipal, mechanical, electrical, geotechnical and civil works to name but a few. Sub-consultants were appointed to assist with the architectural design, as well as the quantities, land surveying and specialised mechanical equipment. Various other specialists were involved in the design, including architects, a ground water specialist, traffic engineers and landscape architects.

The engineers were responsible for putting together the tender documentation for the construction work. The project was divided into three different contracts. One contract (further referred to as C01) involved the construction of all the structures, civil works and infrastructure, as well as the building-related mechanical, electrical and electronic works. This contract was based on the General Conditions of Contract [47]. The value of the works was in the order of R160 million. The other two contracts (C02 and C03) were design and construct contracts that covered the design, supply, installation and commissioning of the mechanical and electrical plant and equipment for the refuse transfer station (RTS) and the recovery facility (MRF) respectively. The successful contractors for these three tenders had to share the site and accommodate one another in order to minimise the impact on one another's deliverables. The case study will focus only on the cost management and changes experienced during the construction phase of contract C01 as that bears the most relevance to the thesis.

4.2.1.3 Management of the Project

The project plan required that all changes made, or new work added to the project by the engineers be written up as a site memorandum or instruction (SM). This was done mainly by the engineers' representative on site. A site memorandum was also used for general instructions from the engineer to the contractor, and thus in some cases an SM contains only information. When a site memorandum is used for instructing the contractor to make changes or to do additional works, it requires a detailed description of the change or new work, as well as what the cost impact on the project will be, if any. If the cost of the change is unknown, a quote is requested from the contractor. The contractor then needs to reply to the SM in the form of a site request (SR) or quoted rate (QR). The new rate is then reviewed by the engineers in order to determine if it is fair and reasonable and is then submitted to the client in the form of a variation order (VO) for their approval.

The contractor is required to submit a monthly payment certificate that contains their monthly expenditure. The monthly payment certificates submitted by the contractor were reviewed by the engineers on behalf of the client. These certificates record all the items of work that has been done, their cumulative quantities, their rates and amounts claimed for the various pay items of the contract. These pay items are recorded in the schedule of quantities (SOQ). The researcher used the final certificate submitted, which contained the complete values of the project's items, as the financial data for the research. These items were then reviewed and analysed and compared against the base tender.

4.2.1.4 Case Study Propositions and Questions

The project value of contract C01 was in the order of R160 million (including VAT and contingencies) with a construction period of 16 months. For the purpose of the case study the researcher reviewed all the site memoranda, requests and quoted rates; as well as the accompanying variation orders against all the new work and changes made to the project during the construction phase, in order to determine the effectiveness of this form of cost management.

Other available data (documentation, meeting minutes etc.) on the project was reviewed to determine the effect the changes had on the overall project. Further, the researcher was part of the project team for the last 8 months of construction and thus had a good understanding and knowledge of the project. An example will be examined in detail to determine what the ripple effects of a change may be.

Some of the questions that the case study aims to answer are as follows:

- How were the costs and risks of the changes managed?
- What are the reasons for changes?
- What was the impact of the changes on the project?
- What was the cost implication of the changes?
- How were the changes recorded?
- How were their effects evaluated?
- Does change create risks for a project?
- What management techniques were used to evaluate the cost and risk impact of the change?
- What were the difficulties with the cost and risk management of changes during the project?
- Are the current methods of managing changes effective and can they be improved?
- Is there a need for a model by which the effects of change in terms of cost and risk can be determined?

4.2.1.5 Field work and Data Capturing

The case study is discussed in three phases. Firstly, the financial data of the project was reviewed, secondly any further findings were listed and lastly a specific change was assessed as an example of a change made to the project and its implications.

New items are defined as items that were not part of the original schedule of quantities on which the contractor had to tender for the project. The researcher also evaluated the variation orders, which record the changes for approval by the client. Then the site instructions, the requests, as well as all the new rates that were quoted by the contractor, were examined. All new items that were identified were reviewed and analysed in order to determine the cost impact of changes on the project, how they were commissioned and how effectively the cost management methodology was applied in practice. To determine how the cost aspect of change was managed, the researcher investigated the method by which new rates were evaluated, the protocol followed in approving the new rates and the effect of these rates on the contract finances.

4.2.1.6 Results and Analysis

4.2.1.6a Phase 1: Cost Management Data of Project

For this project the main schedule of quantities (SOQ) had 753 original pay items. Each pay item of the schedule of quantities (SOQ) has a tender quantity, rate and amount value. The amount value is the tendered quantity multiplied by the tendered rate. All the item amounts add up to the tendered value of the contract.

During construction of this project, 330 site instructions were issued and 445 new pay items were added to the schedule of quantities and 212 pay items of the SOQ were never claimed and were thus omitted from the works. Seven variation orders were issued, containing 182 items of which 13 items were items of omission. The remaining 169 items represent all 445 new rates added to the project’s schedule of quantities, which were combined for the purpose of the variation order. This data is given in Table 4.1.

Table 4.1: Information of item changes to the project

Item Information	
Number of original pay items in the tender schedule of quantities (SOQ)	753
Number of new pay items added to the SOQ	445
Number of original pay items in the tender SOQ that were never claimed	212
Total number of pay items that represent all the changes to the project	657
Number of new items in the variation orders (VO)	182
Number of items of omission in the variation orders (VO)	13
Increase in rates claimed due to new rates added to SOQ	59.1%
Decrease in rates claimed due to omission of tender rates from SOQ	28.2%

Table 4.1 also indicates that the number of pay items in the tendered SOQ increased by a significant 59%, and that 28.2% of the original pay items were never claimed during the construction period of the project. These values clearly indicate that a substantial number of changes were made to the project.

However, it must be borne in mind that it is not unusual for change to occur from the time of tender to the date of final completion of a project. In this specific case extensive design changes were made to the project, due to the impact of the design requirements from the mechanical and electrical plant contracts (C02 and C03) which impacted the civil and structural works of contract C01. Another reason for changes was regulatory and municipal authorities' requirements that only became known after the award of the construction tender. One of the greatest reasons for such a large value of omissions on the project was the reduction in the Clients' available budget for the works. This only became known after receiving the tenders and therefore necessitated various changes and omissions to the initial design.

To determine the impact of changes to the project, the changes had to be quantified. The value of all the works added to the project, any extension of time cost to the project, all omissions, as well as cost of variation between the tendered and claimed values of the scheduled work, had to be determined. These costs could then be expressed as a percentage of the tendered contract value in order to determine the impact of changes to the project as seen in Table 4.2.

Table 4.2: Value of changes to the project

Description	Value (R)	% of Tendered Project Value
Tendered Value of Project (excl. VAT and contingencies)	135 660 389.24	-
Cost of Project at Completion	133 150 703.79	98.2%
Value of New Works Added to Project	17 741 498.48	13.1%
Extension of Time Cost	1 009 330.19	0.7%
Total of additional costs to project	**18 750 828.67**	**13.8%**
Value of Pay Items Omitted from Project	-17 720 274.96	-13.1%
Value of quantity changes to tendered items in the SOQ	-3 540 239.16	-2.6%
Total of omission costs to project	**-21 260 514.12**	**-15.7%**
Total Cost of Changes to the Project	-2 509 685.45	-1.8%

Table 4.2 shows the value of additional costs to the project is 13.1% of the total contract value, which is much greater than the 10% contingency usually allowed for additional works. However, there was a reduction to costs of 13.1% due to work omissions, as well as a 2.6% reduction due to changes to the initial tendered quantities. Of the R17,720,274.96 saved due to omissions, R 10,120,000.00 (7.46% of the tendered project value) was forced omissions due to a budget reduction by the client. Thus it results in an overall 1.8% decrease to the tendered value of the project. The overall cost impact of the changes on the project might have looked differently if there were no budget cuts.

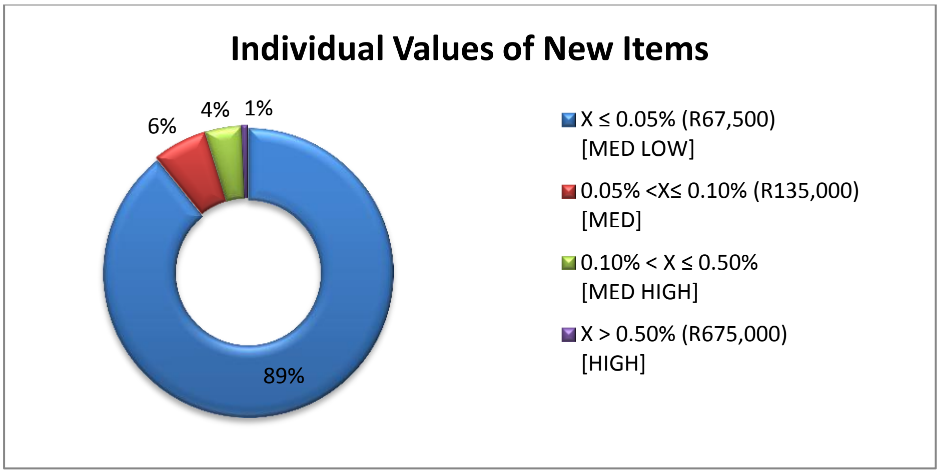

Figure 4.1: Value of new items added to the project (X = Amount value of item)

The cost impact of changes can further be analysed by taking a look at the value categories of the new items added to the project as given in Figure 4.1. The greatest number of items (89% of the 445 new items of work) has a value of less than 0.05% of the contract's tendered value. They represent 28% of the value of additional work added to the project, as shown in Figure 4.2. Only 1% of the additional items to the project have a value greater than 0.5% of the contract's tendered value, but these changes amount to 30% of the total value of additional works. The '*medium high'* and '*high*' categories (as seen in Figure 4.1) amount to 5% of the number of additional items, representing more than 50% of the total value of the items added to the project. These categories thus have a significant impact on the finances of the project. New items with rates falling into these two categories should therefore be carefully examined.

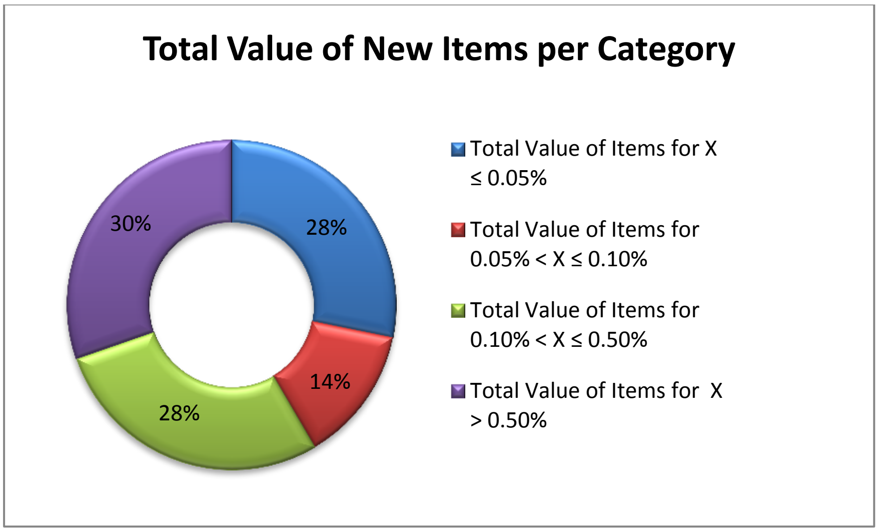

Figure 4.2: Total value of new items (X = Amount value of item)

As stated in Table 4.1 and again in Table 4.3, there are 753 pay items in the original tender schedule of quantities (SOQ). Of these 753 items, 212 items (28.2%) were omitted from the project, thus leaving a remainder of 541 claimed items from the tender. The quantity variance of these claimed items will be broken up into further sub-categories. The contract allowed for all pay item quantities to be re-measurable. The tender quantities listed are based on estimates done during the design phase of the project, however, when the design changes, the quantities also change. The initial quantities might even be incorrect.

As seen in Table 4.3, 146 (19.4%) of the claimed tender items shows a 15% decrease in their tendered quantities, resulting in a saving to the project. The investigation shows that 138 claimed tender items (18.3%) showed a greater than 15% increase in the original quantities. Only 257 items (34.1% of the total) have a quantity variance between -15% and 15%, which can be expected according to the industry standard. Of these 257 items, 177 items have no quantity variance. Thus only 23.5% of all tendered items were claimed without any variance in quantity or cost.

Table 4.3: Quantity variance of items

Quantity Variance of items between the tender SOQ and the final claimed SOQ (Represented by Y)	
Number of items in the tender SOQ	753
Number of original pay items in the tender SOQ that were omitted	212
Number of items in the tender SOQ that were used	541
Number of items for which Y ≤ -15%	146
Number of items for which -15% < Y ≤ 15%	257
Number of items for which -15% < Y < 0	42
Number of items for which 0 < Y ≤ 15%	38
Number of items for which Y = 0	177
Number of items for which Y >15%	138

Table 4.4 indicates a significant cost implication for all tendered items with a decrease or increase to the quantities of more than 15%. These changes to the item quantities amount to values of more than 10% of the tendered project value. It is thus clear that quantity changes of more than 15% can have a significant impact on the project.

Table 4.4: Cost implication of quantity variance of items

Cost implication of Quantity Variance (Y)	**Value (R)**	**% of Tendered Project Value**
Value of Quantity Changes (Y ≤ -15%)	-20 340 820.16	-15.0%
Value of Quantity Changes (-15% < Y < 0)	-1 408 678.08	-1.0%
Value of Quantity Changes (0 < Y ≤ 15%)	1 278 587.39	0.9%
Value of Quantity Changes (Y > 15%)	16 930 671.69	12.5%
Total Value of Quantity Changes	-3 540 239.16	-2.6%

The General Conditions of Contract for construction works [47] used by most public institutions as the basis for the contract of construction projects, states in clause 50 that Contractors may negotiate an adjustment to the general items under the following condition: If the variations to the contract or the quantity changes to re-measurable items result in a greater than 15% variation of the contract price. The limit of 15% is thus an accepted indicator of a great variation in the quantity of an item.

To determine how the changes were evaluated and managed, the paperwork for all the changes were assessed. When a change is made to the project it is recorded by the engineer in a site memorandum (SM) which gives a clear description of the change as well as the cost implication thereof, if it is known. The site memorandum is therefore the engineer's record of the change and its implications. If the change involves work for which there are no rates in the tender schedule of quantities, the engineer requests a quote for it in the site memorandum. The contractor then must supply the engineer with a contractor's quote (CQ) for the works. The CQ is then reviewed by the engineer to determine if it is fair and reasonable. These are two important references (SM and CQ) for managing new items.

In Table 4.5 the statistics of the cost reporting on changes to the project is given. Of the 445 new items added to the schedule of quantities, there were 174 items (39.1%) that were documented in either an engineer's site instruction or a quote by the contractor; only 51 (11.5%) items that had both references and a further 220 items (49.4%) that had no reference at all (see Figure 4.3).

Table 4.5: Cost Reporting of New Items

Description	Number of Items	As % of new items	Value (R)	As % of new works
New items	445	100.0%	17 741 498.48	100.0%
Items that have a Site Memorandums (SM)	136	30.6%	6 465 132.24	36.4%
Items that have no Site Memorandums (SM)	309	69.4%	11 276 366.24	63.6%
Items that have a Contractor's Quotes (CQ)	140	31.5%	12 155 951.27	68.5%
Items that have no Contractor's Quotes (CQ)	305	68.5%	5 585 547.21	31.5%
Items that have either a SM or CQ	174	39.1%	8 814 397.11	49.7%
Items that have both a SM and a CQ	51	11.5%	4 903 343.20	27.6%
Items that have neither a SM nor a CQ	220	49.4%	4 023 758.17	22.7%

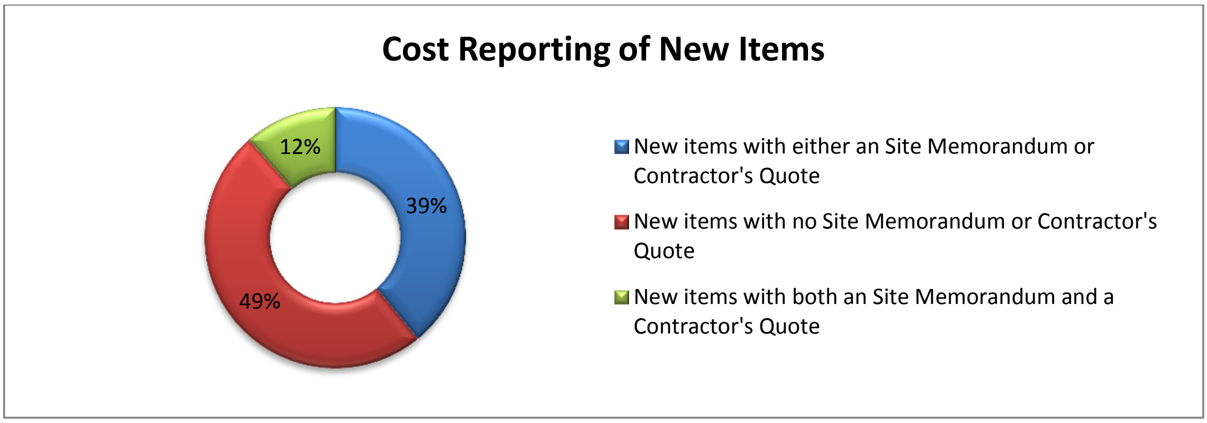

Figure 4.3: Cost reporting of new items

Table 4.5 indicates that for 68.5% of the new items added to the schedule of quantities, there is no record of any quote or information received for the work from the contractor and no indication of any form of review. These items amount to 31% of the value of all new works added to the project. These rates are added to the schedule of quantities without any formal evaluation of fairness towards the client or impact on the project budget. This also implies that no cost, time or quality analysis was made of the changes that necessitated these rates. And, furthermore, it can be assumed that no risk analysis was done for these changes.

Table 4.5 also indicates that site memorandums were issued for only 30.6% of the new works, and thus the remaining 69.4% of the items must have been initiated by other means, which is in contradiction of the project plan. These items amount to a significant 63.6% of the value of the new works. It can therefore safely be assumed that the changes that necessitated these rates were not properly reviewed before the contractor was instructed to do the works, nor were alternative options investigated. The contractor was also not given any written information, instructions or specifications on the changes.

However, it must be noted that the contractor's certificate was evaluated each month, and no rate could be added without the knowledge of the engineer. Even though the rates were not assessed in a formal, paper based manner, they would have been acknowledged and reviewed at each monthly certificate review. Certificate reviews consisted of detailed comparison of the changes between the current and the previous months claimed quantities in order to assess the accuracy of the claim. However, the review examines only those items of work claimed in the certificate which have already commenced. This process would, therefore, have identified any new works added to the certificate only after their initiation. This reactive method is not the ideal way in which to manage cost changes.

Table 4.6: Cost reporting of omitted items

Description	Number of Items	As % of omitted items	Value (R)	As % of value
Number of Items omitted from the SOQ	212	100%	-17 720 274.96	100%
Omitted items recorded	59	27.8%	-12 381 588.09	69.9%
Omitted items not recorded	153	72.2%	-5 338 686.87	30.1%

Of the pay items omitted from the project, only 27.8% were recorded. The remaining 72.2% of the omitted items are not on record and these items amount to a substantial 30.1% of the value of all items of work omitted from the project.

In order to do an appropriate review and risk analysis of a change, an instruction and specification from the engineer (site memorandum) is required, as well as a quote and a programme for the works from the contractor. For this project, 445 new items were added and 212 were omitted from the schedule of quantities. These 657 items (see Table 4.1) represent all the changes made to the project. Only 16.7% of all these items of change have the appropriate records. Thus the remaining 83.3% items of change could not have been accurately reviewed and analysed, as these records are necessary for the analysis. **It is thus clear that the current method of cost and risk management of the changes is not adequate.**

For those items for which the proper documentation exists, an analysis would have been possible. There is, however, no record of such analysis. The researcher did, however, determine that they were reviewed by the engineer in the following manner:

- New rates were compared to rates from the schedule of quantities
- New rates were compared to rates from other similar projects
- New rates were compared to an appropriate supplier's quote
- The contractor provided a rate breakdown of new rates for the engineers perusal
- New rates were compared to an alternative option offered by the contractor

There is no record of the manner in which items were reviewed. It is known that these methods were applied to some items. It is also unclear from the data if the received rates were evaluated by one or all of these methods.

4.2.1.6b Phase 2: Other relevant findings

A relevant finding that should be mentioned is that there was no formal data capturing of the changes as they occurred during the project. By capturing the data related to a change, specifically its cost, time and risk implication to a project, the engineer has valuable information that could be used for future projects of a similar nature.

Another relevant finding is that changes were not always communicated effectively to the rest of the project team. It would be helpful to the project team if, when a change is reviewed, it is communicated to the project team. The communiqué should include the following: who requested the change, who authorised it and to whom it should be communicated as part of the change review process. On large projects a paper trail of all decisions is vitally important, especially to ensure that the engineer's decisions holds up under scrutiny.

4.2.1.6c Phase 3: Example

Once all the data regarding the cost management of the project had been gathered and compiled, the researcher further investigated a specific change to the project.

The client changed the size requirement for the electrical generator. They decided that the generator that was to serve as a backup power source for the facility was not of an adequate size for the facility and should be 550kVa rather than the tendered 250kVa. This change had various implications. Firstly, the new generator had a 14 week manufacturing time and then a 15 day installation and commissioning time. However, this change was made 6 weeks before the programmed start date of the works and 14.5 weeks before the latest start date of the works. Any delay could thus result in a time extension to the contract, which therefore highlights a potential time risk.

Also, the cost of the change was 44% greater than the tendered value of the initially specified generator. The cost of the new generator was 0.52% of the total tendered contract value and this indicates that the change also holds a great financial risk for the project. It furthermore affected various other works and other contractors who were concurrently working on the same site. The generator room and the electrical distribution boards had to be redesigned to accommodate the new generator.

There were also external risks, such as the manufacturer's ability to deliver the generator on time and the ability of the engineers to supply the contractor with the appropriate specification and relevant information in time. The ability of the contractor to manage the manufacturing process effectively and their subcontractor's competence were also potential risks to the project. These were all possible risks associated with the change of which some, unfortunately, did materialise. Had these risks been appropriately identified and mitigated, the generator might have been installed and commissioned on time. However, the work was completed four months later. This contributed to the eventual penalties for the contractor, as well as the extension of time to the contract, which also had a financial implication for the project.

It is therefore clear that an appropriate risk and cost analysis of a change, and especially a large change, could be advantageous for a project.

4.2.1.7 Cross Case Analysis

Love et al. [5] did a case study on a residential construction project (two six-storey residential apartment blocks, containing a total of 43 units) in order to better understand change and rework in construction project management. This case study is discussed in section 2.2.2.2 and 2.2.2.3 of the literature review. There is various aspects of the Love et al. [5] case study that can be compared to the case study conducted by the author. Therefore a short cross case analysis is included which highlights the similar findings. This validates the case study done by the author. Table 4.7 gives a summary of the two case studies discussed.

Table 4.7: Case Study Comparison (including information from the case study by Love *et al*, **[5]**)

Description	Case Study by Love et al. *Residential development*		Case Study by Author *Industrial development*	
	Duration	**Percentage of Original Duration**	**Duration**	**Percentage of Original Duration**
Original contract duration	**43 Weeks**		**72 weeks**	
Extension of time	5 Weeks	11.6%	5 weeks	6.9%
Penalties for late completion			9 weeks	12.5%
	Value	**Percentage of Original Value**	**Value**	**Percentage of Original Value**
Original contract value (excluding VAT and Contingencies)	**$ 10 960 000.00**		**R 135 660 389.24**	
Revised contract value (excluding VAT and Contingencies)	$ 12 065 900.00	110.1%	R 133 150 703.79	98.2%
Variations: Additional Work	$ 753 116.00	6.9%	R 17 741 498.48	13.1%
Variations: Extension of time	$ 53 240.00	0.5%	R 1 009 330.19	0.7%
Variations: Rework	$ 345 504.00	3.2%	R -	-
Variations: Omissions	$ -	-	R -21 260 514.12	-15.7%
Total Cost of Variations	**$ 1 151 860.00**	**10.5%**	**R -2 509 685.45**	**-1.8%**

Both case studies had several weeks of time extension which has a significant impact on the project. The additional work in both case studies resulted in a cost impact of greater than 10%, which is significant. Comparing the two case studies it is clear that projects can have a vast number of changes and that the cost and time impact of changes can be substantial.

4.2.1.8 Summary of Findings

The findings of the case study that are relevant to all construction projects, can be summarised as follows:

- Projects can include a vast number of changes.
- The cost impact of changes can be substantial.
- Changes with a value of greater than 0.1% of the total contract value have a great financial impact on the cost of the project.
- Suggested cost category limits are 0.05%; 0.10% and 0.50%.
- Quantity changes of more than 15% have a significant cost impact on the project.
- Not all changes are recorded in the appropriate manner.
- The cost and risk management of changes, based on this case study, is inadequate.

- Quotes received from a contractor can be reviewed by comparing the rates with those from the tendered schedule of quantities, or those of a similar project or a supplier's quote. In some cases the contractor needs to provide the engineer with a rate breakdown or an alternative option.

4.2.1.9 Critique on the Research

Only one case study was investigated, due to time constraints. A few more case studies would have been ideal. This may, therefore, be an isolated situation. However, the findings are as expected, based on other research as referenced in the literature review. According to a study done by Charles Leonard published in 1988 [17] the changes to a project have major cost and time implications. Professor C.W. Ibbs from the University of California at Berkeley [2] had similar findings. Both found that changes that occur during the construction phase of a project have a more disruptive impact on the project than changes that occur during the design phase of a project. It has also been determined that a project that has many changes would have a less efficient implementation of those changes [15].

4.2.2 Interviews

4.2.2.1 Introduction

To determine how cost and risk management of changes is currently being applied in practice, the researcher interviewed 18 project managers actively involved in the marketplace. In Cape Town there are approximately 20 to 30 engineering consulting companies (based on internet searches). The researcher contacted 21 of them for whom contact details were available. Of the 21 firms contacted, 11 responded positively and agreed to participate in the research. Eighteen interviews were held, most of them (72%) with directors of the firms. The interviewees were asked questions regarding their experience in project management and, more specifically, cost and risk management of changes. The interviews were all audio-taped and later transcribed.

4.2.2.2 Interview Propositions and Questions

The interviews were set up as a semi-structured interview with guiding questions that covered the main topics of the thesis, namely cost and risk management of change. At the start of the interview it was explained to the interviewee that all the questions related to the construction phase of a civil engineering construction project. The complete interview questionnaire used for this research is included in Appendix A: .

The overarching questions that the interviews tried to address were as follows:

- What are the typical reasons for changes?
- How are the costs and risks of changes managed in practice by civil consulting engineers?
- What are the current difficulties with cost and risk management of changes?
- Is there a need for a model by which the effects of changes in terms of cost and risk could be determined?
- If there is, what are the requirements of the model?

The interviews were set up in three sections, with questions covering the following topics:

- General change management of new works added to a project.
- Management of the cost of new works added to a project.
- Risk management of new works added to a project.

4.2.2.3 Data Capturing and Processing

The answers given by the interviewees to the questions were analysed by categorising them into types and grouping them according to the three focus groups. The entire sample was divided into the following three representative groups for data analysis:

- Group 1: Everyone interviewed (N = 18)
- Group 2: Interviewees who are directors (N = 13)
- Group 3: Interviewees involved in civil construction projects (N = 10)

The reason for this was to gain a greater understanding of the data. Those interviewed were of various educational backgrounds and with various degrees of experience. However, experience and education alone does not mean that a person has an understanding of and is well-informed about a matter. Thus the researcher decided to isolate the answers given by those who are directors, as their position is a testament to their being both competent and sensible. The directors also determine the manner in which projects are handled throughout the company.

Those interviewed worked on various types of projects, namely civil, structural, housing and electrical projects. The methods in which projects are managed for a structural project may differ in certain ways to those of a civil project. Thus the researcher decided also to group the answers given by those that work on civil construction projects.

The general demographic of the three groups used is quite similar, see Figure 4.4. The experience, in terms of project value, as well as the education level, of the three focus groups is very similar. Most project managers (78% of everyone interviewed, 77% of the directors group and 70% of the civils group) has experience with projects with a value of greater than R50 million. As expected, the experience of the three groups differs slightly, 77% of the directors have more than 25 years of experience, compared to the 60% and 61% of the other two groups, with only 2 of the directors (15%) having less than 15 years of experience.

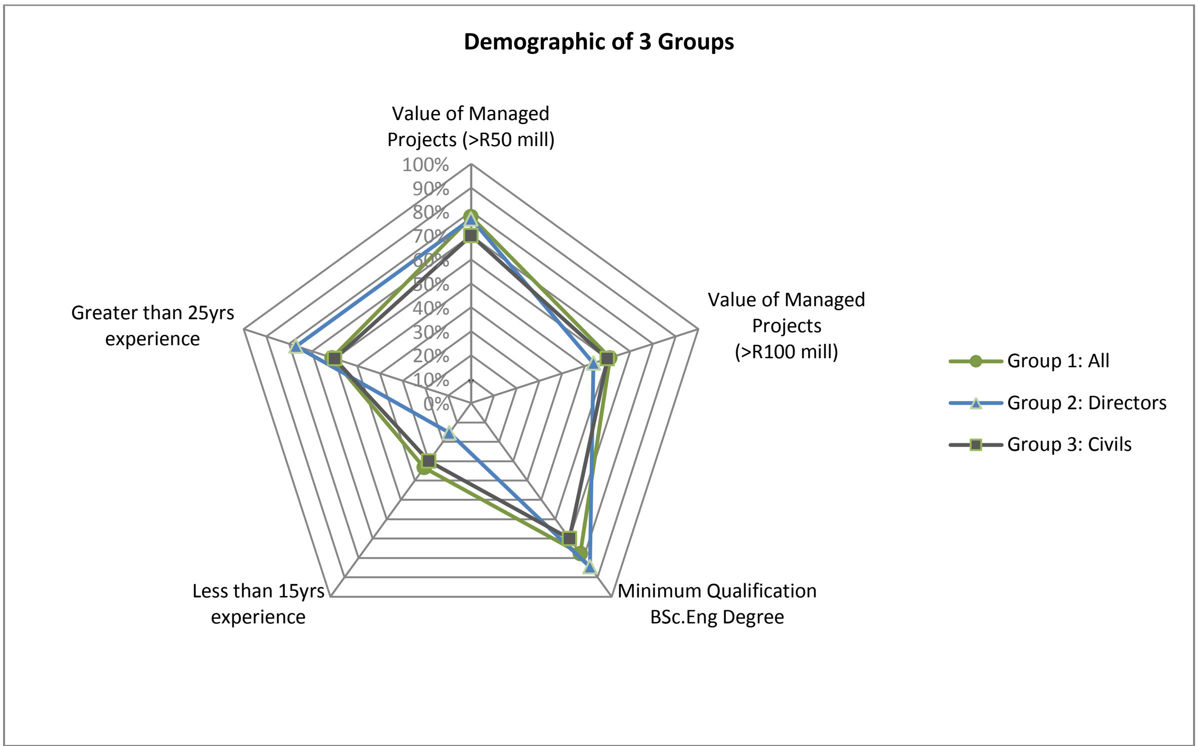

Figure 4.4: Demographic comparison of the three groups

4.2.2.4 Results and Analysis

The results found can be grouped according to the question that it aims to answer.

