

**THE ZACHMAN FRAMEWORK  
APPLIED  
TO  
CONSTRUCTION ENGINEERING  
RISK MANAGEMENT**

by

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## NOMENCLATURE

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Symbol	Meaning
C	Cost
CBD	Central Business District
CEO	Chairperson of Executive Office
CFO	Chairperson of Finance Office
CoJ	Johannesburg Metropolitan Council
CPM	Critical Path Method
EA	Enterprise Architecture
JHB	Johannesburg
IS	Information System
IT	Informational Technology
MS	Microsoft
N	Total number of Samples
PERT	Program Evaluation and Review Technique
PMI <sup>®</sup>	Project Management Institute
R	Rands
SOX	Sarbanes-Oxley
VB	Visual Basics
WE	Work-Element
WBS	Work Breakdown Structure
$\mu$	Mean
$\sigma^2$	Standard Deviation
x	Random Sample
$\infty$	Infinity

## **ABSTRACT**

The research is based on the complexity of project management and risk management fields and how applying each field on its own can be problematic. This poses an everyday challenge to project managers when implemented simultaneously and such a problem predominantly exists in the engineering construction field.

The challenge faced by project managers is approached throughout the research study by introducing a commonly used six order matrix framework with a high success rate in analysing and dissecting complex fields into small fragments. The framework is known as the Zachman Framework for Enterprise Architecture. However this is only done once a thorough literature review of both project and risk management as well as the limitations of the Zachman Framework have been well documented.

Once the Zachman Framework for Construction adaptation is complete, it is then applied to an inner city construction case study. The results of the case study are used to determine if throughout the project lifecycle it has been possible to analyse and implement all project and risk management requirements simultaneously with little or no correction of project constraints.

Using a developed integrated risk management tool which graphically tracks aggregate risk(s) in cost and time together with the Zachman Framework for Construction, the case study results reveal that it is possible to increase the ability to simultaneously manage risk and normal activities by concluding that the project constraints (i.e. cost) are accurately estimated and accomplished.

In conclusion the research study, discussion and recommendations are made in order to implement all cells within the Zachman Framework for Construction therefore increasing the success of any project and risk management construction field.

## OPSOMMING

Die navorsing is op die kompleksiteit van die gebiede van projekbestuur en risikobestuur gegrond. Hoe om elke gebied op sy eie toe te pas, kan problematies wees. Dit bied daaglik 'n uitdaging aan projekbestuurders wanneer dit gelyktydig geïmplementeer moet word. Hierdie probleem bestaan hoofsaaklik op die gebied van ingenieurskonstruksie.

Hierdie uitdaging waarvoor projekbestuurders te staan kom, word in die hele studie benader deur 'n sesordematriksraamwerk met 'n hoë sukseskoers om komplekse gebiede in klein fragmente te ontled en ondersoek, te gebruik. Hierdie raamwerk staan bekend as die Zachman Raamwerk vir Ondernemingsargitektuur. Dit word egter eers gebruik nadat 'n deeglike literatuuroorsig van beide projek- en risikobestuur asook die beperkings van die Zachman Raamwerk gedokumenteer is.

Nadat die Zachman Raamwerk vir Konstruksie se aanpassing afgehandel is, is dit op 'n binnestedelike konstruksiegevallestudie toegepas. Die resultate van die gevallestudie is gebruik om te bepaal of dit deur die hele projeklewensiklus moontlik was om alle projek- en risikobestuurse vereistes gelyktydig te ontled en implementeer, met min of geen regstelling van projekbeperkings nie.

Deur 'n ontwikkelde, geïntegreerde risikobestuursinstrument, wat grafies totale risiko('s) naspoor wat koste en tyd betref, saam met die Zachman Raamwerk vir Konstruksie te gebruik, toon die gevallestudie se resultate dat dit moontlik is om die vermoë te verhoog om gelyktydig risiko en normale aktiwiteite te bestuur, en word tot die gevolgtrekking gekom dat die projekbeperkings (d.i. koste) akkuraat beraam en uitgevoer is.

Ter afsluiting van die navorsingstudie en bespreking word die aanbeveling gedoen dat alle selle in die Zachman Raamwerk vir Konstruksie geïmplementeer word sodat die sukses van enige projek- en riskobestuurskonstruksiegebied verhoog word.

# CHAPTER 1 RESEARCH INTRODUCTION

## 1.1 GENERAL OVERVIEW

Project management and risk management techniques are applied in most, if not all business sectors of today. This is because these techniques, when implemented and executed well at all times determine the factors which makes a business successful. Over the years the challenge in engineering projects has been implementing these techniques as effectively as possible and in order to do so, systematic processes such as the Project Management Institute (PMI®) process have been put into place to apply project and risk management techniques step by step [10].

However the problem still remains in executing each step/phase as efficiently as possible. This is because each phase of a project and risk management tends to be complex on its own as there are different approaches within each phase. Depending on what type of engineering project is taking place, some approaches within the phase(s) are not looked at by most project managers. This leads to an unsuccessful implementation of the techniques resulting in project failure or project requirements not met.

In this research study, each phase of project management and risk management is thoroughly investigated in order to break down the complexity of their processes. This is done by applying and following a commonly used six order matrix framework that has a high success rate in analysing and dissecting complex processes into their simplest form. This framework is known as the Zachman Framework for Enterprise Architecture [16].

The research study does not only provide an effective way of implementing project and risk management in a simplest format using the framework but also discusses the usability of the framework by applying it to a real world project.

## 1.2 RESEARCH AREA

The aim of the research is to investigate the use of modern statistical and option-based risk management techniques in the project management field, specifically in engineering. This is because engineering projects such as construction projects are more likely to apply all the stages of project and risk management.

The use of a focused design schema of the Zachman Framework (commonly used in IT software project management) will be researched and documented thoroughly. Once this is done, the framework will be adapted into a project and risk management framework in order to investigate whether or not the complexity of project and risk management has been simplified.

Also of interest is the development of an integrated tool(s) that will make such a framework more amenable to normal project managers. This will be done in order to graphically represent and sum up the entire framework cells risk(s). Resulting in achieving an overall risk projection in each column and/or row for project managers to easily visualise risk in each stage of a project.

A full case study is envisaged where the process and design techniques will be applied and their use in actually managing the risks attendant with an inner city redevelopment will be discussed. This will be done to provide a clearer conclusion of the adapted Zachman Framework capabilities and limits.

### 1.3 PROJECT MANAGEMENT OVERVIEW

Ever since man has required some type of shelter or protection from the elements of the environment or improving the lifestyle around him, there has been a certain aspect of project management involved. This can be dated to the early ages of pyramids in Egypt and the Great Wall of China [5].

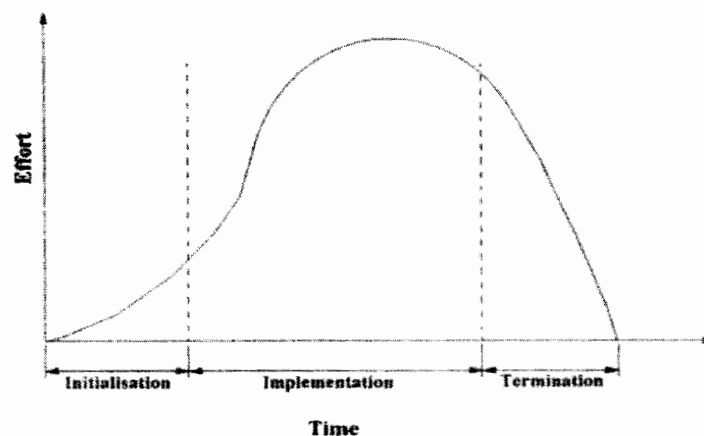
Over the years there have been many definitions of a project. This is because a project can rarely be conformed to one specification as it totally depends on the desired outcome; for example:

1. According to Lewis [1], “a project is a multitask job that has performance, time, cost, and scope requirements and that is done only one time”.
2. By the PMI® [6], “a project is a temporary endeavour undertaken to create a unique product or service within clearly specified cost, time and performance”.

What is common with both of the above definitions; which is the same with any other project definition; is performance, time and cost which are constraints of any project. Another common factor is that all projects are unique in nature. It is a once off occurrence.

Project management is a process that encompasses planning, scheduling and control of all activities so that the project objectives are reached successfully [1].

Project management can be applied in various disciplines but the same methodology is usually followed. This is commonly referred to as the project life cycle. Although there might be many stages/phases in a project's life cycle (i.e. concept, definition, goals, marketing, planning, execution, control, etc), all project life cycles tend to have three phases: project initiation, project implementation and project closure also known as project evaluation [2, 3, 4, 5, 6].



*Figure 1.1: Project life cycle [6]*

It is not uncommon to consider the planning stage as a separate phase in a project life cycle although planning of a project usually falls under the project initiation phase [1].

The project initiation phase can be fully described as that phase in a project where the problem statement, objectives, goals, scope and stakeholders are identified and defined. It is where the research (if any is required) is done, where concepts are drawn up and where a solution is selected for the project.

This is a crucial phase in any project. The entire project management team needs to be involved at this phase so as to have a common understanding of the final destination of the project. This will avoid any misunderstandings along the life cycle that might lead to the failure of the project [1].

The project planning stage; of the project initiation phase; is also where the strategy, tactics and logistics of the project are fully defined. This stage should answer the most common questions in a project- who, what, where, why, when and how [1] by using amongst others scheduling, cost and risk management techniques.

The second phase of the project, project implementation, is also known as the physical phase of the project. This is where the quality of the project is managed. Resources such as human and financial are allocated and communication is performed for the successful completion of the project [2, 3, 4, 6].

Monitoring and control are important stages in the second phase of the project as they initiate corrective action (if any required) when the project deviates from project objectives [1].

Project closure, the final phase, tends to be the least important phase in a project and yet it is the critical aspect in project management [2, 3, 4]. This phase provides the learning process in a project life cycle; therefore allowing recommendations and changes to be acknowledged and made by the project management team. This is done in order to avoid the same mistakes in a similar project and therefore improving the project management field [2, 3, 4, 6].

As long as there is a market need for infrastructure, business or technology, project management will be and has always been a preferred tool for most companies and industries. Even with that being the case and with the well defined project phases, the high percentage of project failures around the world is still evident. According to Yager [29] this is due to the following reasons:

- Not beginning project on time
- Having vague requirements for the project
- Not staying within project parameters
- Stakeholder management
- Breakdown of project communication
- Lack of strategy alignment
- Staff gap develops during project
- Ignorance of disasters
- Team skip feedback stages

All of the above are a contribution of not effectively executing and implementing project management phases but through the adapted Zachman Framework a solution to the problem(s) will be sought.

More Project definitions are listed in Appendix: A

## 1.4 RISK MANAGEMENT OVERVIEW

With every business venture, there is a certain amount of risk management involved with the intention of ensuring that all types of risks and uncertainties in the organization are well managed [5]. Before applying such management one should be familiar with the three major different areas or industries that risk management can be applied to. These include credit risk management, operation risk management and health risk management [12].

Credit risk management specifically applies to money lending businesses, health risk management applies to all health care providers and operation risk management applies to all business sectors as most business have some type of operations involved.

Therefore general risk management of a business can be defined as the process of planning, organizing, leading, and controlling the credit, health and operational activities in order to minimize the negative impact on the business's capital and earnings [13].

When comparing general risk management to project risk management, a difference is seen in the processes that each follows. While general risk management processes follow planning, organizing, leading, and controlling; project risk management processes follows assessment, responding, monitoring and controlling risks associated with project outcomes [5, 10].

Although controlling is the common factor; from the statements above it is reasonable to define project risk management in its own terms. Project risk management is “the preventative and responsive measures taken in the life cycle of a project against direct threats on the outcome objectives of the project” [5]. It also involves identifying, analysing and maximising the positive risks that will or might affect the project objectives [6].

The following figure mapped out by Smith and Merrit [10], show the steps/phases involved in the processes of project risk management.

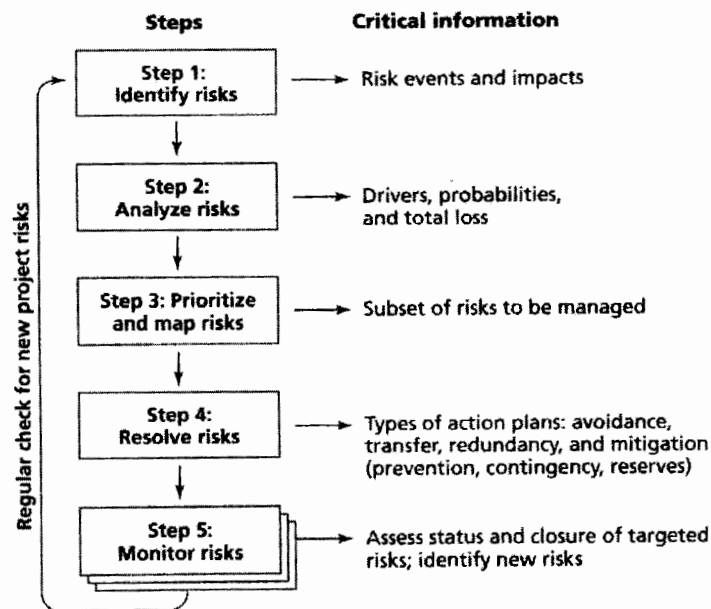


Figure 1.2: Risk management processes [10, 13]



Risk assessment consists of a couple of elements that need to take place for an accurate assessment. This includes risk identification which identifies events that may have a positive or negative impact on the project [10]. The next element is risk qualification which analyses risk according to non-numeric techniques. The last element is risk quantification which analyses risk according to their numeric probability and impact [10]. All of these elements should identify, sort, evaluate and assess the amount of severity on to the project objectives due to risk.

Risk response can be implemented using different response strategies. These include avoidance, acceptance, mitigation and transfer. The most commonly used risk response strategy is risk mitigation. Risk mitigation is to define possible measures that can be taken in order to counter threats or maximize opportunities [5].

The last process in project risk management is to monitor all assessed risk and control risk by applying mitigation if risk occurs. New risks which were not assessed in the beginning might develop during the project life cycle. That is why the last process can prove to be a crucial part in any project risk management application causing it to be linked with the first step, risk assessment as seen in figure 1.2 [10].

Project risk management is a closed loop process. Each process is linked back and forth to another causing a continuous process thus making project risk management an essential aspect in the project management field.

Although this may be the case, many project managers find it difficult to link project risk management with normal project management phases and also reassess risk using monitored data therefore resulting in ignorance toward risks that may involve the project. Through the adapted Zachman Framework, risk processes will be formulated within the framework to automatically link to project phases. The Zachman Framework will also allow the management of reassessment of risk by using data collected to be simpler resulting in the reduction of risk ignorance and an increase in project success.

## **1.5 RESEARCH HYPOTHESIS**

Project management and risk management are complex fields on their own. Together they combine to create a problematic system. This is why methods, techniques and tools are developed or improved all the time to minimise the complexity of managing such a system.

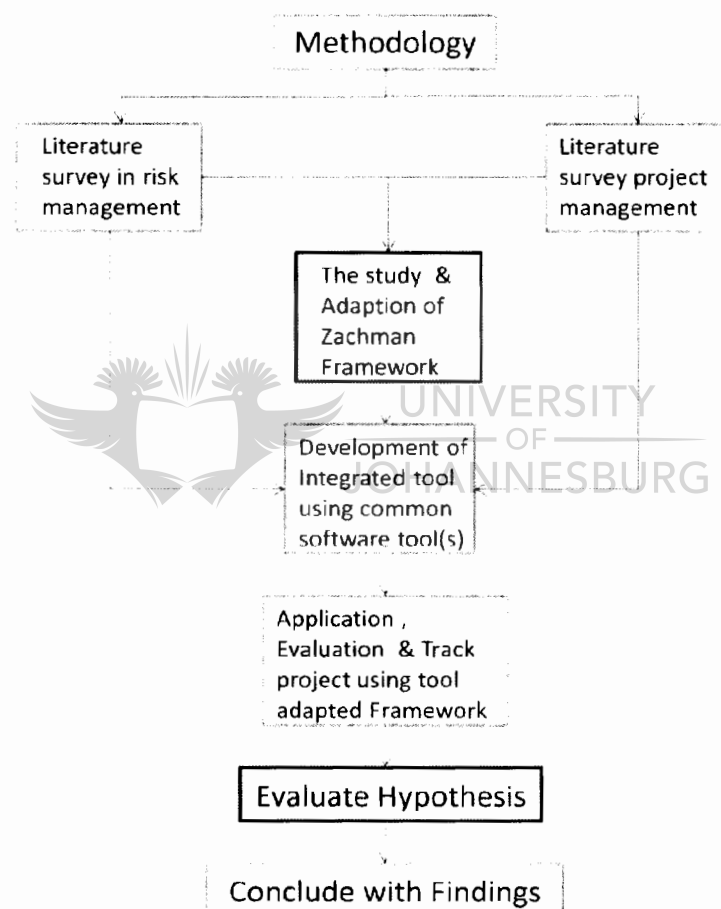
By using the Zachman Framework we can postulate that the risk management of a project can be more accurately managed. Because of each risk and project management phase of a project's complexity; it will be dissected into independent small sections or cells that integrate into a systematic graph of the project's life cycle allowing for a clearer project strategy and requirements.

We can presume that by having each small cell of the Zachman Framework its own objective, tasks and outcomes represented graphically will allow the entire project team including the stakeholder(s) to easily assess and respond sufficiently to the risk involved within a project at any given point in the project life cycle. This will also have an effect on a project to stay within its parameters and/or adapt easily to newer parameters due to risk response selected for that specific row or column of the framework.