4.2.2.4a What are the types of change that occur on projects and what are the reasons for them?

From the interviews the following categories of changes could be determined:

- Design changes
- Contractor related changes
- Architectural changes
- Client related changes
- Political and social reasons for change
- Economic factors
- External Factors

The various reasons given by the interviewees for the occurrence of these changes were:

- Unexpected site conditions that impact the design or construction
- Unexpected geotechnical conditions that impact the design or construction
- Inadequate initial site investigation
- Designs based on inadequate as-built information
- Tendering on the basis of an incomplete design, which then changes during the course of the construction phase
- Flawed or impractical initial designs
- Impact of decisions or designs from the other disciplines collaborating on the project
- Impact of works by other contractors also working on the project
- Construction methodologies that change
- Construction programme delays and the consequent adjustments or changes
- The client changes the scope of work or the requirements
- Budget changes
- Feedback from local authority or regulatory officials on the design
- Scope creep or additional work
- Political and social issues (such as strikes)
- Economic factors (such as a scarcity of steel or bitumen; or exchange rate fluctuation)
- Inclement weather
- Communication related problems
- Change of core project members

Paraphrasing the words of one of the interviewees, he stated that conditions on site can be very different from the expectations during the design phase, due to lack of information or an inadequate initial site investigation due to budget restrictions. This can result in design changes. On multi-disciplinary projects the works of other contractors or the designs of other engineers may impact the civil works. An example of this is the mechanical and electrical plant installations which must be constructed in concurrently with the civil works.

4.2.2.4b How are changes in general managed by engineers?

To answer this question, the researcher asked various questions of the interviewees, starting with their general view of the management of changes based on what company protocol required. Figure 4.5 shows the results. What is significant to note is that changes are mainly managed in two ways, through the requirements of the ISO 9000 certified quality management system, and a paper based exercise of issuing site memorandums (SM), quoted rates (QR), variation orders (VO) and monthly payment certificates (MPC). These methods are both cited by 50% of the interviewees. This substantiates the finding of the case study, which also found that changes are managed through a paper based exercise.

The results also indicate that, although there is a methodology or procedure in place, 33% of those interviewed admitted to not always following the set procedure prescribed by company protocol. This value increases slightly for groups 2 and 3. Another significant observation is that a third (33%) of the project managers (and likewise for the other two focus groups) rely on experience for managing changes to the works.

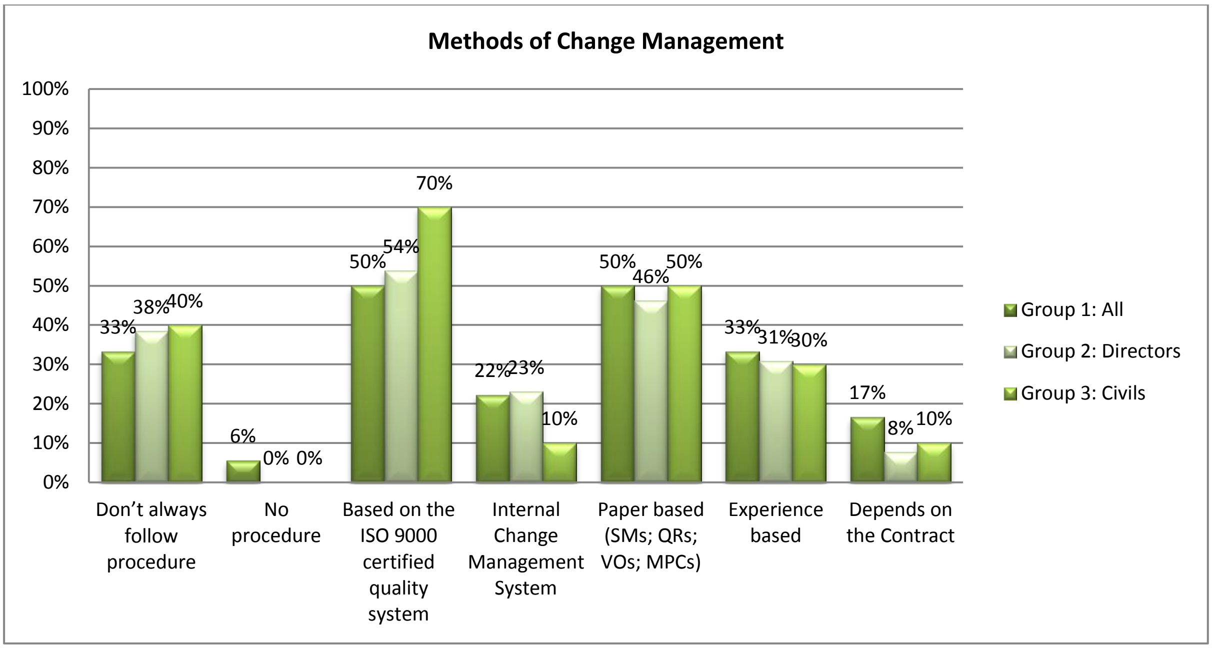

Figure 4.5: Methods of change management

4.2.2.4c How is the cost of the changes managed?

A third of all participants (test group 1), replied that they use primarily their experience and engineering judgement for managing the cost of changes. Other than experience, the participants generally named the following as methods by which they manage the cost of changes of new works:

- Doing a cost estimate of the proposed works
- Asking for rates from the contractor and then assessing whether the rates quoted are fair and reasonable
- Determining the effect of the work on the project budget and contingencies
- Determining if there are any other cost implications of the works due to the change, such as lifecycle or time related costs.

The distribution of the use of these four methods is given in Figure 4.6. What is significant to note is that only 33% of all participants determined the cost impact of the additional works on the overall project, as well as the budget impact of its direct cost. This figure is, however, greater (40%) for those working mostly on civil projects and even higher (46%) for the directors. The importance of determining the impact on the overall project thus increases with more experience and greater understanding – which can safely be attributed to directors.

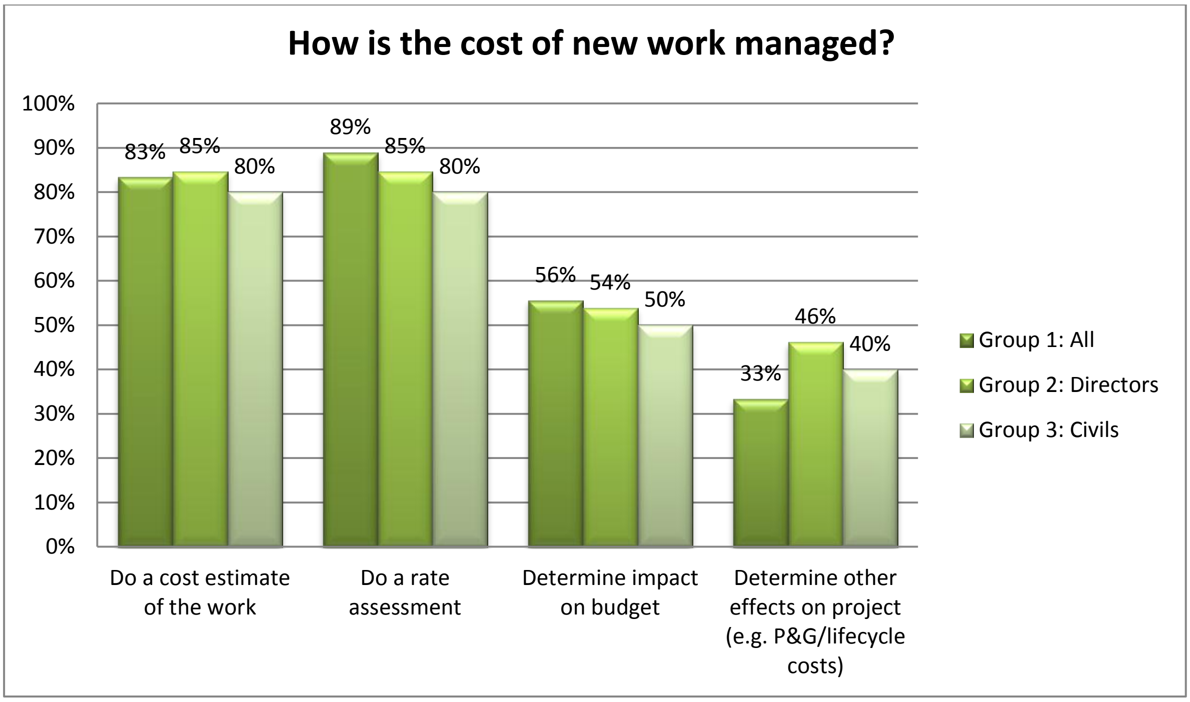

Figure 4.6: Cost management of new work

The general opinion was that an initial cost estimate of the works is done and then the required rates are requested from the contractor. If the rate is found to be acceptable and there is money in the contingencies budget for it, it is added to the project. Quoting one of the participants: "You seldom go out to tender with a complete design, so you know there is going to be additional work, but you don't know how much of your contingencies you are going to use."

The interviewees were then questioned on their process of judging the reasonableness of a rate quoted by a Contractor for new works. The following methods were identified:

- By comparing the given rate to known rates from similar projects.
- By comparing the given rate to relevant rates from project's schedule of quantities (SOQ).
- By requesting that the contractor provides a breakdown of the quoted rate (QR) into components such as material, labour, plant and profit.
- Acquiring supplier quotes for comparison to the quoted rate.
- Judging the reasonableness of the rate based on experience.
- Comparing the rate to indices obtained from the Bureau for Economic Research (BER).
- Transferring the responsibility to the quantity surveyor (QS).

A rate breakdown or the comparison of rates against those from similar projects, or the existing schedule of quantities, are similar methods to those identified by the case study and thus were expected. It is important to note that the experience based decisions of the civils group is approximately 25% more than those of the other two groups. Judgement based on experience can be extremely valuable if used with other methods to validate it, but without this, it can be inaccurate.

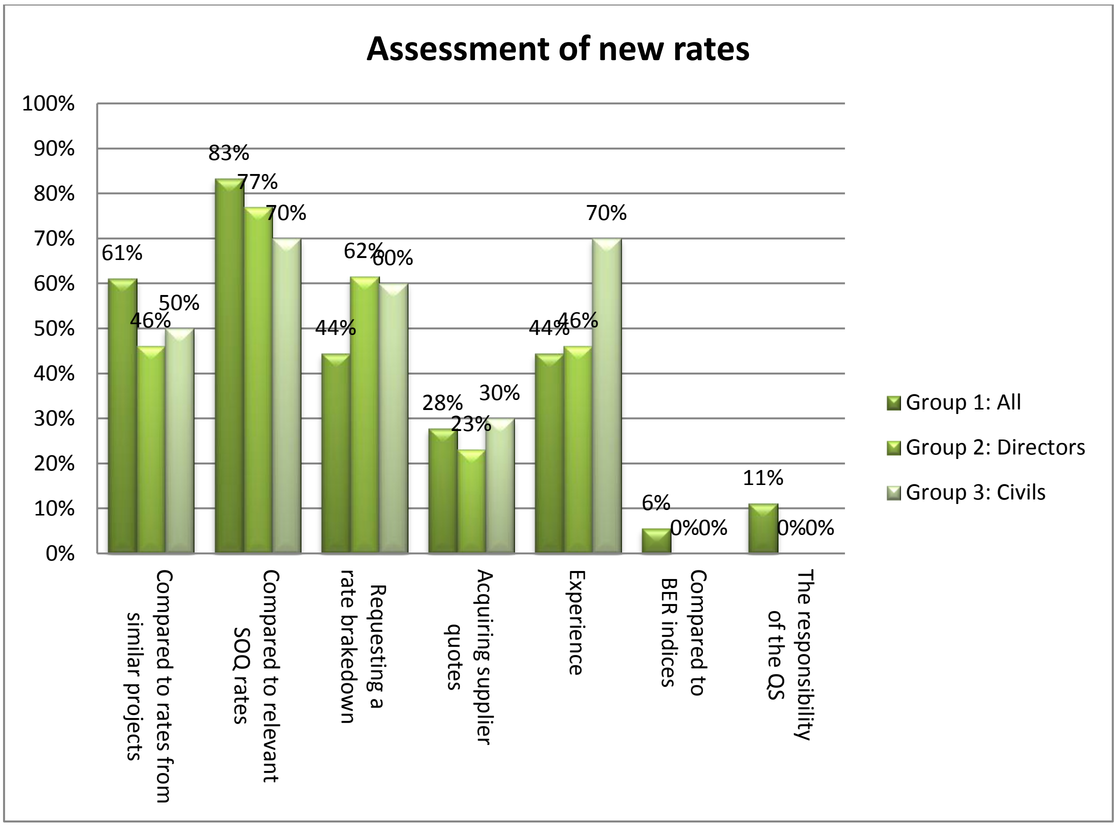

Figure 4.7: Methods by which new rates are assessed

4.2.2.4d How are the risks of the changes managed?

Risk management is theoretically a five step process of planning, identification, assessment, determining the response and monitoring and controlling the risks. However, when asked how they manage risks (see Figure 4.8), only 39% of all interviewees indicated that they followed this process in some way or another. The group of directors (group 2) had the highest percentage for this parameter, at 46%.

More than 50% followed no specific procedure. This value is even higher, at 70%, for the civils group. The civils group also has the highest rating (30%) for handling risks through crisis management. As one of the interviewees said, "Approximately 50% of our time is taken to manage things that go wrong, because everything is such a rush and we don’t do our planning properly. That goes for us as engineers, architects and contractors. You have to keep correcting things and direct them in the right way." This indicates that the risks pertinent to civil projects are not properly identified and managed. The other methods mentioned are preventing scope creep and professional insurance (PI).

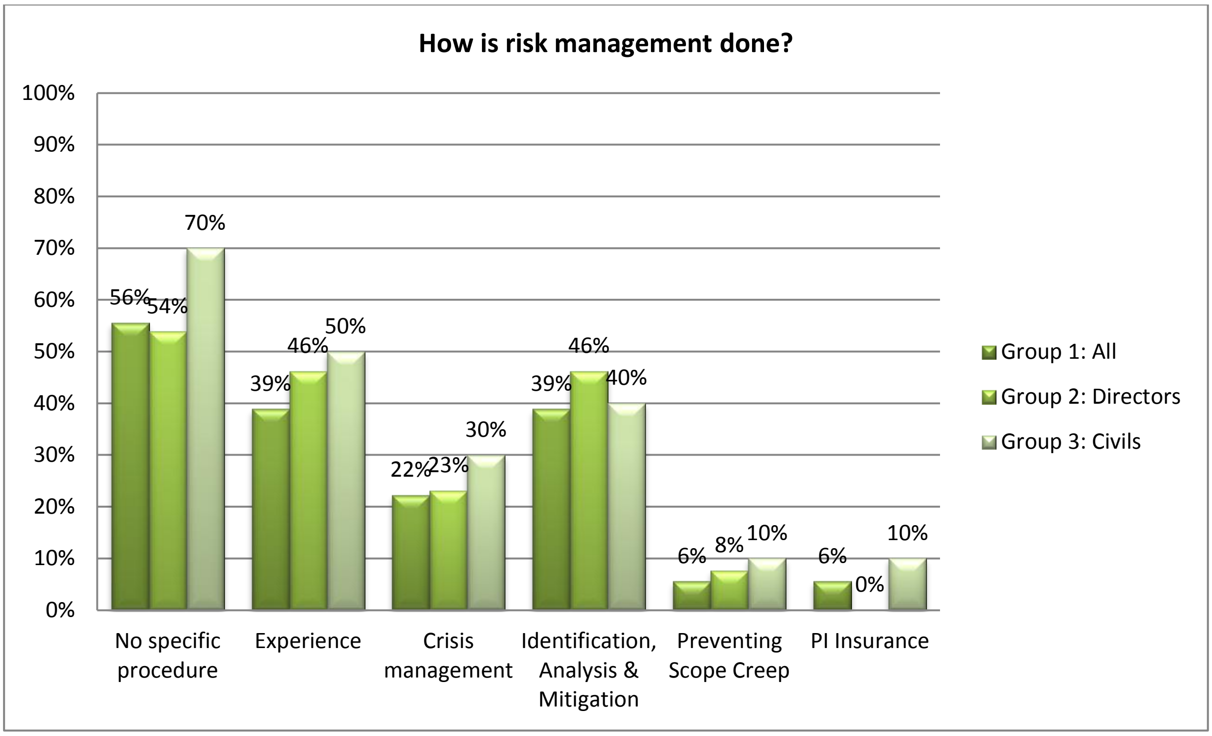

Figure 4.8: Methods of Risk Management

Methods used for assessing the risk impact of a change, are illustrated in Figure 4.9 and listed below:

- According to an internal risk management procedure
- By being proactive
- Based on its possible effect on the programme
- Based on its possible effect on the budget
- Based on its impact on construction
- By comparison to the initial risk assessment
- Based on impact on the rest of design
- Identifying the risk owner and communicating this thoroughly to the relevant stakeholders

Of these methods, determining the probable impact of the change on the project programme and on the budget were the main things to consider when assessing the risk of an item to the project.

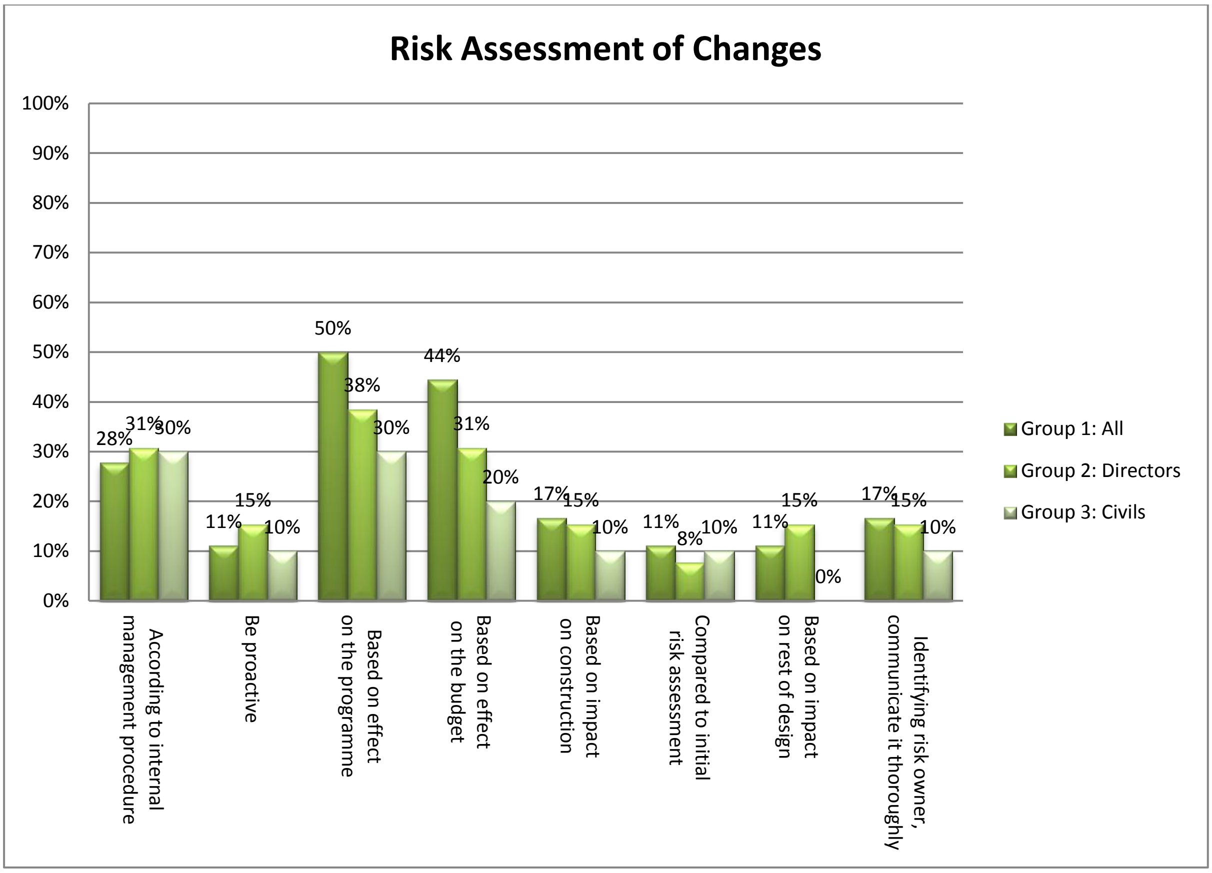

Figure 4.9: Risk Assessment of Changes

Other methods that the interviewees listed as ways in which they manage risks, are given in the list below:

- Brainstorming
- Documentation review and control
- Having a good communication strategy
- Allocated role and responsibility
- Communication Strategy
- What if analysis
- Resource management
- Proper planning
- Weighted risk assessment
- Programme tracking
- Tracking expenditure
- Quality control
- Site supervision
- Monte Carlo analysis

4.2.2.4e What are the current difficulties with cost and risk management of changes?

Most participants commented on the time constraints of cost management. When changes are requested, they often involve design changes which must be implemented as soon as possible and thus the change assessment process delays the work. Therefore the cost assessment has to be fast and effective so that works are not delayed in the process. One of the participants commented that, "This method (doing a rate assessment and determining its impact on the budget) falls short when there are time constraints." Another interviewee was concerned that "there is not enough time to determine the (cost) implications (of the change)."

A general finding was that, cost management merely revolves around ensuring that the budget is not overspent, and that if there is enough money in the contingency budget and the rate is seen to be reasonable according to the engineer's judgement, the change can be implemented. The overall effect of the works on the project, its indirect costs (such as maintenance) and its time related preliminary and general costs (P&Gs) are rarely considered.

The following troublesome theories of cost management were taken from the interviews: When a client (such as a municipality) wants to increase the scope of the work, and there is money available in the budget, it benefits the client to have the already appointed contractor do the works. The procurement effort to appoint another contractor for a small amount of work is too much effort. Therefore the cost of the new work is not considered that important and is solely determined by what the contractor quotes. This is true mostly in the public sector. Paraphrasing the words of one of the interviewees, "If there is money left in the budget and the client wants to spend the money, what they pay for the additional work does not really matter that much. When it's a private client, it is different. They want to know that they are getting value for money." This was confirmed by at least two other participants, and the researcher has had similar experiences in the work place. As one manager put it: "It is important that the contractor is happy with the price he quoted, and therefore I let the contractor make the price." and another: "As long as it fits into the contingencies, its fine."

The biggest hindrance for applying risk management in practice, was found to be time constraints. This, together with knowledge of the subject and practicality, were the three main reasons hindering the application of standard risk management principles (see Figure 4.10). When asked what the greatest stumbling block is for performing risk management, an interviewee replied: "Time and the lack of understanding in the project team that there is value in doing risk management. There is never time to do it (planning and a risk assessment), but always time to do it twice."

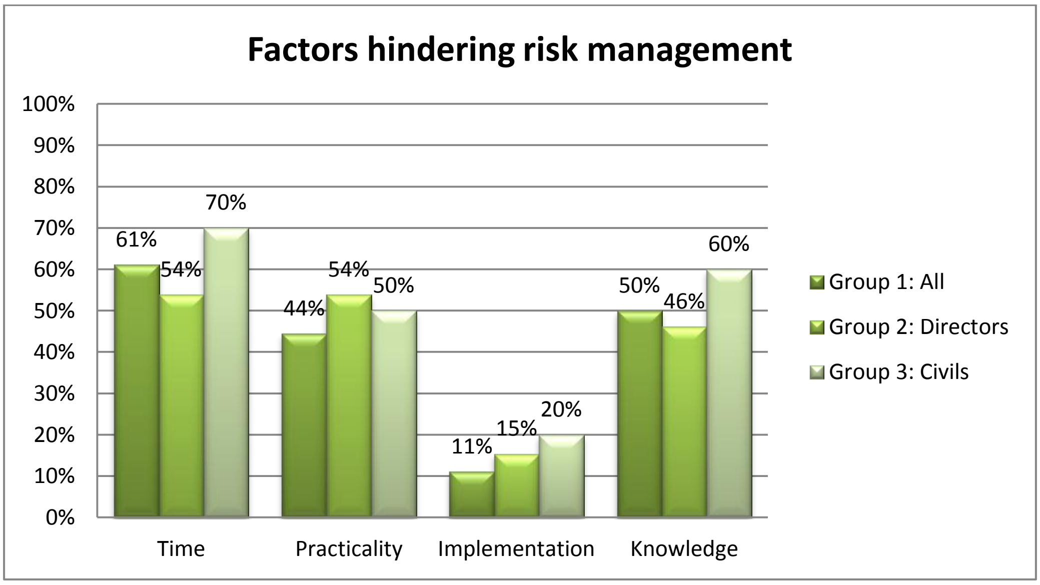

Figure 4.10: Factors hindering risk management

4.2.2.4f Is there a need for a model by which the effects of changes in terms of cost and risk can be determined? If there is, what are the requirements for the model?

Of the participants who responded to this question, 78% believed there was merit in a risk and cost management model, but they would require it to be simple, time efficient and practical.

4.2.2.5 Critique on the Research

The interview questionnaire used for this research, (included in Appendix A:) was evaluated by Dr Dirk Pons from the University of Canterbury, Christchurch, New Zealand. His general finding was favourable, but he did have some criticism. He thought that the questionnaire did not question the effectiveness of the current status quo of change management as practiced by the project managers interviewed. This is, therefore, a shortcoming of the interviews. However, in conjunction with the case study, the researcher believes that the thesis gives a fair representation of the current environment of change management.

Another shortcoming identified by Dr Pons, was that there were no references to the ISO standards, specifically ISO 31000, which is the international standard for risk management. The researcher found that most interviewees did refer to the ISO 9000 standard for quality management, as most consulting firms are ISO 9001:2008 certified, but none of them has ISO 31000 certification and therefore did not see it as relevant.

Dr Pons was also asked to comment on the adequacy of the sample size. According to him, a greater sample size would be preferable, but approximately 20 participants would be enough. The researcher was only able to interview 18 participants. This may be a shortcoming, but of the 18 interviewees, 72% were directors of firms. Directors set the course for the way in which their firms handle change, and their views and methods would be mirrored by their employees. The researcher therefore believes that their views represent the practice of many more project managers.

4.2.2.6 Summary

The interviews confirmed the finding of the case study, namely that there may be various changes to a project for a number of reasons, as listed in paragraph 4.2.2.4a

The results indicate that changes are managed mainly in two ways, through the requirements of the ISO 9000 certified quality management system of a company, as well as by a paper based exercise of issuing site memorandums, variation orders, quoted rates and monthly payment certificates. The results also indicate that, although there is a protocol in place, it is not always followed; project managers seem rather to rely a great deal on their experience.

Other than experience, the participants generally named the following as ways in which they manage the cost of changes of new works:

- Doing a cost estimate of the proposed works
- Asking for rates from the contractor and then assessing whether the rates quoted were fair and reasonable
- Determining the effect of the work on the project budget and contingencies
- Determining whether there are any other cost implications of the work, such as lifecycle or time related costs

The assessment of rates is done mainly by comparison with rates from similar projects or the existing schedule of quantities. Required rate breakdowns and experience are also widely used to assess the fairness of a rate. Most project managers do not follow the theoretical risk management process of planning, identification, analysis and mitigation. They follow no specific procedure and rely on their crisis management abilities. Time constraints were found to be the greatest reason why project managers do not apply generally accepted cost and risk management practices.

4.3 MODEL REQUIREMENTS

The essence of the findings of the case study, interviews, as well as the literature review, is crystallised in this section in order to formulate the model parameters.

4.3.1 Model Requirements based on Literature Review

Based on the literature review done, effective change management is clearly crucial to successfully manage a project. The core values of change management can therefore be listed as:

- Changes should be identified
- All change requests should be reviewed
- The impact of the changes should be analysed
- Changes should be authorised
- Changes should be communicated to project team
- Changes should be documented
- Implementation of changes should be monitored

The analysis of the impact of the item of change must consider the impact of a change on the cost, schedule, quality and risks, as these are the critical success parameters of a project.

The International Organization for Standardization's standard for quality management (ISO 9001:2008), requires that all changes be reviewed, verified and validated as is appropriate, before they are implemented. An evaluation of the effect of the change on the overall project is required to be part of the review process and, along with any necessary action, has to be documented and kept for record purposes.

Risk is a measure of the probability and the impact of not achieving a particular project goal. Risk is therefore a function of probability and impact. Risk management consists of five important phases, namely:

- Risk management planning
- Risk identification
- Risk analysis
- Risk response
- Monitoring and control of risks

There is an interdependency between risk management and change management. Both form part of project management. Every risk management strategy might result in changes to the project which, again, could result in additional risk. Changes that are not managed require more time and money for risk management, which then would be more like crisis management. Managed changes, in comparison, require fewer resources. These aspects should be kept in mind when designing the model [8].

4.3.2 Model Requirements based on Case Study

The findings of the case study, which are relevant to all construction projects, can be summarised as follows:

- The model must be able to support a vast number of changes.
- The cost impact of changes can be substantial and should therefore be identified and analysed.
- Changes with a value of greater than 0.1% of the total contract value have a great impact on the finances of the project.
- Suggested cost category limits are 0.05%; 0.10% and 0.50%.

- Quantity changes by more than 15% have a significant cost impact on the project and should therefore be highlighted by the model.
- Changes should be recorded appropriately.
- The model should enable the user to apply cost and risk management of changes effectively.
- Quotes received from a Contractor can be reviewed by comparing the rates to those from the tendered schedule of quantities, or that of a similar project or a supplier's quote. In some cases the Contractor must provide the Engineer with a rate brake down or an alternative option.

4.3.3 Model Requirements based on Interviews

The interviews confirmed the findings of the case study, that there may be various changes to a project for a number of reasons. The results indicate that changes are managed mainly in two ways, through the requirements of the ISO 9000 certified quality management system of a company, as well as by a paper based exercise of issuing site memorandums, variation orders, quoted rates and monthly payment certificates.

The interviews found that project managers in general rely a great deal on their experience to manage changes. Experience, together with the following methods, should be incorporated into the model as a means of change management:

- Doing a cost estimate of the proposed works
- Asking for rates from the contractor and assessing whether the rates quoted are fair and reasonable
- Determining the effect of the work on the project budget and contingencies
- Determining whether there are any other cost implications of the works due to the change, such as lifecycle or time related costs.

The assessment of rates can be done by comparison with rates from similar projects or the existing schedule of quantities. Required rate breakdowns and experience are also widely used to assess the fairness of a rate. Most project managers don't follow the theoretical risk management process. Therefore the model should incorporate the process of planning, identification, analysis and mitigation of risks.

Time constraints were found to be the greatest reason why project managers do not apply generally accepted cost and risk management practices. Of the participants who responded to this question, 78% believed that there was merit in a risk and cost management model, but would require the model to be simple, time efficient and practical.

4.4 Model Parameters

The model requirements can be summarised into the following model parameters. The change management process should be as follows:

- It should identify any changes to the project
- It should review the intended changes in order to determine if they are the best option
- It should determine the impact of the change on the project in terms of cost, time, quality and risks
- Once the impact of the proposed change is known, it should be authorised before implementation
- Once the change is approved, it should be communicated to all relevant stakeholders
- The change and its impact should be documented and kept for record purposes
- The implementation of the change should be monitored

The following are other attributes required of the model:

- The model should be simple, time efficient and practical
- Changes are requested by means of issuing site memorandums. The model therefore has to incorporate this.
- The model should include the review of a contractor's quote, as this is necessary for a cost estimate of the works.
- The assessment of rates is done mainly by comparison with rates from similar projects or the existing schedule of quantities.
- Required rate breakdowns and experience are also widely used to assess the fairness of a rate.
- To determine the cost impact, the model should determine the effect of the work on the project budget and contingencies.
- Any other indirect cost implications of the works, such as lifecycle or time related costs, should be taken into account.
- Suggested cost category limits by which the cost impact can be measured are 0.05%; 0.10% and 0.50%.
- The suggested quantity change limit is 15%, any quantity change greater than 15% will have a significant impact on the project.
- To determine the time impact of the works, the model has to compare the expected time required by the change to the available float.
- To do a risk assessment of the works, the model can make use of methods such as brainstorming, checklists and cause-and-effect diagrams.
- A risk rating can be determined by means of a risk matrix.

4.5 MODEL DEVELOPMENT

4.5.1 The Change Management Framework

The Model was developed using a change management framework, as it is applied in practice, as the basic structure for model. The Case Study research and various interviews, together with experience in the field, gave the researcher an understanding of the current way in which change management is applied in practice. This knowledge was used to create a preliminary change management framework for the Model. This preliminary change management framework, as shown in Figure 4.11, represents the change management process as it is currently applied in practice. In essence the change management process currently applied involves the following:

- Identification of a change.
- Issuing and receiving the relevant change notes, such as the Site Memorandum and the Contractor's Return of Information (ROI).
- Doing a cost analysis. This involved determining whether a rate quoted by a Contractor is fair and reasonable.
- Requesting authorisation from the Client in the form of a Variation Order (VO).
- Communicating the change to the relevant stakeholders.
- Monitor and control implementation of change

The research conducted through the Literature Study, the Case Study and the various interviews shaped the model parameters. The steps and calculations required to evaluate impact of change and asses the risks, as deemed necessary by the research, were then added to preliminary framework in order to comply with the parameters set for the Model by the conducted research. This created the final change management framework, as shown in Figure 4.12, which forms the basic structure of the Model.

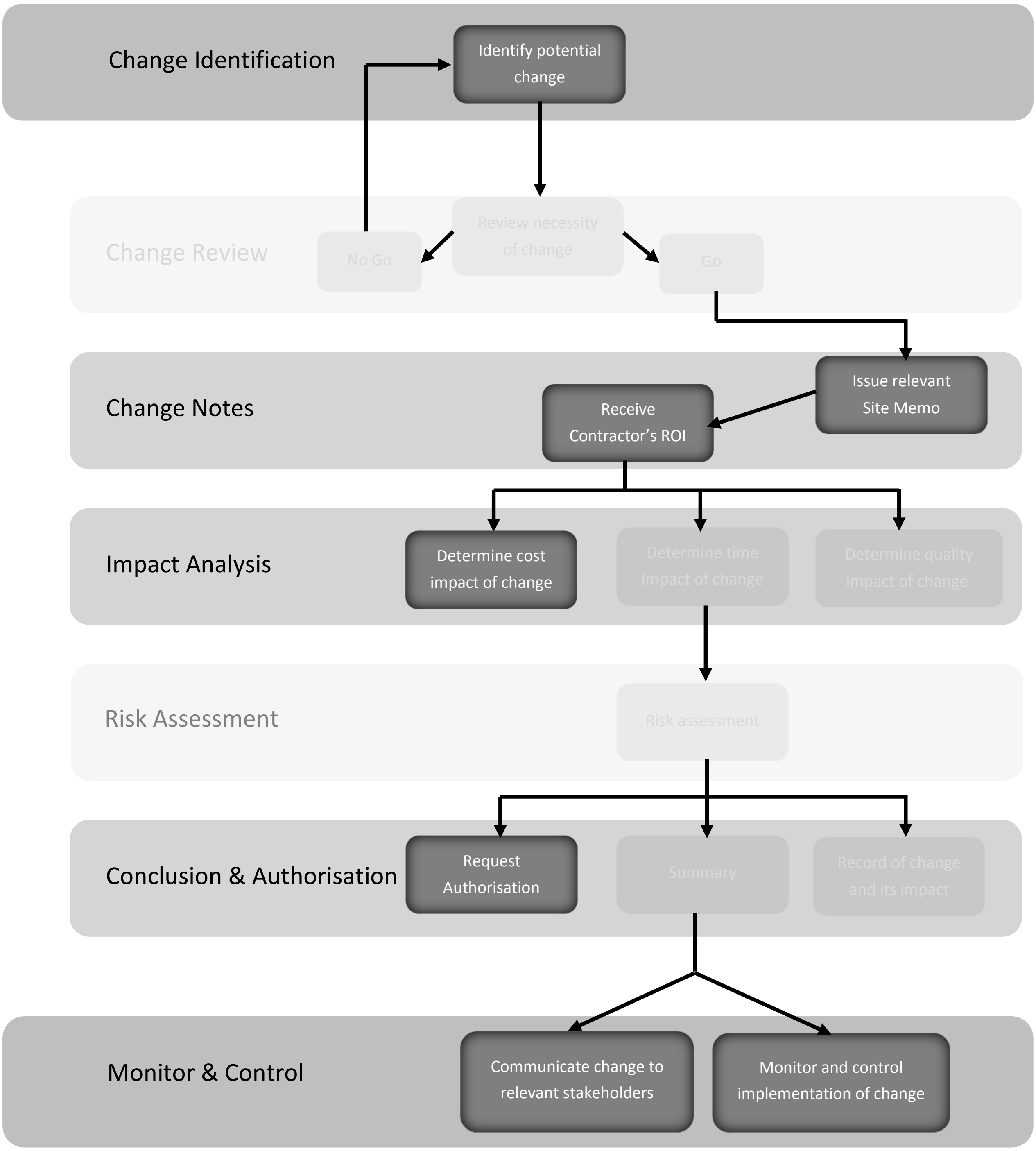

Figure 4.11: Preliminary Change management framework

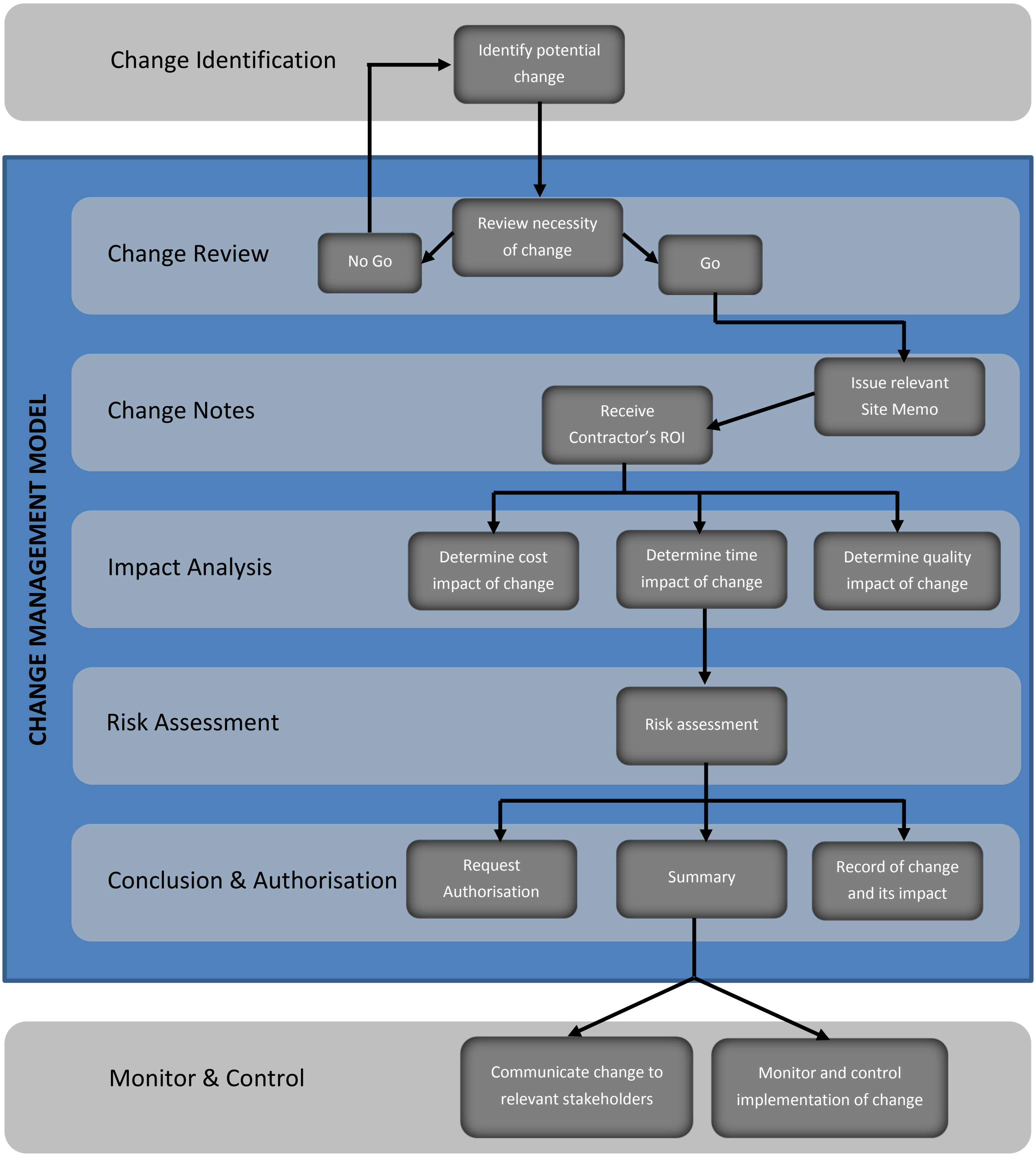

Figure 4.12: Change management framework

The model must be used within the change management framework as given in Figure 4.12. Some of the parameters required of a change management model were not practical for inclusion into the model itself, but they are part of the change management framework. These include identifying the change and the monitoring and controlling of the implementation of the change.

Once a change has been identified, the model can be used to determine its impact on the project and any possible risks associated with it. The findings from the application of the model must be communicated to the relevant stakeholders, such as the client or any sub-consultants assisting with the project design. The implementation of the change should be monitored and controlled based on the findings of the model. As part of the risk assessment, a risk management plan is developed that determines the risk response as well as any monitoring measures or triggers. The purpose of the risk management plan is to assist the project team in monitoring and controlling the implementation of the change.

4.5.2 The Change Management Model

The change management model developed as part of this thesis is a tool that can be used by engineers and their project team to enhance the management of changes during the construction phase of a project. It is a generic tool that can be used for any civil construction project that is managed by the engineers on behalf of their client.

The main purpose of the model is to analyse the cost, time and quality impact of the change, and to do a detailed risk assessment. The model also reviews the proposed change in order to determine whether the change is necessary. Once the change has been found to be appropriate, and its impact has been determined, the change should be authorised and then recorded for future reference. Further instructions to the contractor might require an additional site memorandum and thus the model can be used to this end as well.

The model is therefore a generic tool that can be used to determine the impact of a given change and to determine any potential risks. The model comprises the following key elements in its sequential order:

- The general project information sheet
- Change review
- Process selection
- Site memorandum (SM)
- Contractor's return of information (ROI)
- Cost analysis
- Time analysis
- Quality analysis
- Risk assessment
- Client authorisation
- Summary
- Engineer's record

In the following section, each one of these model elements is discussed in further detail to explain its function and calculations.

Changes can also vary in size. It was found in the case study, and confirmed by literature, that larger changes had a greater impact on the project. The model therefore makes allowance for small, medium and large changes. The process followed for a small change is a lot simpler than that required for a large change. One of the reasons for this is time constraints. The user would not want to spend a lot of time determining the risks of a simple change, but it would be useful when there is a large change that might affect the project objectives. The various processes are explained in depth in section 4.5.4.

4.5.3 Each individual step of the model explained

In essence, the model has the following purposes:

- To review a possible change in order to determine its necessity
- To analyse the impact of a change once it has been deemed necessary
- To issue the relevant instruction to the contractor
- To analyse the data received back from the contractor, such as quoted rates and projected durations
- To do a risk assessment of the change
- To record all changes once they have been issued

This is made possible through the various steps which have been divided into worksheets in the model, each having a unique purpose. In this section, each worksheet in the model is explained in terms of its aim, the formulas used to derive certain answers and the outcome of that worksheet. However the worksheets are not explained it the order that they appear in the model. This is done in order to clarify the key concepts first.

In order to understand the application, this section should be read with continual reference to Appendix B: Example of Model Usage, which contains examples of how the model can be used.

4.5.3.1 Project Information Worksheet

The project information worksheet only has to be completed once, at the start of a project. It contains all the basic project information, such as the project name, contract number, duration of construction and construction contract amount. It also has a contact list of all the project team members involved. This list is used as the reference list for the project team in the rest of the model.

4.5.3.2 Site Memorandum (SM)

A site memorandum is the written communication to a contractor and can have various functions. It can be used to issue information or an instruction to a contractor. It can also be used to issue a change to the design or for additional work. The model has been designed to support the aforementioned uses. In both scenarios, a site memorandum is issued to the contractor. Thus the site memorandum is critical to the change management system.

The following information needs to be entered into the site memorandum:

- The reason for the SM
- General scope of the works / instruction / information
- Breakdown of works and its known impact
- Required information
- Attached information
- Signatures

Firstly, the user must select the appropriate reason for issuing a site memorandum. Based on experience and the interviews conducted, these reasons have been found to be one of the following:

- Change to the Works or Design
- Request for Information
- Additional or New Works
- Site Instruction
- Information for the Contractor

Then the user must give a clear description of the scope of work, instruction or the information being relayed to the contractor. If it is an instruction of works to be done, it must be broken down into work items. The specification of the works and the known impact of these items are then listed. The cost impact of an item at this stage during the process can be identified as one of the following:

- The tendered schedule of quantities (SOQ) rate(s) applies
- Contractor to quote for the works listed
- The works shall have no cost impact
- The cost impact of the works is unclear
- There is a saving to the project

If tendered SOQ rates apply to the new works, the user must specify which rates are applicable. The contractor will be instructed to use these rates for the works listed in the site memorandum. If the contractor has to quote for the works listed, the change management process requires that the user acquire the rates from the Contractor before the cost impact analysis can be done.

The known time impact of an item at this stage during the process would be one of the following:

- No time impact
- Definite time impact
- Uncertain time impact
- Contractor to determine the time impact

If there is a definite time impact that the user is aware of, it should be specified. If the user requires the contractor to determine the duration of the works listed in the site memorandum, this information is required before the time impact analysis can be done.

Any information that the contractor must supply to the engineer (such as rates, test results, guarantees or an updated project program) should be specified by the user. Any information attached to the site memorandum (such as drawings, bending schedules, documentation or specifications) must be specified as well. At the bottom of the site memorandum the relevant signatures are required (of those that issued, authorised and received the SM).

4.5.3.3 Process Selection

Once the need for a site memorandum or change has been established, the user is given guidance on which of the four available processes to follow. First the user is asked the reason for the site memorandum to be issued and the following options are given:

- Site instruction / Information for contractor
- Change to the works or design
- Additional or new works
- Request for information

If the user selects "*Site instruction / Information for contractor*" or "*Request for information*", then he is instructed to follow process one. Process one is applicable when the user only wants to issue an instruction to the contractor and it does not require a change analysis. Therefore only a site memo is issued which is summarised and recorded in the Engineer's Record (further explained in subsequent sections).

If the user selects "*Change to the works or design*" or "*Additional or new works,*" he is then asked to select the estimated size of the change to the works or additional works. The user is given a choice between 'Small', 'Medium' and 'Large'. If the user selects "Small", he is instructed to use process two. If the user selects "Medium", he is instructed to use process three, and if the user selects "Large", he is instructed to use process four. To assist the user in making this choice, he is given expected values of a small, medium and large change, to assist him in choosing the correct size. At this point the user might not know what the exact value of the change is, but he should be able to put it in a ballpark category.

In the case study it was found that changes with a cost of less than 0.05% of the contract value (excluding contingencies and VAT) can be considered as small. Therefore this value is given to the user as the suggested limit of a small change to the works. It was found that a change greater than 0.50% of the contract value can be considered as a large change. Changes with a cost between 0.10% and 0.50% of the contract value can be considered as medium large. Changes with a cost between 0.05% and 0.10% of the contract value can be considered to be medium small.

The model, however, has been simplified to use only three categories, with the following suggested ranges: A change with an expected cost of greater than 0.25% of the contract value can be considered a large change to the project. A change that has an expected cost between 0.05% and 0.25% of the contract value is considered to be a medium size change. A change with an expected cost of less than 0.05% of the contract value can be considered a small change to the project.

Process four is the most comprehensive change management process that follows all the steps, as explained in this section. Processes two and three, however, omit certain steps in the model and simplify the process. Exactly how these various processes work is further explained in section 4.5.4.

4.5.3.4 Change Review

Right at the start of the model the user has to select his/her reason for wanting to issue a site memorandum. If that reason involves new work or any change to the existing design or works, a change review must be done, even before the site memorandum can be issued. This is important as it should first be established if the change is necessary and if it is the best available option. The change review requires the user to describe the intended change.

The change review also records the reason for the change, the name of the person who requested it, the person who authorised it and the person who did the change analysis. To ensure that the user has carefully considered the change, a few guiding questions are asked to assist the thought process of the user. The questions are as follows:

- Is this change necessary?
- Have alternative options been considered?
- Is this the best option available?
- Will the works add value to the project?
- Do the works adversely affect any other stakeholders?
- Do the works negatively impact other works on the project?

These questions should prompt the user to consider the known impact of the works, whether the change is necessary and whether it is the best option available.

Once the change review is complete, the user can complete the site memorandum for the change and request the required information from the contractor. The contractor must then supply the engineer with the requested information.

4.5.3.5 Return of Information (ROI) from Contractor

In the site memorandum, the engineer might request certain information from the contractor, such as rates and the duration of the works. The site memorandum should be accompanied by the return of information (ROI) page that should be completed by the contractor. This page is divided into the following four sections:

- Section 1: Cost of Work
- Section 2: Duration of Work
- Section 3: Quality of Work
- Section 4: Signatures

In section 1, the contractor should provide the engineer with all the requested new rates. Each rate also requires a rate breakdown, which means that the rate should be broken down into its main components of material, labour, supervision, transport and plant cost, as well as the overheads and profit component. Any back-up information that is relevant to a rate, such as a supplier's quote or guarantee should be specified and attached to the ROI. A rate breakdown is important as it clarifies to the engineer how a rate has been compiled as deemed important by the interviews conducted. It is easier to judge the reasonableness of each core component of a rate than that of a lump sum value that cannot be compared to anything.

In section 2, the contractor provides the engineer with the expected duration of the work, for each item of work specified in the site memorandum. For each item the user must provide the optimistic, expected and pessimistic time duration as well as each item's predecessors. Next, the time impact of the items of work on the project programme are required. The contractor has to state all the activities impacted by the proposed works, such as whether it will affect the critical path and the length of any anticipated delays. The contractor must also specify any lead-time of resources and any anticipated indirect costs to the project due to the duration of the work. The main aim of section 2 is to determine the total duration of the proposed work, the expected lead-time of the resources and the time effect on the project's critical path.

In section 3, the contractor has to answer two questions to ensure the quality of proposed work. These two questions are:

- Will it affect any work to be done by other disciplines / contractors? And, if yes, how?
- Will it affect the contractor's methodology of construction? And, if yes, how?

Section 4 is simply contains a list of any other information added to the ROI, as well as the signatures of the writer and recipient of the ROI.

4.5.3.6 Cost Analysis

The cost analysis is broken down into three sections, namely:

- Section 1: Direct cost of works
- Section 2: Indirect cost of works
- Section 3: Cost size of works

In section 1, the direct cost implication of the works is determined. The rates and rate breakdown provided by the contractor is analysed by comparison. This is done by comparing the rate received to a known rate such as a similar rate from the existing schedule of quantities, a rate from another similar type of project or a rate from a supplier. The variance between the given rate and the one it is compared to is worked out as a percentage. Right at the beginning of the section the user is asked to fill in the allowable variance between rates. This is then used as a guideline. All rates that have a greater variance than the allowable, are flagged as a rate that the engineer has to reconsider, as it might be unreasonable.

Next, a sensitivity analysis is done to determine the sensitivity of the quoted rate to a quantity increase or decrease. This is important, as the quantity of the item of work in many cases is only a guesstimate of the actual quantity that is eventually claimed. To perform the sensitivity analysis the cost percentage limits are required. The suggested values, that are the default cost percentage limits, are based on the findings of the case study, but can be adjusted by the user. They are given as a percentage of the budgeted value of the project as shown in Table 4.8. The cost percentage limits are the values that indicate the risk categories of a rate.

Table 4.8: Cost percentage limits, with the suggested values

Cost % Limits (as a % of Tendered Construction Value of Project)				
Low	Medium Low	Medium	Medium High	High
None	≤0.05%	0.05% - 0.10%	0.10% - 0.50%	≥ 0.50%

As determined by the case study, quantity variances of greater than 15% can have a great impact on a project. The sensitivity analysis determines the value of the item amount if the quantity were to increase by 15%. This value is then compared to cost percentage limits multiplied with the tendered contract value to determine in which sensitivity category it falls. The following equations apply:

Let $\mathrm{x} =$ the quoted quantity of the item

Let $\mathrm{y} =$ the quoted rate of the item

Let $\mathrm{z} =$ the tendered construction contract value

Let $\mathrm{s} =$ the sensitivity of the quantity change

$$\mathbf{s = 'medium\ low', if\ 0 < 1.15(xy) \leq 0.05\%(z)} \quad (4.1)$$

$$\mathbf{s = 'medium', if\ 0.05\%(z) < 1.15(xy) \leq 0.10\%(z)} \quad (4.2)$$

$$\mathbf{s = 'medium\ high', if\ 0.10\%(z) < 1.15(xy) \leq 0.50\%(z)} \quad (4.3)$$

$$\mathbf{s = 'high', if\ 1.15(xy) > 0.50\%(z)} \quad (4.4)$$

A medium low sensitivity is considered not very sensitive to quantity change and a medium sensitivity might need further consideration. If an item has a medium high or high sensitivity, the item is considered sensitive to change.

Once the sensitivity of a rate and its variance to other rates has been determined, the cost risk of that item can be determined. An item is listed as risky if it has a variance greater than the allowable variance chosen by the user or if it has a high or medium high sensitivity.

In section 2, the indirect cost of the works is considered. This is done through leading the user through the following questions:

- Does the change add greater maintenance cost to the end product?
- Are there any savings due to omission of works that will be brought about by the change?
- Are there any additional time related preliminary and general costs due to the change?
- Are there any other time related costs due to change?
- Are there any other indirect costs due to change?

If any question has an affirmative answer, the value of that indirect cost has to be entered into the model.

The totals of the direct and indirect costs of the works (in section 1 and 2) are carried over into section 3. Their cumulative value is calculated and its percentage of the tendered contract value of the project is computed. This section also contains the tendered contract value and contingency amount. The user then has to fill in the value of the works completed to date (including the retention money) and the value of the contingency amount already used.

The cumulative value of the works as a percentage of the tendered contract value of the project is further referred to as the CIV. The overall **cost impact rating** of the works is calculated based on the CIV by comparing it to the cost percentage limits entered by the user (as shown in Table 4.8).

The cost impact rating is considered to be '*medium low*' if the CIV is less than 0.05% of the tendered value of the project and '*medium*' if the CIV is between 0.05% and 0.10% of the tendered project value. If the CIV is between 0.10% and 0.50% of the tendered project value, the cost impact rating is '*medium high*' and if the CIV exceeds 0.50% of the tendered project value, the cost impact rating is indicated as '*high*'. The category limits of 0.05%, 0.10% and 0.50% are suggested values based on the findings of the case study, but can be changed by the user.

The cost impact rating is used for the risk assessment (discussed in section 4.5.3.9) to determine the general risk rating of the works.

4.5.3.7 Time Analysis

The time impact assessment of the works is determined in two stages. First the effect on the project programme is determined and then the lead time of resources for the works is also calculated.

In the ROI, the contractors provided the engineer with a breakdown of the works into specific activities and assigned an expected duration to each item. This is carried forward to the time analysis page. Here the engineer has to make use of the project programme to determine the time impact of the works. First the user has to decide whether the activity is a new item to be added to the project programme. If so, the user should determine the time available for the activity from the project programme (further referred to as AT_n). This might require the use of MS Project®. The model then calculates the resulting time effect (further referred to as RTE_{n1}, where n represents the activity number) which is the difference between the expected duration of the activity (further referred to as ED_n) and the available time.

$$RTE_{n1} = AT_n - ED_n \quad (4.5)$$

Next the user has to determine whether the new activity affects any existing programme activities and, if so, the time the new activity consumes from the planned duration of the existing programme activity should be determined. The user also has to enter the known float of the affected programme activity (this might require the use of MS Project®). The model then calculates the resulting time effect (further referred to as RTE_{n2}), which is the difference between the available float of the affected existing programmed activity (further referred to as AF_n) and the time effect of the new activity on the existing programmed activity (further referred to as TE_n).

$$RTE_{n2} = AF_n - TE_n \quad (4.6)$$

In the ROI, the contractor had to determine whether an activity would affect the critical path and give the description of the affected activities. He also had to list any lead times on resources for the works. All this information is brought forward to the time analysis page.

Now the model has all the necessary information to determine the time impact rating (TIR) for the works. This is done by assigning an effect number to both the RTE_{n1} and RTE_{n2} values. The effect number (EN_n) is a value between 1 and 5, which represents an impact, where 1 is '*low*'; 2 is '*medium low*'; 3 is '*medium*'; 4 is '*medium high*' and 5 is '*high*'. For an RTE_{nx} (where x represents either 1 or 2) value that is greater than 50% of the expected duration of that activity, EN_n is equal to one. This means that the duration of the activity has an insignificant impact on the project. For an RTE_n value that is positive but less or equal to 50% of the expected duration of that activity, the EN_n is equal to two, which means the duration of the activity has a '*medium low*' impact on the project. If the RTE_n value equals zero, it means there is no float available for the activity. If the duration estimate is incorrect, it could impact the critical path. In this case the EN_n value is three, because the duration of the activity has a '*medium*' impact on the project. If the RTE_n value is less than zero, it means that the activity duration is greater than the time available for it and thus it will impact the critical path. Any impact on the critical path is seen as a high impact on the project, and thus the EN_n value is 5.

$$EN_{nx}=1, \text{ if } RTE_{nx} > 0.5(ED_n) \quad (4.7)$$

$$EN_{nx}=2, \text{ if } 0 < RTE_{nx} \leq 0.5(ED_n) \quad (4.8)$$

$$EN_{nx}=3, \text{ if } RTE_{nx} = 0 \quad (4.9)$$

$$EN_{nx}=5, \text{ if } RTE_{nx} < 0 \quad (4.10)$$

An EN_n value is determined for both RTE_{n1} and RTE_{n2} in exactly the same way. A third effect number (EN_{n3}) is determined based on whether the critical path is affected or not, and if so EN_{n3} equals 5, if not, it equals zero. The time impact (TI_n) for each activity is taken as the maximum of the three effect numbers (EN_{n1}, EN_{n2} and EN_{n3}). The overall **time impact rating** (TIR) for the works is taken as the maximum of the time impact of all activities.

$$TI_n = \max(EN_{n1}, EN_{n2}, EN_{n3}) \quad (4.11)$$

$$TIR = \max(TI_1, TI_2, \ldots TI_n) \quad (4.12)$$

The time impact rating is used for the risk assessment to determine the general risk rating of the works.