By having these small cells of the framework we can also assume that roles and responsibilities will be easily appointed and understood by all involved within a project resulting in fewer communication errors. This will in turn remove any gap that may develop between staff during a project life cycle.

In the final stage of using the Zachman Framework we hypothesize that by adding the common independent cells in the framework through a developed integrated tool, we will have the summation of risk areas, drivers and factors in a project therefore providing a good quantification on how each cell within the framework has an effect on a project's time and budget. By doing this, we will also be able to easily manipulate the likelihood of the success of a project.

## 1.6 RESEARCH METHODOLOGY



*Figure 1.3: Research methodology process*

To achieve successful adoption of the Zachman Framework and determine whether the hypothesis is correct, the research methodology process shown in figure 1.3 above will be followed.

By thoroughly studying, analysing and compiling a literature survey of project management and risk management fields separately, it will simplify the complexity of each process being adapted according to the Zachman Framework to be more manageable. Through this approach we will be able to see how project management fits into Zachman Framework on its own and how risk management does the same without compromising the rules of the framework.

However the error that might occur by following this approach is that two different Zachman Frameworks may develop, one for project management and one for risk management; and thus making the implementation phase of research complex to execute.

A clear view on how project and risk management interlink with one another must be kept in mind at all times when adapting the Zachman Framework to avoid such an error.

When developing the integrated tool using simple common software(s), research from the project and risk management literature survey will be used as well as the framework format. This will make certain that the tool developed properly reflects both project and risk management outputs while staying within framework boundaries.

Although the advantage of using simple common software may be easier for the user to understand and use, a limit by the simplicity of the software(s) may result in the interface of all three inputs (project, risk and Zachman Framework) to not be possible.

To eliminate this disadvantage, software(s) which can capture and manage data of all three inputs as one spreadsheet format should be selected in order to allow the user to integrate each input model by model resulting in a complete functioning tool.

To evaluate the statements given in the hypothesis of section 1.5 of the study, the developed integrated tool together with the adapted Zachman Framework will be implemented in tracking an inner city development project. In this stage of the methodology, the framework allows data to be managed by documented feedback report(s) of time, cost and performance variables throughout the project life cycle.

However the challenge in collecting accurate data under a non-experimentally setup is that when collecting reported information one cannot control and manipulate the surroundings to suite experimental design(s).

Therefore to have accurate data collected is to formulate a feedback system report(s) through the framework that allows all project leaders to report strictly on the same fixed variables of the project and at the same time. This will determine the conclusion and the success of the research study in the final stage of the research methodology.

## **1.7 OVERVIEW OF DISSERTATION**

The research introduction provides a general overview of the expected work to be completed and the results including the data that is to be collected and analysed. By providing an introduction to both project management and risk management in Chapter 1 merely gives a small insight of the large amount of detailed research required for a successful research study.

Chapter 2 will discuss in much more detail the phases in project management. The chapter will look at the pivotal role that a project manager plays in a project, the selection process and how to structure an organisation according to the uniqueness of a project. To conclude the chapter, scheduling techniques are introduced in the chapter, as well as cost and resource techniques that can be implemented depending on project objectives are introduced.

Chapter 3 will discuss in much more detail the phases in risk management. This chapter shall research how to estimate probability of risk in a project will be documented as well as risk assessment techniques such as threshold mapping and risk matrix. The chapter will look at the importance of responding to risk by drafting a contingency plan and how it may reduce risk in a project. To conclude the chapter, simulation techniques such as Monte Carlo simulation are introduced to calculate risk quantification.

Chapter 4 introduces the philosophy of the Zachman Framework in detail. This will be done by thoroughly documenting the background and rules on developing the framework together with how its matrix format has been successful in the industry it has been formulated for. Examples on other industries that the Zachman Framework has been adapted too will be discussed briefly, their advantages and disadvantages, in order to find a correlation in adapting Zachman Framework for construction. To conclude the chapter, the adapted Zachman Framework for Construction mapping is discussed in detail row by row and column by column in project management and risk management.

Chapter 5 of the research study is the implementation of the adapted Zachman Framework for Construction. It will discuss the case study of a current inner development project by applying the Framework. The chapter will show how the complexity of project and risk management of the applied case study is simplified by thoroughly and graphically going through each cell of the Framework.

Chapter 6 will be where an integrated risk management tool to be used to quantify risk within the framework for the case study will be developed. Tabulation of the data tracked by the tool is collected through the implementation of the adapted Zachman Framework used in Chapter 5. The results will be graphically represented for an easy analysis of risk(s) in cost and time thus reducing uncertainty.

Chapter 7 will be the conclusion of the research study. In this chapter, all findings will be discussed in detail and compared to the research hypothesis in order to determine the success of the study. To conclude the chapter and the research study recommendation will be documented.

## CHAPTER 2 PROJECT MANAGEMENT

### 2.1 THE IMPORTANCE OF PROJECT MANAGEMENT

Project management is a profession that has grown drastically throughout the years. It should not be confused with general management as project management is more schedule-bound than general management [1]. More emphasis has been put into project management than in any other field by many companies. This is because well structured project management delivers an end product/service within budget while being on schedule. That is always a positive output for any stakeholder as there is a better customer relation and high returns on their investment.

The Project Management Institute (PMI<sup>®</sup>) defines project management as “the application of knowledge, skills, tools and techniques to project activities to meet project requirements” [1]. To single out a few of the nine knowledge points identified by the PMI<sup>®</sup>: cost management, quality management and time management. This is the typical knowledge required by any project manager to achieve a successful project that satisfies all requirements stipulated for the project.

### 2.2 THE PROJECT MANAGER

As mentioned in the previous chapter, project management is a process that facilitates planning, scheduling and control of activities throughout the project life cycle and this is normally done by a project manager. Project managers can be considered to be the mind, heart and soul of a project as their existence is required for all elements of the body, project life cycle, to function smoothly.

Most of the time, stakeholders choose a project manager based on their previous work achievements. But that is not the only point that distinguishes a quality project manager; it is the skills, tools and techniques that they possess that makes them rise above the rest.

A project manager should have the following qualities [1, 2, 5, 6]:

- Facilitator
- Generalist
- Organiser
- Negotiator
- Motivator
- Risk analyser
- Resource manager

With these skills in hand, a project manager should be able to see a project from its initial phase straight through the implementation phase until the closure phase with a minimum of errors, conflicts and problems.

## 2.3 PROJECT INITIATION

Project initiation is the beginning phase of any project that normally consists of two stages- the initiation process stage and the planning process stage. The initiation process deals with identifying and defining the constraints of the project and the organisation structure to be implemented in the project. It also provides a decision model for project selection purposes [2, 3, 4, 5].

The planning process is where the scheduling time and cost management of project are developed. It is the stage where the project management team is assembled to provide a general overview of the entire project [1].

### 2.3.1 Initiation Process

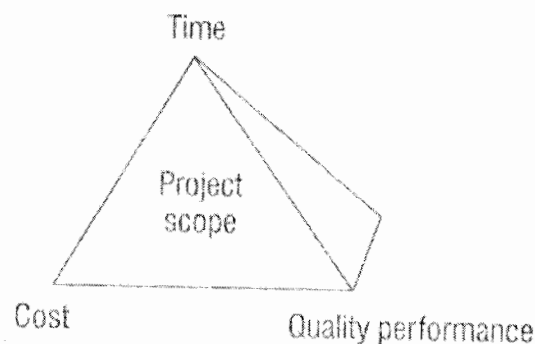
#### a) The Stakeholder

Stakeholders of a project can be directly or indirectly involved in the decisions of the project depending on the organisation structure implemented. This can have a positive or a negative impact on the project [5].

The following are examples of stakeholders that can be involved in a project:

- Client
- Project Sponsor
- Government
- Private Company

With every project, the stakeholder defines one of the three project constraints. In most cases, if not all, cost is the chosen one. From this, it can be determined how much time and performance is required to complete the project with the given scope as cost is a function of these constraints [1]. This can be clearly seen with equation 1.1 and figure 2.1 below.



$$\text{Cost} = f(\text{Performance}, \text{Time}, \text{Scope}) \quad (1.1)$$

**Figure 2.1:** Triangle of constraints [1, 5]

## *b) Project Selection*

Project selection is a process that determines whether the stakeholder wants to undertake and invest in the project. It provides a project proposal that documents the estimated outcomes of the project, with its benefits and the risks involved by using decision models and selection techniques [2, 3, 4, 6].

All the project selection models and techniques can be divided into two categories- nonnumeric methods and numeric methods [2, 3, 4, 5].

Nonnumeric methods (also known as benefit measurable methods) consist of the following models and techniques:

- Comparative approach
- Scoring models
- Benefit contribution
- Product line extension
- Economic models
- Operating necessity
- Competitive necessity

Numeric methods (also known as constrained optimisation methods) consist of the following models and techniques:

- Benefit cost ratio/Profitability index
- Payback period
- Present value/Discounted cash flow
- Average rate of return
- Internal rate return
- Sensitivity analysis

The most important factors considered for any project selection model(s) is that the model must adhere to all project constraints and requirements while being flexible, capable and realistic to the project investigated [6].

## *c) Problem Statement*

A project problem statement is clearly defined by both the stakeholder and the project team. The project problem statement is the specification rather than the goal of the project. [1, 5]. When defining the project specification, there are five frequently occurring errors which are often over-looked and need to be noted [7]:

1. The holistic perspective
2. The interfaces
3. Time scale
4. External dependencies
5. Resources

When these specification errors are not looked at; the problem statement tends to sound unclear, un-concise and ambiguous [7]. Therefore it is imperative that these errors are considered when defining the project problem statement.

d) Objectives

Objectives are the ideal required results of a project. They are time bound as they state measurable check points that need to be accomplished along the project life cycle.

A simple way to develop project objectives is to do it “SMART” [1].

- S- Specific
- M- Measurable
- A- Attainable
- R- Realistic
- T- Time-limited.

e) Organisation

An organisation is a communication structure that needs to exist in order for the project team, stakeholders and other members who are directly or indirectly involved in the project to share information and report about and during the project life cycle [2, 3, 4 6]. As mentioned under the stakeholder section a), organisation structure can allow the stakeholders to have some impact on the project.

There are different types of organisational structures that can be chosen for a project [2, 6, 7]:

- Line Structure
  - It is commonly preferred in civil engineering projects where the operational staff is limited and the work is routine.
  - Throughout the organisation there is a clear line of responsibility and authority.
  - Communication is poor especially at the lower level due to lack/no feedback systems put in place.

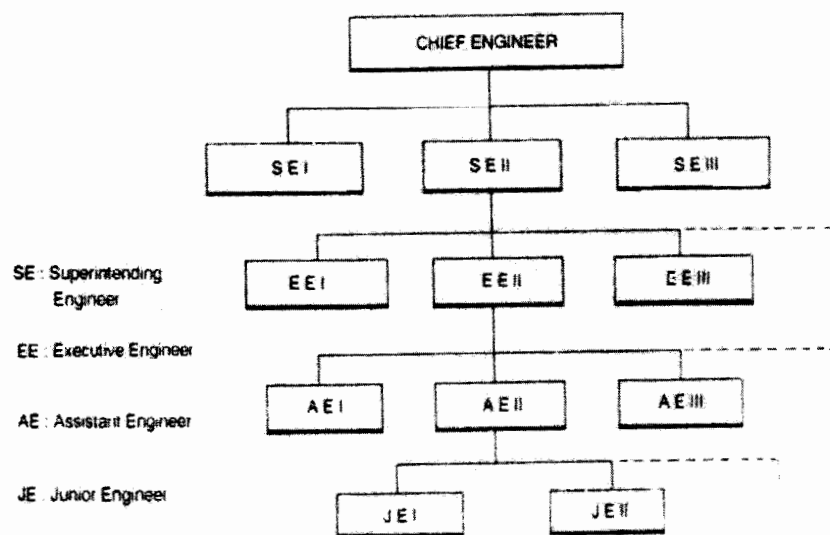


Figure 2.2: Line Structure diagram [5]



- **Line & Staff Structure**
  - This organisation structure comprise of staff being the experts and line being advisory.
  - It is mostly considered for medium to large companies depending on their business area because of specialisation by staff, human and physical resource are more effective.
  - However it is not suitable for complex projects due to that authority, duties and responsibility are not well defined in structure resulting in ineffective staff and breakdown of communication between line and staff.
  
- **Functional Structure**
  - This organisation is suitable for large manufacturing and research companies, as the work are not of routine nature it requires technical experts/specialists relevant to the project and it is also limited to specific tasks.
  - Due to limited tasks, quality and efficiency are improved.
  - Its main disadvantage is that there is no clear line of authority as each expert has to report to a number of superiors resulting in confusion, lack of discipline and authority.
  
- **Pure Project Structure**
  - This organisational structure exists when a parent organisation allows the project full freedom by separating it from its system.
  - It is a simple, flexible, easy to understand and implement structure.
  
- **Matrix Structure**
  - This structure is a combination of the functional and pure project organisation structures.

Each organisational structure has its own advantages and disadvantages. It is recommended for a company to construct its own organisational structure with every new project using the basics of the existing structures (i.e. Line structure). The newly developed structure should consider the nature of activities, scope and area(s) of operation as each project is unique in nature.

Although there might not be a set of rules or consistence, the developed organisational structure generally has the following team structure [2, 3, 4, 7]:

- Project Manager
- Field Manager(s)
- Supervisor(s)/Project Administrator(s)
- Project Controller(s)
- Junior Engineer(s)
- Forman(s)/Quality Controller(s)
- Labourers

Other organisation structure diagrams can be found in Appendix B

## 2.3.2 Planning Process

### a) Scheduling

Scheduling is the process of converting the project plan into a timetable scale that shows sequential activities to be completed. Each activity is given a start and completion time; with slack time if required. Therefore scheduling becomes the main tool that a project manager uses to monitor and control the project [5, 6, 7].

The basics of scheduling were introduced in 1917 by Henry Gantt who developed a technique known as the Gantt Bar Chart. The chart is made of two axis, time axis and activity axis [2, 7]. It is simple to construct as the bar's length indicates the duration of the activity. Like any technique, it has its advantages and disadvantages.

Advantages:

- Easy to maintain and understand
- Helps with expediting
- Tracking activities

Disadvantages:

- Does not show interdependencies clearly amongst activities
- Does not indicate the quantity of work
- Does not indicate critical activities

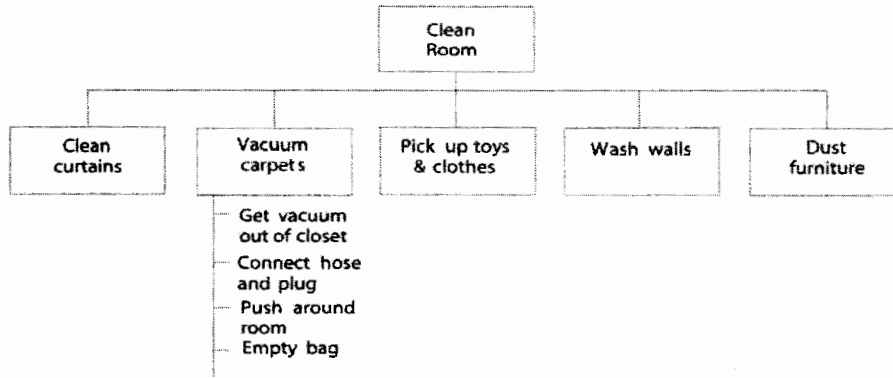
From the bar chart came improved scheduling tools, such as the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM). Together; these are known as the Network Techniques.

PERT was developed in 1957-58 by the United State Navy. It is event-time orientated and is used mostly for first time non-repetitive projects with high degree of uncertainty [2, 5, 7].

CPM was developed in 1958-60 by engineers working for Dupont Corporation in the United State of America. It is activity-time orientated, identifies critical activities and is used mostly for repetitive similar projects [2, 5, 7].

The major difference between the two network techniques is that the PERT places emphasis on reduced project completion time without cost constraints; while CPM places emphasis on minimising the entire project costs by optimisation of resources allocation [5, 6, 7].

Another scheduling technique is the Work Breakdown Structure (WBS). WBS can be used for any project planning process, as shown in figure 2.3 on page 25. It is essentially considered before applying the network techniques as it has no sequences. It is a level format and breaks down the complexity of project's activities into small, simple and manageable task(s) that its time and cost can be defined to the desired accuracy [1, 7].



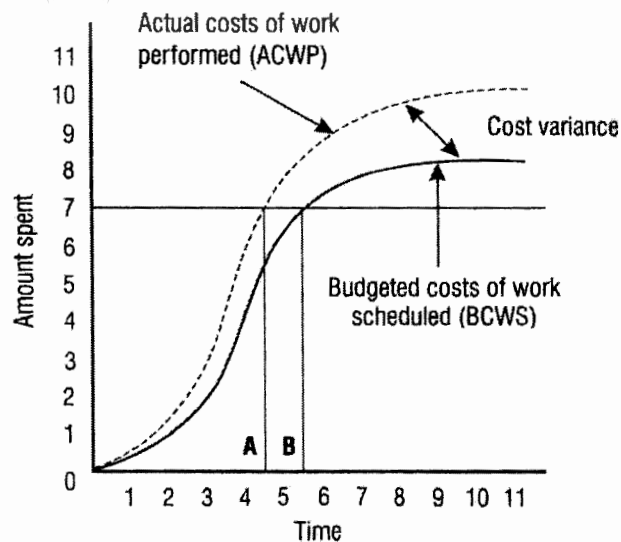
**Figure 2.3: WBS of Cleaning a Room [1]**

Scheduling is probably the most important tool in project management. Without a well planned documented schedule, it becomes impossible to accomplish project objectives on time and therefore exceeding the budget limit.