4.5.3.8 Quality Analysis

The quality impact assessment of the works described in the site memorandum is in the form of a questionnaire that the user has to complete. It is divided into three main topics, namely:

- Effect of change on stakeholders
- Effect of change on the project works
- Effect of change on the project's quality

At the end of each section of questions, the user is required to give a general rating of the impact of the works based on the questions in that section. Each time the user is asked to select a rating, a value between 1 and 5 must be selected. A value of 1 would represent a '*low*' rating, a value of 3 would represent a '*medium*' rating and 5 would represent a '*high*' rating. A value of 2 or 4, would signify a rating of 'medium *low*' or '*medium high*', respectively.

To determine the effect of the works on stakeholders, the following questions are asked:

- Will it affect any work to be done by other disciplines/contractors?
- Will it affect the contractor's methodology of construction?
- Does the works adversely affect any other stakeholders?

To determine the effect of the change on the project works, the following questions are asked:

- Does it alter previously completed works?
- Does it omit previous designs?
- Does it replace or change previous designs?
- Will it affect any part of the construction?

To determine the effect of the change on the project's quality, the following questions are asked:

- Does the change add value to the project?
- Does the product still meet the client's expectations?
- Does the change require any guarantees/warranties?
- Does the change affect any guarantees/warranties?

If any question yields a positive answer, the user is asked to elaborate and give a description of the relevant work, name the stakeholders affected by it and in which way they are affected.

And finally the user is asked the following questions which have specific follow-up questions:

- Will the quality of the works be measured or tested? And, if yes, specify how.
- Does the change require any specific resources that could affect its quality? And, if yes, specify them.

The user is then asked to select a general rating of the impact of the works based on the last two quality questions.

The overall **quality impact rating** is then determined by taking the maximum of the above-mentioned four general ratings entered. The quality impact rating is used for the risk assessment to determine the general risk rating of the works.

4.5.3.9 Risk Assessment

The risk assessment of the works is divided in to three sections:

- Section 1: General risk of the works as identified by the cost, time and quality impact analysis
- Section 2: Identification of other risks to the project
- Section 3: Risk register and risk management plan

In Section 1 the cost, time and quality impact analyses, completed in previous worksheets, are used to form a general assessment of the risk rating of the works. An example of this is given in Table 4.9. This is done by taking the impact rating of each one of these three analyses, and adding them to their respective probabilities in order to determine the maximum risk value. The reason for doing this is that risk is a function of both impact and probability as given in equation 2.8 in the literature review. The cost, time and quality impact rating are all three determined by accurate, known data, therefore their probabilities are taken as '*highly probable*'. The maximum risk of the three values is calculated and then used as the general risk rating of the works. The calculation of the risk rating is explained in the following paragraphs.

Table 4.9: Example of risk analysis brought forward from cost, time and quality analysis

RISK IDENTIFICATION		COST		TIME		QUALITY		RISK RATING
Category	Description	Impact	Probability	Impact	Probability	Impact	Probability	
General	Works as described in general scope of site memo listed above	Medium Low	Highly Probable	High	Highly Probable	Medium	Highly Probable	HIGH

Section 2 is about the identification of other risks. This is done using four suggested methods, namely:

- Experience
- Brainstorming
- Checklist
- Cause-and-effect diagram

These methods (as explained in following paragraphs) are used to identify other potential risks. Once the risks have been identified, they are given an impact and probability rating. Throughout the risk assessment, five categories are used for both the impact as well as the probability scale. These five general categories (low, medium low, medium, medium high and high) can have various associated meanings and also represent a numerical number used for calculation purposes, as explained in Table 4.10.

Table 4.10: Impact and probability scale and their respective connotations

IMPACT				PROBABILITY	SCALE	
Cost	Time	Quality	Other	All	Name	Value
Minimal or no impact	Minimal or no impact	Minimal or no impact	Minimal or no impact	Highly Unlikely	LOW (L)	1
X ≤ 0.05% cost increase	Additional resources required, able to meet scheduled dates	Acceptable - slightly affects product quality though still meet client expectations	Small impact, but acceptable	Low probability	MEDIUM LOW (ML)	2
0.05% < X ≤ 0.1% cost increase	Minor slip in key milestones, not able to meet need date	Acceptable - slightly affects product quality and client expectations	Moderate impact, but acceptable	Medium probability	MEDIUM (M)	3
0.1 < X ≤0.5% cost increase	Major slip in key milestone or critical path impacted	Acceptable - significantly affects product quality and /or client expectations	Significant impact, but acceptable	Most Likely	MEDIUM HIGH (MH)	4
X >0.5% cost increase	Will not be able to achieve project objectives	Unacceptable - reduces product value and does not meet client expectations	Tremendous impact, unacceptable	Highly Probable	HIGH (H)	5

NOTE: Cost limit values as entered in the cost analysis worksheet. The current values used are based on suggested values determined in the case study.

Each of the impact and probability ratings is converted from a text scale to its correlating value. These values are used to determine a risk value for each potential risk identified. Table 4.11 is an example of a technical risk that has been identified and analysed. The impact and probability in terms of its cost, time, quality and other aspects are chosen. They are then used to compute a risk rating.

Table 4.11: Example of a risk analysis

RISK IDENTIFICATION		**RISK ANALYSIS**								**RISK RATING**
		COST		TIME		QUALITY		OTHER		
Category	Risk	Impact	Probability	Impact	Probability	Impact	Probability	Impact	Probability	
Technical	The design is impractical for construction	X ≤ 0.05% cost increase	Most Likely	Minor slip in key milestones, not able to meet need date	Medium probability	X ≤ 0.05% cost increase	Most Likely	Small impact, but acceptable	Medium probability	**MEDIUM**

A risk rating is calculated (as shown in Table 4.12) according to the values that each impact and probability scale represents as given in Table 4.10. The impact (I) and probability (P) value of each category (such as Cost) is added to form a total (T) risk value. This is based on Kerzner's method explained in section 2.2.3 of the literature review, and was chosen as it is the most conservative method.

Table 4.12: Example of a risk rating calculation

COST			TIME			QUALITY			OTHER			RISK	
I	P	T	I	P	T	I	P	T	I	P	T	Max	Rating
2	4	6	3	3	6	4	4	8	2	3	5	8	HIGH

NOTE 1: I = '*impact*'; P ='*probability*'; T = '*total*';

NOTE 2: T = I + P

NOTE 3: MAX = max(T); The maximum of all the T-values calculated

Once the maximum risk value of the various risk categories have been determined, the risk rating can be calculated using a risk mapping matrix. The supporting literature, as given in section 2.2.3, recommends an nxn symmetrical risk mapping matrix. A 5x5 matrix was chosen and symmetrically divided into 5 regions. Each region represents a risk rating of either low (L), medium low (ML), medium (M), medium high (MH) or high (H). The risk mapping matrix is populated with values based on the two axes (impact and probability) of the matrix. Each value is calculated by adding its corresponding impact to its probability rating.

In order to determine what region a calculated value would fall in, it is compared to the risk mapping matrix. The risk mapping matrix used for this analysis is given in Figure 4.13. Thus the maximum risk value of '8' calculated in the example given in Table 4.12, falls in the 'H' region of the risk mapping matrix, as seen in Figure 4.13. Therefore the risk rating for the technical risk identified in Table 4.11 is '*High*'.

		Impact				
		1	2	3	4	5
Probability	5	6	7	8	9	10
	4	5	6	7	8	9
	3	4	5	6	7	8
	2	3	4	5	6	7
	1	2	3	4	5	6

		Impact				
		A	B	C	D	E
Probability	E	M	MH	H	H	H
	D	ML	M	MH	H	H
	C	L	ML	M	MH	H
	B	L	L	ML	M	MH
	A	L	L	L	ML	M

Figure 4.13: Risk mapping matrix

The risk rating shown in Table 4.9 was calculated in exactly the same way. Now that the calculation of the risk is clear, the methods by which a risk can be identified should be explained. As determined in the literature review, there are many ways in which risks can be identified.

Based on the interviews conducted as part of the research for the model, it was found that all engineers make use of their experience as their primary means of risk identification. Brainstorming with colleagues and the use of a predetermined checklist were also found to be commonly used methods of risk identification. Thus the researcher chose these three methods to form part of the model. The checklist provided in the model (Table 4.13) was compiled based on the literature, the knowledge gained through the interviews as well as the researcher's own experience in the field.

Table 4.13: Risk checklist

RISK CHECK LIST CATEGORIES	SOURCES OF RISK
MACRO LEVEL RISKS	
1. External, Legal & Political Risks	Local communities pose objections
	Vandalism
	Theft
	Labour disruptions / strike
	Political factors change
	Stakeholders change their requirements
	New stakeholders emerge and demand change
	Stakeholders choose time and/or cost over quality
	Change of local law
	Political factors change
	Legislation change
2. Financial and Economic	Project budget changes
	Market conditions change
	Project budget restraints
	Contract Price Adjustment
	Inflation volatility
	Exchange rate fluctuation
	Unavailability of clients' project funds
	Inaccurate cost estimate
	Inaccurate quantity estimate
	Possible time extension to contract
	Power blackout
3. Force Majeure / Acts of God	Normal natural calamities
	Abnormal natural calamities
	Earthquake
	Hail
	Fire
	Rockslide or Landslide
	Tidal waves
	Large Storm
	Other
4. Contractual	Delay in solving contractual issues
	Delay in solving disputes
	Delay in contractual progress payment
	Additional work issued to contractor
5. Health and Safety / Environmental	Impractical safety requirements
	Dangerous work conditions
	Safety risks (e.g. Collapse; Pipe breaks; High water table, Gas leakage etc.)
	Potential accidents
	Sensitive environments nearby (e.g. Wetland)
	Potential Pollution (e.g. noise, air or water)
	Third party risk of impacting on surrounding elements/ businesses/ others
	Violation of legal requirements
	Archaeological finds
MESO LEVEL RISKS	
1. Technical	Specification inaccurate, impractical or unclear
	Technology selection inadequate
	Implementation of methodology impractical
	Equipment risk

	Material Risk
	Inaccurate technical assumptions in planning stage
2. Construction	Inaccurate duration estimates
	Undesired geotechnical conditions
	Contaminated soil
	Contractor's expertise/ experience
	Deletion of work after its construction has commenced
	Material availability
	Use of substandard materials
	Inappropriate material selection
	Subcontractor's failure to comply / errors in work
	Subcontractor's liquidity
	Quality of work unsatisfactory
	Insufficient onsite supervision and sample testing
	Construction programme (Poor/Rough/Incomplete)
	Poor workmanship
	Untrained and inexperienced labour force
	Insufficient onsite supervision and sample testing
3. Design	Engineering / design changes
	Design incomplete
	Outstanding information
	Lack of detailed design
	Surveys late and/or surveys in error
	Materials/geotechnical/foundation in error
	Structural designs incomplete or in error
	Consultant design not up to standard
	Stipulation of specific codes and standards
	Inadequate design specification and documentation
	Amendment of national standards
	Design mistakes
	Design variations
	Insufficient design time
	Lack of experienced designers
	Conflict of designs on interface between adjacent areas
	Delay in construction drawings / information supply
4. Geotechnical	Uncertain geotechnical or hydrological conditions
	Complex geological or hydrological conditions
	Subsurface cultural relic protection
	Subsurface barriers (rocks, holes, etc.)
MICRO LEVEL RISKS	
1. Organisational Risks	Communication risk
	Lack of coordination
	Uncertainty on who will perform the task
	Communication breakdown with project team
	Skill Shortage
	Inexperienced staff assigned
	Unanticipated project manager workload
	Delay in getting required approvals or decisions
	Inadequate planning
	Priorities change on existing programme
	Inconsistent cost, time, scope, and quality objectives
	Project purpose and need are poorly defined
	Project scope definition is poor or incomplete
	Pressure to deliver project on an accelerated schedule

Consultant or contractor delays
Estimating and/or scheduling errors
Unplanned work that must be accommodated
Lack of formalities/documents/permits

The researcher chose to use the following four methods, as depicted in Figure 4.14, namely:

- Experience
- Brainstorming
- Checklist
- Cause-and-effect diagram

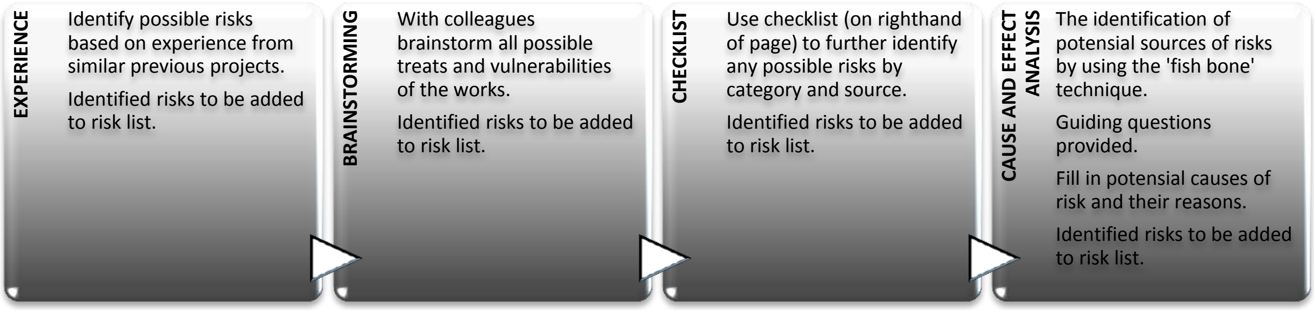

Figure 4.14: Identification of other risks to the project (as shown in model)

The cause-and-effect diagram was added as an option for risk identification, so that if the engineer wants to investigate possible threats and vulnerabilities further, this will be a useful method of doing so. A template with guiding questions is provided and is shown in Figure 4.15. The cause-and-effect diagram, as explained in the literature review, section 2.2.3, is also known as a fishbone diagram because it was drawn to resemble the skeleton of a fish. The purpose of a cause-and-effect diagram is to identify all the potential causes and the relevant factors of each responsible for a certain event, effect or risk. It is thus also an indication of the risk symptoms and their warning signs. These are visible signs that a risk has materialised and they should be taken as triggers for the contingency plans to be set into motion. This was chosen as it helps the engineer to identify the core reasons and problems behind a risk, which enables him to better mitigate the risk [9] [24] [25] [26].

The identified causes are grouped together under major categories used to identify all potential sources of variation. The typical categories used are: ‘People’, ‘Methods’, ‘Machines’, ‘Materials’, ‘Measurements’ and ‘Environment’. However, for this application the researcher chose to add ‘Design’, ‘Stakeholders’, ’Information’, ‘Health and Safety’, ‘Management’, and leave out the ‘Measurements’ category [9] [24] [25] [26].

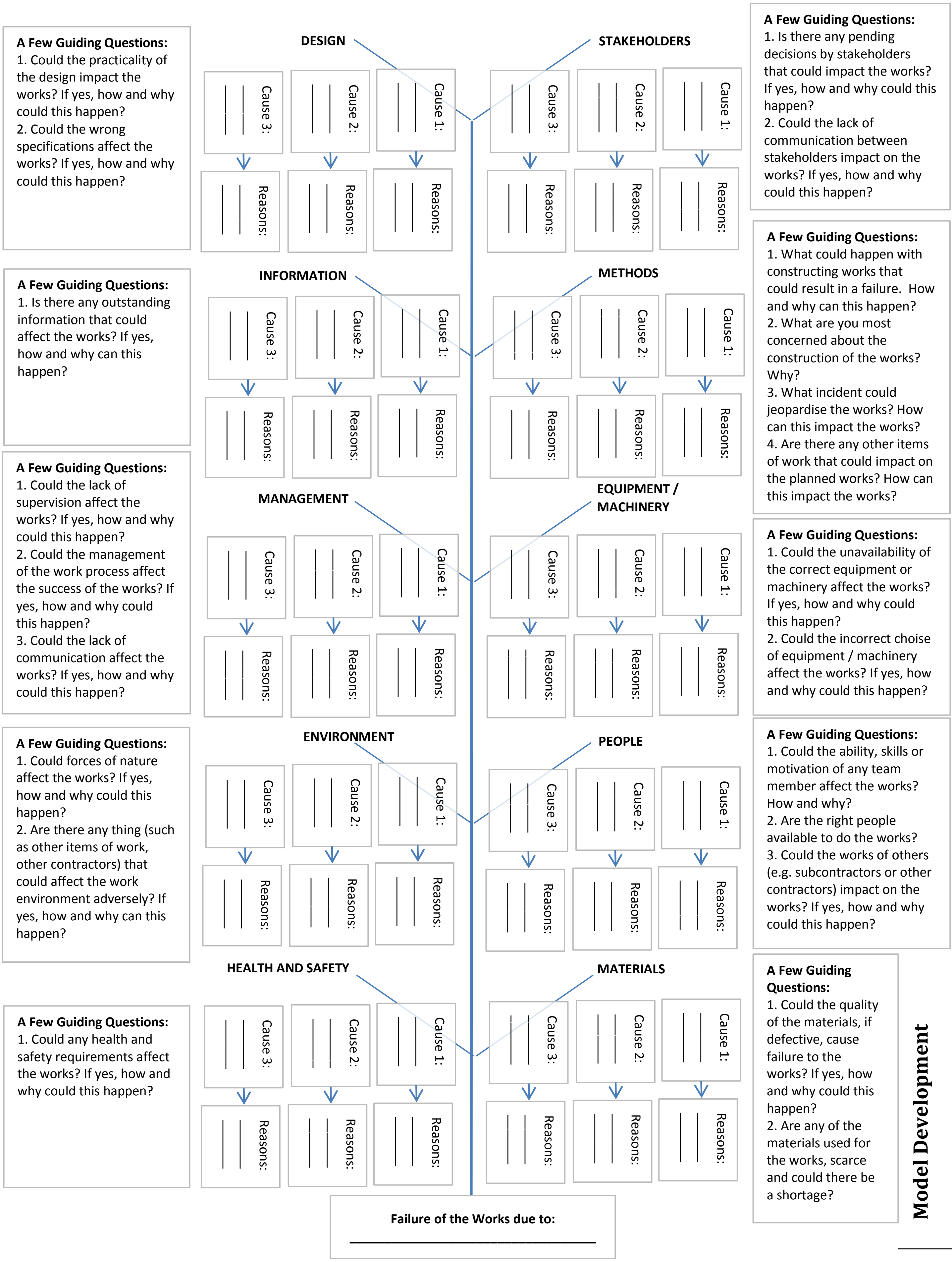

Figure 4.15: Cause-and-Effect Diagram

Section 3 contains the risk register and risk management plan for the change. Once the risks have all been identified, they are sorted from highest risk rating to the lowest in the risk register. The user then has to enter his mitigation and management plan for each risk. The user first has to choose a risk response. Based on the literature, there are four risk responses, namely [9]:

- To transfer the risk partly or completely to another stakeholder.
- To avoid the risks by altering the project in certain ways.
- To control or reduce the risk by implementing certain measures and/or contingency plans.
- To accept the risk and not to do anything about it, as the benefit of any other form of response is far less than the resources required to do so. It is advisable to have a contingency plan for these risks as well.

When the user has chosen a risk response and given a description of what he intends to do, based on the response chosen, he should also identify the monitoring measures (if relevant) and name the person that will take responsibility for that risk response. Lastly, an evaluation date is entered for the risk to be re-evaluated once the control measures have been put into practice.

The final step in the risk assessment is to appoint a single person that must take responsibility for all the risks of the change and the mitigation measures decided on.

4.5.3.10 Client Permission

The client permission request is simply a summary of the proposed change. It includes the type and reason for the works and the name of the stakeholder who requested it. It also gives a summary of the cost and time impact of the works, as calculated in the cost and time analysis. And lastly it gives the overall risk rating and the list of risks that the client should be aware of.

4.5.3.11 Summary Sheet

The penultimate worksheet of the model is the summary page. This can be printed and filed as a record of the change, or given to the relevant stakeholders.

It contains the following information:

- A description of the planned works
- The site memorandum (SM) number
- The date the SM was issued
- The return of information (ROI) number
- The date the ROI was received
- The direct cost of the works
- The duration of the works
- The risk rating of the works
- The person responsible for monitoring the risks
- Any relevant links to drawings etc.

It further contains a summary of the cost and time analysis. This includes,

- The total cost of the works

- The total cost as a percentage of the tendered construction value of the project
- The overall cost impact rating
- The total lead time of the change
- The total duration of the change (excluding lead times)
- The total time effect on the project's critical path
- Date when works shall commence
- Time needed to implement the works
- Overall time impact rating

It also shows a graph of the change relevant to the entire project in terms of time and cost. This would give the engineer a visual understanding of the impact of the change.

Further, it contains the risk register and the risk mitigation and management plan, exactly as it is in the risk assessment page. And, lastly, the user has to enter the names, companies and email addresses of the stakeholders who need to be informed of the works. This is important, as the case study found that better communication of changes could be valuable to a project.

4.5.3.12 Engineer's Record

The last worksheet of the model is the engineer's record page and is simply a record of all changes to the project up to date. It contains the following information:

- A description of the planned works
- The site memorandum (SM) number
- The date the SM was issued
- The return of information (ROI) number
- The date the ROI was received
- The direct cost of the works
- The duration of the works
- The risk rating of the works
- The person responsible for monitoring the risks

The engineer's record page keeps a record of all site memorandums issued up to date for the project. It is thus a record of all changes and their impact.

4.5.4 The Various Processes within the Model

As explained in section 4.5.2, changes can vary in size. The model therefore makes allowance for small, medium and large changes. The process followed for a small change is a lot simpler than that required for a large change. The model also makes allowance for the issuing of a site memorandum that includes no change, but is simply an instruction or request for information. In Figure 4.16 a diagram of these four processes is given.

For process one, there is a completely separate site memorandum and summary sheet from those used by processes two, three and four, because it is different. However, the site memorandum sheet is similar to the one used by the other processes. The summary sheet contains only the description of the works (or instruction), the site memo number and date of issue, as this is the only relevant information that is required and recorded in the Engineer's Record sheet.

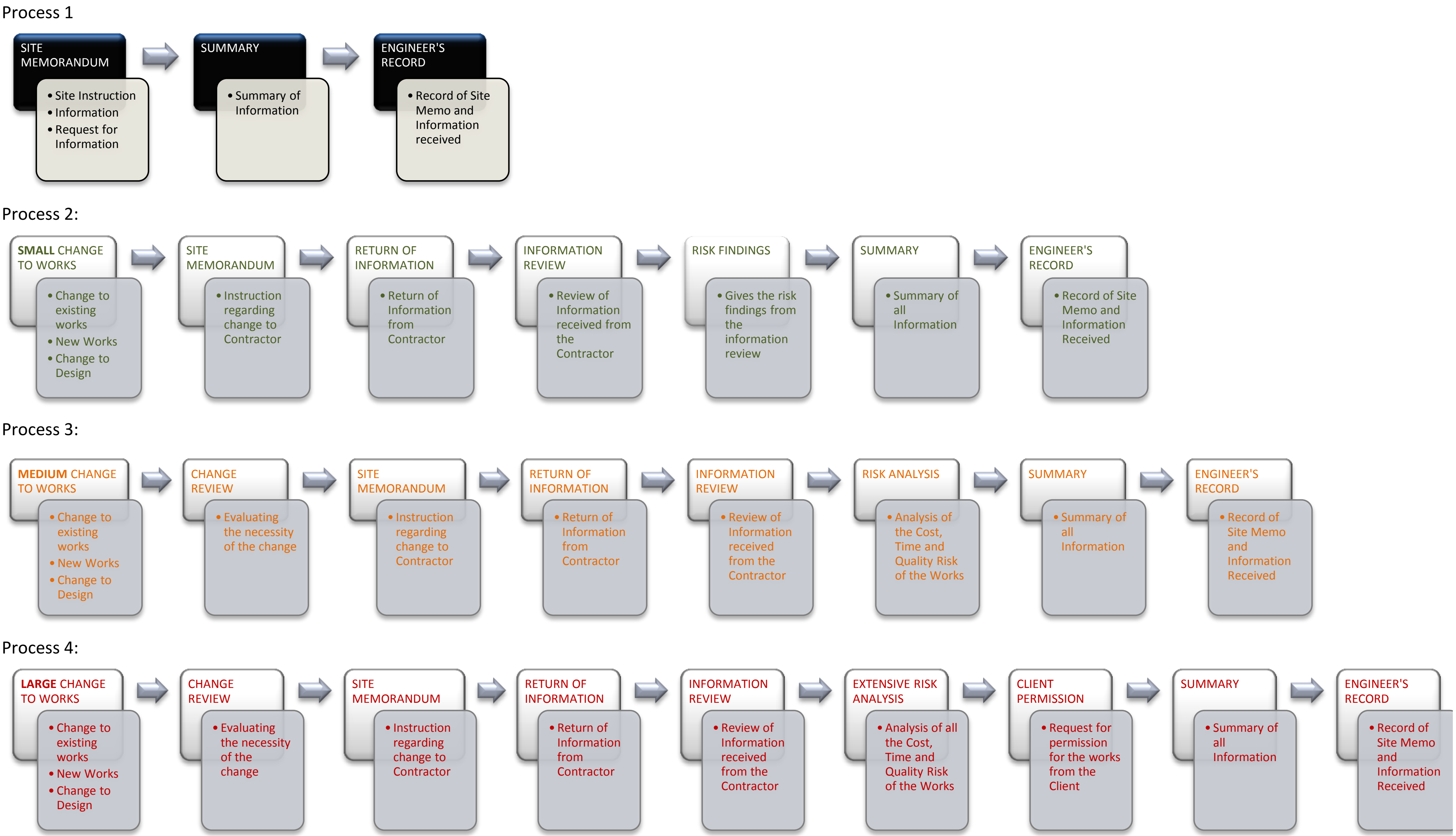

Figure 4.16: The four model processes

Process two, which is for small changes, skips the change review page, as the impact of and necessity for a small change is much easier to comprehend, without any need for an analysis. It thus starts at the site memorandum page which is similar for all processes. In many cases, for a small change, a site memo is issued and once the rate has been provided by the contractor, it is approved and the works are implemented. However, the model still takes the user through the ROI page, where the rates and durations provided by the contractor must be completed, but it hides the quality section. Even for a small change the engineer should record the rates and durations provided and approve them.

Once the ROI input is complete the model takes the user to the cost analysis worksheet which gives the user the opportunity to determine the fairness of the quoted rate, the sensitivity of the rate and its impact. The user may, however, choose not to complete this page. The same is true for the time analysis that follows.

The user is then taken to a simplified risk assessment worksheet that shows the user only the general risk assessment (risk rating) of the change, based on all the information entered into the ROI, cost analysis and time analysis sheets. The user has to complete only the risk response plan for the overall change. The penultimate step is the summary page which summarises the critical information entered and requires the user to fill in the communication plan. And lastly the model records this change in the engineer's record, where the critical information on all changes up to date is recorded.

Process three, which is for medium sized changes, starts with the change review page, then takes the user to the site memorandum page and then to the complete return of information page. Once the user has completed the requested information, the model proceeds to the comprehensive cost, time and quality analysis worksheets. Once again, the user may choose not to complete these pages, or to fill in only certain sections. Process 3 then proceeds to the comprehensive risk assessment. The penultimate step is the summary page which summarises the critical information entered and requires the user to fill in the communication plan. And lastly the model records this change in the engineer's record.

Process four is similar to process three. The only difference is the formal client permission request sheet that must be completed by the user once the risk assessment has been done. Thereafter the model proceeds to the summary page.

4.6 USE OF THE MODEL

The model was developed as a Microsoft Excel® spread sheet with programmed macros in order to calculate certain values based on the input given by the user. Each sheet has a black column on the left in which all the instructions for that page are given. These instructions guide the user as to what input is required. The instruction column also contains any buttons that help the process along, such as the button for the “next” page or to “clear the page”.

The data entered into the project information worksheet is used for the entire project and thus only needs to be completed once. The user would thus begin the model on the process page for each change review, where he is instructed to select a reason for the site memorandum and then, if applicable, the size of the change. This enables the model to suggest one of the four model processes to be followed. The black column on the left of each worksheet in the model contains the process buttons and based on the information entered into the process sheet, the user is told which process button to click. This enables the model to guide the user through the process, and skip and hide certain pages and information, based on the appropriate process chosen. This improves the time effectiveness of the model.

The user only has to complete the ‘green’ blocks. These are also the only cells on the page where the user is able to fill in any detail. All other cells are locked and cannot be tampered with. In most cases, the user only needs to complete the cells he chooses. If there is some information missing, the model will be able to proceed without it. However, when any compulsory information is required, this is clearly communicated to the user in the instruction column. Some of these cells would also have suggested values, enabling the model to proceed.

4.7 Chapter Conclusion

In this chapter, the change management model that was developed as part of this thesis was examined. This Model was developed as a tool for engineers and their project team to enhance the management of changes that happen during the construction phase of a project.

To be able to develop a model that could be used in practice to manage the impact of changes in terms of their risks and costs, the researcher had to first gain a thorough understanding how cost and risk management of changes are applied in practice. For this purpose the researcher undertook a case study of a civil engineering construction project as well as several interviews with project managers within the field of engineering. In this chapter the data collected and the results of the research were analysed and discussed. This research provided some answers to several of the chapter questions and are summarised below.

4.7.1 How great is the impact of changes on a project?

From the research, it was found that projects can have a vast number of changes and that the cost impact of changes can be substantial. Where the value of a change is greater than 0.1% of the total contract value of the project, it was found that the change will have a great financial impact on the cost of the project. It was also found that work items which underwent quantity changes of more than 15%, would have a significant cost impact on the project.

4.7.2 What are the reasons for changes?

From the interviews and the case study, it was found that there may be various changes to a project for a number of reasons. Some of these reasons are listed below:

- Unexpected site conditions that impact the design or construction
- Unexpected geotechnical conditions that impact the design or construction
- Inadequate initial site investigation
- Designs based on inadequate as-built information
- Tendering on the basis of an incomplete design, which then changes during the course of the construction phase
- Flawed or impractical initial designs
- Impact of decisions or designs from the other disciplines collaborating on the project
- Impact of works by other contractors also working on the project
- Construction methodologies that change
- Construction programme delays and the consequent adjustments or changes
- The client changes the scope of work or the requirements
- Budget changes
- Feedback from local authority or regulatory officials on the design
- Scope creep or additional work
- Political and social issues (such as strikes)
- Economic factors (such as a scarcity of steel or bitumen; or exchange rate fluctuation)
- Inclement weather
- Communication related problems
- Change of core project members

4.7.3 How are the costs and risks of changes managed in practice by civil consulting engineers?

The results indicate that changes are managed mainly in two ways; through the requirements of the ISO 9000 certified quality management system of a company, as well as by a paper based exercise of issuing site memorandums, variation orders, quoted rates and monthly payment certificates. The results also indicate that, although there is a protocol in place, it is not always followed; project managers seem rather to rely a great deal on their experience.

From the research, it was found that not all changes are recorded in the appropriate manner and that the cost and risk management of changes in most cases were inadequate. Most project managers do not follow the theoretical risk management process of planning, identification, analysis and mitigation. They follow no specific procedure and rely on their crisis management abilities.

4.7.4 What are the current difficulties with cost and risk management of changes?

Time constraints were found to be the greatest reason why project managers do not apply generally accepted cost and risk management practices.

4.7.5 Is there a need for a model by which the effects of changes in terms of cost and risk can be determined? And if there is, what are the model requirements?

Most of the interviewed participants (78%) believed there was merit in a risk and cost management model, but they would require it to be simple, time efficient and practical.

4.7.6 What would such a model look like and how can it be used?

The Case Study research and various interviews, together with experience in the field, gave the researcher an understanding of the current way in which change management is applied in practice. This knowledge was used to formulate the model parameters and create a change management framework for the Model. This framework was then used to develop the Model.

The change management model developed as part of this thesis is a tool that can be used by engineers and their project team to enhance the management of changes during the construction phase of a project. The main purpose of the model is to analyse the cost, time and quality impact of the change, and to do a detailed risk assessment. The model also reviews the proposed change in order to determine whether the change is necessary. Once the change has been found to be appropriate, and its impact has been determined, the change should be authorised and then recorded for future reference.

The model is therefore a generic tool that can be used to determine the impact of a given change and to determine any potential risks. The model comprises the following key elements in its sequential order:

- The general project information sheet
- Change review
- Process selection
- Site memorandum (SM)
- Contractor's return of information (ROI)
- Cost analysis
- Time analysis

- Quality analysis
- Risk assessment
- Client authorisation
- Summary
- Engineer's record

5 VALIDATION

5.1 CHAPTER INTRODUCTION

The validation of the model that was developed as part of this thesis was done based on two methods. First the model was used to evaluate three change examples, which investigated the use of the model. In this chapter, the results generated when using the example, will be discussed and analysed as part of section 5.2.

The completed model was also evaluated by professional engineers from a consulting civil engineering company that manages various civil construction projects. Their feedback and review of the model is discussed in further detail in sections 5.3 and 5.4 of this chapter.

Both of these methods were used to determine whether the model is practical, user-friendly and easy to understand. Another purpose of the validation is to determine whether the results are comprehensive, credible and useful.

Chapter Questions

- Is the model practical and useful?
- Would the model add value to the change management process as part of the project management of a civil construction project?
- Is the model time effective?
- What are the shortcomings of the model?

5.2 MODEL ANALYSIS

5.2.1 Example used for analysis

In this section a few examples, which were set up to illustrate the use of the model, are discussed. A printout of each worksheet is attached to this thesis in Appendix B: Example of Model Usage to demonstrate the respective results of each example. The examples were also used to analyse the model. The results generated and effectiveness of the model is further discussed in section 5.2.2.

5.2.1.1 Project Parameters of the example

The project used as an example is the earthworks and infrastructure construction for the Wellington Heights property development, phase 1. It was an 8 month low cost housing project for the Wellington Municipality that entailed the earthworks, infrastructure development and a network of roads connecting this development with the town. The tendered construction contract amount (excl. contingencies and VAT) was R16,500,450.00 and it totalled R 20,691,564.30 with contingencies and VAT.

The Municipality appointed ABC Consulting Engineers for the design and construction management of the works. ABC Consulting Engineers was also responsible for compiling the tender documentation. AT Construction submitted the winning tender and was appointed by the client as the contractor for the project.

The following three change scenarios and a request for information were tested:

1. New Work: Installation of a borehole for landscaping purposes.
2. Request for information: Request test results for the road layer works
3. New Work: An additional section of 375mm stormwater pipe had to be laid as well as the construction of two new manholes.
4. Change to the design: Relocation of the trees.

For scenario one, the client decided that the development needed a borehole for watering landscaped areas such as gardens. This involved new work and the expected value of the work is greater than 0.25% of the tendered contract value, excluding contingencies and VAT. This, therefore, was a large change that was made to the project and the model's process four should be selected.

Scenario two is a request for information, which includes no change and therefore process one should be used. This scenario entails a request by the engineer for test results of the road layer works. A request is issued to the contractor through a site memorandum.

Scenario three involves a change to the stormwater design, due to a design oversight. An additional section is added to the design and two new manholes are constructed. The change involves new work and the expected value of the works is between 0.05% and 0.25% of the tendered contract value, excluding contingencies and VAT. It can therefore be considered a medium sized change and the model's process three should be chosen.

Scenario four is a change requested by the traffic authorities, due to the trees planted obscuring the view of the traffic lights. It simply involves the relocation of the 15 trees obscuring the view to a more appropriate location. The expected value of this work should be less than 0.05% of the tendered contract value, excluding contingencies and VAT. It can therefore be considered a small change and the model's process two should be followed.

5.2.2 Example results and analysis

The various steps followed for each scenario and the outcome produced is shown in Appendix B: Example of Model Usage. This section should be read with continual reference to those worksheets.

Scenario one entailed the installation of a borehole for landscaping purposes, which was additional work. This change consisted of the installation of a borehole, the various pipework involved, the supply and installation of a borehole pump and lastly, the testing of the borehole water quality. The model's process four was used.

Once the rates had been received from the contractor, as indicated on the ROI page, the impact of this change on the project was determined by doing a complete cost, time and quality analysis as well as a risk assessment. In the cost analysis, the rates received from the contractor were compared with rates from a similar type of project as well as with rates received from a supplier. The sensitivity analysis indicated that the some of the rates had a medium high sensitivity to quantity change. However, the cost of the change was between 0.1% and 0.5% of the project budget, and thus the cost impact of the works was calculated to be 'medium high'.

The time analysis found that there was not enough float available to install of the borehole, and thus the critical path would be impacted. This would also have an indirect cost impact on the works, due to the resulting time extension or the crashing of certain activities in order to accommodate the works within the contract duration. This was therefore added to the cost impact analysis. Due to the impact on the critical path, the time impact rating was determined as 'high'.

Both the time and cost impact ratings convey to the user the extent of the impact of the change under discussion and would assist a project manager in managing and controlling the implementation of the change. If a project manager noticed the high cost impact of the change, he could calculate whether the contingency budget would allow for the work or whether he needed to review the change. Similarly, if a change has a high time impact rating, it may be required to adjust the project programme to accommodate the work in a different way, by moving or 'crashing' certain activities.

In the quality analysis for scenario one, it was found that the work does not impact on the quality objectives of the project or affect any other works or contractors negatively. Thus the quality impact rating was found to be 'medium low'.

In the risk assessment the cost, time and quality impact ratings were brought forward, resulting in a general risk rating of 'high'. Using the risk checklist and experience, a few other potential risks were also identified. These risks were then sorted from the highest risk to the lowest. A risk management plan was completed for the risks identified. The risk management plan is valuable, as it forces the user to decide what their response would be to the expected risks. Risk management is vital to successful project management. This section therefore definitely adds value to the model.

In the client permission request sheet the client is informed of the type of change and the reason for it. The results from the cost and time analysis, as well as the overall risk rating, are provided. All the risks that the client should be aware of are also listed.

The summary sheet captures the essence of the change. It gives a description of the works, the impact ratings of the cost, time and quality analysis, as well as a summary of the risk assessment. It also shows a graph of the contract and contingency spending.

Time, cost and quality are three very important project objectives and knowledge of the effect of the change on these three objectives is vital for a project manager. It logically follows that the knowledge of these three impact ratings together with the risk assessment of the works, will assist the project manager or engineer in making better informed decisions during the project.

Scenarios 2, 3 and 4 were used to determine whether the various process options are useful. It was found that process one is useful for writing a site memo without any further analysis. Process four is comprehensive, thought provoking and useful for large changes. Process two has a short cost and time analysis as well as a simplified risk assessment; it should, however, ideally be less time consuming to complete. Process three is almost exactly like process four and therefore perhaps too thorough a process for a medium change. The increase in the time taken to complete each of the processes two, three and four should be more gradual.

5.2.3 Benefits of the model, based on the analysis

The model forces the user to consider the various impacts of a change that he might not normally consider, such as the quality impact on the works, the reason for the change and the indirect costs of the works. A risk assessment of a change can be very valuable in assisting the decision making during a project, yet is rarely done in practice. The risk checklist is a useful tool during this process.

Time, cost and quality are three very important project objectives, therefore knowing the effect of the change on these three objectives, is vital for a project manager. The knowledge of these three impact ratings, together with the risk assessment of the works, will assist the project manager or engineer in making better informed decisions during the project.

A risk management plan is very valuable, as it forces the user to think about how these risks would be handled and managed. Risk management is vital to successful project management.

5.2.4 Critique on the model, based on the analysis

The time analysis should be done before the cost analysis, because a time delay could have an indirect cost impact on the works.

Processes one, two and four are all distinctly different. Process three, however, is almost exactly like process four. It merely does not have the client permission request worksheet. It would therefore be better if the differences between processes two, three and four are more graduated. Or perhaps process three should be omitted, leaving the user with a choice between only 3 processes and thus simplifying the model.

5.3 Model Testing by Professionals

Expert evaluation is the final step in the validation of the model developed as part of this thesis. The completed model was evaluated by professional engineers in order to determine whether the model is practical and could add value to the change management process of a civil engineering consulting company.

A practicing consulting engineering company offered to participate in the validation process of the model. The researcher gave them a presentation on the model. The presentation involved a detailed explanation of the model, how it works, the input it requires and the output that it can provide. The validation participants consisted of two directors of the consulting company and a senior project manager, an associate of the firm. They were asked to complete a review sheet containing various questions rating the performance of the model.

The review sheet contained the following questions:

1. Were the instructions provided in the model clear and unambiguous, so that it was easy to use?
2. Is the model practical?
3. Were the functions of the four different processes clear and easily understood?
4. Did you find the various processes practical and useful?
5. Was the cost analysis page comprehensive and practical?
6. Was the time analysis page comprehensive and practical?
7. Was the risk assessment page comprehensive and practical?
8. Is the general risk rating of the works credible and useful?
9. Does the “Summary” page provide enough information to ensure the credibility of the conclusions made?
10. Will the model enable the engineer to make better informed decisions?
11. Is the model time effective?
12. Would you make use of the model?
13. What is your overall impression of the model?
14. What recommendations do you have that would enhance the model?

Each reviewer was asked to give a rating between 1 and 5 for each question, where 1 meant '*not at all*', 2 meant '*no*', 3 meant '*sometimes*', 4 meant '*yes*' and 5 meant '*definitely*'. The reviewer was also encouraged to comment on each question. And lastly, the review sheet provided them with the opportunity to list any recommendations that could enhance the model. The completed review sheets are attached to this thesis in Appendix C: Model Review Questionnaire and Answer Sheets.

5.4 Feedback and Validation

5.4.1 Rating Review

In Table 5.1 the feedback from the reviewers is given. It contains the rating they gave for each question as well as the mean, standard deviation and variance for each question, each sample group and the overall data series.

Table 5.1: Model validation by professionals

	Questions	Reviewer 1	Reviewer 2	Reviewer 3	Overall (1, 2 & 3)	Mean (x)	Standard Deviation (s)	Variance (s^2)
1	Were the instructions provided in the model clear and unambiguous, so that it was easy to use?	5	5	4		4.67	0.47	0.22
2	Is the model practical?	3.5	4	3		3.50	0.41	0.17
3	Were the functions of the four different processes clear and easily understood?	5	4	2		3.67	1.25	1.56
4	Did you find the various processes practical and useful?	5	4	3		4.00	0.82	0.67
5	Was the cost analysis page comprehensive and practical?	4	5	3		4.00	0.82	0.67
6	Was the time analysis page comprehensive and practical?	5	5	3		4.33	0.94	0.89
7	Was the risk assessment page comprehensive and practical?	4	5	2.5		3.83	1.03	1.06
8	Is the general risk rating of the works credible and useful?	4	4	-		4.00	0.00	0.00
9	Does the "Summary" page provide enough information to ensure the credibility of the conclusions made?	4	5	4		4.33	0.47	0.22
10	Will the model enable the engineer to make better informed decisions?	5	5	3		4.33	0.94	0.89
11	Is the model time effective?	4	3	2		3.00	0.82	0.67
12	Would you make use of the model?	5	5	3		4.33	0.94	0.89
13	What is your overall impression of the model?	-	5	3		4.00	1.00	1.00
	Mean (x) =	4.46	4.54	2.96	**4.00**			
	Standard deviation (s) =	0.56	0.63	0.59	**0.94**			
	Variance (s^2) =	0.31	0.40	0.35	**0.88**			

The mean is the average or expected value of a data set. It is the sum of the values in a sample, divided by the number of values [48]. The mean for each question is greater than 3. The overall mean value of the review was found to be 4. An overall rating of 4 can therefore be considered to indicate that the model more than satisfies the objectives tested through this review. The variance is an indicator of the how far the numbers are placed from the mean. It is a parameter that gives an indication of the distribution of the answers in the sample [48]. The overall variance of the complete sample group, is less than one, which indicates that the reviewers were in agreement.

One of the objectives of the validation process was to determine whether the model was practical and useful. Questions 2, 4, 5, 6, 7, 8, 10, 11 and 12 all measure the practicality and usefulness of the model. The mean for these questions is 3.92, as seen in Table 5.2. A rating of 3 means "*sometimes*" and 4 means "*yes*", thus 3.92 can be considered to mean that the reviewers found the model to be practical and useful.

By looking at the results for questions 1 and 3 in Table 5.1, it can be concluded that the model is user friendly, as their mean rating of 4.17 indicates. Another purpose of the validation process is to determine whether the results are comprehensive and credible. This was determined through questions 5, 6, 7 and 9 in Table 5.1. The mean for these questions is 4.13, as seen in Table 5.2. Therefore it can also be inferred that the model is comprehensive and credible.

Table 5.2: Rating of certain questions

	Useful / Practical Q 2, 4-8, 10-12	Ease of Use Q 1,3	Comprehensive Q 5-7, 9
Mean (x) =	3.92	4.17	4.13
Standard deviation (s) =	0.93	1.07	1.09
Variance (s^2) =	0.86	1.14	1.19

Based on the review done of the model, it can be concluded, that the model is practical and useful. It is also user-friendly and the results generated are comprehensive.

5.4.2 Feedback and Recommendations

The people taking part in the model review process were asked to give their comments on the various questions asked. They were also requested to list any recommendations they may have that would enhance the model. The feedback and recommendations given by the reviewers are summarised in this section.

The following feedback was given on the process selection of the model:

- Choosing the size of a change should also be dependent on the size of the project. A sliding scale for the size of the change would thus be more relevant. For example, 0.05% of the contract value of a small contract, is not necessarily the limit of a small change.
- Choosing the correct process should not only depend on the size of the change, factors such a time impact or its environmental impact may indicate that it is a large change, when the cost is relatively low.
- The model is extensive and can take time to use, hence it is important to ensure that the user chooses the right process upfront and does not waste unnecessary time.
- Allow more analysis before choosing the relevant process.

The comments supplied by the reviewers on the cost analysis of the model, are as follows:

- When a rate from another project is used as comparison against a quoted rate, it may be from a project that is three years old for example. Rates therefore have to be escalated for comparison against current date rates. This was not provided for in the model.
- Sometimes it is necessary to interpolate between two rates taken from another project or the current schedule of quantities as comparison against a quoted rate. As an example: If the new item is the construction of a 200mm diameter pipe, and the rates for the construction of a 150mm diameter pipe and a 250mm diameter pipe are known, the expected rate can be determined by interpolating between these two values. The model does not make allowance for this.

The following feedback was received on the summary worksheet of the model:

- The results on the summary page should be more graphical and contain less text.
- The risk assessment summary data should be on the *Client Permission Request* page.

The reviewers made the following general remarks on the usage of the model:

- The model is a useful tool to enable site management to focus more on and give proper attention to this very important aspect of managing changes accurately on site.
- The model must be user-friendly in terms of the time it takes to use.
- It is not always practical to complete the analysis before issuing a site memorandum.
- It may be too time-consuming for some projects.

5.5 Chapter Conclusion and Implications for Practitioners

It was found from this research that it is important to assess the impact of change. This is important as change could affect the project's objectives. The project schedule, budget and required quality all might be affected by a change to the works. Change could also results in more risk for the Client, Contractor and Consultant involved in the project. However, it was shown from the research that practitioners do not really make use of a formal change impact review methodology and rarely assess the risks of a proposed change.

From the research, a change management model was created that could be used to assess the impact and associated risks of a change. This can enable practitioners to understand the impact a change might have on the project objectives, as well as assist him to identify possible risks it might pose on the project and put mitigation processes in place to prevent it. In essence the research results try to show practitioners that the current way in which changes are managed is not ideal or effective, and that there is a better way.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 THESIS CONCLUSIONS

This thesis had two separate goals. Firstly to understand the current change management process followed in practice and to identify its short-comings. The findings of the case study and various interviews with project managers on the current state of change management of construction projects in practice, is summarised in section 6.1.1.

The second aim of the thesis was to explored what a change management process for a civil engineering project should look like, specifically for the cost and risk management of changes. Using the findings of the research, a model was developed for managing the costs and risks of changes, based on theoretical and industry requirements. This model was evaluated by project managers in industry to determine whether it would add value to the change management process. Section 6.1.2 lists the conclusions of the change management model development.

6.1.1 The current state of Change Management in Practice

Based on the literature review, the following can be concluded regarding the necessity of change management:

- Change can have a significant impact on a project and its objectives.
- Project managers should understand the implications of change in terms of its impact on cost, time and quality.
- Risk management should form an integral part of change management.

For a project manager to assess the risks of a change, it is necessary to have a risk management plan in place; to identify the potential risks; to analyse them; to determine the correct response to the identified risks and to monitor and control them as determined by the risk response plan. These are the basic steps of risk management.

The case study and various interviews with project managers explained how change management is approached in practice, specifically the risk and cost management of changes. The requirements for the change management model, developed as part of this thesis, are based on the findings of both the case study and the interviews. The findings are as follows:

- Projects can be subject to a vast number of changes.
- The cost impact of changes can be substantial.
- Larger changes have a greater impact on the project than small changes.
- Project managers are not managing these changes appropriately.
- Changes are not recorded systematically.
- Project managers do not have any formal way in which they assess the cost, time and risk impact of a change.

Most companies seem to have a quality management protocol in place, but the practical application of that process is not clear. Changes to projects are captured through a paper based exercise of site memorandums, variation orders, quoted rates and monthly payment certificates. Neither the interviews, nor the findings of the case study indicated any current use of a formal change impact review methodology. However, project managers do take measures to determine whether a quoted rate for implementing a change is fair and reasonable and the implication of the works on the project programme is assessed by most of them. Thus it can be concluded that a systematic change management model would be able to add value to the change management process in practice.

The cost of a change is assessed based on experience, by doing a cost estimate based on known rates, acquiring rates from the contractors and assessing whether the rates quoted were fair and reasonable. The cost is also assessed based on the effect of the work on the project budget and contingencies and determining whether there are any other cost implications of the works, such as lifecycle or time related costs. The assessment of rates is done mainly by comparing the rates to those from similar projects or the existing schedule of quantities. Required rate breakdowns are also widely used to assess the fairness of a rate.

Most project managers do not follow the theoretical risk management process of planning, identification, analysis and mitigation. Time constraints were found to be the greatest reason why project managers do not apply generally accepted cost and risk management practices. They therefore often follow no specific procedure and rely on their crisis management abilities. A systematic risk management process is therefore clearly necessary.

Some of the other findings of the case study and interviews are listed below:

- Changes with a value of greater than 0.1% of the total contract value have a great financial impact on the cost of the project.
- Suggested cost category limits are 0.05%; 0.10% and 0.50%.
- The suggested quantity change limit is 15%, as it was found that quantity changes of more than 15% have a significant cost impact on the project.

Seventy eight per cent of the interviewees believed that there is a need for a model by which the effects of changes in terms of cost and risk could be determined. Their main requirements for such a model were that it must be simple, time efficient and practical.

Based on the findings of the case study, interviews and literature review, it can be concluded that a change management model should include the following:

- It should review the intended change in order to determine whether it is the best option
- It should accommodate different types and sizes of change, as the procedure for a small change might be different than that for a large change.
- It should determine the impact of the change on the project in terms of cost, time and quality.
- A risk assessment of the change should be conducted.
- Once the impact of the proposed change is known, it should be authorised before implementation
- Once the change is approved, it should be communicated to all relevant stakeholders
- The change and its impact should be documented and the documents kept for record purposes

6.1.2 The Change Management Model

The model that was developed as part of this thesis incorporated the above mentioned requirements. The main purpose of the model is the analysis of the cost, time and quality impact of a change, and provision of a detailed risk assessment. The model reviews the proposed change in order to determine whether the outcome of the change are not perhaps achievable through other means. Once the change has been found to be appropriate, and its impact has been determined, the change should be authorised and then recorded for future reference.

To determine the cost impact of a change, the effect of the change on the project budget and contingencies is taken into account. In order to calculate the time impact of a change, it is measured against the project programme. The expected duration of a change is compared with the available float in order to determine its effect on the programme.

The model makes allowance for small, medium and large changes. The process followed for a small change is much simpler than the comprehensive process followed for a large change. The implementation of these different processes was done in order to accommodate the time efficiency required for small changes and the comprehensive results required for large changes that might affect the project objectives.

Based on the expert review of the model it can be concluded that the model satisfies its objectives. The model was found to be practical and useful. It is also user-friendly and the results generated are comprehensive.

6.2 PROOF OF HYPOTHESIS

The case study and interviews conducted with practicing project managers, gave the author an understanding of the current way in which changes are managed on construction projects as well as their potential impact on a project. This understanding was used to create the model.

Based on the outcomes of the model validation, it can be concluded that the change management model, developed as part of this thesis, could improve the management of changes during the construction phase of a civil engineering project. The knowledge of the impact that a change could have on the cost, time, quality and risks of the project, will enable the project manager to make better informed decisions in order to complete the project successfully.

6.3 Recommendations

6.3.1 Recommendations on the Research Conducted

The research that was done in order to create a change management model, that could be used to determine the cost, time, quality and risk impact of changes, could have been improved in various ways. These are listed and discussed below:

- The difference in efficiency between cases where the model was and was not used for change management could have been measured.
- The change management protocol of a company's quality management system could have been investigated to determine how the model would be used within that system.
- Further case studies could have been conducted.
- More project managers could have been interviewed.
- More reviews of the model would have enhanced the validation of the model.

Further investigation into the 'before and after' efficiency of change management on construction projects might have enhanced the study's findings. The questionnaire used for the interviews did not question the effectiveness of the current status quo of change management as practiced by the project managers interviewed. The validation could also not measure the effectiveness of using the model for managing and determining the effect of changes on a construction project. It would have been valuable to the research if the efficiency of the change management process of a project could have been tested both with and without the use of the model developed. This method would have been more successful in testing the practicality and applicability of the model.

It was found that most civil engineering consulting firms are ISO 9001:2008 certified and therefore should have a quality management system that encompasses some change management protocol. A study of a company's quality management system, specifically its change management protocol, would have added value to the research. Determining how the model would fit in with such a protocol as part of the validation process would also have added value to the study.

6.3.2 Recommendations for Enhancing the Model

Based on the findings made during the validation of the model, some recommendations can be made for enhancing the model. They are subsequently listed and discussed:

- Enhancing the process selection of the model.
- Enhancing the cost analysis of the model to support escalation and interpolation of rates.
- The summary page should be more graphical
- The time analysis should be completed before the cost analysis.

Selecting the appropriate process to use should not only depend on the probable cost size of the change. Other factors such as the likely time or environmental impact may be indicative of the size of a change, while the cost may be relatively low. The cost size of a change should not depend merely on the probable cost of the works, but it should also be based on the project size. A sliding scale for the size of the change would thus be more relevant. For time efficiency, it is important that the correct process is selected upfront.

Processes one, two and four are all distinctly different. Process three, however, is almost exactly like process four. It merely does not have the client permission request worksheet. It would therefore be better if the differences between processes two, three and four are more graduated. Or perhaps process three should be omitted, leaving the user with a choice between only 3 processes and thus simplifying the model.

The cost analysis should support escalation of rates as well as interpolation between two known rates to determine a third. When a rate from another project is used as comparison against a quoted rate, it must be considered whether the rates are up-to-date. Rates therefore have to be escalated for comparison against current date rates. Sometimes it is necessary to interpolate between two rates taken from another project or the current schedule of quantities as comparison against a quoted rate.

The feedback received during the validation of the model suggested that the results on the summary page should be more graphical and contain less text. This would allow for a more time effective way of viewing the results of the model. It would enhance the usefulness of the model if a summary of the risk assessment is also on the client permission request worksheet. The time analysis should be done before the cost analysis, because a time delay could have an indirect cost impact on the works.

6.4 FURTHER STUDIES

A further study that would add value to this subject would be to implement the recommendations from the validation process and then to test the model and its effectiveness in practice. This would enable the scholar to determine whether this model is able to enhance the decision making process around changes and how the model can be adjusted or enhanced to make it more practical and effective.

The study could be extended to create a change management model that is applicable for each phase of the project lifecycle. The existing model has been created to only manage changes that occur during the construction phase of the project. However, changes that occur during the feasibility study, planning and design phase as well as the closedown, all have a cost and risk impact on the project as well, and thus should be analysed.

The study could be extended to create a change management model that is more applicable to specific engineering projects such as structural, housing and roads and rail. Each of these disciplines of engineering is different in the manner with which they deal with change, the stakeholders that is generally involved in the project and the means of communication required. Thus to adapt the model for each specific discipline, would add value to the change management field.

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INFORMATION PAGE

Once you have signed the consent form, please complete the following table:

Your name:			
Your age:		Your gender:	M ☐ F ☐
Company you work for:		Position held:	
Years of experience:		Years of experience in Project Management:	
Value of largest project you've managed:		Qualifications:	

To Note:
Clarify to interviewee that all questions relate to the **construction phase** of a civil engineering construction project.

1. What types of changes do you commonly experience on construction projects?

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2. What would you say are the main reasons for them?

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3. What is the company protocol for managing changes?

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4. How do you assess what the **impact** of changes will be in terms of cost, time and risk **on the overall project?**

____
COST ____
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____
____
TIME ____
____

____
____
____
RISK____
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____
____

5. When new work is issued to a project, how is the cost of that work evaluated and managed before it is commissioned?

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6. How do you judge if a new rate quoted by a Contractor is fair and reasonable?

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7. What would you consider the strengths and weakness of this way of cost management?

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8. Do you have any formal risk management training?

Yes ☐ if yes, what ____

No ☐

9. How would you define risk?

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10. What type of risks does a consultant need to manage?

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11. How do you manage risk, what techniques/models do you use and why?

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____
____

12. Do you create a risk register / list for each project

Always ☐ Often ☐ Sometimes ☐ Never ☐

13. Do you appointed a team member / yourself the role of risk manager on a project

Always ☐ Often ☐ Sometimes ☐ Never ☐

14. Do you know and make use of any of the following techniques **for risk management** (identification and analysis):

Technique / Model	Know	Don't know	Use Often	Use Sometimes	Use Never
Brainstorming					
SWOT analysis					
Delphi Technique					
Nominal Group Technique					
Risk Checklist					
Documentation reviews					
Scenario Analysis					
Sensitivity Analysis					
Expert Interviews / Outsourcing					
Lessons learned file					
Work Breakdown Structure / Plan decomposition					
Monte Carlo Analysis					
Other:					

15. Which of the following hinders you from using these techniques mentioned in the previous three questions? And which of these would you consider the greatest stumbling block?

Time ☐ Practicality ☐ Implementation ☐ Knowledge ☐

Other:____

____

____

16. Do you feel there is merit in a formal risk and cost management model/methodology and why? And what would you require of such a model?