**b) Cost Management**

Every activity or event in a project links back to cost. That is why it is significant to realise that “time is money”. Cost management is a process where cost of a project is estimated as accurately as possible by using historical information, project activities, resources rates and the WBS [5]. It is also used to identify both direct and indirect costs while monitoring the cash flow and budget of a project [7].

The figure below shows an example of how cost varies over a given period of time.



**Figure 2.4: The cost s-curve graph [5]**

The following are methods/techniques that can be used in cost estimation of a project [2, 3, 4, 5]:

- Top-down estimating
    - Cost estimations are done via collection of information from top and middle managers, and from available past data. These are handed to lower managers to continue to break down costs according to scheduled tasks.
  - Activity based costing
    - This is when cost estimation is documented as activity orientated. This is done by budgeting for each department and division in an organisation in order to classify and assign individual cost lines (i.e. phone, utilities).
- Table 1 below shows an example of activity based cost estimating

*Table 1: Parametric model for Activity based costing [5]*

Activity	Time	Unit labour rate	Cost
Manufacture garments	12 hrs	R100.00 per hour	R1 200.00
Pack garments	3 hrs	R50.00 per hour	R150.00
Ship garments	24 hrs	R150.00 per hour	R3 600.00

- Bottom-up estimating
  - Cost estimation is done by consulting the actual workers on the time and budget required for each task assigned to them. It is then handed to top and middle management to rectify and improve the accuracy in the estimations. Table 2 below shows an example of bottom up estimating

*Table 2: Bottom up estimating [5]*

Activity/items	Task/sub-activities	Time	Item costs	Total
Manufacture 1 000 garments	Compile samples	4 hrs	R150.00	R600.00
	Appoint factory	2 hrs	R200.00	R400.00
	Buy material	12 hrs	R1 000.00	R12 000.00
	Cut material	20 hrs	R75.00	R1 500.00
	Sew garments	20 hrs	R100.00	R2 000.00
	Trim garments	7 hrs	R100.00	R700.00
	Wash garments	5 hrs	R55.00	R275.00

- Work Element costing
  - The cost of each resource is estimated by analysing the elements in the WBS as work per hour. It is important to add allowance for personal time (i.e. smoke break) in the calculations as no one can work for eight hours straight. Table 3 below shows an example of work element cost estimating.

**Table 3: WBS Element Costing [5]**

Activity/Task (WBS)	Duration	Resource	Cost per unit/resource	Total costs
Compile business plan	10 days	Tsepho	R100.00 per day	R1 000.00
Do risk analysis	15 days	Thabo/John	R100.00 per day per resource	R3 000.00
Buy 2 000 bricks	2 weeks	Suzi (temp)	R1.00 per brick	R2 000.00
Pay weekly wages for temps	1 day	Wages	R300.00 per week (one temp – Mpumi)	R300.00

- Computerised tools
  - Tools such as excel (i.e. mean absolute deviation) can be used to estimate cost accurately. This is because the cycle can be repeated as often possible, therefore decreasing the margin of error.

Excluding the direct and indirect costs, there are other project costs that project managers tend to overlook, such as overhead charges, and General and administrative (G&A) charges. Overhead charges are used for general office equipment (i.e. copy machines) and G&A charges are various staff functions including costs that are excluded in the overhead charges. It is recommended that project manager prepare two budgets, one without the G&A and overhead charges and one with [2, 3, 4].

It is essential that cost management is done properly, accurately and honestly. This can be the deciding factor for a stakeholder about whether or not to undertake the project and can measure the success of the project manager.

## 2.4 PROJECT IMPLEMENTATION

Project implementation can arguably be the most important phase in a project life cycle. In this phase; quality, resources and control management of the project are implemented in order ensure the success of the project. Monitoring management is also part of this phase as it advises the project management team on problem areas which may arise or be encountered during the project life cycle. [2, 5, 6, 7]. Therefore it is vital at this point that the project manager is hands on and present as frequently as possible at the project site.

### 2.4.1 Quality Management

Most projects fail or are terminated due to lack of quality management. This can translate into thousands, if not millions of rands loss to an investor/stakeholder [1]. Quality involves

the accuracy of work results and it usually suffers by being compromised due to cost and time [5].

In order to have a sufficient quality management process in a project without negatively affecting the project constraints, there are four stages that need to be developed [5, 7]:

1. Inspection
2. Control
3. Assurance
4. Management

Each of these stages has five quality related concepts that must be implemented by a project manager:

1. Performance
2. Economy
3. Efficiency
4. Benchmarking
5. Assessment

To ensure that there are no defects at the end of a project life cycle; customer quality, professional quality and process quality must be met by the project otherwise quality management may be compromised during the four stages mentioned above [5].

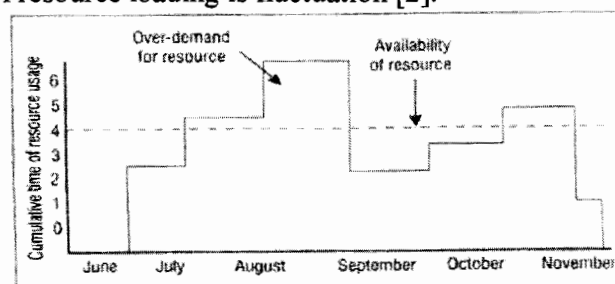
## 2.4.2 Resource Management

Resource management is a process of allocating resources to the project as efficiently as possible. There are four types of resources that are present in a project- human, financial, technological and information resources [7, 12].

Human resources is the man power required to do the physical work of the project, financial resources is the money required to fund the entire project, technological resources is the machinery/equipment required for the project and information resources is the administration structure/space required for the project [7, 12].

Managing these four types of resources in a project; resource allocation needs to be applied. According to J. Meredith, resource allocation deals with “determining the best trade-offs between available resources, throughout the duration of a project” [6]. There are two stages that need to take place in order for resource allocation to be achieved, namely resource loading and resource levelling.

Resource loading is depicted as a function of time. It is a process of determining the load from each project activity for each resource as required per time period [2, 3, 4, 6]. The most undesired outcome of resource loading is fluctuation [2].

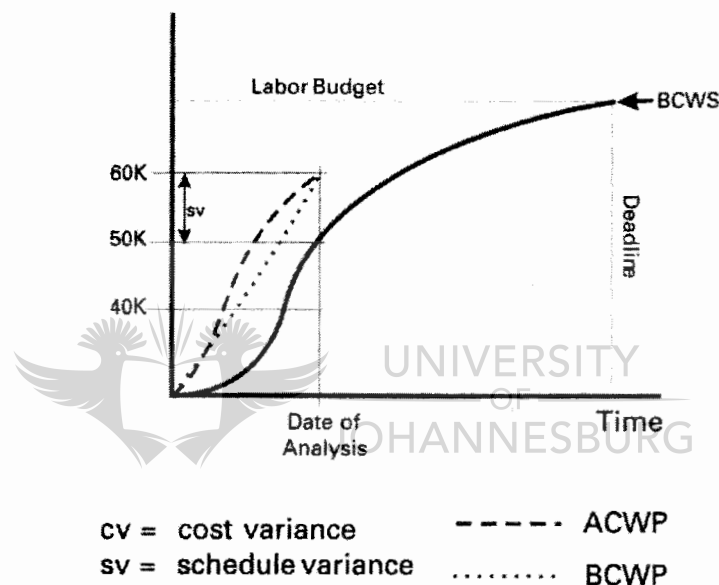


**Figure 2.5: Resource loading graph [5]**

The main purpose of monitoring is to document reports. Project reports are generally of three types which are normally dated near the end of project objectives [2, 3, 4, 6]:

1. Routine report
  - Issued on a regular basis.
2. Exception report
  - Special information requirements, especially for decision makers.
3. Special analysis report
  - Research and results of special studies concerning the project.

With each report, it is simpler to provide an earned value charts/graphs that shows actual cost and progress therefore making it simpler to identify whether or not control is required.



**Figure 2.7:** Project ahead schedule & overspent [1]

*b) Control*

Control is the process of using the data collected during monitoring to initiate corrective action. This is done by altering and regulating the human and financial resources of the project [1, 2, 3, 4].

There are three types of control systems that can be applied during the project life cycle- cybernetic control, go/no-go control and post-control [2, 3, 4, 6].

Cybernetic control can be placed as high as a third order system which has a negative feedback loop. It requires information such as standards, measurements and comparison of data to be controlled. This is why it is the most common used control system [2, 3, 4].

Go/no-go control system provides early deviation warnings from the project. This is achieved by testing if precondition standards such as performance were met [2, 3, 4].

Please see Appendix: C for more earned value charts/graphs

Post-control system is mostly directed towards a future project meeting its goals. It is applied through formal documentation and should consist of comparing actual versus ideal project objectives and highlight project deviations [2, 3, 4].

A good project control system is essential as it focuses on project objectives. It is also cost effective, flexible and fully documented. But it must be noted that control must be exerted only to the degree required as high control can dampen creativity and increase costs [1].

Monitoring and controlling management should be directed at correcting the project by improving performance and maintaining the project on track. It should not be used to shift blame or punishment [1, 2, 3, 4].

## **2.5 PROJECT CLOSURE**

Project closure, also known as project evaluation is the process of determining the overall final value of project output versus project planned. This is the learning phase of the project life cycle as feedback to the system such as cost, time, resources, risk and communication is applied to build team skills and morality for a competitive advantage [1].

There are two stages involved in this phase, which are project audit and project termination.

### **2.5.1 Project Audit**

Project auditing is done in a project to seek clarification in current/future status of the project, risk assessment, status of crucial tasks and limitation on accuracy of audit. There are two types of project auditing that can be performed- internal audit and external audit [2, 3, 4, 6].

An internal audit will be done by the project team to certify that proper initiatives have been taken to safeguard the project resources.

An external audit will be performed by the parent organisation as an independent evaluation of the project.

With both types of project auditing that can be performed, there are three stages that will take place [2, 3, 4]:

1. General audit- constrained by time and money
2. Detailed audit- follows up to general audit
3. Technical audit- specific technical problem

All above stages are kept as simple as possible while consisting of a report that includes the elements that seek to be clarified (i.e. current/future status of the project).

During project auditing, the project can or might be altered by the results from the reports. This is the reason why timing, depth and members contribution to project audit is critical. These results also determine the process of project termination.



## 2.5.2 Project Termination

Project termination is inevitable with all projects and it can be a long and difficult procedure as it has a high impact on the people directly involved in the project [2, 6].

There are various project termination procedures that can take place [2, 3, 4, 6]:

1. Termination by extinction
  - This is when the project objectives are all successfully achieved resulting in project ending without any extensions.
2. Termination by addition
  - This is when the project is incorporated into the parent organisation as a progressing division.
3. Termination by integration
  - This is when the project is broken down into components such as personnel, property, and functions and distributed through existing divisions in the parent organisation.
4. Termination by starvation
  - This is when the budget is decremented without crippling the project, usually caused by political solutions.

Project termination results in the final report being documented, also known as the project history report. Its main purpose is to improve the project management field by addressing factors such as project/administrative performance, organisation structure, project team and techniques used of the previous projects for future projects.

## 2.6 CONSTRUCTION MANAGEMENT

Construction management is the application of project management in the construction industry as it encompasses all project activities such as planning, implementation closure. Its main objective is to complete the project within estimated budget and time, motivate and provide a safe satisfactory environment and to ensure quality assurance.

To achieve these objectives; functions such as planning, scheduling, organising, staffing, directing, controlling and co-ordinating need to be applied [7].

There are three categories in construction which can occur [7, 8, 9]:

1. Light Construction
  - This includes both residential and building projects. Construction such as offices, shopping malls, individual homes and apartment buildings.
  - In this category, no use of heavy plant equipment is required.
2. Infrastructure and Heavy Construction
  - Examples of projects that fall under this category are roadways, bridges, dams and tunnels.
  - These are all projects that require use of heavy plant equipment and the scope of the work is very large.

### 3. Industrial Construction

- Projects that are included in this category require special technology, plant and equipment.
- These are chemical plants, steel plants, and petroleum plants including the automobile and the aircraft industries.

With every construction there has to be an existence of a contract. A contract is a signed formal agreement between two or more individuals during an exchange. This exchange can consist of providing goods/service or to perform a specific task [7, 8, 9].

There are five types of contracts considered in the construction industry [7, 8, 9]:

#### 1. Lump Sum contract also known as the Single Fixed Price contract

- This contract offers to do the specified work for the total specified sum of money.
- Advantage with this type of contract is that the owner (stakeholder) knows the final cost of project before work commences.
- The disadvantage is that if the scope of the contract changes, the owner is at high risk in increasing financials.

#### 2. Item Rate contract also known as the Unit Price contract

- The contract stipulates that the work by the contractor will be charged on the bases of execution of work per unit on major elements on the project.
- Advantage of such a contract is that it is simple to make changes to drawings and quantities.
- Disadvantage is that the total cost of the project is not known, therefore making it difficult for the owner to budget.

#### 3. Lump Sum and Schedule contract

- This contract is the combination of both the lump sum and item rate contracts.
- Advantage of this contract is that the total cost of project is known and the contract is build per scheduled unit.
- Disadvantage is that the contractor turns to press for higher rates than the market rates thus causing disputes with the owner.

#### 4. Cost Plus Fixed Fee contract

- This contract is considered and suitable when the scope of the work is defined largely.
- Advantage of this contract is that the work can be executed speedily and the contractor works in the best interest of the owner.
- Disadvantage is similar to item rate contract.

#### 5. Cost Plus Percentage contract

- The contract awards the work on certain percentage over the actual cost of construction.
- Advantages and disadvantages are similar to the cost plus fixed fee contract.

The construction industry is a major economic contributor in any country as it plays an important role in the development of a nation's economy. It is for this reason that professionalism in construction management is required to make sure that the invested resources in the construction industry are distributed equally and efficiently through project management [7].

## 2.8 CONCLUSION

Project management is a very broad field that can be applied to many if not all industries. It is a process that consists of all phases and stages to complete a project successfully, which makes it popular when it comes to a company or market's needs.

But it should be considered that with every phase and stage of a project, there is some sought of risk involved as people make decisions implicitly or explicitly. This is due to that the project constraints and elements are estimated most of the time and this introduces a level of uncertainty.

Therefore it is imperative that the next chapter discusses sound risk management principles and applications in detail to provide an understanding and ways in decreasing risks involved in project management.



## CHAPTER 3 RISK MANAGEMENT

### 3.1 FUNDAMENTALS OF RISK

With every project there is a certain amount of risk and uncertainty involved. Therefore the reason risk management is introduced, is to ensure that the project is completed successfully by managing the levels of risk and uncertainty correctly throughout the project life cycle [5].

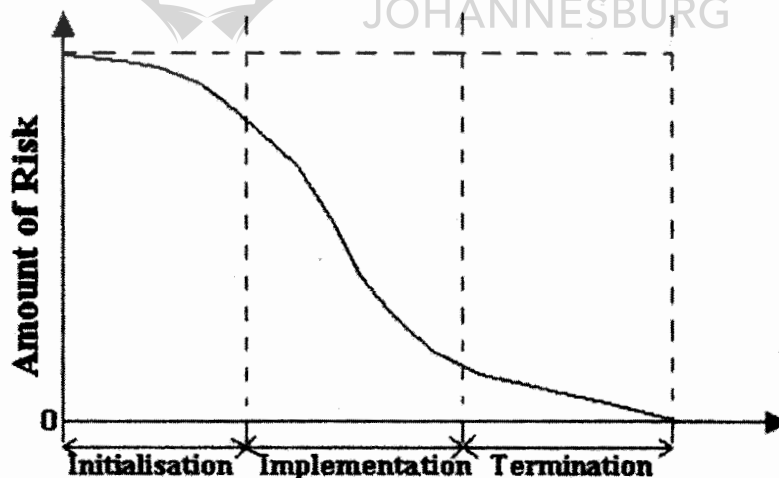
It is important to note that risk and uncertainty do not have the same definition. Risk is defined as the probability and impact of uncertain events that may positively or negatively influence the project objectives. Uncertainty only takes the event into consideration and probability is unknown [10].

The following equation is the basic formula for calculating risk [5, 13]:

$$\text{Risk} = \text{Impact} \times \text{Probability} \times \text{Frequency} \quad (3.1)$$

- Probability- Likelihood that the risk event will occur
- Impact- The severity or consequences that could result if risk occurs
- Frequency- How often does the risk occur

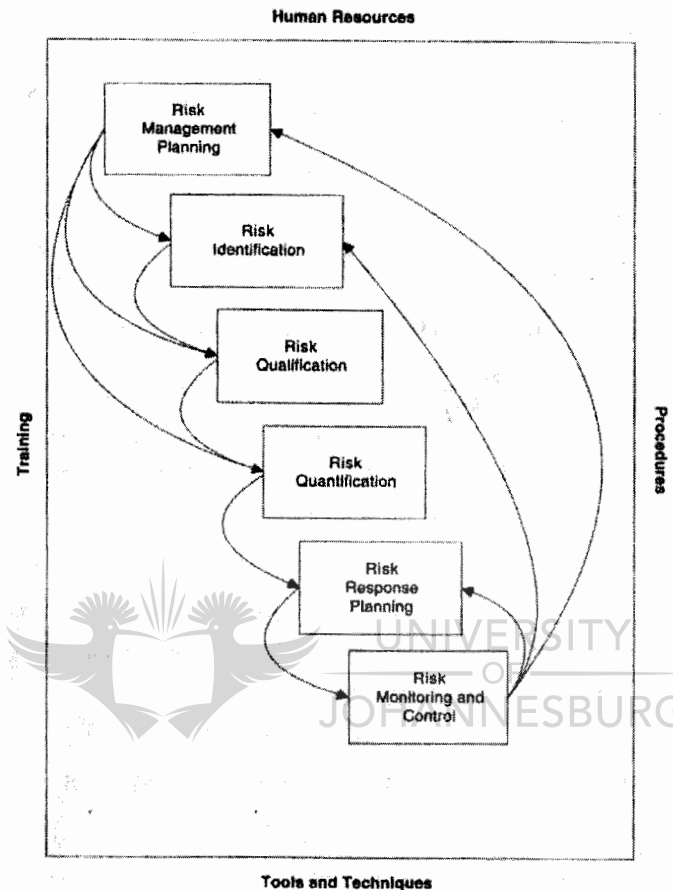
As shown in figure 3.1, the amount calculated in the initial phase of the project using the above equation is higher than in the termination phase of the project. This is due to that the probability of risk occurring in the final stage is lower than in the initial phase. Therefore it can be argued that risk is also a function of time [5].