____

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---END---

Information Form: Project Data

INSTRUCTIONS

1. Complete all the project information - Fill in the GREEN blocks
2. All essential information to be completed is marked with a red asterisk (*)
3. The Main Project Members are those that represent the main role players as identified in the project Contract
4. All other important role players, project contracts or team members to be listed under "Project Team Members"

Next Page →

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1. *

Project Contract Number: 102C/2010/02 *

Project File Number: C7501 *

Project Duration: 8 Months *

Construction Start Date: 01/02/2010 *

Construction Completion Date: 13/10/2010 *

Tendered Construction Contract Amount:

R	16 500 450.00	(excl.VAT & Cont.)	*
R	1 650 045.00	Contingencies at	10% *
R	18 150 495.00	Sub-Total	
R	2 541 069.30	14% VAT	
R	**20 691 564.30**	**TOTAL**	

Project Size: Medium Small [R5 - R20 million]

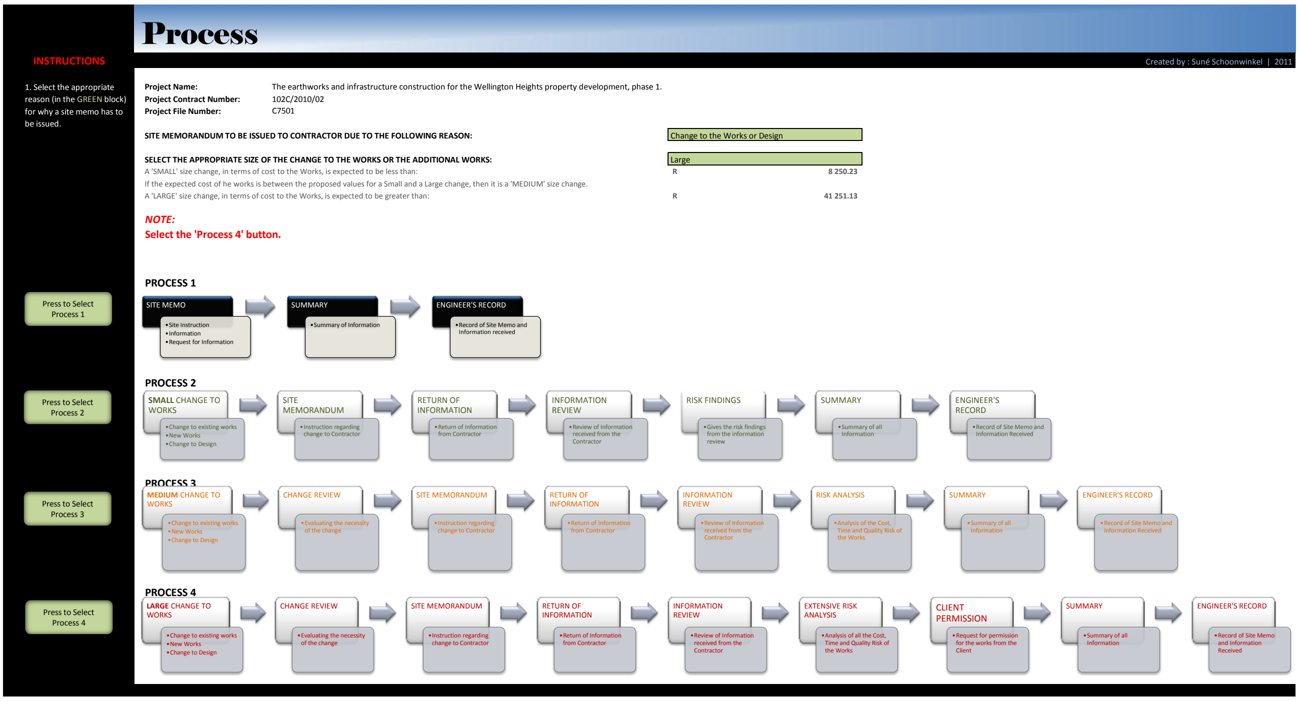
* **Main Project Members:**

MAIN PROJECT MEMBERS			PERSONAL INFORMATION OF REPRESENTITIVES				
Role	Occupation / Profession	Company	Name	Tel No.	Cell No.	Fax No.	E-mail Address
ENGINEERS	Civil and Structural Engineers (Contract Manager)	ABC Consulting Engineers	John Adams	021 555 6464	074 589 6060	021 555 6466	john@abc.co.za
CLIENT	Engineer (Contract Manager)	Wellington Municipality	Ben Reed	021 564 5825	084 589 5896	021 564 5825	ben@wellington.gov.za
CONTRACTOR	Civil Contractors (Contract Manager)	AT Construction	Leo Marais	021 589 5878	084 587 5005	021 587 5888	leo@atc.co.za

* **Project Team Members & Important Project Contacts:**

PROJECT TEAM MEMBERS			PERSONAL INFORMATION				
Role	Occupation / Profession	Company	Name	Tel No.	Cell No.	Fax No.	E-mail Address
Design Engineer	Civil Engineer	ABC Consulting Engineers	Duncan Howard	021 808 9136	082 565 5896	021 808 9136	duncan@abc.co.za
Design Engineer	Civil Engineer (Roads)	ABC Consulting Engineers	Louise Meyer	021 636 9154	083 565 5698	021 636 9154	louise@abc.co.za
Design Engineer	Civil Engineer (Housing)	ABC Consulting Engineers	Johan Fourie	021 856 0236	084 565 4587	021 856 0236	johan@abc.co.za
Engineer's Representitive	Civil Engineer	ABC Consulting Engineers	Emile Herselman	021 565 9874	082 547 2587	021 565 9874	emile@abc.co.za
Site Agent	Contractor	AT Construction	William Thorpe	021 564 5825	084 589 5896	021 564 5825	william@atc.co.za
Foreman	Contractor	AT Construction	Mark Henderson	021 589 5878	084 587 5005	021 587 5888	mark@atc.co.za
Sub-Consultant	Geotechnical Engineer	HFG Consulting	Iain Farrel	021 636 9173	083 565 1111	021 636 9175	iain@hfg.com
ECO	Environmental Consultant	Enviromasters	Lee Howard	021 856 0136	084 025 4587	021 856 0135	lee@enviromasters.com
OHS inspector	Health and Safety Consultant	Palmer OHS	Eric Palmer	021 369 9874	082 547 6667	021 360 9874	eric@palmerOHS.co.za

Project Manager for this Project: Duncan Howard


Process
Created by : Suné Schoonwinkel | 2011
INSTRUCTIONS
1. Select the appropriate reason (in the GREEN block) for why a site memo has to be issued.
Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501
SITE MEMORANDUM TO BE ISSUED TO CONTRACTOR DUE TO THE FOLLOWING REASON:
Change to the Works or Design
SELECT THE APPROPRIATE SIZE OF THE CHANGE TO THE WORKS OR THE ADDITIONAL WORKS:
Large
A 'SMALL' size change, in terms of cost to the Works, is expected to be less than: R 8 250.23
If the expected cost of he works is between the proposed values for a Small and a Large change, then it is a 'MEDIUM' size change.
A 'LARGE' size change, in terms of cost to the Works, is expected to be greater than: R 41 251.13
NOTE:
Select the 'Process 4' button.
PROCESS 1
Press to Select Process 1
SITE MEMO
• Site Instruction
• Information
• Request for Information
SUMMARY
• Summary of Information
ENGINEER'S RECORD
• Record of Site Memo and Information received
PROCESS 2
Press to Select Process 2
SMALL CHANGE TO WORKS
• Change to existing works
• New Works
• Change to Design
SITE MEMORANDUM
• Instruction regarding change to Contractor
RETURN OF INFORMATION
• Return of Information from Contractor
INFORMATION REVIEW
• Review of Information received from the Contractor
RISK FINDINGS
• Gives the risk findings from the information review
SUMMARY
• Summary of all Information
ENGINEER'S RECORD
• Record of Site Memo and Information Received
PROCESS 3
Press to Select Process 3
MEDIUM CHANGE TO WORKS
• Change to existing works
• New Works
• Change to Design
CHANGE REVIEW
• Evaluating the necessity of the change
SITE MEMORANDUM
• Instruction regarding change to Contractor
RETURN OF INFORMATION
• Return of Information from Contractor
INFORMATION REVIEW
• Review of Information received from the Contractor
RISK ANALYSIS
• Analysis of the Cost, Time and Quality Risk of the Works
SUMMARY
• Summary of all Information
ENGINEER'S RECORD
• Record of Site Memo and Information Received
PROCESS 4
Press to Select Process 4
LARGE CHANGE TO WORKS
• Change to existing works
• New Works
• Change to Design
CHANGE REVIEW
• Evaluating the necessity of the change
SITE MEMORANDUM
• Instruction regarding change to Contractor
RETURN OF INFORMATION
• Return of Information from Contractor
INFORMATION REVIEW
• Review of Information received from the Contractor
EXTENSIVE RISK ANALYSIS
• Analysis of all the Cost, Time and Quality Risk of the Works
CLIENT PERMISSION
• Request for permission for the works from the Client
SUMMARY
• Summary of all Information
ENGINEER'S RECORD
• Record of Site Memo and Information Received

Review of Proposed Works

INSTRUCTIONS

1. Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

DESCRIPTION OF PROPOSED WORKS	
Subject Line:	Installation of new borehole
The Contractor to supply the Client with three rates for the complete supply and installation of a watering borehole and all associated pipework and pumps.	

Reason for proposed works:

Type of Change :	**Client related change**
Reason for Change :	Scope creep / Additional work
Specify:	
Is this change necessary?	YES
Have any alternative options been considered?	YES
What were they?	Using potable water for landscaping purposes
Why were they rejected?	Too costly
Why is this option better?	
Is this the best option available?	YES
Will the works add value to the project?	YES
Does the works adversely affect any other stakeholders?	NO
Does the works negatively impact other works on the project?	NO
Specify:	

Record of whom requested the works:

WORKS REQUESTED BY:	
Name	Company
Ben Reed	Wellington Municipality

When:	25/02/2010
How:	Verbally

Authorization:

CHANGE ANALYSIS AUTHORISED BY:	
Name	Company
John Adams	ABC Consulting Engineers

When :	26/02/2010
How :	Email

Select the 'Process 4' button.

Analysis:

CHANGE ANALYSIS DONE BY:	
Name	Company
Emile Herselman	ABC Consulting Engineers

When :	01/03/2010

Process 3: Next →

Process 4: Next →

Created by: Suné Schoonwinkel 2011

Site Memorandum

INSTRUCTIONS

1. Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 15
Date: 01/05/2010

Reason for Site Memo: Additional or New Works

DESCRIPTION OF THE WORKS	
Subject Line:	Installation of new borehole
The Contractor to supply the Client with three rates for the complete supply and installation of a watering borehole and all assosiated pipework and pumps.	

Breakdown of works and its known impact:

Item No.	Description of Works	Specification of Works	IMPACT OF WORKS: Cost Impact on Budget	Time impact on Project Program	Specify
15.01	Borehole	Attached to SM	Contractor to quote	Contractor to determine	
15.02	Testing of Borehole		Contractor to quote	Contractor to determine	
15.03	Borehole pipework		Billed rates apply	Definite	Item F.2.5.3-F.2.5.10 in SOQ
15.04	Borehole pump and installation		Contractor to quote	Contractor to determine	

3. Tick the relevant items.

The Contractor shall provide the Engineer with the following Information:

- [x] A quote for the works specified in this Site Memo
- [x] Rates to be backed up by a Rate Breakdown & Supplier's Quote
- [ ] One or more alternative options
- [x] The relevant Warrantees / Guarantees
- [ ] Test Results as specified in this Site Memo
- [x] Schedule impact of the works
- [ ] Updated project program

Please Specify:

The following information has been attached to the Site Memo:

- [x] Drawings or Sketches of the works
- [ ] Bending Schedule(s)
- [ ] Documentation
- [x] Other Information

Please Specify:
DRW 102C/2010/02/C01-02 rev2

Select the 'Process 4' button.

Process 2: Next →
Process 3: Next →
Process 4: Next →

SITE MEMO WRITTEN BY:					
Name	**Emile Herselman**	Signature		Date	
SITE MEMO RECEIVED BY:					
Name	**Ben Reed**	Signature		Date	
SITE MEMO CHECKED AND APPROVED BY:					
Name	**Duncan Howard**	Signature		Date	

Created by: Suné Schoonwinkel 2011

Return of Information from Contractor

INSTRUCTIONS

1.The Contractor to complete all three sections.

2. The Contractor to fill in all GREEN blocks.

3. Some Instructions are shown when a cell is selected.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	15
ROI Number:	12
Date:	01/05/2010

SECTION 1 : COST OF WORK

Rate Breakdown for Option 1

Item No.	Description of Main Item	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	RATE BREAKDOWN OF THE ITEM: Type	Description	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Attached	Specify
						MATERIAL		Sum	1	5 000.00	5 000.00		
						LABOUR	3 men for 4 days	man hr(s)	96	45.00	4 320.00		
						PLANT	Borehole rigging machine	hr	8	2 750.00	22 000.00		
											-		
											-		
						OVERHEADS & PROFIT		%	10%	31 320.00	3 132.00		
12.01	Borehole installation complete	Sum	1.00	34 452.00	34 452.00	SUB - TOTAL					34 452.00	Supplier's Quote	
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
12.02	Testing of borehole	Sum	1.00	2 550.00	2 550.00	SUB - TOTAL					-	Supplier's Quote	
						MATERIAL	Pump and all assosiated material	Sum	1	7 010.00	7 010.00		
						LABOUR	1 man for 1 day	man hr(s)	8	45.00	360.00		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%	8%	7 370.00	552.75		
12.03	Borehole pump supply and installation	Sum	1.00	7 922.75	7 922.75	SUB - TOTAL					7 922.75		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
12.04					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
12.05					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
12.06					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
12.07					-	SUB - TOTAL					-		
				TOTAL =	44 924.75								

SECTION 2 : DURATION OF WORK

SM Item No.	Description of Main Item	DURATION OF THE WORK				Predecessor	IMPACT ON CRITICAL PATH				LEAD TIME OF RESOURCES		INDIRECT COST IMPACT	
		Unit	Optimistic Time	Expected Time	Pessimistic Time		Affectig the Critical Path	Description of Activity Impacted by the Works	Length of Delay	Unit	Yes / No	How Long	Yes / No	Explain the impact
15.01	Installation of the complete borehole and all assosiated works	Day(s)	3.5	5	6.5	-	No	-	-		Yes	2 Week(s)	No	
15.02	Testing of Borehole	Day(s)	0.5	1	1.5	15.01	No	-	-		No		No	

Total lead time of resources	2	Week(s)
Total duration of the works (excluding lead times)	6	Day(s)
Total time affect on project critical path	0	

SECTION 3 : QUALITY OF WORK

Will it affect any work to be done by other disciplines / contractors?		No
Description of Work	Whom is affected	How are they effected

Will it affect the contractor's methodology of construction?		Yes
Description of Work	What is affected	How is it effected
	Irrigation installation	The irrigation installation has to be delayed untill the borehole installation is complete

SECTION 4 : SIGNATURES

Any other information that the Contractor attached to the ROI:
None

ROI WRITTEN BY:					
Name	**William Thorpe**	Signature		Date	
ROI RECEIVED BY:					
Name	**Emile Herselman**	Signature		Date	
ROI CHECKED AND APPROVED BY:					
Name	**John Adams**	Signature		Date	

Select the 'Process 4' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

INSTRUCTIONS

1. In section 1 & 2, the user do not have to fill in all the GREEN blocks, only those he/she wish to complete.

2. The GREEN blocks in section 3 has to be filled in.

3. The Cost % limits are critical for the Cost Impact Analysis - Please complete it!

COST ANALYSIS BY ENGINEER

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 15
ROI Number: 12
Date: 01/05/2010

Description of the Works: **Installation of new borehole**

It is essential that this table is completed:

Cost % Limits (as a % of Tendered Construction Value of Project)				
Low	Medium Low	Medium	Medium High	High
None	0.05%	0.10%	0.50%	Greater
Note: The suggested values are 0.05%, 0.10% and 0.50%				
Allowable Variance between rates (%) :				15%
Note: the suggested value is 15%				

SECTION 1 : DIRECT COSTS

Rates received from the Contractor: / **Cost Impact Analysis by Engineer:**

						RATE BREAKDOWN OF THE ITEM					SIMILAR RATE IN EXISTING SOQ			RATE FROM SIMILAR TYPE OF PROJECT				RATE FROM SUPPLIER				SENSITIVITY TO QTY INCREASE		
Item No.	Description of Main Item	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Type	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Item No. in BoQ	Rate	Variance	Ref No.	Description	Rate	Variance	Ref No.	Description	Rate	Variance	Absolute Value of a 15% qty increase or decrease	Sensitivity of Project to qty change	Risky Item
						MATERIAL		1.00	5 000.00	5 000.00										4 000.00	20%			
						LABOUR		96.00	45.00	4 320.00		45.00	0%											
						PLANT		8.00	2 750.00	22 000.00														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	0.10	31 320.00	3 132.00														
12.01	Borehole installation complete	Sum	1.00	34 452.00	34 452.00	SUB - TOTAL				R 34 452.00				105Q/2009/10		27 000.00	22%		PJ & Pike	31 086.00	10%	39 619.80	Medium high	Yes
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
12.02	Testing of borehole	Sum	1.00	2 550.00	2 550.00	SUB - TOTAL				R -				105Q/2009/10		2 300.00	10%					2 932.50	Medium low	
						MATERIAL		1.00	7 010.00	7 010.00														
						LABOUR		8.00	45.00	360.00														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	0.08	7 370.00	552.75														
12.03	Borehole pump supply and installation	Sum	1.00	7 922.75	7 922.75	SUB - TOTAL				R 7 922.75				105Q/2009/10		6 350.50	20%					9 111.16	Medium	Yes
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
12.04			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
12.05			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
12.06			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
12.07			-	-	-	SUB - TOTAL				R -												-		
				[A] TOTAL =	R 44 924.75																			

SECTION 2 : INDIRECT COSTS

Description	Select	Amount	Comments
Does the change add greater maintenance cost to the end product?	Yes		An expected yearly maintanace cost, starting with R1585.00, but has no reference on the project budget
Is there any saving due to omission of works brought about by the change?	No		
Is there any additional time related preliminary and general costs?	No		
Is there any other time related costs due to change?	Yes	R 6 560.50	An extension of a day
Is there any other indirect cost due to change?	No		
	[B] TOTAL =	6 560.50	

Select the 'Process 4' button.

SECTION 3 : COST SIZE OF WORKS

Description	Value	% of Budget	% of Contingency
Tendered Construction Value of Project (excl. VAT & Contingencies) =	R 16 500 450.00	-	-
Tendered Contingency Value =	R 1 650 045.00	-	-
Value of Work completed (incl. Retention) =	R 3 550 358.95	21.517%	-
Value of Contingency already used =	R 251 359.00	-	15.233%
[A] Total =	R 44 924.75	0.272%	2.723%
[B] Total =	R 6 560.50	0.040%	0.398%
Total Cost of Change =	**R 51 485.25**	**0.312%**	**3.120%**
		(CIV)	

Overall Cost Impact Rating =	Medium High

Process 2: Next →

Process 3: Next →

Process 4: Next →

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected.

TIME ANALYSIS BY ENGINEER

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	15
ROI Number:	12
Date:	01/05/2010

Description of the Works: **Installation of new borehole**

ASSESSMENT OF THE TIME AFFECT OF THE WORKS

Time needed to do the works:

					AFFECT ON PROJECT PROGRAM									LEAD TIME OF RESOURCES		
Item No.	Description of Main Item	Predecessor Items	Unit	Most Likely Duration of Work (ED_n)	New activity added to Program	Time available for Activity (AT_n)	Resulting time effect of Item (RTE_{n1})	Affecting existing activity of program	Time effect on those activities (TE_n)	Available Float of those Activities (AF_n)	Resulting time effect of Item (RTE_{n2})	Affecting the Critical Path	Description of Activity Impacted by the Works	Is there a lead time on the resources	How Long	Time Impact on Project
15.01	Installation of the complete borehole and all assosiated works	-	Day(s)	5	Yes	6	1	Yes	5	4	-1	Yes	-	Yes	2 Week(s)	High
15.02	Testing of Borehole	15.01	Day(s)	1	Yes	1	0	Yes	1	3	2	No	-	No		Medium
		-														
		-														
		-														
		-														
		-														
		-														
		-														
		-														

Select the 'Process 4' button.

Total lead time of change	2	Week(s)
Total duration of change (excluding lead times)	6	Day(s)
Total time affect on project critical path	0	

Date when works shall commence	25/05/2010	
Time needed to implement the works	6	Days

Overall Time Impact Rating =	High	(TIR)

Process 2: Next →

Process 3: Next →

Process 4: Next →

QUALITY ANALYSIS BY ENGINEER

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

2. Fill in the CLEAR blocks if relevant

3. Some Instructions are shown when a cell is selected.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	15
ROI Number:	12
Date:	01/05/2010
Description of the Works:	**Installation of new borehole**

ASSESSMENT OF THE QUALITY AFFECT OF THE CHANGE

AFFECT ON OTHERS			COMMENTS
Will it affect any work to be done by other disciplines / contractors?		No	
Will it affect the contractor's methodology of construction?		Yes	
Does the works adversely affect any other stakeholders?		No	
Rate the impact of the above mentioned between 1 and 5 (1 = Low; 3 = Medium; 5 = High)		2	
Description of Work	Whom / What is affected		How are they affected

AFFECT ON PROJECT WORKS			COMMENTS
Does it alter previously completed works?		No	
Does it omit previous designs?		No	
Does it replaces / changes previous designs?		Yes	The irrigation design is altered slightly
Will it affect any part of the construction?		Yes	The irrigation installation
Rate the impact of the above mentioned between 1 and 5 (1 = Low; 3 = Medium; 5 = High)		2	
Description of Work	Whom / What is affected		How are they affected

AFFECT ON PROJECT'S QUALITY		COMMENTS
Does the change add value to the project?	Yes	
Does the product still meet the client's expectations?	Yes	
Does the change require any guarantees / warrantees?	No	
Does the change affect any guarantees / warrantees?	No	
Rate the risk impact of the above mentioned between 1 - 5 (1 = Low; 3 = Medium; 5 = High)	1	
Will the quality of the works be measured / tested?	Yes	
Please specify how:	The borehole water is tested once it has been installed	
Does the change require any specific resources that could affect its quality?	No	
Please specify them:		
Rate the risk impact of the above mentioned between 1 - 5 (1 = Low; 3 = Medium; 5 = High)	1	

Select the 'Process 4' button.

Process 3: Next →

Process 4: Next →

Overall Quality Impact Rating =	**Medium Low**

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

RISK CHECK LIST
(click on source, to see more options)

CATEGORIES	SOURCES OF RISK
MACRO LEVEL RISKS	
1. External, Legal & Political	Theft
2. Financial and Economic	Market conditions change
3. Force Majeure / Acts of God	Abnormal natural calamities
4. Contractual	Delay in contractual progress payment
5. Health and Safety / Environmental	Safety risks (e.g. Collapse; Pipe breaks; High water table, Gas
MESSO LEVEL RISKS	
1. Technical	Inaccurate technical assumptions in planning stage
2. Construction	Deletion of work after its construction has commenced
3. Design	Materials/geotechnical/foundation in error
4. Geotechnical	Subsurface cultural relic protection
MICRO LEVEL RISKS	
1. Organisational	Inconsistent cost, time, scope, and quality objectives

2. IDENTIFY and list all potential RISKS

RISK ASSESSMENT BY ENGINEER

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 15
ROI Number: 12
Date: 01/05/2010

Description of the Works: **Installation of new borehole**

SECTION 1: GENERAL RISK OF THE WORKS IDENTIFIED BY COST, TIME AND QUALITY ANALYSIS

Table 1: General Risk Assessment

RISK IDENTIFICATION			COST		TIME		QUALITY		
Category	Risk	Description	Impact	Probability	Impact	Probability	Impact	Probability	RISK RATING
General	Risk of Change	Works as described in general scope of site memo listed above	0.1 < X ≤0.5% cost increase	Highly Probable	High	Highly Probable	Medium Low	Highly Probable	**HIGH**

NOTE: Values from Cost, Time and Quality Analysis completed

SECTION 2: RISK IDENTIFICATION

IDENTIFICATION OF OTHER RISKS TO THE PROJECT

EXPERIENCE
- Identify possible risks based on experience from similar previous projects
- List them in Table 2 below

BRAINSTORMING
- With colleagues brainstorm all possible treats and vulnerabilities of the works.
- List them in Table 2 below

CHECKLIST
- Use checklist (on right-hand of page) to further identify any possible risks by category and source.
- List them in Table 2 below

CAUSE AND EFFECT ANALYSIS
- The identification of potential sources of risks by using the 'fish bone' technique.
- Guiding questions provided.
- Fill in potential causes of risk and their reasons.
- Identified risks to be added to risk list in Table 2 below.

Press to do a Cause-and-Effect analysis →

Table 2: Other risks related to the project

RISK IDENTIFICATION			RISK ANALYSIS								
			COST		TIME		QUALITY		OTHER		
Category	Risk	Description	Impact	Probability	Impact	Probability	Impact	Probability	Impact	Probability	RISK RATING
Technical	Usability of the borehole	The water extraction rate is unknown. It is also unknown whether the water quality is sufficient.	0.1 < X ≤0.5% cost increase	Low probability	Minor slip in key milestones, not able to meet need date	Low probability			Moderate impact, but acceptable	Low probability	**MEDIUM**
Acts of God	Abnormal natural calmaty	The occurance of a natural desaster.	0.05% < X ≤ 0.1% cost increase	Highly Unlikely	Major slip in key milestone or critical path impacted	Highly Unlikely	significantly affects product quality and /or client expectations	Highly Unlikely			**MEDIUM LOW**
Organisational	Incorrect time estimates	Could use the entire avalable float and impact the critical path. Lead time estimate wrong	0.1 < X ≤0.5% cost increase	Low probability	Won't be able to achieve project objectives	Low probability					**MEDIUM HIGH**

3. The RISK REGISTER is given. CLARIFY how each risk will be MANAGED.

SECTION 3: RISK REGISTER AND RISK MANAGEMENT PLAN

Table 3: Risk Register and Mitigation Strategy

RISK REGISTER				RISK MANAGEMENT PLAN				
Category	Risk	Description	Risk Rating	Risk Response	Description of how risk response will be implemented	Person Responsible for it	Monitoring Measures	Evaluation Date
General	Risk of Change	Works as described in general scope of site memo listed above	HIGH	Control / Mitigation	Monitor the works	John Adams	Monitoring the cost, time and quality of the works	01/06/2010
Organisational	Incorrect time estimates	Could use the entire avalable float and impact the critical path. Lead time estimate wrong	MEDIUM HIGH	Control / Mitigation	Monitor the works	John Adams	Monitor the duration of the works. Ensure that the works start on the planned date	01/06/2011
Technical	Usability of the borehole	The water extraction rate is unknown. It is also unknown whether the water quality is sufficient.	MEDIUM	Control / Mitigation	Testing the water quality and delivery rate	John Adams	Testing measures	01/06/2012
Acts of God	Abnormal natural calmaty	The occurance of a natural desaster.	MEDIUM LOW	Transfer	Insurance	John Adams	-	-

Person taking responsibility for the Risk Management of these works: Duncan Howard

Select the 'Process 4' button.

Process 2: Next → | Process 3: Next → | Process 4: Next →

CLIENT PERMISSION REQUEST

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	15
ROI Number:	12
Date:	01/05/2010
Description of the Works:	**Installation of new borehole**

Type of Change:	Client related change
Reason for Change:	Scope creep / Additional work
Works Requested by:	Ben Reed

Total Direct Cost of Works:	R	44 924.75	% of Tender Value:	0.27%
Possible Indirect Cost of Works:	R	6 560.50	% of Tender Value:	0.04%
Total Value of Works:	R	51 485.25	% of Tender Value:	0.31%
To be funded from:	The contingency budget			

Total Duration of Works:	6	Day(s)
Date when work can commence:	25/05/2010	
Total effect on Critical Path:	0	
New Completion Date:	-	

Overall Risk Rating of Works:	HIGH

List all Risks that Client should be made aware of:
The costof the works is quite high, and thus poses a risk to the project
The time estimate of the works may be incorrenct, if so, it could use the float availableand impact the CP
The water extraction rate is unknown. It is also unknown whether the water quality is sufficient.