#### Phases in the Project Life-Cycle

Figure 3.1: Risk amount in project life cycle [6]

Risk management should be approached in different ways for every different project as each project is unique in nature. Risk models such as the standard risk model, the Cascade risk model and the Ishikawa risk model may characterise the risk management process but the same methodology is usually followed throughout every project which is shown in figure 3.2 below [13]. This is the system process approach to risk management suggested by the Project Management Institute 2000 (PMI®).



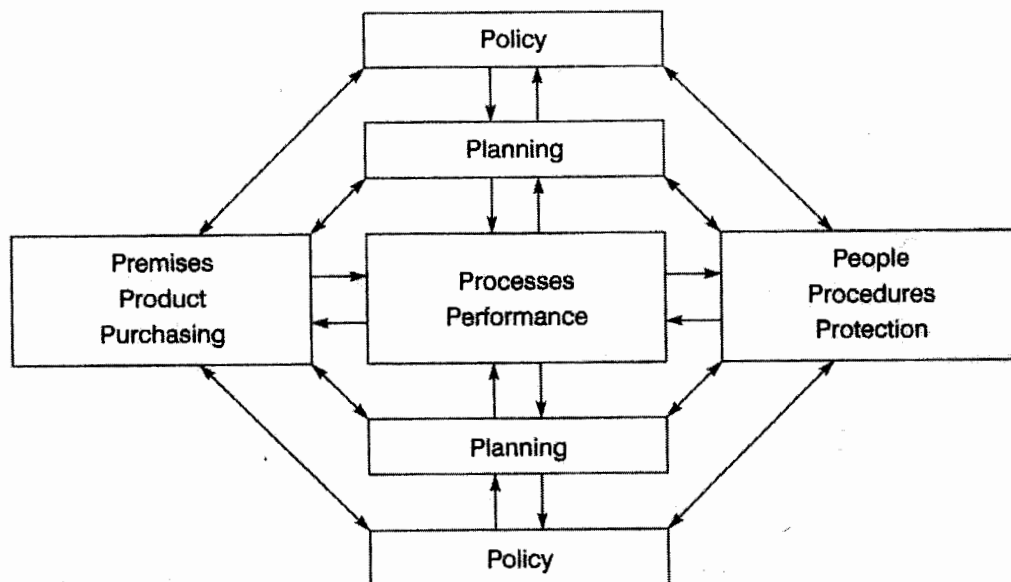
**Figure 3.2: Risk Management process [10]**

### 3.2 RISK MANAGEMENT PLANNING

Risk management planning involves developing an organisation and project-specific infrastructure for effective and efficient risk management to be applied. This infrastructure consists of the entire risk management process and the effect it has on the scope of the project.

Proper risk planning begins by analysing the actual plan (schedule or work breakdown structure) of the project. This will provide information on potential parameters of project risks involved and define how much risk management will be adequate [10].

By targeting the ten (10) risk areas shown in figure 3.3 on page 38 that affect an organisation risk management planning can provide the risk policies, practices and procedures to be followed by the affected organisation [6, 9, 10, 11, 13].



**Figure 3.3: 10 Risk Areas [6]**

Therefore in order to achieve an effective infrastructure, sufficient leadership skills by project managers must be displayed and commitment from stakeholder(s) must exist [6, 10].

Risk management planning puts risk into perspective either on a short/partial basis and/or long/overall basis depending on the project scope; therefore risk assessment has to be applied continuously in the project and the parent organisation [10, 12].

### 3.3 RISK ASSESSMENTS

Risk assessment is defined as “identifying, sorting and evaluating risks and risk interactions to assess the range of possible project outcomes” [5]. As mentioned in chapter 1, there are three main sections that risk assessment is divided into-risk identification, risk qualification and risk quantification. These sections need to be completed as accurately as possible for a full and successful assessment of risk involved in a project [5, 6, 10].

#### 3.3.1 Risk Identification

Risk identification involves a thorough approach and documentation in determining which risk events are associated with the project. The approach is based on identifying risk events which may negatively or positively affect the project objectives. By clearly and intensely documenting the facts leading to the potential occurrence and justifying how it may impact on the project, risk event can be determined whether to be internal or external [5, 10, 13].

Internal risks are risk events that can be controlled such as cost estimates and external risk are risk events that are beyond project control or influence such as political risk [5],

Sum of the techniques used to identify risk are the following [10, 12]:

- Assumption analysis
- Expert interview
- Delphi technique
- Documentation reviews
- Fault tree analysis
- Brainstorm
- Plan evaluation
- Crawford Slip Method

The results of risk identification enable one to classify under which category the risk falls into. Risk can be classified under the following categories [6, 12]:

- Financial or Non-financial
- Static or Dynamic
- Pure or Speculative
- Fundamental or Particular
- Market and Economy
- Natural
- Political
- Technological
- Behavioural

By allowing risk to be classified, the next process of sorting and evaluating the probability of occurrence and impact of the risk to the project can be achieved by applying risk qualification and risk quantification.

### 3.3.2 Risk qualification

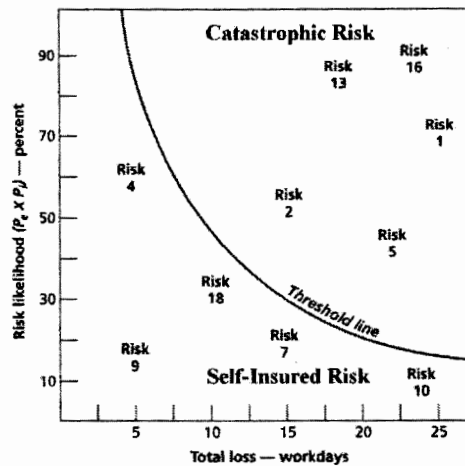
Risk qualification is process of sorting and rating risk into its probability and impact. Most project managers use the risk rating matrix (figure 3.3) and/or the baseline threshold method (figure 3.4) for risk qualification [5, 8, 9, 10].

Probability \ Impact	Low probability (1)	Moderate probability (2)	High probability (3)
Low impact (1)	Low probability, low impact (1x1=1)	Moderate probability, low impact (2x1=2)	High probability, low impact (3x1=3)
Moderate impact (3)	Low probability, moderate impact (1x3=3)	Moderate probability, moderate impact (2x3=6)	High probability, moderate impact (3x3=9)
High impact (6)	Low probability, high impact (1x6=6)	Moderate probability, high impact (2x6=12)	High probability, high impact (3x6=18)

**Figure 3.4: Risk rating matrix [10]**

Appendix D: Risk methodology, layouts and pros/cons risk model

Appendix E: The risk techniques used in risk models



**Figure 3.5: Threshold map [13]**

Both techniques should yield the same results; the major difference and advantage between the two techniques is that the baseline threshold method is more graphical which allows risk to be mapped against expected loss such as time, cost, schedule and performance making it easier to sort risk [5, 6, 10].

Expected losses can be calculated by using the formula below [10, 13]:

$$\text{Expected loss} = \text{Impact} \times \text{Probability} \times \text{Total loss} \quad (3.2)$$

- Total loss- Time, Cost, Schedule, Resources or Performance

Risk qualification is considered to be a non-numeric way of estimating risk. In order to have a more accurate numeric estimation, risk quantification is applied.

### 3.3.3 Risk quantification

Risk quantification is the process of examining risk by assigning hard numeric metric values to increase confidence levels in probability and impact measured [10].

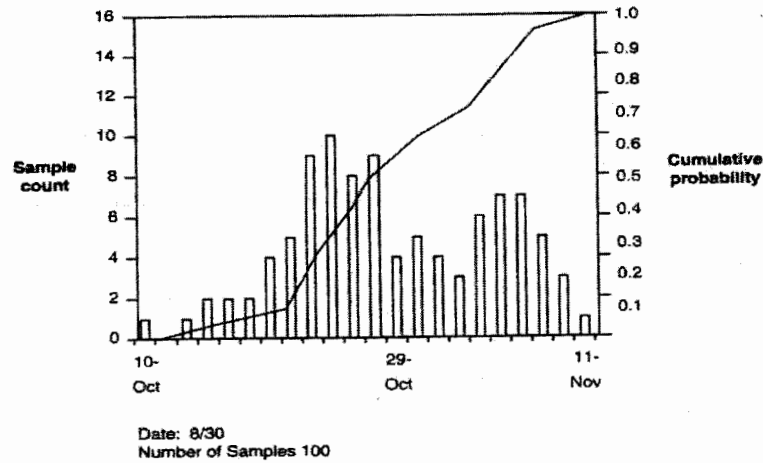
This process enables project managers to visualise risk in terms of cost and time by simulation techniques. The most popular simulation technique used is the Monte Carlo technique which uses probability density to estimate the uncertainty and risk in each element of the WBS so that an aggregated risk estimate can be generated.

It is used in the following way [11]:

- A probability distribution of each risk present is defined from the estimated range values given by the risk
- Random values are chosen from the distribution given by a specified range
- Depending on the project constraint selected, the quantification of each risk is calculated.
- The above three steps are repeated multiple times depending on the accuracy required.

This simulation enables project managers to establish the probability whether the project can be completed successfully within the given all project constraints (i.e. time) [5, 10, 11] as seen in figure 3.6 below.





**Completion Probability Table**

Probability	Date	Probability	Date
0.05	10/17	0.55	10/28
0.10	10/21	0.60	10/30
0.15	10/22	0.65	10/31
0.20	10/23	0.70	11/01
0.25	10/23	0.75	11/04
0.30	10/24	0.80	11/05
0.35	10/24	0.85	11/06
0.40	10/25	0.90	11/06
0.45	10/25	0.95	11/07
0.50	10/26	1.00	11/11

*Figure 3.6: Monte Carlo Time Simulation [10]*

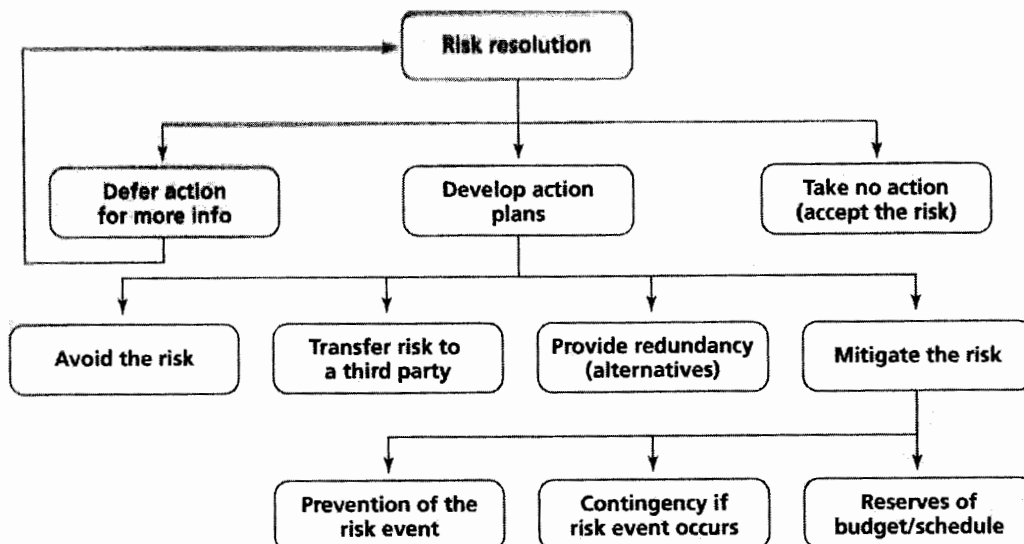
Other risk quantification techniques [10]:

- Decision analysis—commonly used to recommend alternative projects and the effect design and choices on project finance.
- Network analysis
- Program Evaluation and Review technique (PERT)

Risk quantification is the last major section that completes risk assessment. This allows project managers to have a clear view and accurate estimation on the consequences of each risk towards the project objectives therefore allowing a complete risk analysis for a response to be planned by the project team.

### 3.4 RISK RESPONSE PLANNING

Risk response planning is the process of defining proactive strategic measures that will be taken against the evaluated risk in the risk assessment process. There are various actions that can be considered, as described in the following pointers and shown in figure 3.7 below [5, 10, 13].



*Figure 3.7: Risk Response process [13]*

- **Risk Avoidance**

Risk avoidance is introduced when the risk assessed is not beneficial to the project. When project losses outweigh project benefits then risk avoidance is considered. By also eliminating potential threats to the project, risk avoidance is introduced but this requires critical continuous communication within the organisation [5, 10, 13].

An example of risk avoidance is not having a construction project near a 50 year flood line [5].

- **Risk Transfer**

Risk transfer is the process of deflecting or shifting the assessed risk responsibility or consequences to a third party. This usually occurs when the project team lacks experience in the assessed risk.

An example of risk transfer in a project is when the project manager determines that a specific task requires five months to finish but his current team will require twice the time (10 months) due to lack of experience, and would take another two months to develop the technology. However if he hires an engineering company who specializes in the task, the task will be completed within five months therefore it is best hire the engineering company. By doing this, risk is transferred to the engineering company as it is now up to them to actively manage all the risk involved within the task.

- **Risk Acceptance**

Risk acceptance can be either active or passive. Active acceptance is acknowledging the assessed risk and introducing contingency plans; while passive acceptance is not taking any action besides documenting the assessed risk.

An example of passive risk acceptance is when an organisation accepts low profit returns and/or profit loss on the first two runs of their product in a new market knowing definitely that their third run would be their turn around in profit gain.

An example of active risk acceptance is when the same organisation is uncertain if their third run will yield profit gain and this would result in crippling the organisation. Therefore a contingency plan which is an alternative definite revenue stream for the product is developed [13].

- **Risk Alternative**

Risk alternative is also known as risk redundancy and is a process of providing protection against the assessed risk. This can be done by introducing redundancy of parallel solution paths to the design.

For example, if the project manager believes that the layout specification of a plant may not produce desired output at the end of construction, he may decide to have two independent designers have a look and develop alternatives layout specification of the plant in order to reach desired outputs [13].

- **Risk Mitigation**

Risk mitigation is the most commonly used risk strategy. Risk mitigation is defined as “the process of taking specific course of action to reduce the probability and/or the impact of the assessed risk” [5]. There are two approaches to risk mitigation. These are pre-emptive action also known as prevention planning and contingency action plan.

Pre-emptive action reduces the probability of the assessed risk. This decreases the risk and expected losses (equations 3.1 and 3.2). For an example, the probability of a 20 year old non-serviced vehicle breaking down on a long trip is high. Therefore in order to try and prevent the breakdown, a full inspection of the vehicle has to be done and a replacement of all parts that may fail has to take place; thus decreasing the probability of a breakdown during the long trip [13].

Contingency action plan reduces the impact of the assessed risk. Therefore also decreasing the risk and expected losses. Contingency plans can be physical control and/or behavioural control and/or organisational control and/or procedural control [8, 9]. For example, an organisation decides to switch from an old 24 hours operating system to a new operating system but this would result in a full day revenue loss. A contingency plan that reduces the impact on revenue loss for the organisation would be upgrading the operating system during the lowest production time [13].

### **3.5 RISK MONITORING AND CONTROL**

Risk monitoring and control is the process of extensive tracking of assessed risk and the implementation of risk response strategies if risk occurs [10].

Risk monitoring and control is very similar to project monitoring and control. Risk monitoring involves collecting data similar to project monitoring but focussing solely on risks assessed in order to identify the status of the risk.

Risk control involves using the data collected during risk monitoring to initiate risk response strategies (i.e. contingency action plan) depending on the occurred risk [6, 10].

One of the simplest ways to implement risk monitoring and control during the execution of a project is to track risk through a spreadsheet process [13]. The first spreadsheet notes the risk assessed. The second spreadsheet contains collected data from the project and is presented continuously in a form of a report to determine if risk assessed is materialising or not. The third spreadsheet notes the risk response action if risk occurs. The fourth spreadsheet shows the amount of impact on project if risk occurs and depending on how it is handled the amount of impact will increase or decrease with time.

If the amount of impact increases with time, then new risks may occur which have to be assessed from the risk assessment phase through to the current phase. If the amount of impact decreases with time then either risk has not yet occurred and/or has been mitigated effectively [13].

Risk monitoring and control is an ongoing process as it can identify new risks to the project objectives thus making the process of risk management being a closed continuous loop (figure 3.2). It requires effective communication amongst the project team members [13].

As project audit and review are critical to project management, so is it to risk management. Risk audit and risk review involves the examination of assessed risk and the success of the project team towards the response and control of risk. This provides a learning process for the entire team and organisation for risks involved in future projects [10].

### **3.6 CONSTRUCTION RISK MANAGEMENT**

Construction risk management is the application of risk management in the construction industry as it encompasses all the risk management processes. Irrespective of how big or small the construction project is, risk and uncertainty will always be present. That is why construction risk management is so imperative [11].