Process 4: Next →

SUMMARY

INSTRUCTIONS

1.This page summarises all the information

2. Complete only the GREEN blocks.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Summary of Critical Information

Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk	Relevant Links to Drawings etc.
Installation of new borehole	15	01/05/2010	12	01/05/2010	R 44 924.75	0.312%	6 Day(s)	HIGH	Duncan Howard	DRW 102C/2010/02/C01-02 rev2

SUMMARY OF COST, TIME AND RISK ASSESSMENT

Summary of Cost Analysis

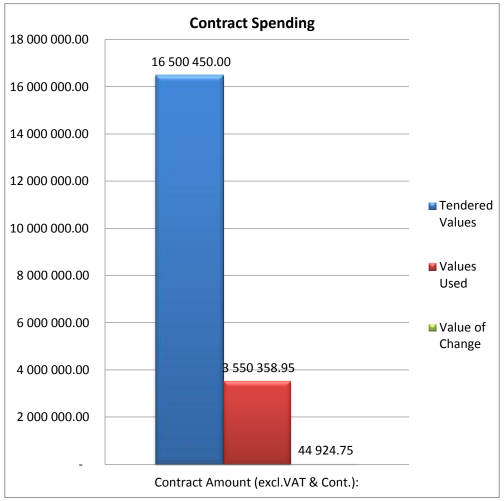
Description	Value	% of Budget	% of Contingency
Tendered Construction Value of Project (excl. VAT & Contingencies) =	R 16 500 450.00	-	-
Tendered Contingency Value =	R 1 650 045.00	-	-
Value of Work completed (incl. Retention) =	R 3 550 358.95	21.52%	-
Value of Contingency already used =	R 251 359.00	-	15.23%
[A] Total =	R 44 924.75	0.272%	2.723%
[B] Total =	R 6 560.50	0.040%	0.398%
Total Cost of Change =	R 51 485.25	0.312%	3.120%
Overall Cost Impact Rating =	**Medium High**		

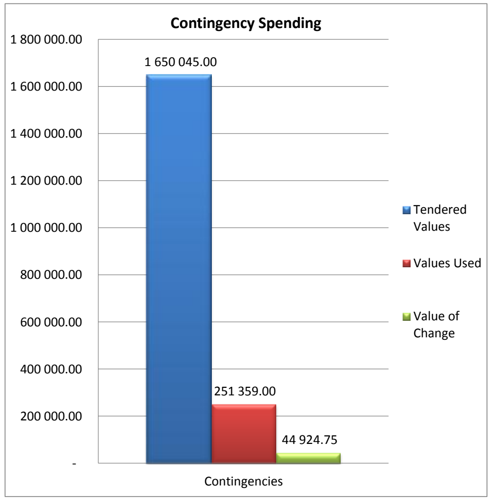
Summary of Time Analysis

Total lead time of change	2	Week(s)
Total duration of change (excl. lead times)	6	Day(s)
Total time affect on project critical path	0	
Date when works shall commence	25/05/2010	
Time needed to implement the works	6	Days
Overall Time Impact Rating =	**High**	

Summary of Quality Analysis

Overall Quality Impact Rating =	**Medium Low**





Summary of Risk Assessment

RISK REGISTER				RISK MANAGEMENT PLAN				
Category	Risk	Description	Risk Rating	Risk Response	Implementation of risk response	Responsible Person	Monitoring Measures	Evaluation Date
General	Risk of Change	Works as described in general scope of site memo listed above	HIGH	Control / Mitigation	Monitor the works	John Adams	Monitoring the cost, time and quality of the works	01/06/2010
Organisational	Incorrect time estimates	Could use the entire avalable float and impact the critical path. Lead time estimate wrong	MEDIUM HIGH	Control / Mitigation	Monitor the works	John Adams	Monitor the duration of the works. Ensure that the works start on the planned date	01/06/2011
Technical	Usability of the borehole	The water extraction rate is unknown. It is also unknown whether the water quality is sufficient.	MEDIUM	Control / Mitigation	Testing the water quality and delivery rate	John Adams	Testing measures	01/06/2012
Acts of God	Abnormal natural calmaty	The occurance of a natural desaster.	MEDIUM LOW	Transfer	Insurance	John Adams	-	-

Communication of Change

WORKS TO BE COMMUNICATED TO:		
Name	Company	Email Address
Duncan Howard	ABC Consulting Engineers	duncan@abc.co.za
William Thorpe	AT Construction	william@atc.co.za
Ben Reed	Wellington Municipality	ben@wellington.gov.za
When:	02/03/2010	
How:	Email	

Select the 'Process 4' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

RECORD OF SITE MEMO'S

INSTRUCTIONS

1.This page keeps a record of all the information

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Record of all site memorandums

Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk
Installation of new borehole	15	01/05/2010	12	01/05/2010	R 44 924.75	0.312%	6 Day(s)	HIGH	Duncan Howard
Modification to retaining wall	14	29/04/2010	7	26/04/2010	R 35 005.50	0.312%	2 Week(s)	MEDIUM	Duncan Howard
Request for test results	13	29/04/2010							
Change to barrier design	12	27/04/2010	6	27/04/2010	R 15 000.00	0.091%	3 Day(s)	LOW	Duncan Howard
Traffic Control Arrangements	11	25/04/2010							
Change to Gate Motor	10	25/04/2010	5	26/04/2010	R 2 630.00	0.016%	1 Day(s)	LOW	Duncan Howard
Change to Fense	9	20/04/2010	4	22/04/2010	R 60 000.00	0.364%	3.5 Week(s)	MEDIUM HIGH	Duncan Howard
Contractor to provide the Engineer with a new Project Program	8	19/04/2010							
Change the wastewater pipe diameter	7	09/04/2010	3	10/04/2010	R 7 530.10	0.046%	6 Day(s)	MEDIUM	Duncan Howard
New Stormwater Manhole	6	22/03/2010	2	23/03/2010	R 5 235.25	0.032%	3 Day(s)	LOW	Duncan Howard
Change to the Road design, SV 250-SV350	5	15/03/2010	1	15/03/2010	R 55 359.25	0.336%	4 Week(s)	HIGH	Duncan Howard
Contractor instructed to appoint Community Liaison Person	4	09/03/2010							
Request for Environmental Management Plan	3	01/03/2010							

Process

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INSTRUCTIONS

1. Select the appropriate reason (in the GREEN block) for why a site memo has to be issued.

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

SITE MEMORANDUM TO BE ISSUED TO CONTRACTOR DUE TO THE FOLLOWING REASON: Request for Information

NOT APPLICABLE

NOTE:
Select the 'Process 1' button.

Press to Select Process 1

PROCESS 1

SITE MEMO → SUMMARY → ENGINEER'S RECORD

- SITE MEMO
  - Site Instruction
  - Information
  - Request for Information
- SUMMARY
  - Summary of Information
- ENGINEER'S RECORD
  - Record of Site Memo and Information received

Press to Select Process 2

PROCESS 2

SMALL CHANGE TO WORKS → SITE MEMORANDUM → RETURN OF INFORMATION → INFORMATION REVIEW → RISK FINDINGS → SUMMARY → ENGINEER'S RECORD

- **SMALL** CHANGE TO WORKS
  - Change to existing works
  - New Works
  - Change to Design
- SITE MEMORANDUM
  - Instruction regarding change to Contractor
- RETURN OF INFORMATION
  - Return of Information from Contractor
- INFORMATION REVIEW
  - Review of Information received from the Contractor
- RISK FINDINGS
  - Gives the risk findings from the information review
- SUMMARY
  - Summary of all Information
- ENGINEER'S RECORD
  - Record of Site Memo and Information Received

Press to Select Process 3

PROCESS 3

MEDIUM CHANGE TO WORKS → CHANGE REVIEW → SITE MEMORANDUM → RETURN OF INFORMATION → INFORMATION REVIEW → RISK ANALYSIS → SUMMARY → ENGINEER'S RECORD

- **MEDIUM** CHANGE TO WORKS
  - Change to existing works
  - New Works
  - Change to Design
- CHANGE REVIEW
  - Evaluating the necessity of the change
- SITE MEMORANDUM
  - Instruction regarding change to Contractor
- RETURN OF INFORMATION
  - Return of Information from Contractor
- INFORMATION REVIEW
  - Review of Information received from the Contractor
- RISK ANALYSIS
  - Analysis of the Cost, Time and Quality Risk of the Works
- SUMMARY
  - Summary of all Information
- ENGINEER'S RECORD
  - Record of Site Memo and Information Received

Press to Select Process 4

PROCESS 4

LARGE CHANGE TO WORKS → CHANGE REVIEW → SITE MEMORANDUM → RETURN OF INFORMATION → INFORMATION REVIEW → EXTENSIVE RISK ANALYSIS → CLIENT PERMISSION → SUMMARY → ENGINEER'S RECORD

- **LARGE** CHANGE TO WORKS
  - Change to existing works
  - New Works
  - Change to Design
- CHANGE REVIEW
  - Evaluating the necessity of the change
- SITE MEMORANDUM
  - Instruction regarding change to Contractor
- RETURN OF INFORMATION
  - Return of Information from Contractor
- INFORMATION REVIEW
  - Review of Information received from the Contractor
- EXTENSIVE RISK ANALYSIS
  - Analysis of all the Cost, Time and Quality Risk of the Works
- CLIENT PERMISSION
  - Request for permission for the works from the Client
- SUMMARY
  - Summary of all Information
- ENGINEER'S RECORD
  - Record of Site Memo and Information Received

Site Memorandum

INSTRUCTIONS

1. Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected.

3. Tick the relevant items.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	16
Date:	16/05/2010
Reason for Site Memo:	Request for Information

DESCRIPTION OF REQUEST

Subject Line: Request for test results

The Contractor to provide the Engineer with the test results of the road layerworks.

Breakdown of works and its known impact:

Item No.	Description of Works	Specification of Works	IMPACT OF WORKS: Cost Impact on Budget	Time impact on Project Program	Specify

The Contractor shall provide the Engineer with the following Information:

- ☐ A quote for the works specified in this Site Memo
- ☐ Rates to be backed up by a Rate Breakdown & Supplier's Quote
- ☐ One or more alternative options
- ☐ The relevant Warrantees / Guarantees
- ☑ Test Results as specified in this Site Memo
- ☐ Schedule impact of the works
- ☐ Updated project Program

Please Specify:

The following information has been attached to the Site Memo:

- ☐ Drawings or Sketches of the works
- ☐ Bending Schedule(s)
- ☐ Documentation
- ☐ Other Information

Please Specify:

SITE MEMO WRITTEN BY:					
Name	**Emile Herselman**	Signature		Date	
SITE MEMO RECEIVED BY:					
Name	**Ben Reed**	Signature		Date	
SITE MEMO CHECKED AND APPROVED BY:					
Name	**Louise Meyer**	Signature		Date	

Next Page →

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SUMMARY

INSTRUCTIONS

1.This page summarises all the information

Next Page →

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Summary of Critical Information

Description of Works	Site Memo Number	Date of SM Issue
Request for test results	16	16/05/2010

RECORD OF SITE MEMO'S

INSTRUCTIONS

1.This page keeps a record of all the information

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Record of all site memorandums

Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk
Request for test results	16	16/05/2010							
Installation of new borehole	15	01/05/2010	12	01/05/2010	R 44 924.75	0.312%	6 Day(s)	HIGH	Duncan Howard
Modification to retaining wall	14	29/04/2010	7	26/04/2010	R 35 005.50	0.312%	2 Week(s)	MEDIUM	Duncan Howard
Request for test results	13	29/04/2010							
Change to barrier design	12	27/04/2010	6	27/04/2010	R 15 000.00	0.091%	3 Day(s)	LOW	Duncan Howard
Traffic Control Arrangements	11	25/04/2010							
Change to Gate Motor	10	25/04/2010	5	26/04/2010	R 2 630.00	0.016%	1 Day(s)	LOW	Duncan Howard
Change to Fense	9	20/04/2010	4	22/04/2010	R 60 000.00	0.364%	3.5 Week(s)	MEDIUM HIGH	Duncan Howard
Contractor to provide the Engineer with a new Project Program	8	19/04/2010							
Change the wastewater pipe diameter	7	09/04/2010	3	10/04/2010	R 7 530.10	0.046%	6 Day(s)	MEDIUM	Duncan Howard
New Stormwater Manhole	6	22/03/2010	2	23/03/2010	R 5 235.25	0.032%	3 Day(s)	LOW	Duncan Howard
Change to the Road design, SV 250-SV350	5	15/03/2010	1	15/03/2010	R 55 359.25	0.336%	4 Week(s)	HIGH	Duncan Howard
Contractor instructed to appoint Community Liaison Person	4	09/03/2010							
Request for Environmental Management Plan	3	01/03/2010							

Process

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INSTRUCTIONS

1. Select the appropriate reason (in the GREEN block) for why a site memo has to be issued.

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

SITE MEMORANDUM TO BE ISSUED TO CONTRACTOR DUE TO THE FOLLOWING REASON: Change to the Works or Design

SELECT THE APPROPRIATE SIZE OF THE CHANGE TO THE WORKS OR THE ADDITIONAL WORKS: Medium

A 'SMALL' size change, in terms of cost to the Works, is expected to be less than: R 8 250.23
If the expected cost of he works is between the proposed values for a Small and a Large change, then it is a 'MEDIUM' size change.
A 'LARGE' size change, in terms of cost to the Works, is expected to be greater than: R 41 251.13

NOTE:
Select the 'Process 3' button.

PROCESS 1

Press to Select Process 1

SITE MEMO
- Site Instruction
- Information
- Request for Information

SUMMARY
- Summary of Information

ENGINEER'S RECORD
- Record of Site Memo and Information received

PROCESS 2

Press to Select Process 2

SMALL CHANGE TO WORKS
- Change to existing works
- New Works
- Change to Design

SITE MEMORANDUM
- Instruction regarding change to Contractor

RETURN OF INFORMATION
- Return of Information from Contractor

INFORMATION REVIEW
- Review of Information received from the Contractor

RISK FINDINGS
- Gives the risk findings from the information review

SUMMARY
- Summary of all Information

ENGINEER'S RECORD
- Record of Site Memo and Information Received

PROCESS 3

Press to Select Process 3

MEDIUM CHANGE TO WORKS
- Change to existing works
- New Works
- Change to Design

CHANGE REVIEW
- Evaluating the necessity of the change

SITE MEMORANDUM
- Instruction regarding change to Contractor

RETURN OF INFORMATION
- Return of Information from Contractor

INFORMATION REVIEW
- Review of Information received from the Contractor

RISK ANALYSIS
- Analysis of the Cost, Time and Quality Risk of the Works

SUMMARY
- Summary of all Information

ENGINEER'S RECORD
- Record of Site Memo and Information Received

PROCESS 4

Press to Select Process 4

LARGE CHANGE TO WORKS
- Change to existing works
- New Works
- Change to Design

CHANGE REVIEW
- Evaluating the necessity of the change

SITE MEMORANDUM
- Instruction regarding change to Contractor

RETURN OF INFORMATION
- Return of Information from Contractor

INFORMATION REVIEW
- Review of Information received from the Contractor

EXTENSIVE RISK ANALYSIS
- Analysis of all the Cost, Time and Quality Risk of the Works

CLIENT PERMISSION
- Request for permission for the works from the Client

SUMMARY
- Summary of all Information

ENGINEER'S RECORD
- Record of Site Memo and Information Received

Review of Proposed Works

INSTRUCTIONS

1. Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

DESCRIPTION OF PROPOSED WORKS	
Subject Line:	Extension of SW system and installation of 2 new manholes

Reason for proposed works:

Type of Change :	**Design change**
Reason for Change :	Unexpected site conditions
Specify:	
Is this change necessary?	YES
Has any alternative options been considered?	NO
What were they?	
Why were they rejected?	
Why is this option better?	
Is this the best option available?	YES
Will the works add value to the project?	YES
Does the works adversely affect any other stakeholders?	NO
Does the works negatively impact other works on the project?	NO
Specify:	

NOTE:
It is recommended that the user reconsider if this change to the works is in the best interest of the project

Record of whom requested the works:

WORKS REQUESTED BY:	
Name	Company
Emile Herselman	ABC Consulting Engineers

When:	25/02/2010
How:	Verbally

Authorization:

CHANGE ANALYSIS AUTHORISED BY:	
Name	Company
John Adams	ABC Consulting Engineers

When :	26/02/2010
How :	Email

Select the 'Process 3' button.

Process 3: Next →

Process 4: Next →

Analysis:

CHANGE ANALYSIS DONE BY:	
Name	Company
Emile Herselman	ABC Consulting Engineers

When :	01/03/2010

ed by: Suné Schoonwinkel 2011

Site Memorandum

INSTRUCTIONS

1. Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 17
Date: 01/05/2010

Reason for Site Memo: Change to the Works or Design

DESCRIPTION OF THE WORKS	
Subject Line:	Extension of SW system and installation of 2 new manholes
The Contractor to extend the 375mm dia stormwater pipe from road B, SWI 19, to catchpit SWC15. Length 50m	

Breakdown of works and its known impact:

			IMPACT OF WORKS		
Item No.	Description of Works	Specification of Works	Cost Impact on Budget	Time impact on Project Program	Specify
17.01	Trench Excavation	SANS 1200	Billed rates apply	Contractor to determine	DB 5.6.3
17.02	Bedding SW pipe	SANS 1200	Billed rates apply	Contractor to determine	F 2.3.1 and F 2.3.2
17.03	375mm dia Concrete Stormwater Pipe (Class 100D)	SANS 1200	Contractor to quote	Contractor to determine	
17.04	2 Stormwater manholes between 2 - 3m deep	SANS 1201	Contractor to quote	Contractor to determine	

3. Tick the relevant items.

The Contractor shall provide the Engineer with the following Information:

- [x] A quote for the works specified in this Site Memo
- [x] Rates to be backed up by a Rate Breakdown & Supplier's Quote
- [ ] One or more alternative options
- [ ] The relevant Warrantees / Guarantees
- [ ] Test Results as specified in this Site Memo
- [x] Schedule impact of the works
- [ ] Updated project program

Please Specify:

The following information has been attached to the Site Memo:

- [x] Drawings or Sketches of the works
- [ ] Bending Schedule(s)
- [ ] Documentation
- [ ] Other Information

Please Specify:
DRW 102C/2010/02/C01-02 rev2

Select the 'Process 3' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

SITE MEMO WRITTEN BY:					
Name	**Emile Herselman**	Signature		Date	
SITE MEMO RECEIVED BY:					
Name	**Ben Reed**	Signature		Date	
SITE MEMO CHECKED AND APPROVED BY:					
Name	**Duncan Howard**	Signature		Date	

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Return of Information from Contractor

INSTRUCTIONS

1.The Contractor to complete all three sections.

2. The Contractor to fill in all GREEN blocks.

3. Some Instructions are shown when a cell is selected.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	17
ROI Number:	13
Date:	01/05/2010

SECTION 1 : COST OF WORK

Rate Breakdown for Option 1

Item No.	Description of Main Item	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	RATE BREAKDOWN OF THE ITEM: Type	Description	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Attached	Specify
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.01	Trench Excavation	m	50.00	38.50	1 925.00	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.02	Bedding	m³	26.50	21.38	566.57	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.03	375mm dia Concrete SW pipe (Class 100D)	m	50.00	360.89	18 044.50	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.04	SW manholes (1-2m deep)	No.	2.00	5 681.00	11 362.00	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.05					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.06					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
13.07					-	SUB - TOTAL					-		
				TOTAL =	31 898.07								

SECTION 2 : DURATION OF WORK

		DURATION OF THE WORK					IMPACT ON CRITICAL PATH				LEAD TIME OF RESOURCES		INDIRECT COST IMPACT	
SM Item No.	Description of Main Item	Unit	Optimistic Time	Expected Time	Pessimistic Time	Predecessor	Affectig the Critical Path	Description of Activity Impacted by the Works	Length of Delay	Unit	Yes / No	How Long	Yes / No	Explain the impact
17.1	Pipe laying	Day(s)	1.5	2	3	-	No	-	-		No		No	
17.2	Constructing 2 manholes	Day(s)	4	5	7	17.10	No	-	-		No		No	

Total lead time of resources	0	Day(s)
Total duration of the works (excluding lead times)	7	Day(s)
Total time affect on project critical path	0	

SECTION 3 : QUALITY OF WORK

Will it affect any work to be done by other disciplines / contractors?		No
Description of Work	Whom is affected	How are they effected

Will it affect the contractor's methodology of construction?		No
Description of Work	What is affected	How is it effected

SECTION 4 : SIGNATURES

Any other information that the Contractor attached to the ROI:
None

ROI WRITTEN BY:					
Name	**William Thorpe**	Signature		Date	
ROI RECEIVED BY:					
Name	**Emile Herselman**	Signature		Date	
ROI CHECKED AND APPROVED BY:					
Name	**John Adams**	Signature		Date	

Select the 'Process 3' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

COST ANALYSIS BY ENGINEER

INSTRUCTIONS

1. In section 1 & 2, the user do not have to fill in all the GREEN blocks, only those he/she wish to complete.

2. The GREEN blocks in section 3 has to be filled in.

3. The Cost % limits are critical for the Cost Impact Analysis -

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	17
ROI Number:	13
Date:	01/05/2010

Description of the Works: **Extension of SW system and installation of 2 new manholes**

It is essential that this table is completed:

Cost % Limits (as a % of Tendered Construction Value of Project)				
Low	Medium Low	Medium	Medium High	High
None	0.05%	0.10%	0.50%	Greater
Note: The suggested values are 0.05%, 0.10% and 0.50%				
Allowable Variance between rates (%) :				**15%**
Note: the suggested value is 15%				

SECTION 1 : DIRECT COSTS

Rates received from the Contractor:

Item No.	Description of Main Item	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	RATE BREAKDOWN OF THE ITEM: Type	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.01	Trench Excavation	m	50.00	38.50	1 925.00	SUB - TOTAL			R	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.02	Bedding	m³	26.50	21.38	566.57	SUB - TOTAL			R	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.03	375mm dia Concrete SW pipe (Class 100D)	m	50.00	360.89	18 044.50	SUB - TOTAL			R	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.04	SW manholes (1-2m deep)	No.	2.00	5 681.00	11 362.00	SUB - TOTAL			R	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.05			-	-	-	SUB - TOTAL			R	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.06			-	-	-	SUB - TOTAL			R	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
								-	-	-
						OVERHEADS & PROFIT	%	-	-	-
13.07			-	-	-	SUB - TOTAL			R	-
				[A] TOTAL =	R 31 898.07					

Cost Impact Analysis by Engineer:

Item No.	SIMILAR RATE IN EXISTING SOQ: Item No. in BoQ	Rate	Variance	RATE FROM SIMILAR TYPE OF PROJECT: Ref No.	Description	Rate	Variance	RATE FROM SUPPLIER: Ref No.	Description	Rate	Variance	SENSITIVITY TO QTY INCREASE: Absolute Value of a 15% qty increase or decrease	Sensitivity of Project to qty change	Risky Item
13.01												2 213.75	Medium low	
13.02												651.56	Medium low	
13.03				105Q/2009/10		345.50	4%					20 751.18	Medium high	Yes
13.04				105Q/2009/10		5 258.00	7%					13 066.30	Medium	
13.05												-		
13.06												-		
13.07												-		

SECTION 2 : INDIRECT COSTS

Description	Select	Amount	Comments
Does the change add greater maintenance cost to the end product?	Yes		
Is there any saving due to omission of works brought about by the change?	No		
Is there any additional time related preliminary and general costs?	No		
Is there any other time related costs due to change?	No		
Is there any other indirect cost due to change?	No		
	[B] TOTAL =	-	

Select the 'Process 3' button.

SECTION 3 : COST SIZE OF WORKS

Process 2: Next →

Process 3: Next →

Process 4: Next →

Description		Value	% of Budget	% of Contingency
Tendered Construction Value of Project (excl. VAT & Contingencies) =	R	16 500 450.00	-	-
Tendered Contingency Value =	R	1 650 045.00	-	-
Value of Work completed (incl. Retention) =	R	4 250 375.95	25.759%	-
Value of Contingency already used =	R	320 125.00	-	19.401%
[A] Total =	R	31 898.07	0.193%	1.933%
[B] Total =	R	-	0.000%	0.000%
Total Cost of Change =	**R**	**31 898.07**	**0.193%**	**1.933%**
			(CIV)	

Overall Cost Impact Rating =	Medium High

TIME ANALYSIS BY ENGINEER

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	17
ROI Number:	13
Date:	01/05/2010

Description of the Works: **Extension of SW system and installation of 2 new manholes**

ASSESSMENT OF THE TIME AFFECT OF THE WORKS

Time needed to do the works:

Item No.	Description of Main Item	Predecessor Items	Unit	Most Likely Duration of Work (ED_n)	AFFECT ON PROJECT PROGRAM									LEAD TIME OF RESOURCES		Time Impact on Project
					New activity added to Program	Time available for Activity (AT_n)	Resulting time effect of Item (RTE_{n1})	Affecting existing activity of program	Time effect on those activities (TE_n)	Available Float of those Activities (AF_n)	Resulting time effect of Item (RTE_{n2})	Affecting the Critical Path	Description of Activity Impacted by the Works	Is there a lead time on the resources	How Long	
17.1	Pipe laying	-	Day(s)	2	Yes	6	4	Yes	1	6	5	No	-	No		Low
17.2	Constructing 2 manholes	17.1	Day(s)	5	Yes	8	3	Yes	1	3	2	No	-	No		Medium Low
		-														
		-														
		-														
		-														
		-														
		-														
		-														
		-														

Select the 'Process 3' button.

Total lead time of change	0	Day(s)
Total duration of change (excluding lead times)	7	Day(s)
Total time affect on project critical path	0	

Date when works shall commence	25/05/2010	
Time needed to implement the works	7	Days

Overall Time Impact Rating =	Medium Low	(TIR)

Process 2: Next →

Process 3: Next →

Process 4: Next →

QUALITY ANALYSIS BY ENGINEER

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

2. Fill in the CLEAR blocks if relevant

3. Some Instructions are shown when a cell is selected.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 17
ROI Number: 13
Date: 01/05/2010

Description of the Works: **Extension of SW system and installation of 2 new manholes**

ASSESSMENT OF THE QUALITY AFFECT OF THE CHANGE

AFFECT ON OTHERS			COMMENTS
Will it affect any work to be done by other disciplines / contractors?		No	
Will it affect the contractor's methodology of construction?		No	
Does the works adversely affect any other stakeholders?		No	
Rate the impact of the above mentioned between 1 and 5 (1 = Low; 3 = Medium; 5 = High)		2	
Description of Work	Whom / What is affected		How are they affected

AFFECT ON PROJECT WORKS			COMMENTS
Does it alter previously completed works?		No	
Does it omit previous designs?		No	
Does it replaces / changes previous designs?		No	
Will it affect any part of the construction?		No	
Rate the impact of the above mentioned between 1 and 5 (1 = Low; 3 = Medium; 5 = High)		2	
Description of Work	Whom / What is affected		How are they affected

AFFECT ON PROJECT'S QUALITY		COMMENTS
Does the change add value to the project?	Yes	
Does the product still meet the client's expectations?	Yes	
Does the change require any guarantees / warrantees?	No	
Does the change affect any guarantees / warrantees?	No	
Rate the risk impact of the above mentioned between 1 - 5 (1 = Low; 3 = Medium; 5 = High)	1	
Will the quality of the works be measured / tested?	Yes	
Please specify how:	The pipe is tested	
Does the change require any specific resources that could affect its quality?	No	
Please specify them:		
Rate the risk impact of the above mentioned between 1 - 5 (1 = Low; 3 = Medium; 5 = High)	1	

Overall Quality Impact Rating = **Medium Low**

Select the 'Process 3' button.

Process 3: Next →

Process 4: Next →

RISK ASSESSMENT BY ENGINEER

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 17
ROI Number: 13
Date: 01/05/2010

Description of the Works: **Extension of SW system and installation of 2 new manholes**

SECTION 1: GENERAL RISK OF THE WORKS IDENTIFIED BY COST, TIME AND QUALITY ANALYSIS

Table 1: General Risk Assessment

RISK IDENTIFICATION			COST		TIME		QUALITY		RISK RATING
Category	Risk	Description	Impact	Probability	Impact	Probability	Impact	Probability	RISK RATING
General	Risk of Change	Works as described in general scope of site memo listed above	0.1 < X ≤0.5% cost increase	Highly Probable	Medium Low	Highly Probable	Medium Low	Highly Probable	**HIGH**

NOTE: Values from Cost, Time and Quality Analysis completed

SECTION 2: RISK IDENTIFICATION

RISK CHECK LIST
(click on source, to see more options)

CATEGORIES	SOURCES OF RISK
MACRO LEVEL RISKS	
1. External, Legal & Political	Theft
2. Financial and Economic	Market conditions change
3. Force Majeure / Acts of God	Abnormal natural calamities
4. Contractual	Delay in contractual progress payment
5. Health and Safety / Environmental	Safety risks (e.g. Collapse; Pipe breaks; High water table, Gas
MESSO LEVEL RISKS	
1. Technical	Inaccurate technical assumptions in planning stage
2. Construction	Deletion of work after its construction has commenced
3. Design	Materials/geotechnical/foundation in error
4. Geotechnical	Subsurface cultural relic protection
MICRO LEVEL RISKS	
1. Organisational	Inconsistent cost, time, scope, and quality objectives

2. IDENTIFY and list all potential RISKS

IDENTIFICATION OF OTHER RISKS TO THE PROJECT

EXPERIENCE
- Identify possible risks based on experience from similar previous projects
- List them in Table 2 below

BRAINSTORMING
- With colleagues brainstorm all possible treats and vulnerabilities of the works.
- List them in Table 2 below

CHECKLIST
- Use checklist (on right-hand of page) to further identify any possible risks by category and source.
- List them in Table 2 below

CAUSE AND EFFECT ANALYSIS
- The identification of potential sources of risks by using the 'fish bone' technique.
- Guiding questions provided.
- Fill in potential causes of risk and their reasons.
- Identified risks to be added to risk list in Table 2 below.