In construction; the delay in time, overlooking quality and overrunning of costs can prove to be fatal to the project. Construction risk management monitors these factors and makes sure that are well controlled.

These construction risk management factors are usually defined in four categories [8, 9, 15]:

1. Technical Risk
2. Financial and Economical Risk
3. Clearance and Act of God Risk
4. Owner Organization Risk

Depending on the type of construction project, some of these factors may be classified as internal risk and others as external risk as shown in figure 3.8 below.

Under these four risk factors categories, there are sub-risk factors which the likelihood probability of each can be defined as seen in Table 4, using some of the risk assessment techniques in Chapter 3.3. of this study. This can include but not limited to brain-storming technique and data from past projects together with interview of key participants [11].

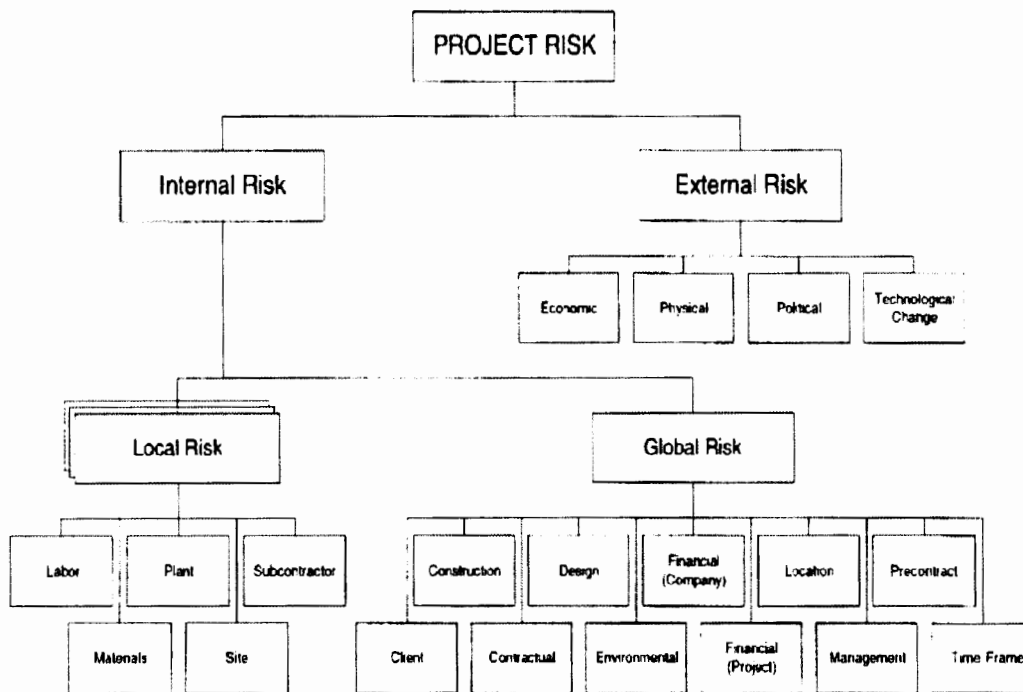


Figure 3.8: Project Risk [14]

Table 4: Likelihood of Construction Risk Factors [15]

Factors	Likelihood	Subfactors	Likelihood	
			LP	GP
Technical risk	0.479	Scope change	0.36	0.172
		Technology selection	0.124	0.059
		Implementation methodology	0.13	0.062
		Equipment risk	0.073	0.035
		Materials risk	0.08	0.038
		Engineering and design change	0.233	0.112
Financial & economic risk	0.228	Inflation risk	0.152	0.035
		Fund risk	0.383	0.087
		Changes in local law	0.105	0.024
		Changes in govt. policy	0.105	0.024
		Improper estimate	0.255	0.058
Organizational risk	0.146	Capability of owner's project group	0.106	0.015
		Contractor's capability	0.283	0.041
		Vendor's capability	0.448	0.065
		Consultant's capability	0.183	0.024
Acts of God	0.064	Calamity, normal	0.44	0.028
		Calamity, abnormal	0.56	0.036
Clearance risk	0.083	Environmental clearance	0.026	0.022
		Land acquisition	0.461	0.038
		Explosive clearance	0.133	0.011
		Other clearances	0.142	0.012

LP= Local Percentage, GP= Global Percentage

As contracts are present in majority of construction projects, risk managerial relationship will exist. In order to deal with this element, proper strategies chosen through drafting an organizational structure can influence risk management. Without these, construction risk management would prove difficult to implement.

Appendix F: Risk assessments and sub-factors

Since then, the Zachman Framework has been at the forefront of combining Information Systems with many other industries such as the Financial and Security institutions. One of such examples is by Dinned and Kolber where they map the Sarbanes-Oxley (SOX) Act into the Zachman Framework [17].

The SOX Act is the regulatory framework for CEOs and CFOs that defines their accountability to corporate and public governance in the United States[17]. As there are thousands of documents covering policies and procedure that have to be continuously analysed, IT systems are required to assist in the analyses.

In their study, Dinned and Kolber provided a solution on how the problem of developing such an IT system should be managed [17]. By mapping the SOX three principal focal points; transparency, governance and stewardship into the Zachman Framework, Dinned and Kolber showed the process which must be interpreted by the IT group. The governance focal point was mapped as the second row of the framework as it showed the interaction between the business and its processes. The stewardship focal point was mapped as the third row of the framework as it established the appropriate processes and controls. While the focal point transparency was mapped as the fourth and six row of the framework as it provided the ability of determining data elements for reports and functionality.

Dinned and Kolber solution of the Zachman Framework for SOX can be seen in figure 4.2 below [17].

	Data (What)	Process (How)	Location (Where)	People (Who)	Time (When)	Motivation (Why)
<b>Objective/ Scope (Ballpark view)</b>	Basel II - Requires the entire data column					
<b>Model of the business (Business view)</b>	SOX 404 - Definitions, terms. Basel II - Vocabulary, Business Definitions	SOX 409 - Process Improvement	SOX - Jurisdiction issues: Basel II - Home - Host	SOX 404 - Data Governance and other roles. Basel II - Data Governance	SOX 409 - Triggering business events	SOX 404 - Rules, KPIs Basel II - Corporate Governance
<b>Unconstrained system model (Architect's view)</b>	SOX 302 / 906 Understanding and measure of data. 404 Specs & standards data elements: 409 - Data relevance. Basel II - Data structures	SOX 404 / 409 - Business Intelligence		SOX 404 - Data Stewardship and security requirements Basel II - Data Stewardship	SOX 409 - Triggering systems events	
<b>Technology Model (Designer's view)</b>	Basel II - Data structures	SOX - List of financial reports and its fields. Basel II - Transformations and predictive models				
<b>Technology model (Builder's view)</b>						
<b>Production (Functioning) system</b>	SOX 302/906 - Reconciliation, completeness, B2 tracking duplicates, accuracy. Basel II - Taxonomies	SOX 409 - Data availability, timeliness: 302/906 & Basel II - Data lineage & transformations		SOX 404 - Usability & metrics on usability		

Figure 4.2: Zachman Framework for SOX [17]

However it should be noted that from Dinned and Kolber final solution of their study, not all columns and rows in the Zachman Framework are complete. This can be seen with the first row where only the first column is modelled and the others are not. This could be because it is not important for the IT group to describe the nature and purpose of the business scope when interpreting the IT system for the SOX Act yet modelling its governance is important, and this could be the reason why the entire second row of the framework cells has been modelled.

A similar argument(s) can be raised with the third and sixth column of the framework cells not being modelled fully as it is relatively unimportant for the IT group to encourage enterprise existence and locations in this case. This is because the SOX Act only regulates and defines accountability and this is what the IT system needs to show.

Even though Dinned and Kolber were not able to model all cells of the Zachman Framework for SOX due to the case study and its environment, the cells which were modelled was done by following, understanding and applying the rules and descriptions of the Zachman Framework to follow.

## **4.2 THE ZACHMAN FRAMEWORK RULES & DESCRIPTION**

As with any framework, Zachman developed general rules to follow for each row and column. In this case the rules are basic and simple. There are only six rules as described by Ertaul, Sudarsanam, Sowa and Zachman [16, 20].

1. The columns have no order; do not add rows or columns to the framework. Order creates bias and implies priority. All the columns are equally important, for all are abstractions of the same enterprise.
2. Each column has a simple, basic model. The abstraction of each column corresponds to basic entities suggested by the interrogatives.
3. The basic model of each column must be unique. No entity or connector in the basic column model is repeated by name or concept. They may be related as they are the abstract of the enterprise but they are separate and unique.
4. Each row represents a distinct, unique perspective and the order is fixed. The definition of each entity reflects the perspectives of different constraints.
5. Each cell is unique and should have an architectural primitive, a single (graphical) model describing the enterprise from a certain point of view.
6. The composition or integration of all cell models in one row constitutes a complete model from the perspective of that row. Each cell is dependent upon the above cell, below cell and cell in the same row. Any change in a cell would have an effect on the dependent cells of the row.

With the six rules well defined, Zachman also notes that “one can also choose not to produce deliverables for every cell. In that case, one makes assumptions about them. All columns, rows and cells are always present in the framework, though some cells can be left implicit” [18].

In order to understand each cell and each row in detail, a descriptive analysis is provided by Ertaul, Sudarsanam, Sowa and Zachman by first looking at the columns then the rows of the framework [16, 20]:

#### 1. Columns-:

- *Data (what)*: This column defines what an enterprise/organization is made of. It consists of sections indicating the material composition that influence its direction and purpose of the enterprise.
- *Function (how)*: This column defines how an enterprise works. It describes how a process is transformed by taking in the goals of an enterprise as the input that alters the output.
- *Location (where)*: This column discusses the geographical location and the interconnection of an enterprise. The cells may comprise of business offices, their service providers and vendor connections.
- *People (who)*: This column answers the question about who is responsible. It describes the authority, responsibility or the workflow of the organization and the people who are involved in the business.
- *Time (when)*: This column defines the most important element in any enterprise which is time. It focuses on the scheduling of events, which are affected by triggers.
- *Motivation (why)*: This column defines the reasons, which encourage the enterprise's existence.

#### 2. Rows-:

- *Scope (Planner's view)*: This row defines the purpose and nature of the business. The planner lists all the important things that manages and affects the business policies and its outcome.
- *Business Model (Owner's view)*: This row defines the interaction between the entity and the business processes. The owner describes this relationship taking into consideration the desires of the users.
- *System Model (Architect's view)*: The architect analyzes both the business and technical perspectives of the enterprise and produces a design to the builder from the specifications provided by the owner and the planner.
- *Technology Model (Builder's view)*: The builder takes the specifications from the architect and owner's perspective to implement technology to address information processing.
- *Detailed Representation (Programmer's view)*: This row produces the component from the architectural drawings and builder information from the previous rows.
- *Functioning System*: This model depicts the operational system. This is the product of all planning, designing and development produced in the previous rows.



From understanding the rules together with the meanings and applications of each row and column of the Zachman Framework, one can begin to adapt and formulate the framework to suite the research study while maintaining the same original layout.

### 4.3 ADAPTING THE ZACHMAN FRAMEWORK

Although the rules of the Zachman Framework are simple to understand and have played a strong role in EA, they are too rigid to implement directly in other sectors and may lack practicality when it comes to adapting [19]. This can be seen in the lack of publicly practical management use of the framework outside EA.

With most if not all adapted Zachman Framework not all cells can be completed and Fatolah, Shams, Ylimakia and Halttunenb sum up in their studies the reasons behind non-completed cells into the following points [18, 19]:

1. Insufficient methodology covering all the aspects of the framework
2. Insufficient repository storing the framework in accordance with the integrity rules
3. Insufficient popular modeling notation for all the columns
4. The rules are too complex to utilize without modification
5. The framework does not sufficiently analyze the interconnections between the cells

Similar arguments can be raised about adapting the Zachman Framework to project and risk management. As seen from the previous chapters, there are many models and techniques that are used in project and risk management which can be comprised from more than one cell of the framework. However Zachman states for the framework a unique primitive model need to exist for each cell and this raises a concern when adapting the framework.

Another concern is in repeated concepts in basic column models, as Zachman states in his rules that this is not allowed. Conversely when analyzing a project lifecycle, certain concepts such as WBS and logistics are repeated throughout the lifecycle.

Therefore it can be concluded that in order to complete the study efficiently, it is necessary to modify some rules without changing any boundaries of the Zachman Framework. Only three modifications are made to the rules of the framework and they are the following:

1. A name and/or concept can be repeated in more than one basic column model; however its application process should be unique in each cell.
2. Some project and risk management phases may represent an entire column and/or row. Such phases are not placed in cells but are mentioned and placed on top of the matrix in corresponded to how the Zachman Framework is labeled.
3. Unique architectural primitive models do not exist in each cell for the entire project and risk management spectrum. They may only exist when the field of project and risk management is applied to a specific sector, i.e. manufacturing, construction; however this is not a must.

One supporting main factor about the framework when it comes to adapting project and risk management is that according to Zachman and Sowa [20]; “each row is supposed to be directly engineered from the previous row and reverse engineered from the following row”; thus supporting the notion that project and risk management are a closed loop and also a back and forth looping process.

From the disadvantages of the framework and the modifications done to some of the rules, it is evident that adapting the entire project and risk management field to the Zachman Framework would be too unrealistic for this research. Therefore it is only reasonable to breakdown the field to the construction sector as already suggested by the point 3 on pervious page.

Not only does the construction management cover the main important factors and functions of project and risk management but also the case study that the research is subjected to is based on a construction project. Therefore this assumption is correct for the research study.

However; similar to Zachman developing the Zachman Framework for EA [16, 17, 18]; before developing each cell in the Zachman Framework for Construction it is important to adapt the framework to the points that dominate the project and risk management industry holistically first.

The points that dominate the project management industry from our research study in Chapter 2 are:

- Project Team/Management
- Project Sponsor
- Consultant/Specialist
- Contractor
- Monitoring & Control
- Commissioning/Closure
- Strategy
- Logistic
- Tactic



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The points that dominate the risk management industry from our research study in Chapter 3 are:

- Management Issues
- Physical Properties
- People Elements
- Action/Processes
- Risk Identification
- Risk Quantification & Qualification
- Risk Response
- Risk Monitoring & Control

Therefore if we look at the points mentioned above that dominate the project and risk management industry, we can now begin to adapt and relate them to the same views of Zachman without adding rows and/or columns to the matrix but merely graphically representing them on the same matrix order.

The project management points are adapted and related in the following way to the Zachman Framework:

1. Since *Strategy* in a project is the overall method one employs to do the task [1] which contains data analyses and motivation of the existence of the method; it is related to the *what* and *why* columns of the framework as they both look at data and motivation in EA respectively.
2. *Tactic* is the process and functions in which the task(s) is to be completed in a project and it can be related to the *how* column of the framework as it looks at the functions in a EA.
3. *Logistics* in a project defines and has an impact on people performance, timing of goods and conditions of a location. Thus it can be related to *where*, *who* and *when* columns of the framework as they all discuss network, people and time in a EA respectively.
4. *Project Team* in a project are the developers of the entire project and are involved with all contextual of the project. Therefore it is related to the *planner* row of the framework as the row looks at the complete perspective model of a scope in EA.
5. *Project Sponsor* in a project is defined as the organisation that invests in the project thus giving it sole rights the project and its conceptual business outcomes. Therefore it is related to the *owner* row of the framework as the row looks at the complete perspective model of a business in EA.
6. *Consultant* in a project is the professional and/or specialist that can be involved in anything from design to drawings within a project. Thus it can be related to the *designer* row of the framework as the row looks at the complete perspective model of a logical designer EA.
7. *Contractor* in a project is the company in charge of the physical implantation of a project's task(s). It is therefore related to the *builder* row of the framework as the row looks at the complete perspective model of a physical building in EA.
8. *Monitoring & Control* in a project is the procedures of guiding a project to represent and reach the desired outcomes. Therefore it can be related to the *as built* row of the framework as the row looks at the complete perspective model of a detailed representation in EA.
9. *Commissioning* of a project is the closure and functionality of the outcomes in a project. It is related to the *functioning* row of the framework as the row looks at the complete perspective model of a functioning system in EA.

The risk management points are adapted and related in the following way to the Zachman Framework:

1. *Risk Identification* in a project is the identifying of events and their consequences that could lead to project not reaching its end goals by using data and knowing the constraints of the project. Therefore it is related to the *what* and *why* columns of the framework as they both identify at data and constraints in a EA respectively.

2. *Risk Quantification and Qualification* is the process and functions which are implemented to analyse identified risks in a project and it can be related to the *how* column of the framework as it looks at which functions are implemented to analyse EA.
3. *Risk Response* in a project defines the action that would be taken together with the responsible individual to the identified risk. Thus it can be related to the *who* column of the framework as it discusses the responsibility and action of each person in an EA.
4. *Risk Monitoring and Control* in a project defines the process of reviewing risk timely in order to respond adequately and noting new risks that may appear on the organisation structure. Thus it can be related to *when* and *where* columns of the framework as they focus on triggers that affect events and the network of the organisation in an EA respectively.
5. *Management Issues* in a project deals with the risks involved in the planning of an entire project and its risk policies. Therefore it is related to the *planner* row of the framework as the row looks at the complete perspective model of management and policies in EA.
6. *People Elements* in a project are risks within the interaction of the business systems and workers/public together with how their acquired skills fit in the near future. Therefore it is related to the *owner* and *functioning* rows of the framework as they look at the complete perspective model of relationships, operation system and development produced in EA respectively.
7. *Physical Properties* in a project are risks involved in suitability, size, repairs and expansions of the designs and premises. Thus it can be related to the *designer* row of the framework as the row looks at the complete perspective model of architect analyses of specification in EA.
8. *Action Processes* in a project are the risks involved in the controls put in place, techniques used, technological impact and available skilled staff. It is therefore related to the *builder* and *as built* rows of the framework as the rows look at the complete perspective model of implanted technology and builder information in EA respectively.

The process of adapting the dominant points in project and risk management through Zachman views not only makes adapting and analysing each cell for the construction sector easier but it is also noted that the process labels and sorts out risk areas in a construction project automatically within the framework. This is shown completely in the following section of adapting the Zachman Framework for Construction.

#### 4.4 THE ZACHMAN FRAMEWORK FOR CONSTRUCTION

From analysing the rows and columns of Zachman with reference to the project and risk management, it is now possible to start mapping and adapting construction management together with its risk construction management procedures into the framework cells.

- First row- *Project Team*:

**What-** This cell modules and describes the initial process of a construction project. This is where data concerning scope, problem statement, specifications and other inputs required to reach the objectives of the construction project are stored.

The cell from a risk perspective it develops a risk management plan and policies to be used in the construction project. This is where initial inputs from the scope, problem statements and specification are used to identify whether the risk is internal or external to the project by using data.

**How-** This cell defines the planning process modelling in a construction project. Research is done and scheduling models are produced in this cell.

This cell also defines the risk techniques to asses risk in the construction project. A risk model to be used in the project is selected in this cell.

**Where-** This cell provides a geographic view of the entire site of the construction project including the nearest towns and site orientation.

The cell also provides the monitoring of the global and local risk impact on the construction site and its orientation.

**Who-** This cell models the key players in the construction project in order to make the project financially and technically feasible.

The cell also models the key individual players who are responsible for responding to risk if it occurs. Depending on the classified risk(s), different risk respond techniques are selected in this cell for the construction project.

**When-** This cell models estimation of the construction project; this including cash, time and activities.

This cell also models the estimation of the financial and economic risk to be monitored and managed in the construction project.

**Why-** This cell gives restrictions and reasons of processing a country's rules and regulations together with its needs and thus providing the existence of the construction project.

The cell identifies the positive and negative risks involved that impact the existence of the construction project.

- Second row- *Project Sponsor*:

**What-** This cell allows a proper business plan to be documented for the construction project. The data in the plan will have information such as management and administration structures in the construction project.

The cell also allows a full documentation plan of the risk(s) managed in the project sponsor organisation structure. The data in the plan will have risk information such as people, procedure and protection structures in the construction project.

**How-** This cell provides techniques and modules in which the construction project is selected. It offers ways in which the inputs are equally balanced with the outputs.

The cell also provides techniques and models in which the construction project risk drivers such as cultural issues and skills availability are determined and assessed.

**Where-** This cell allows the organisation structure of the construction project to be modelled; this includes operations and marketing models.

The cell also allows a risk monitoring and control structure of the construction project to be modelled; which includes the processes of identifying new risk effectively in the construction project that may impact the organisation structure.

**Who-** This cell defines the general management of the construction project. This includes legal aspects and specifications in contract agreements.

The cell also defines the organizational risk response to the legislative requirements and specifications in contract agreement such as contractors and consultant's capability to deliver.

**When-** This cell models the construction project's constraints as in cost, time, scope and performance.

This cell also models the thresholds of client and time frame risk to be monitored and managed in the construction project.

**Why-** This cell gives reason according to sound business process of the construction project. All benefits of the venture are modelled here together with the internal/external environmental impact.

The cell also identifies the normal and abnormal calamity risk(s) that may affect the benefits of the business future processes in the construction project.

- Third row- *Engineering Consultant*:

**What-** This cell provides data storage in the technical process which includes detail designs and problem solving modules in the construction process.

The cell also provides data that identifies risk in outsourcing subcontractors, location of site and its affects on the final product of the construction project.

**How-** Engineering and science methodologies are described in this cell. These comprise of methods, theories and calculations.

The cell also describes techniques that modules and measures the design risk of the construction project as well as its influence on project scope.

**Where-** This cell defines the ecological and economical structures concerning the impact of the construction project.

The cell also defines environmental risk involved such as health in the premises of the construction project and its risk in not complying with the codes of standards.

**Who-** In this cell, consultant's disciplines are well defined together with their roles and responsibilities in the construction project.

This cell also modules the roles of the different disciplines in defining their risk response techniques to their responsibilities in the organization of the construction project.

**When-** This cell represents the construction project life cycle, defining the course of upgrading and re-engineering (the construction).

This cell also represents and defines the process of controlling pre-contract risk during the project life cycle so that impact on change in constraints (i.e. design) is monitored.

**Why-** This cell provides a module that shows the easy usage and accessibility of the construction project. It also shows the availability of the technology towards the design.

The cell also provides a module which identifies new risk that may occur from the usage and accessibility of the construction project final premises, product and/or services.

- Fourth row- *Contractor:*

**What-** This cell stipulates the construction implementation process by defining the required data in organising, allocating and co-ordinating all construction resources.

The cell also defines the data that are used to identify the material risks involved in the processes and performance of the construction project.

**How-** This cell illustrates people and technical skills model in place that delegates motivates guides and directs the construction plan through authority and staffing.

The cell also assesses the risk impact of the changes in technological development together with how it affects the people and technical skills model in the construction project.

**Where-** The cell defines heritage regulatory situations and resources through export and/or import.

The cells also defines the monitoring and controlling the risks involved in labour law and trading risk through export and/or import of resources for the construction project.

**Who-** The cell clearly gives a model that shows the authorised duties line of communication and which tasks their committed to in the construction project.

The cell also provides a model that shows who is change and the techniques that can be selected to respond to site risk and/or human error risk.

**When-** This cell illustrates the mile stones and deadlines of the construction project together with its application of contingency plans if need occurs.

The cell also shows at each milestone monitoring of financial risk that may occur due to contingency plan if implemented.

**Why-** The cell shows models of the end building product desired.

The cell also shows models of positive impact of the desired actions if negative impact is identified on time.

- Fifth row- *Control Procedure:*

**What-** This cell models the procedure of benchmarking where the data of quality, safety and inspection is stored.

The cell also models the process of identifying risk involved in the benchmarks used to determine quality and safety in the construction project.

**How-** This cell provides the systems of monitoring and controlling the collection of construction data and continues analysis techniques.

The cell also provides techniques that assess the complete internal risk continuously in order to justify the control procedure.

**Where-** This cell models site oriented issues in resource delays, availability and natural disasters.

The cell also models the process to monitor the risks involved in resource delays and availability and control its impact on site issues such as performance.

**Who-** The cell defines the security order system in the construction project in order protect on site resources.

The cell also defines the response procedure to the security risk factors to the site of the construction project.

**When-** This cell models the closed loop system of observing the progress of the construction project through routine reports and correction evaluation.

The cell also models a systematic procedure of monitoring and controlling risks documenting routine reports and corrections in order not to have a major negative impact on time constrain.



**Why-** This cell shows comparison between plan and actual construction project through measured valued charts.

The cell also shows a comparison of the impact between a newly identified risk and previously identified risks.

- Sixth row- *Commissioning Process:*

**What-** This cell defines the construction project closure. This is where final data is audited, evaluated and stored for future use in similar construction projects.

The cell also defines the risk auditing process. Tabulating all the risk that has been identified during the project lifecycle and storing it in data for future use in similar construction projects.

**How-** The cell shows a model that provides clarification procedures through processes such as group discussion techniques and questionnaire methods.

The cell also shows a model that provides the procedure of selecting the techniques to quantify risk clearance of the entire construction project audited risk.

**Where-** The cell models the final areas of access through the complete operational site for local communities.

The cell also models the monitoring and controlling of community risk due to people elements during operation of the complete construction site.

**Who-** This cell defines any team member who has been re-assigned on the construction project model during the project lifecycle.

The cell also defines the risk response technique to be selected by the team member according the re-assigned task and the time frame in the project lifecycle.

**When-** The cell defines the construction project history through previous and output analysis.

The cell also defines all the controlling risk procedures used throughout the construction project lifecycle and analyses which procedure yielded high results.

**Why-** This cell reviews the teams strategies in order to boost and build team morality and spirit.

The cell also reviews the risk management processes and identifies positive and negative impact it has had on the project team.

## 4.5 CONCLUSION

Through analysis and adaptation of each cell in the Zachman framework for EA to fit in construction management, one can now represent and illustrate the Zachman framework for construction graphically as seen in figure 4.4 on the following page.

Although we have been able to successfully simplify the complexity of project and risk management by mapping it into a Zachman Framework for Construction, this only provides the foundation which solves only half of the research area study.

The next step is to determine how usable and effective the developed Zachman Framework for Construction is in a construction project. This will determine if the framework is able to hold the fundamentals of project and risk management without inconveniencing its rules throughout the project lifecycle.



## CHAPTER 5 THE CASE STUDY

### 5.1 THE IMPORTANCE OF THE CASE STUDY

When researching further about the Zachman Framework, it seems that the framework has been mostly used as a general framework in research studies instead of an applied methodology in practise. Having the gap between theoretical and practical application of the framework widened even further. This causes the framework matrix to be more known than its usability and efficiency in practise/case studies [18].

Therefore it is important to always to link the two, theory and practical, by having more practical studies of the framework being analysed and reducing this gap. Otherwise, according to Ylimakia and Halttunen [18], the framework will merely become a referred tool instead of an everyday used tool.

In this chapter, the developed Zachman Framework for Construction is applied to a concurrent ongoing construction project. This provides away on how to critically examine and analyse the usability of the developed framework and its limits in practise giving the research study more depth to it.

Our construction project is based on an inner city development in Johannesburg, South Africa. Therefore it is reasonable that the next section discusses briefly the significance of the project.

### 5.2 INNER CITY DEVELOPMENT PROJECT

#### 5.2.1 Background

Developing countries around the world such as India, Nigeria and South Africa have realised that their inner cities are becoming investment destinations; specifically property investors. Looking at South Africa, particularly due to the FIFA World Cup 2010, the inner city such as the Johannesburg (JHB) Central Business District (CBD) needs to be rejuvenated.

The inner city of JHB forms part of the Region 8 administrative area of Johannesburg Metropolitan Council (CoJ), its geographical outline sketch is shown in figure 5.1 on page 65 [21]. The inner city has close to 800 000 commuters that enter it on a daily basis while there are more than 350 000 shoppers who visit each year. Currently an investment of R19 billion represent the 7 million m<sup>2</sup> of office space and R1.2 billion represents 3 million m<sup>2</sup> of housing/residential space [21, 22, 23].

#### 5.2.2 The Construction Project

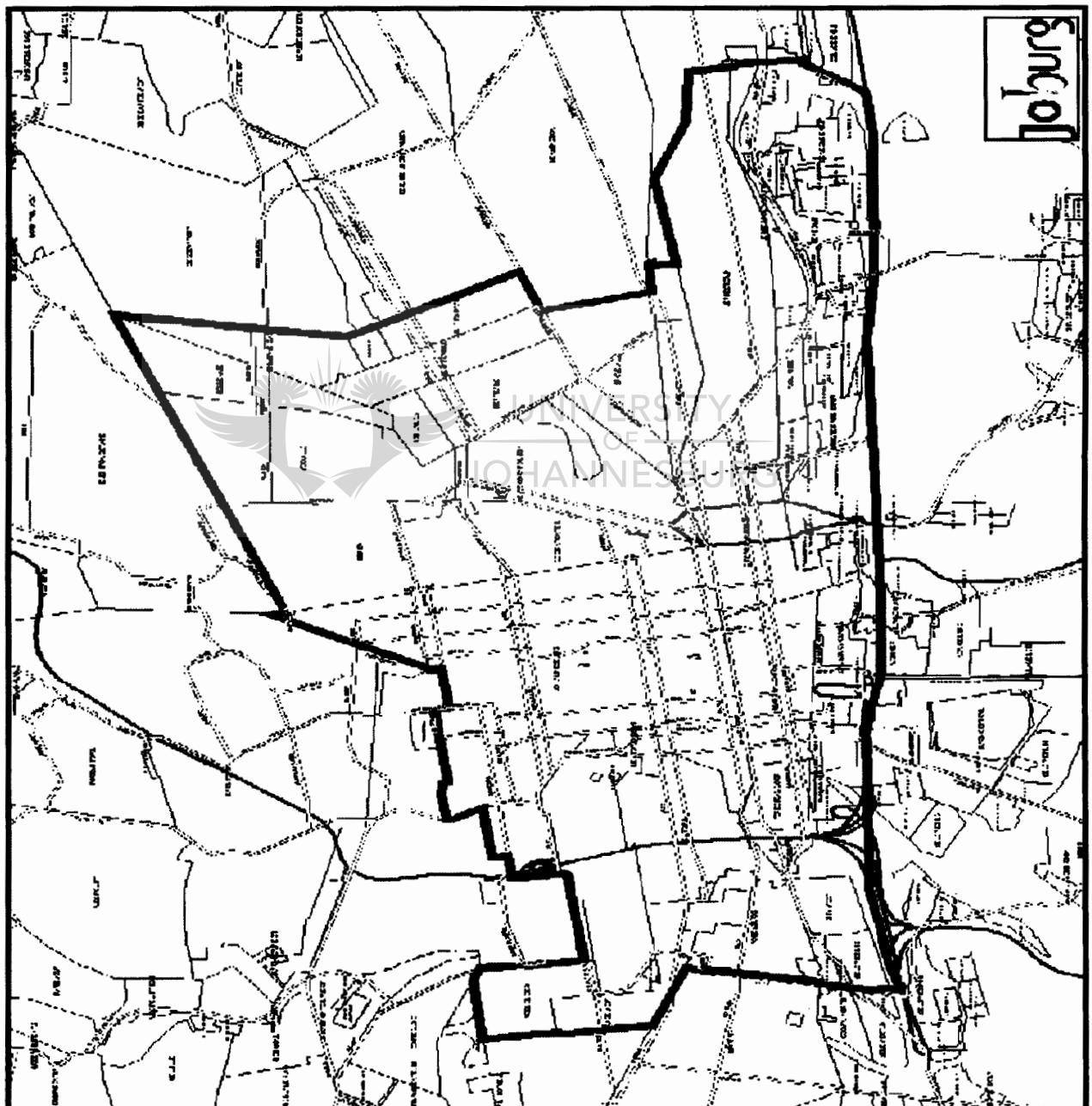
With a population of more than 250 000 causing tremendous pressure on the infrastructure, the city council of Johannesburg has put into place strategies to upgrade and sustain private investment and therefore increase the value in property. These strategies include but are not limited to improving and maintaining of an attractive infrastructure that draws business and residents [21, 22, 23].

In this case study, the construction project is upgrading one of the city's heritage buildings, the Loveday House, into residential apartments. This building was once the office space of

the law firm where the Freedom Charter was drafted in the 1950's and has tremendous history behind it. The construction project must preserve and maintain the external architectural views.

The building has eight floors with each floor being 46.8m by 21.7m with three (3) operational lifts. After completion, each floor will consist of three basic furnished residential apartments. The layout of each floor is given in figure 5.2 on page 65.

With constant new projects being implemented in the inner city and the current economic challenges faced by South Africa, it is an interesting environment for the Zachman Framework for Construction to be implemented and simplify the complexity of the residential construction project as well as to highlight potential risks associated with the development.



*Figure 5.1: Inner City of Johannesburg [21]*

### 5.2.3 Analysis of construction project according to Zachman Framework for Construction

Ideally one would like to examine each cell of the Zachman Framework for Construction using the inner city construction project for the case study. However due to the time constraints of the research study and it being more of an introduction to the possibilities of using the Zachman Framework as a project and risk management simplifying tool; it is only reasonable to reduce the adapted framework for better and more accurate results. Therefore analysis and assumptions are made about the inner city construction project according to the Zachman Framework for Construction.