Press to do a Cause-and-Effect analysis →

Table 2: Other risks related to the project

RISK IDENTIFICATION			RISK ANALYSIS								RISK RATING
			COST		TIME		QUALITY		OTHER		
Category	Risk	Description	Impact	Probability	Impact	Probability	Impact	Probability	Impact	Probability	RISK RATING

3. The RISK REGISTER is given. CLARIFY how each risk will be MANAGED.

Select the 'Process 3' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

SECTION 3: RISK REGISTER AND RISK MANAGEMENT PLAN

Table 3: Risk Register and Mitigation Strategy

RISK REGISTER				RISK MANAGEMENT PLAN				
Category	Risk	Description	Risk Rating	Risk Response	Description of how risk response will be implemented	Person Responsible for it	Monitoring Measures	Evaluation Date
General	Risk of Change	Works as described in general scope of site memo listed above	HIGH	Control / Mitigation	Monitor the works	John Adams	Monitoring the cost, time and quality of the works	01/06/2010

Person taking responsibility for the Risk Management of these works: Duncan Howard

SUMMARY

INSTRUCTIONS

1.This page summarises all the information

2. Complete only the GREEN blocks.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501

Summary of Critical Information

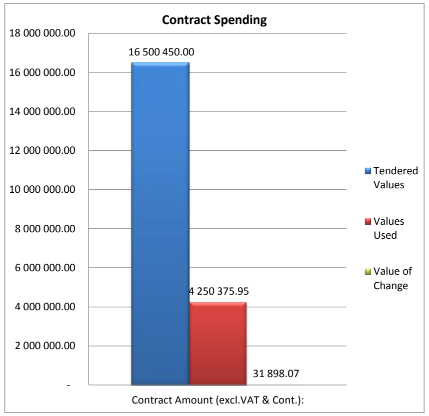
Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk	Relevant Links to Drawings etc.
Extension of SW system and installation of 2 new manholes	17	01/05/2010	13	01/05/2010	R 31 898.07	0.193%	7 Day(s)	HIGH	Duncan Howard	DRW 102C/2010/02/C01-02 rev2

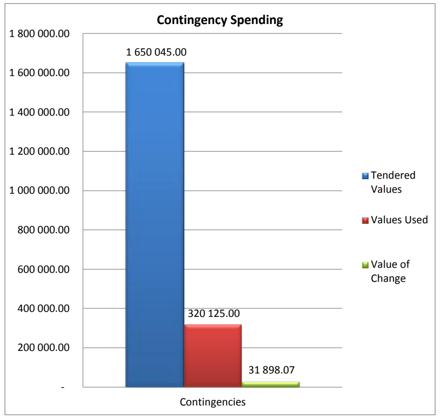
SUMMARY OF COST, TIME AND RISK ASSESSMENT

Summary of Cost Analysis

Description	Value		% of Budget	% of Contingency
Tendered Construction Value of Project (excl. VAT & Contingencies) =	R	16 500 450.00	-	-
Tendered Contingency Value =	R	1 650 045.00	-	-
Value of Work completed (incl. Retention) =	R	4 250 375.95	25.76%	-
Value of Contingency already used =	R	320 125.00	-	19.40%
[A] Total =	R	31 898.07	0.193%	1.933%
[B] Total =	R	-	0.000%	0.000%
Total Cost of Change =	R	31 898.07	0.193%	1.933%

Overall Cost Impact Rating =	**Medium High**





Summary of Time Analysis

Total lead time of change	0	Day(s)
Total duration of change (excl. lead times)	7	Day(s)
Total time affect on project critical path	0	
Date when works shall commence	25/05/2010	
Time needed to implement the works	7	Days
Overall Time Impact Rating =	**Medium Low**	

Summary of Risk Assessment

RISK REGISTER					RISK MANAGEMENT PLAN				
Category	Risk	Description		Risk Rating	Risk Response	Implementation of risk response	Responsible Person	Monitoring Measures	Evaluation Date
General	Risk of Change	Works as described in general scope of site memo listed above		HIGH	Control / Mitigation	Monitor the works	John Adams	Monitoring the cost, time and quality of the works	01/06/2010

Select the 'Process 3' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

Communication of Change

WORKS TO BE COMMUNICATED TO:		
Name	Company	Email Address
Duncan Howard	ABC Consulting Engineers	duncan@abc.co.za
William Thorpe	AT Construction	william@atc.co.za
Ben Reed	Wellington Municipality	ben@wellington.gov.za
When:	02/03/2010	
How:	Email	

RECORD OF SITE MEMO'S

INSTRUCTIONS

1.This page keeps a record of all the information

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Record of all site memorandums

Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk
Extension of SW system and installation of 2 new manholes	17	01/05/2010	13	01/05/2010	R 31 898.07	0.193%	7 Day(s)	HIGH	Duncan Howard
Request for test results	16	16/05/2010							
Installation of new borehole	15	01/05/2010	12	01/05/2010	44924.75	0%	6 Day(s)	HIGH	
Modification to retaining wall	14	29/04/2010	7	26/04/2010	R 35 005.50	0.193%	2 Week(s)	MEDIUM	Duncan Howard
Request for test results	13	29/04/2010							
Change to barrier design	12	27/04/2010	6	27/04/2010	R 15 000.00	0.091%	3 Day(s)	LOW	Duncan Howard
Traffic Control Arrangements	11	25/04/2010							
Change to Gate Motor	10	25/04/2010	5	26/04/2010	R 2 630.00	0.016%	1 Day(s)	LOW	Duncan Howard
Change to Fense	9	20/04/2010	4	22/04/2010	R 60 000.00	0.364%	3.5 Week(s)	MEDIUM HIGH	Duncan Howard
Contractor to provide the Engineer with a new Project Program	8	19/04/2010							
Change the wastewater pipe diameter	7	09/04/2010	3	10/04/2010	R 7 530.10	0.046%	6 Day(s)	MEDIUM	Duncan Howard
New Stormwater Manhole	6	22/03/2010	2	23/03/2010	R 5 235.25	0.032%	3 Day(s)	LOW	Duncan Howard
Change to the Road design, SV 250-SV350	5	15/03/2010	1	15/03/2010	R 55 359.25	0.336%	4 Week(s)	HIGH	Duncan Howard
Contractor instructed to appoint Community Liaison Person	4	09/03/2010							
Request for Environmental Management Plan	3	01/03/2010							

Process

Created by : Suné Schoonwinkel | 2011

INSTRUCTIONS

1. Select the appropriate reason (in the GREEN block) for why a site memo has to be issued.

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

SITE MEMORANDUM TO BE ISSUED TO CONTRACTOR DUE TO THE FOLLOWING REASON: Change to the Works or Design

SELECT THE APPROPRIATE SIZE OF THE CHANGE TO THE WORKS OR THE ADDITIONAL WORKS: Small

A 'SMALL' size change, in terms of cost to the Works, is expected to be less than: R 8,250.23
If the expected cost of he works is between the proposed values for a Small and a Large change, then it is a 'MEDIUM' size change.
A 'LARGE' size change, in terms of cost to the Works, is expected to be greater than: R 41,251.13

NOTE:
Select the 'Process 2' button.

Press to Select Process 1

PROCESS 1

SITE MEMO → SUMMARY → ENGINEER'S RECORD

- SITE MEMO: • Site Instruction • Information • Request for Information
- SUMMARY: • Summary of Information
- ENGINEER'S RECORD: • Record of Site Memo and Information received

Press to Select Process 2

PROCESS 2

SMALL CHANGE TO WORKS → SITE MEMORANDUM → RETURN OF INFORMATION → INFORMATION REVIEW → RISK FINDINGS → SUMMARY → ENGINEER'S RECORD

- SMALL CHANGE TO WORKS: • Change to existing works • New Works • Change to Design
- SITE MEMORANDUM: • Instruction regarding change to Contractor
- RETURN OF INFORMATION: • Return of Information from Contractor
- INFORMATION REVIEW: • Review of Information received from the Contractor
- RISK FINDINGS: • Gives the risk findings from the information review
- SUMMARY: • Summary of all Information
- ENGINEER'S RECORD: • Record of Site Memo and Information Received

Press to Select Process 3

PROCESS 3

MEDIUM CHANGE TO WORKS → CHANGE REVIEW → SITE MEMORANDUM → RETURN OF INFORMATION → INFORMATION REVIEW → RISK ANALYSIS → SUMMARY → ENGINEER'S RECORD

- MEDIUM CHANGE TO WORKS: • Change to existing works • New Works • Change to Design
- CHANGE REVIEW: • Evaluating the necessity of the change
- SITE MEMORANDUM: • Instruction regarding change to Contractor
- RETURN OF INFORMATION: • Return of Information from Contractor
- INFORMATION REVIEW: • Review of Information received from the Contractor
- RISK ANALYSIS: • Analysis of the Cost, Time and Quality Risk of the Works
- SUMMARY: • Summary of all Information
- ENGINEER'S RECORD: • Record of Site Memo and Information Received

Press to Select Process 4

PROCESS 4

LARGE CHANGE TO WORKS → CHANGE REVIEW → SITE MEMORANDUM → RETURN OF INFORMATION → INFORMATION REVIEW → EXTENSIVE RISK ANALYSIS → CLIENT PERMISSION → SUMMARY → ENGINEER'S RECORD

- LARGE CHANGE TO WORKS: • Change to existing works • New Works • Change to Design
- CHANGE REVIEW: • Evaluating the necessity of the change
- SITE MEMORANDUM: • Instruction regarding change to Contractor
- RETURN OF INFORMATION: • Return of Information from Contractor
- INFORMATION REVIEW: • Review of Information received from the Contractor
- EXTENSIVE RISK ANALYSIS: • Analysis of all the Cost, Time and Quality Risk of the Works
- CLIENT PERMISSION: • Request for permission for the works from the Client
- SUMMARY: • Summary of all Information
- ENGINEER'S RECORD: • Record of Site Memo and Information Received

Site Memorandum

INSTRUCTIONS

1. Complete all the GREEN blocks and follow the given instructions.

2. Some instructions are shown when a cell is selected.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 18
Date: 15/05/2010

Reason for Site Memo: Change to the Works or Design

DESCRIPTION OF THE WORKS	
Subject Line:	Relocation of trees
The Contractor to move the 12 trees planted on the northern side of Road A1 to the southern side of Road B3.	

Breakdown of works and its known impact:

Item No.	Description of Works	Specification of Works	IMPACT OF WORKS: Cost Impact on Budget	IMPACT OF WORKS: Time impact on Project Program	IMPACT OF WORKS: Specify
18.01	Move Trees	SANS 1200	Contractor to quote	Contractor to determine	

3. Tick the relevant items.

The Contractor shall provide the Engineer with the following Information:

- [x] A quote for the works specified in this Site Memo
- [ ] Rates to be backed up by a Rate Breakdown & Supplier's Quote
- [ ] One or more alternative options
- [x] The relevant Warrantees / Guarantees
- [ ] Test Results as specified in this Site Memo
- [ ] Schedule impact of the works
- [ ] Updated project program

Please Specify:

The following information has been attached to the Site Memo:

- [x] Drawings or Sketches of the works
- [ ] Bending Schedule(s)
- [ ] Documentation
- [ ] Other Information

Please Specify:
A sketch of the new location of the trees is attached.

Select the 'Process 2' button.

Process 2: Next →
Process 3: Next →
Process 4: Next →

SITE MEMO WRITTEN BY:					
Name	**Emile Herselman**	Signature		Date	
SITE MEMO RECEIVED BY:					
Name	**Ben Reed**	Signature		Date	
SITE MEMO CHECKED AND APPROVED BY:					
Name	**Duncan Howard**	Signature		Date	

Created by: Suné Schoonwinkel 2011

Return of Information from Contractor

INSTRUCTIONS

1.The Contractor to complete all three sections.

2. The Contractor to fill in all GREEN blocks.

3. Some Instructions are shown when a cell is selected.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	18
ROI Number:	14
Date:	15/05/2010

SECTION 1 : COST OF WORK

Rate Breakdown for Option 1

Item No.	Description of Main Item	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	RATE BREAKDOWN OF THE ITEM: Type	Description	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Attached	Specify
											-		
						OVERHEADS & PROFIT		%		-	-		
14.01	Moving trees	No.	12.00	55.60	667.20	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
					-	SUB - TOTAL					-		
											-		
						OVERHEADS & PROFIT		%		-	-		
					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
					-	SUB - TOTAL					-		
											-		
											-		
											-		
											-		
											-		
						OVERHEADS & PROFIT		%		-	-		
					-	SUB - TOTAL					-		
				TOTAL =	667.20								

SECTION 2 : DURATION OF WORK

SM Item No.	Description of Main Item	DURATION OF THE WORK: Unit	Optimistic Time	Expected Time	Pessimistic Time	Predecessor	IMPACT ON CRITICAL PATH: Affectig the Critical Path	Description of Activity Impacted by the Works	Length of Delay	Unit	LEAD TIME OF RESOURCES: Yes / No	How Long	INDIRECT COST IMPACT: Yes / No	Explain the impact
18.01	Move trees	Day(s)	0.5	1	1.5	-	No	-	-		No		No	
								-	-					

Total lead time of resources	0	
Total duration of the works (excluding lead times)	1	Day(s)
Total time affect on project critical path	0	

SECTION 4 : SIGNATURES

Any other information that the Contractor attached to the ROI:
None

Name		Signature		Date	
ROI WRITTEN BY:					
Name	**William Thorpe**	Signature		Date	
ROI RECEIVED BY:					
Name	**Emile Herselman**	Signature		Date	
ROI CHECKED AND APPROVED BY:					
Name	**John Adams**	Signature		Date	

Select the 'Process 2' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

COST ANALYSIS BY ENGINEER

INSTRUCTIONS

1. In section 1 & 2, the user do not have to fill in all the GREEN blocks, only those he/she wish to complete.

2. The GREEN blocks in section 3 has to be filled in.

3. The Cost % limits are critical for the Cost Impact Analysis - Please complete

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 18
ROI Number: 14
Date: 01/05/2010

Description of the Works: **Relocation of trees**

It is essential that this table is completed:

Cost % Limits (as a % of Tendered Construction Value of Project)				
Low	Medium Low	Medium	Medium High	High
None	0.05%	0.10%	0.50%	Greater
Note: The suggested values are 0.05%, 0.10% and 0.50%				
Allowable Variance between rates (%) :				15%
Note: the suggested value is 15%				

SECTION 1 : DIRECT COSTS

Rates received from the Contractor: / Cost Impact Analysis by Engineer:

						RATE BREAKDOWN OF THE ITEM					SIMILAR RATE IN EXISTING SOQ			RATE FROM SIMILAR TYPE OF PROJECT				RATE FROM SUPPLIER				SENSITIVITY TO QTY INCREASE		
Item No.	Description of Main Item	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Type	Unit	Quantity	Rate (excl. VAT)	Amount (excl. VAT)	Item No. in BoQ	Rate	Variance	Ref No.	Description	Rate	Variance	Ref No.	Description	Rate	Variance	Absolute Value of a 15% qty increase or decrease	Sensitivity of Project to qty change	Risky Item
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
14.01	Moving trees	No.	12.00	55.60	667.20	SUB - TOTAL				R -												767.28	Medium low	
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
			-	-	-	SUB - TOTAL				R -												-		
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
								-	-	-														
						OVERHEADS & PROFIT	%	-	-	-														
			-	-	-	SUB - TOTAL				R -												-		
					[A] TOTAL = R 667.20																			

SECTION 2 : INDIRECT COSTS

Description	Select	Amount	Comments
Does the change add greater maintenance cost to the end product?	No		
Is there any saving due to omission of works brought about by the change?	No		
Is there any additional time related preliminary and general costs?	No		
Is there any other time related costs due to change?	No		
Is there any other indirect cost due to change?	No		
	[B] TOTAL =	-	

Select the 'Process 2' button.

SECTION 3 : COST SIZE OF WORKS

Description	Value	% of Budget	% of Contingency
Tendered Construction Value of Project (excl. VAT & Contingencies) =	R 16,500,450.00	-	-
Tendered Contingency Value =	R 1,650,045.00	-	-
Value of Work completed (incl. Retention) =	R 4,250,375.95	25.759%	-
Value of Contingency already used =	R 320,125.00	-	19.401%
[A] Total =	R 667.20	0.004%	0.040%
[B] Total =	R -	0.000%	0.000%
Total Cost of Change =	**R 667.20**	**0.004%**	**0.040%**
		(CIV)	

Overall Cost Impact Rating =	Medium Low

Process 2: Next →

Process 3: Next →

Process 4: Next →

TIME ANALYSIS BY ENGINEER

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

2. Some Instructions are shown when a cell is selected.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501
Site Memo Number:	18
ROI Number:	14
Date:	01/05/2010

Description of the Works: **Relocation of trees**

ASSESSMENT OF THE TIME AFFECT OF THE WORKS

Time needed to do the works:

					AFFECT ON PROJECT PROGRAM									LEAD TIME OF RESOURCES		
Item No.	Description of Main Item	Predecessor Items	Unit	Most Likely Duration of Work (ED_n)	New activity added to Program	Time available for Activity (AT_n)	Resulting time effect of Item (RTE_{n1})	Affecting existing activity of program	Time effect on those activities (TE_n)	Available Float of those Activities (AF_n)	Resulting time effect of Item (RTE_{n2})	Affecting the Critical Path	Description of Activity Impacted by the Works	Is there a lead time on the resources	How Long	Time Impact on Project
18.01	Move trees	-	Day(s)	1	Yes	6	5	No				No	-	No		Low
		-														
		-														
		-														
		-														
		-														
		-														
		-														
		-														
		-														

Select the 'Process 2' button.

Total lead time of change	0	
Total duration of change (excluding lead times)	1	Day(s)
Total time affect on project critical path	0	

Date when works shall commence	25/05/2010	
Time needed to implement the works	7	Days

Overall Time Impact Rating =	Low	(TIR)

Process 2: Next →

Process 3: Next →

Process 4: Next →

RISK ASSESSMENT BY ENGINEER

INSTRUCTIONS

1.Complete all the GREEN blocks and follow the given instructions.

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Site Memo Number: 18
ROI Number: 14
Date: 15/05/2010

Description of the Works: **Relocation of trees**

SECTION 1: GENERAL RISK OF THE WORKS IDENTIFIED BY COST, TIME AND QUALITY ANALYSIS

Table 1: General Risk Assessment

RISK IDENTIFICATION			COST		TIME		QUALITY		
Category	Risk	Description	Impact	Probability	Impact	Probability	Impact	Probability	RISK RATING
General	Risk of Change	Works as described in general scope of site memo listed above	X ≤ 0.05% cost increase	Highly Probable	Low	Highly Probable			**MEDIUM HIGH**

NOTE: Values from Cost, Time and Quality Analysis completed

SECTION 3: RISK REGISTER AND RISK MANAGEMENT PLAN

3. The RISK REGISTER is given. CLARIFY how each risk will be MANAGED.

Table 3: Risk Register and Mitigation Strategy

RISK REGISTER				RISK MANAGEMENT PLAN				
Category	Risk	Description	Risk Rating	Risk Response	Description of how risk response will be implemented	Person Responsible for it	Monitoring Measures	Evaluation Date
General	Risk of Change	Works as described in general scope of site memo listed above	MEDIUM HIGH	Control / Mitigation	Monitor the works	John Adams	Monitoring the cost, time and quality of the works	01/06/2010

Person taking responsibility for the Risk Management of these works: Duncan Howard

Select the 'Process 2' button.

Process 2: Next → | Process 3: Next → | Process 4: Next →

SUMMARY

INSTRUCTIONS

1.This page summarises all the information

2. Complete only the GREEN blocks.

ENGINEERS:	ABC CONSULTING ENGINEERS
CLIENT:	WELLINGTON MUNICIPALITY
CONTRACTOR:	AT CONSTRUCTION
Project Name:	The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number:	102C/2010/02
Project File Number:	C7501

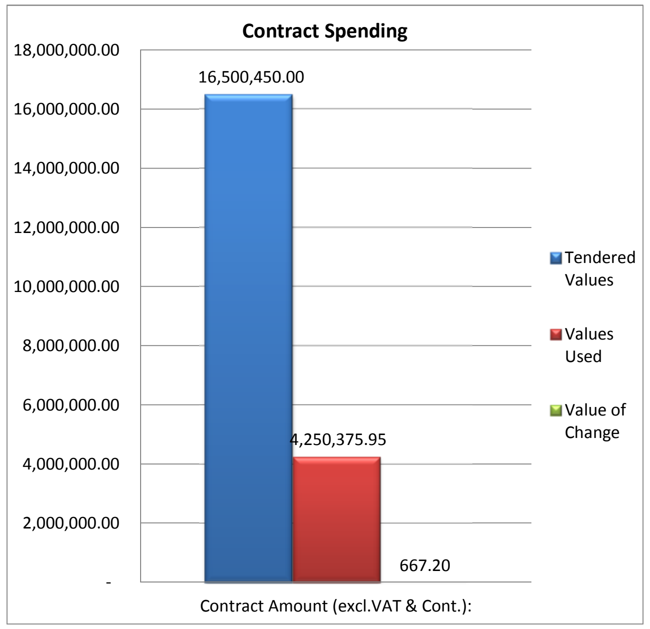
Summary of Critical Information

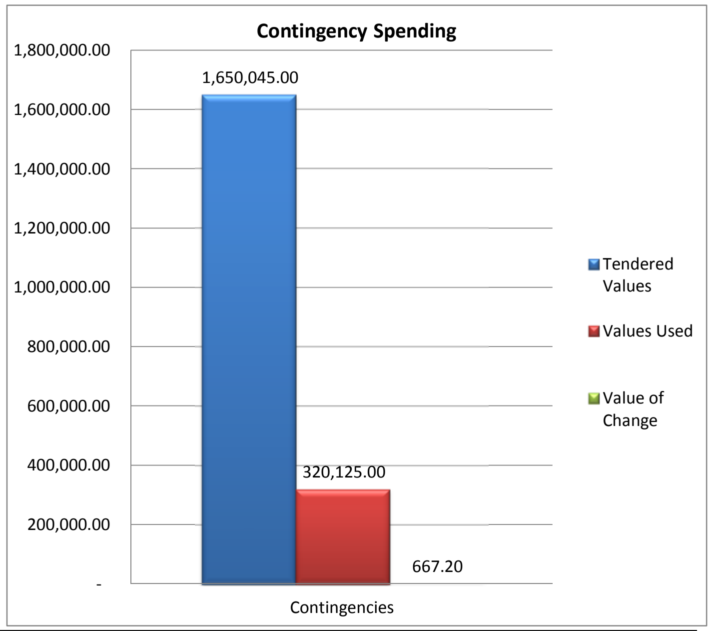
Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk	Relevant Links to Drawings etc.
Relocation of trees	18	15/05/2010	14	15/05/2010	R 667.20	0.004%	1 Day(s)	MEDIUM HIGH	Duncan Howard	A sketch of the new location of the trees is attached.

SUMMARY OF COST, TIME AND RISK ASSESSMENT

Summary of Cost Analysis

Description	Value	% of Budget	% of Contingency
Tendered Construction Value of Project (excl. VAT & Contingencies) =	R 16,500,450.00	-	-
Tendered Contingency Value =	R 1,650,045.00	-	-
Value of Work completed (incl. Retention) =	R 4,250,375.95	25.76%	-
Value of Contingency already used =	R 320,125.00	-	19.40%
[A] Total =	R 667.20	0.004%	0.040%
[B] Total =	R -	0.000%	0.000%
Total Cost of Change =	R 667.20	0.004%	0.040%
Overall Cost Impact Rating =	**Medium Low**		





Summary of Time Analysis

Total lead time of change	0	
Total duration of change (excl. lead times)	1	Day(s)
Total time affect on project critical path	0	
Date when works shall commence	25/05/2010	
Time needed to implement the works	7	Days
Overall Time Impact Rating =	**Low**	

Summary of Quality Analysis

Overall Quality Impact Rating =	**Low**

Summary of Risk Assessment

RISK REGISTER				RISK MANAGEMENT PLAN				
Category	Risk	Description	Risk Rating	Risk Response	Implementation of risk response	Responsible Person	Monitoring Measures	Evaluation Date
General	Risk of Change	Works as described in general scope of site memo listed above	MEDIUM HIGH	Control / Mitigation	Monitor the works	John Adams	Monitoring the cost, time and quality of the works	01/06/2010

Select the 'Process 2' button.

Process 2: Next →

Process 3: Next →

Process 4: Next →

Communication of Change

WORKS TO BE COMMUNICATED TO:		
Name	Company	Email Address
Duncan Howard	ABC Consulting Engineers	duncan@abc.co.za
William Thorpe	AT Construction	william@atc.co.za
Ben Reed	Wellington Municipality	ben@wellington.gov.za
When:		
How:	Email	

RECORD OF SITE MEMO'S

INSTRUCTIONS

1.This page keeps a record of all the information

ENGINEERS: ABC CONSULTING ENGINEERS
CLIENT: WELLINGTON MUNICIPALITY
CONTRACTOR: AT CONSTRUCTION

Project Name: The earthworks and infrastructure construction for the Wellington Heights property development, phase 1.
Project Contract Number: 102C/2010/02
Project File Number: C7501

Record of all site memorandums

Description of Works	Site Memo Number	Date of SM Issue	ROI Number	Date of ROI Received	Direct Cost of Works	% of Tendered Contract	Duration of Works	Risk Rating of Works	Person Responsible for Risk
Relocation of trees	18	15/05/2010	14	15/05/2010	R 667.20	0.004%	1 Day(s)	MEDIUM HIGH	Duncan Howard
Extension of SW system and installation of 2 new manholes	17	01/05/2010	13	01/05/2010	R 31,898.07	0.193%	7 Day(s)	HIGH	Duncan Howard
Request for test results	16	16/05/2010							
Installation of new borehole	15	01/05/2010	12	01/05/2010	R 44,924.75		6 Day(s)	HIGH	Duncan Howard
Modification to retaining wall	14	29/04/2010	7	26/04/2010	R 35,005.50	0.004%	2 Week(s)	MEDIUM	Duncan Howard
Request for test results	13	29/04/2010							
Change to barrier design	12	27/04/2010	6	27/04/2010	R 15,000.00	0.091%	3 Day(s)	LOW	Duncan Howard
Traffic Control Arrangements	11	25/04/2010							
Change to Gate Motor	10	25/04/2010	5	26/04/2010	R 2,630.00	0.016%	1 Day(s)	LOW	Duncan Howard
Change to Fense	9	20/04/2010	4	22/04/2010	R 60,000.00	0.364%	3.5 Week(s)	MEDIUM HIGH	Duncan Howard
Contractor to provide the Engineer with a new Project Program	8	19/04/2010							
Change the wastewater pipe diameter	7	09/04/2010	3	10/04/2010	R 7,530.10	0.046%	6 Day(s)	MEDIUM	Duncan Howard
New Stormwater Manhole	6	22/03/2010	2	23/03/2010	R 5,235.25	0.032%	3 Day(s)	LOW	Duncan Howard
Change to the Road design, SV 250-SV350	5	15/03/2010	1	15/03/2010	R 55,359.25	0.336%	4 Week(s)	HIGH	Duncan Howard
Contractor instructed to appoint Community Liaison Person	4	09/03/2010							
Request for Environmental Management Plan	3	01/03/2010							

①

Review of Model

INSTRUCTIONS

Created by : Suné Schoonwinkel | 2011

1. Please fill in all the GREEN blocks.

Expert evaluation and opinion is the final step in the development methodology of the Change Management Model. Your contribution will be anonymous and the information obtained from this evaluation form will be used strictly for academic purposes. Please be sure to answer all the questions provided. Your opinion is valued and suggestions made will be considered in the finalization of the tool.

In the *RATING* column, please enter the appropriate value between 1 and 5 (where 1='Not at all', 2='No', 3='Sometimes', 4='Yes', 5='Definitely')

	Question	Rating	Comments
1	Were the instructions provided in the model clear and unambiguous, so that it was easy to use?	5	
2	Is the Model practical?	3-4	See 5 below.
3	Were the functions of the four different processes clear and easily understood?	5	
4	Did you find the various processes practical and useful?	5	
5	Was the cost analysis page comprehensive and practical?	4	See 6 below.
6	Was the time analysis page comprehensive and practical?	5	
7	Was the risk assessment page comprehensive and practical?	4	
8	Is the general risk rating of the works credible and useful?	4	See 3 below
9	Does the "Summary" page provide enough information to ensure the credibility of the conclusions made?	4	See 3 below.
10	Will the Model enable the Engineer to make better informed decisions?	5	
11	Is the Model time effective?	4	See 5 below
12	Would you make use of the Model?	5	
13	What is your overall impression of the Model?	extensive,	thought provoking, thorough.

14 What recommendations do you have that would enhance the model?

1. Incorporate CPA to spreadsheet (ie. escalation, de-escalation)
2. Risk assessment summary data should be on sheet going to client ~~to~~ + to Contractor
3. Make summary more graphical of results.
4. Allow more analysis before choosing process 1 or 2, etc.
5. As the programme is extensive and usefull, it can take time, hence the importance of ensuring the user chooses the right process upfront.
6. Issues such as CPA, escalation, importation etc could complicate the spreadsheet so the user must be ~~more~~ knowledgable in this field of assessment.

Well done -

[signature] 04/11/2011

②

Review of Model

INSTRUCTIONS

Created by : Suné Schoonwinkel | 2011

1. Please fill in all the GREEN blocks.

Expert evaluation and opinion is the final step in the development methodology of the Change Management Model. Your contribution will be anonymous and the information obtained from this evaluation form will be used strictly for academic purposes. Please be sure to answer all the questions provided. Your opinion is valued and suggestions made will be considered in the finalization of the tool.

In the *RATING* column, please enter the appropriate value between 1 and 5 (where 1='Not at all', 2='No', 3='Sometimes', 4='Yes', 5='Definitely')

	Question	Rating	Comments
1	Were the instructions provided in the model clear and unambiguous, so that it was easy to use?	5	A useful tool to enable site management to focus more (and proper) attention to this very important aspect i.e. management of changes occurring on site.
2	Is the Model practical?	4	
3	Were the functions of the four different processes clear and easily understood?	4	
4	Did you find the various processes practical and useful?	4	
5	Was the cost analysis page comprehensive and practical?	5	
6	Was the time analysis page comprehensive and practical?	5	
7	Was the risk assessment page comprehensive and practical?	5	
8	Is the general risk rating of the works credible and useful?	4	
9	Does the "Summary" page provide enough information to ensure the credibility of the conclusions made?	5	
10	Will the Model enable the Engineer to make better informed decisions?	5	
11	Is the Model time effective?	3	
12	Would you make use of the Model?	5	
13	What is your overall impression of the Model?	5	

14 What recommendations do you have that would enhance the model?

- Size of change – sliding scale of cost of project.
- User-friendly, multi-changeable sheets for good communications.
- Consideration for escalation (present-day value)
- Consideration should be given to Contract Escalation calculation.
- Grouping of changes – model needs to be "user-friendly" in terms of time available.
- Not always practical to complete the analysis before issuing a site memo.

[signature] 4/11/2011

③

Review of Model

INSTRUCTIONS

Created by : Suné Schoonwinkel | 2011

1. Please fill in all the GREEN blocks.

Expert evaluation and opinion is the final step in the development methodology of the Change Management Model. Your contribution will be anonymous and the information obtained from this evaluation form will be used strictly for academic purposes. Please be sure to answer all the questions provided. Your opinion is valued and suggestions made will be considered in the finalization of the tool.

In the *RATING* column, please enter the appropriate value between 1 and 5 (where 1='Not at all', 2='No', 3='Sometimes', 4='Yes', 5='Definitely')

	Question	Rating	Comments
1	Were the instructions provided in the model clear and unambiguous, so that it was easy to use?	4	
2	Is the Model practical?	3	
3	Were the functions of the four different processes clear and easily understood?	2	
4	Did you find the various processes practical and useful?	3	Some of them
5	Was the cost analysis page comprehensive and practical?	3	
6	Was the time analysis page comprehensive and practical?	3	
7	Was the risk assessment page comprehensive and practical?	3/2	Not sure if people would use this
8	Is the general risk rating of the works credible and useful?		
9	Does the "Summary" page provide enough information to ensure the credibility of the conclusions made?	4	
10	Will the Model enable the Engineer to make better informed decisions?	3	Change size/type dependent
11	Is the Model time effective?	2	
12	Would you make use of the Model?	3	
13	What is your overall impression of the Model?	3	May be too onerous for some projects

14 What recommendations do you have that would enhance the model?

Sliding scale for size of change
Escalation for rates comparison