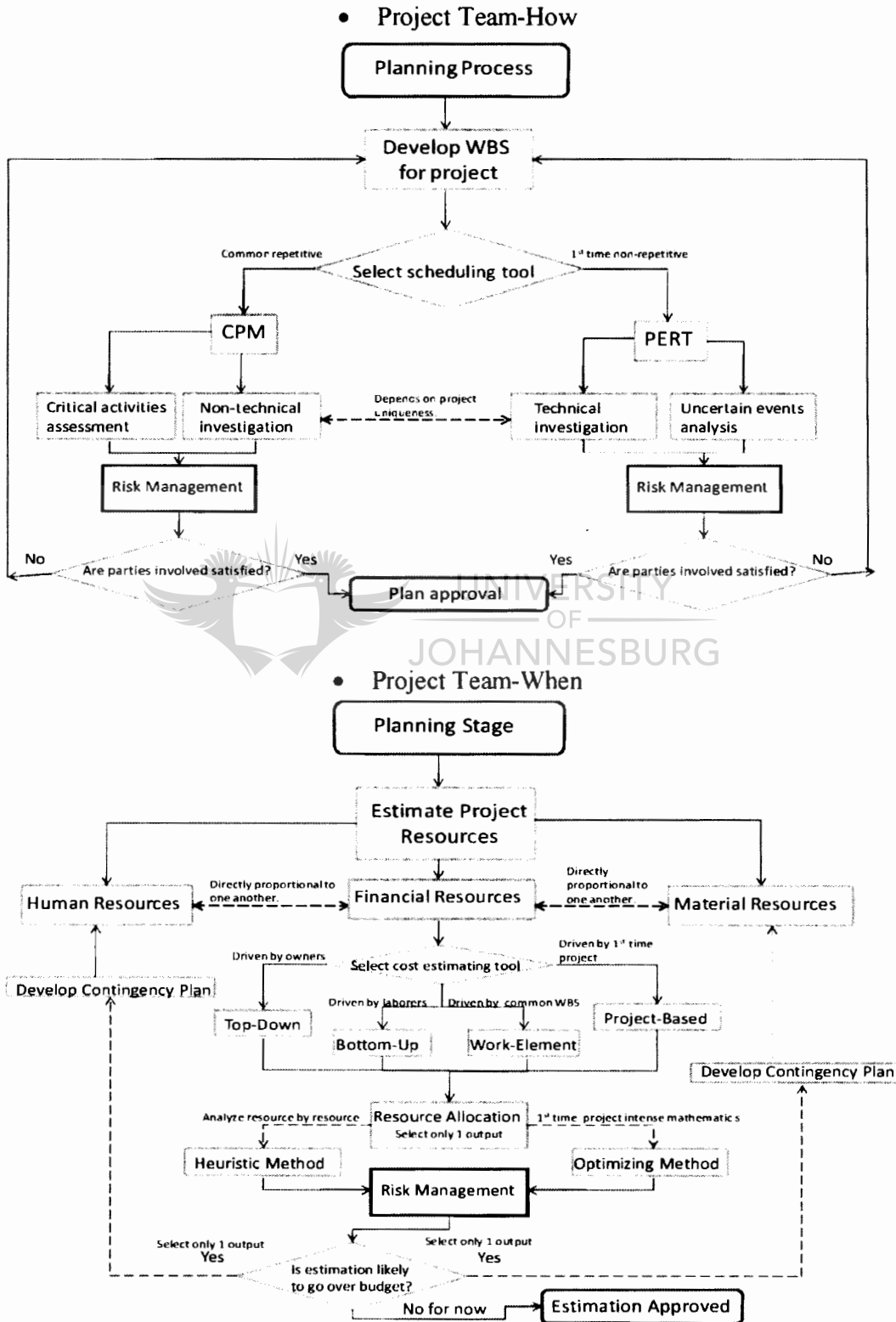
1. When looking at the second row of the framework, *Project Owner*, being that the inner city construction project has been approved by the sponsor; we can safely make the assumption that the construction project business procedures, organisation structures and outcomes are approved. Therefore making the second row relatively unimportant for the case study. However business project constraints needs to be always known throughout the project lifecycle therefore, the *When* cell of the row is important and will be considered.
2. From sections 5.2.1 and 5.2.2 of this chapter, we see that it is highly important for the inner city construction project to exist in order for the city of JHB to achieve its goals thus assuming the outcomes are well defined. Therefore motivating and encouraging the outcomes of each process in the project, the *Why* column, becomes relatively unimportant for the case study.
3. The construction company that is in charge of the inner city construction project has tremendous experience and is ready to commence with the project. Together with the geographical location of the project, well described in sections 5.2.2 and approved by the municipality, it is reasonable to assume that the *Data* cell, *Where* cell and *Who* cell of the first row, *Project Team*, are well defined respectively.
4. As commissioning of a project happens at the end of the project lifecycle, due to the time limits put on the research study the sixth row, *Commissioning Process*, becomes relatively unimportant to the case study. However it is important to clarify the processes of closure of one of the floors (8<sup>th</sup> floor) in the project to compare accurate data for the case study this results in *how* cell of the row to be considered.
5. Seeing that the construction company has historical data of the quality is required in such a project as well as the location of the project has good security; it is assumed that the *What*, *Where* and *Who* cells of the fifth row, *Control Procedure*, are well defined. Therefore becoming unimportant for the case study, however the control and collecting procedures of data is important for the case study in order to receive correct information from the project. Thus the *How* and *When* cells of the row are to be considered.

With all the assumptions and comments made above, we see that in order to have an accurate and correct analysis of the case study using the adapted Zachman Framework for Construction, the *Consultant* and *Contractor* rows respectively together with the already mentioned cells need to be considered when applying the developed framework to the case study.

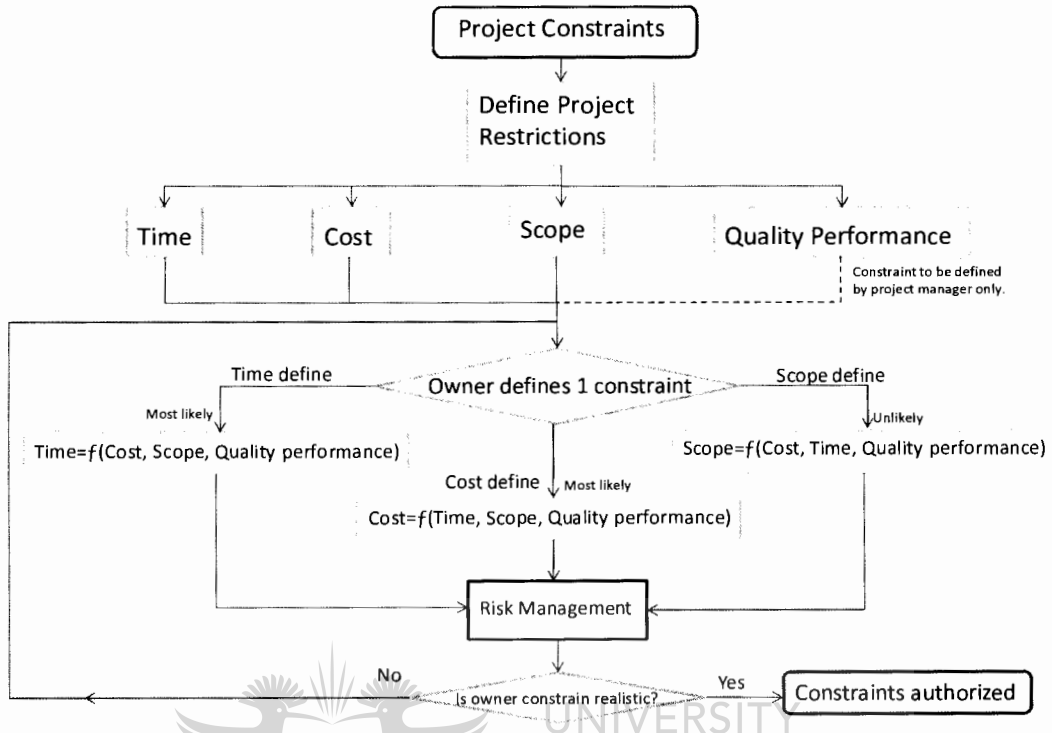
Therefore this reduces the Zachman Framework for Construction to be the solutions and implementation processes of the inner city construction project according to the current state of the case study which is represented in figure 5.3 on the following page.

### 5.2.4 Graphical Representation of Reduced Zachman for Construction

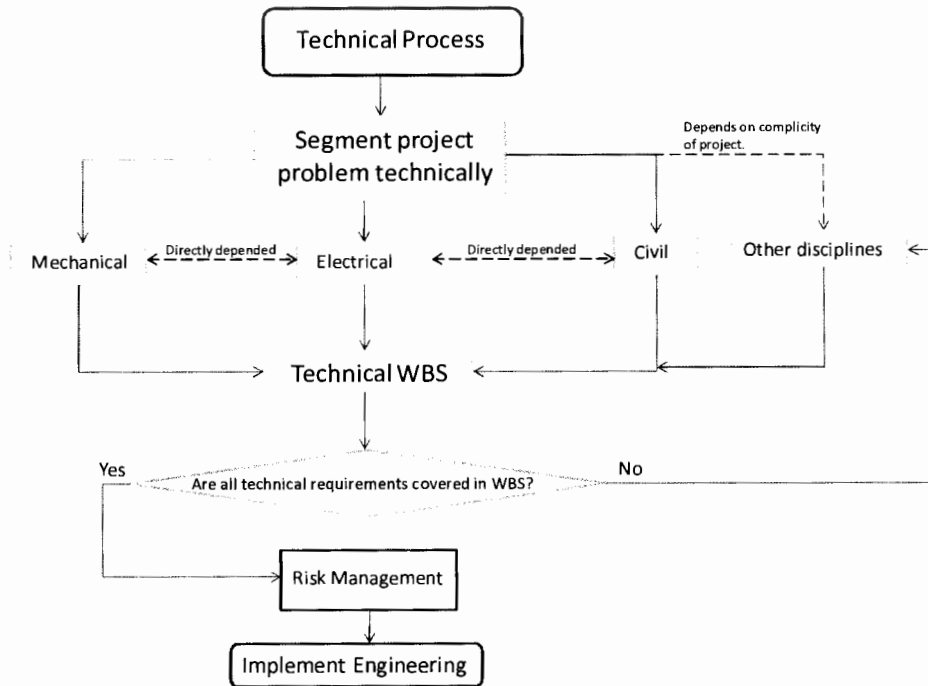
One of the aims of the research study is to make the proposed solutions processes more amenable to normal project managers. In order to do that the reduced Zachman Framework for Construction can be more effective to project managers at best representing each cell graphically row by row.



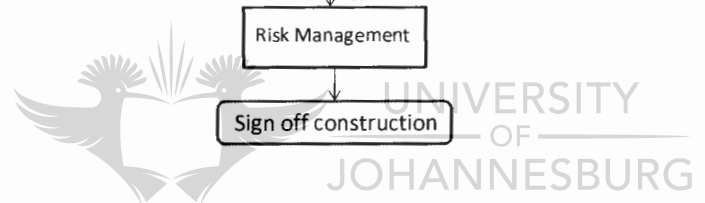
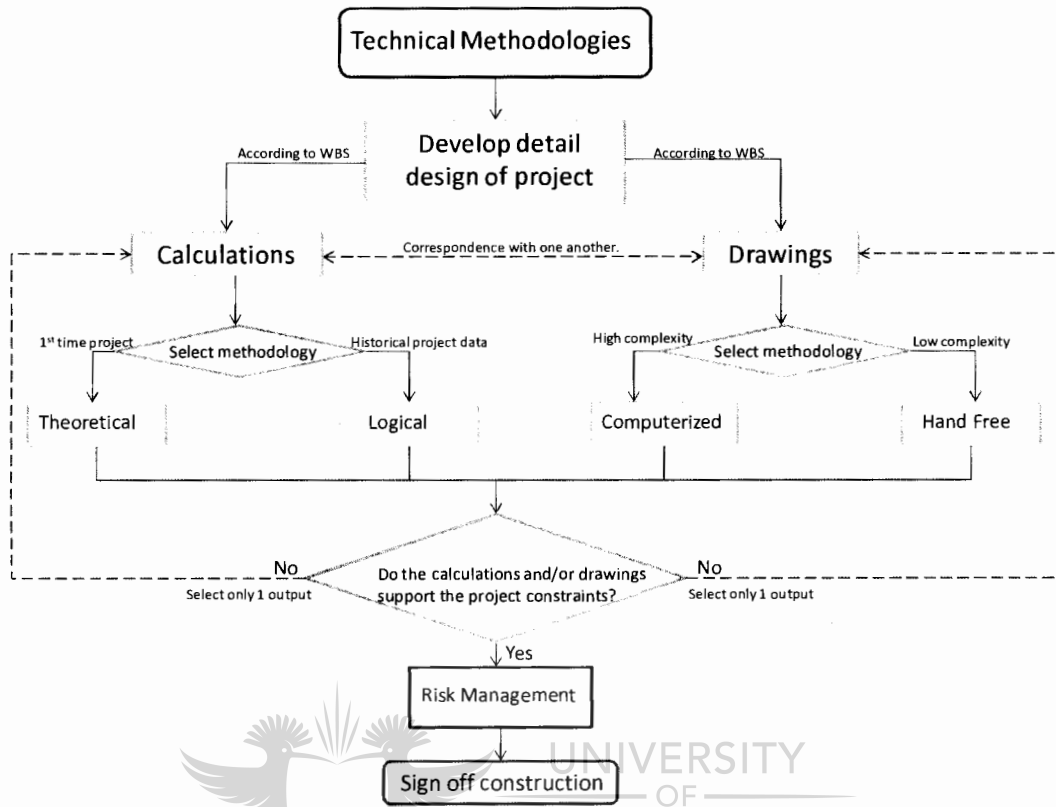
- Project Sponsor-When



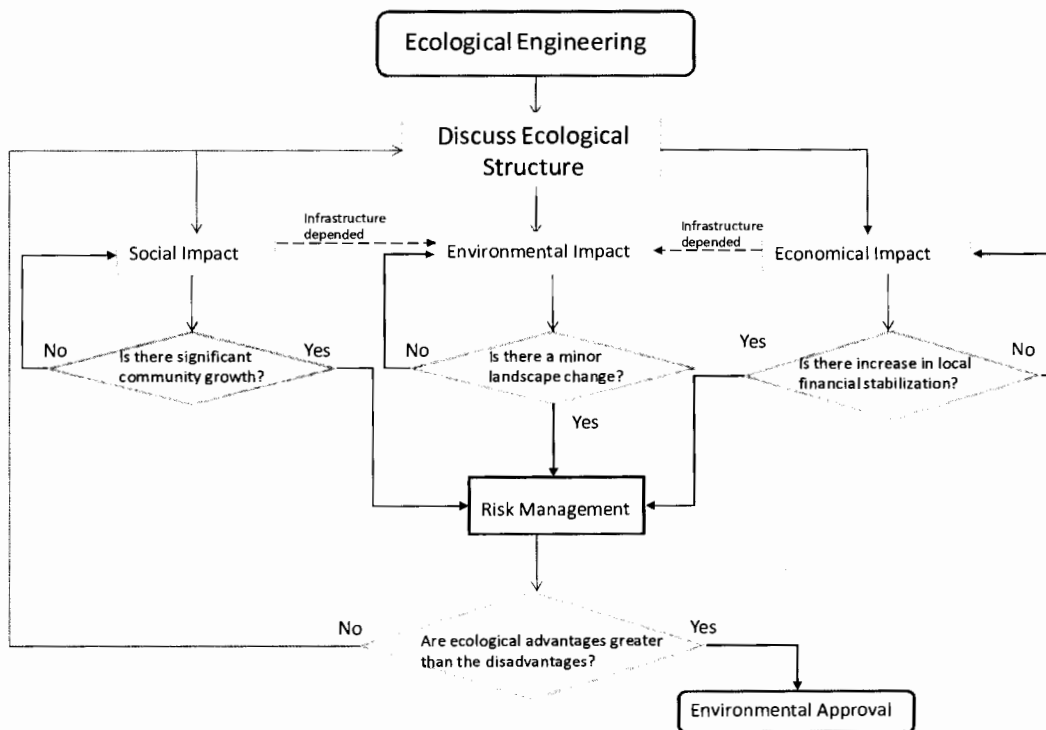
- Consultant-What



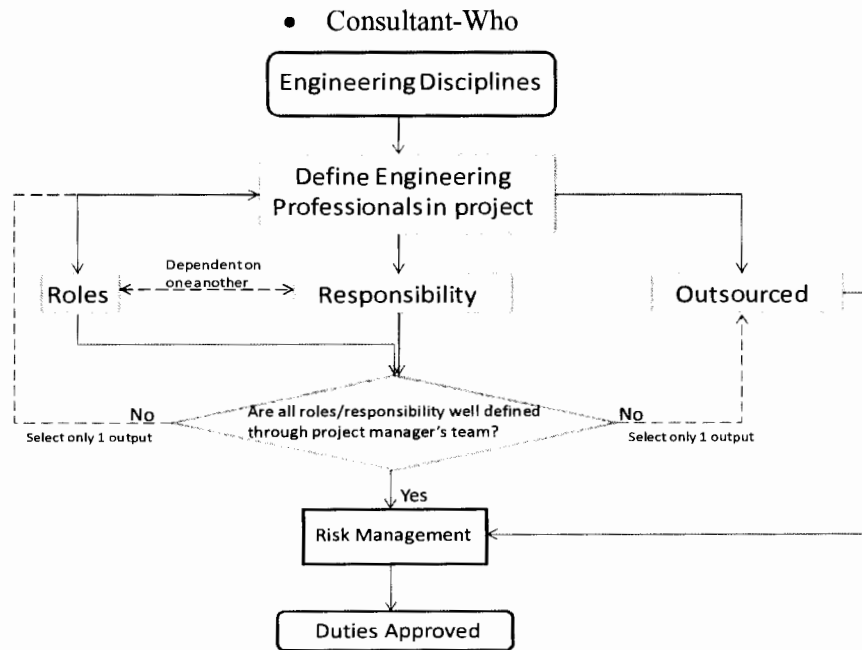
• Consultant-How



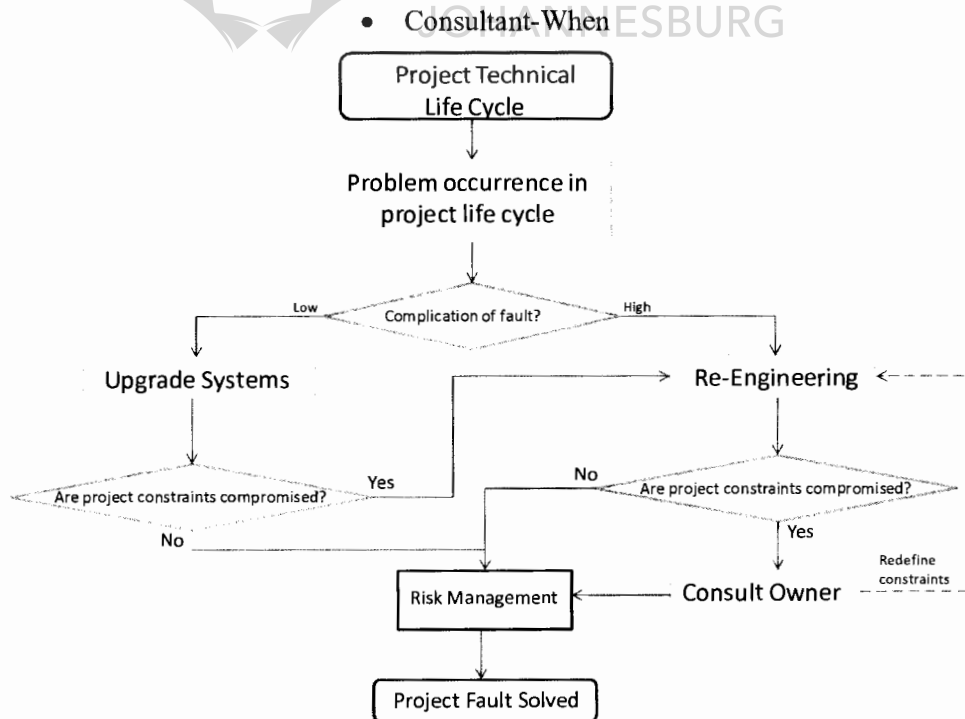
• Consultant-Where



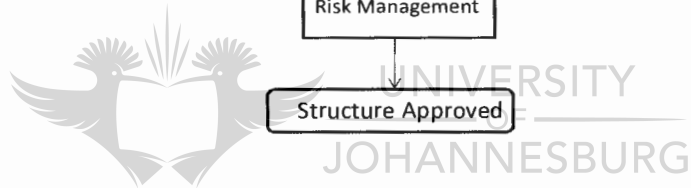
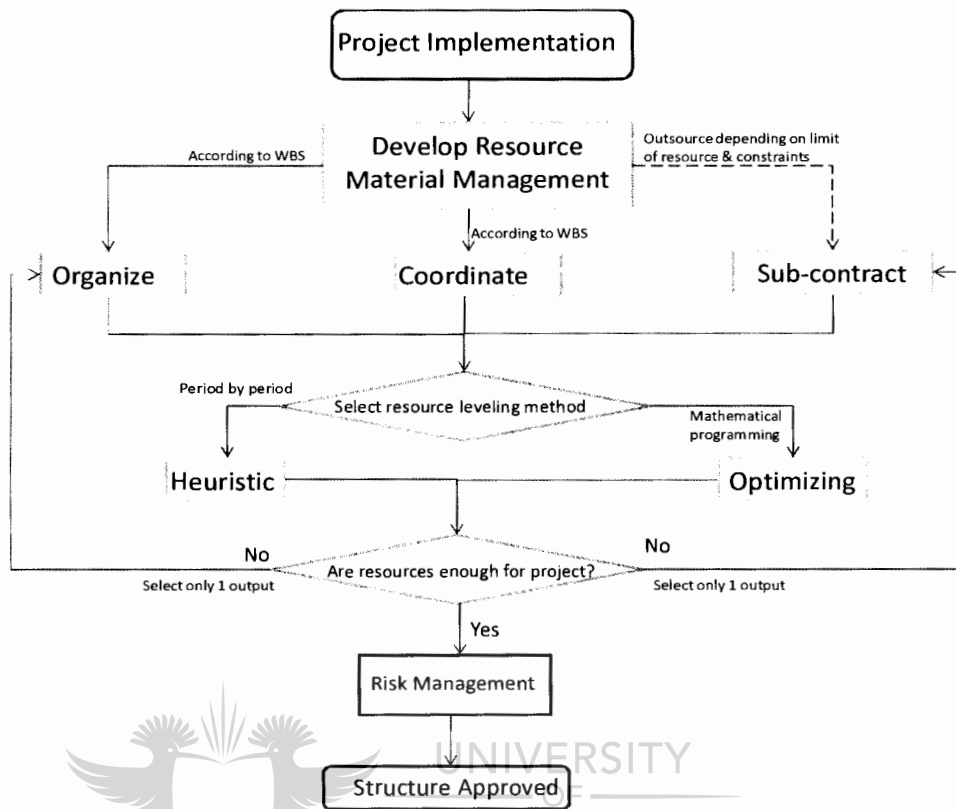




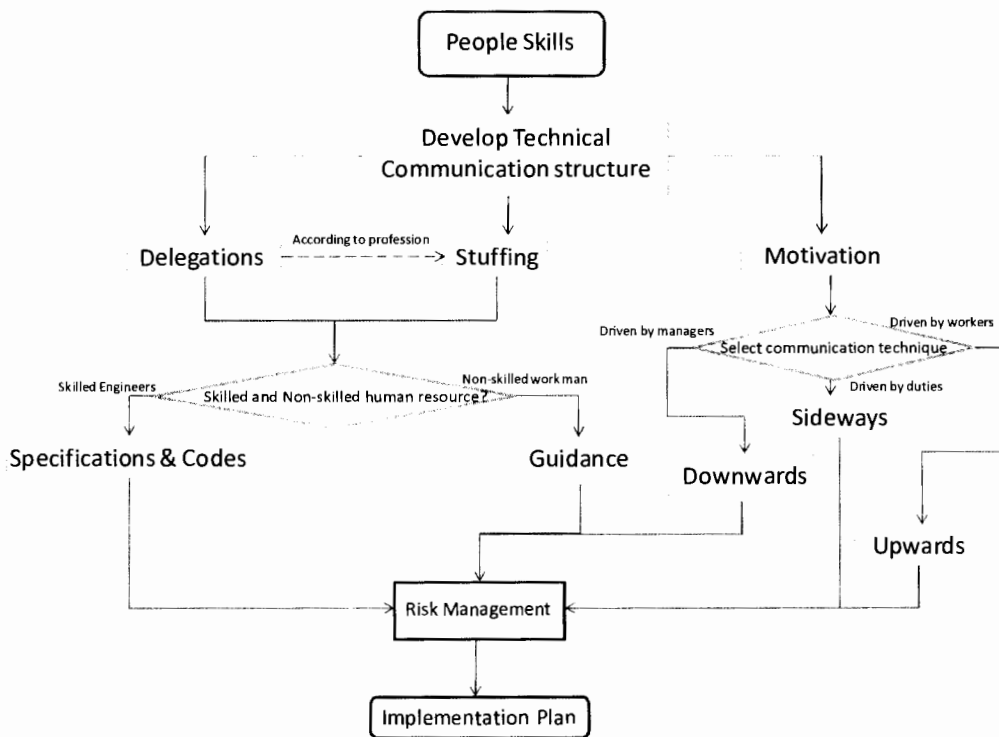
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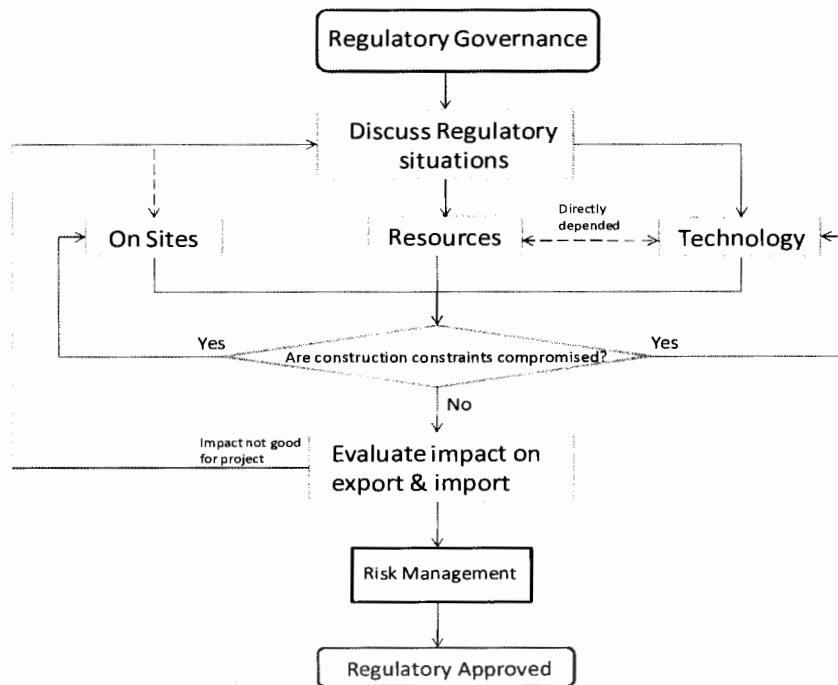
• Contractor-What



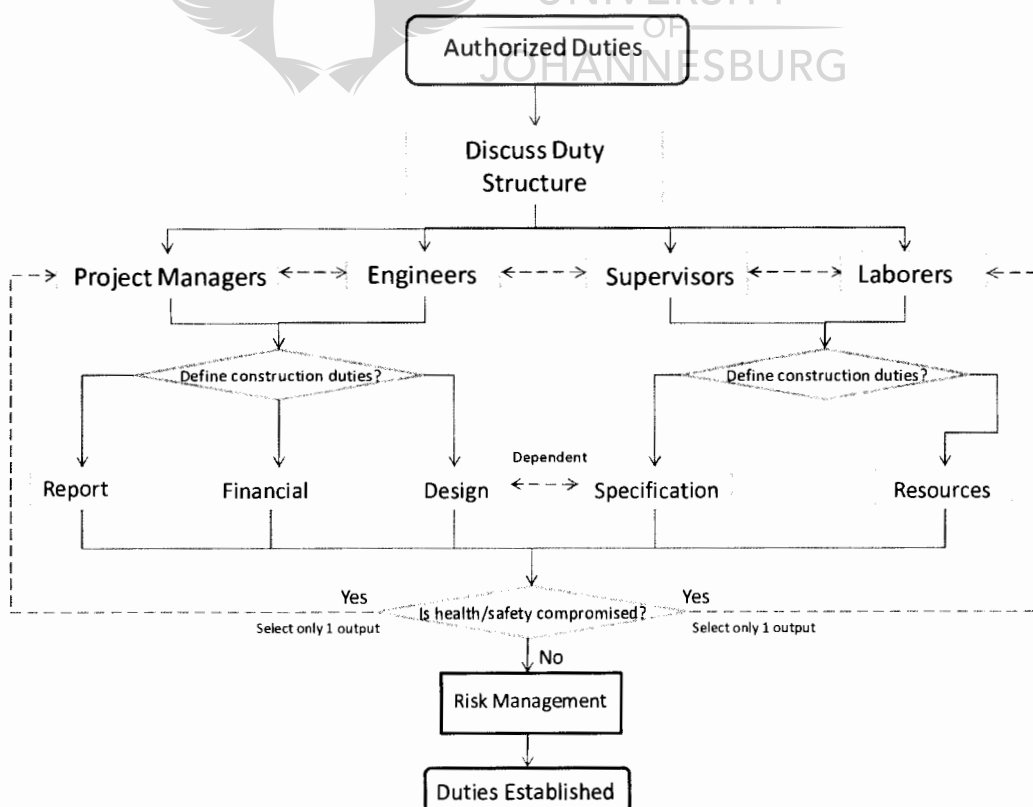
• Contractor-How



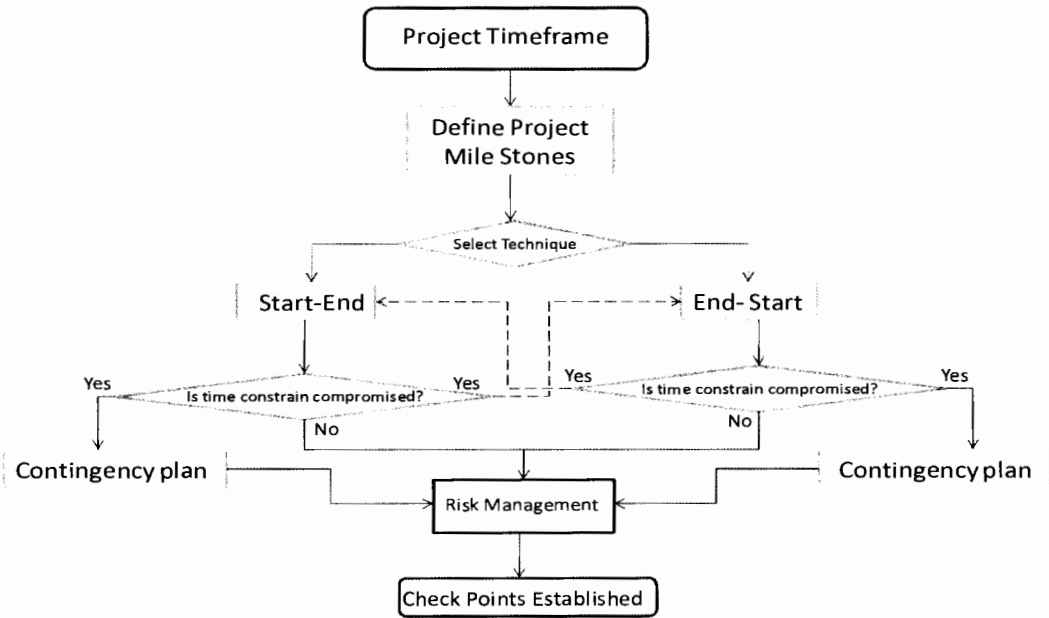
• Contractor-Where



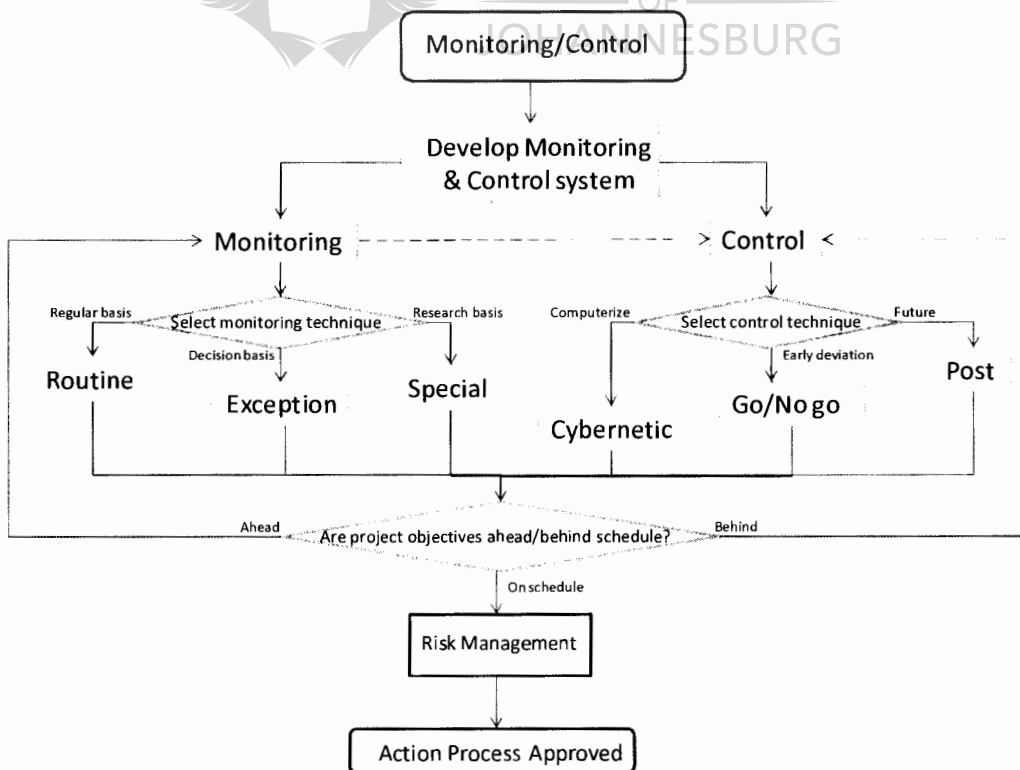
• Contractor-Who



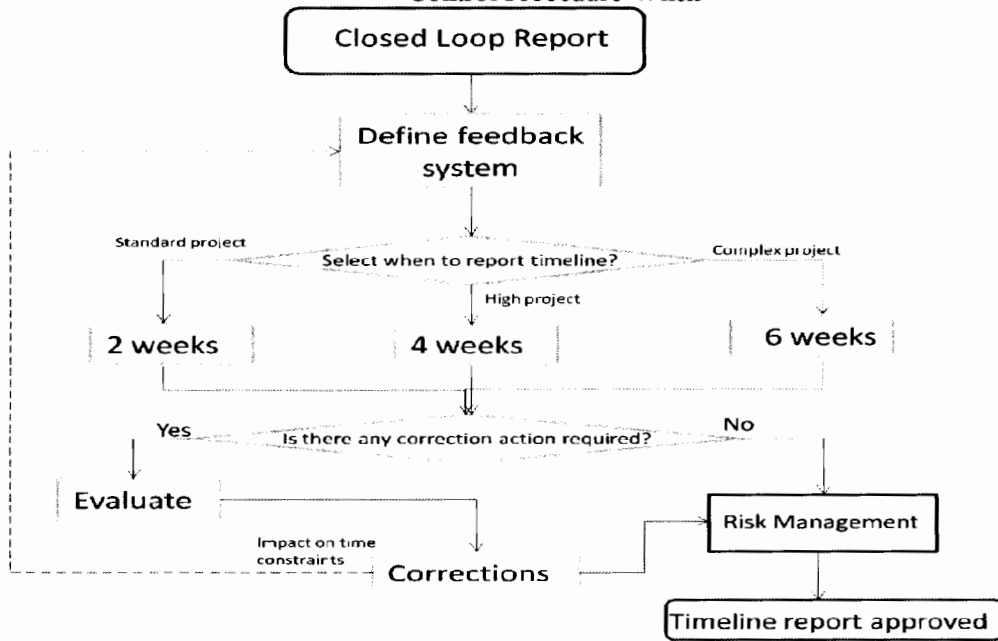
• Contractor-When



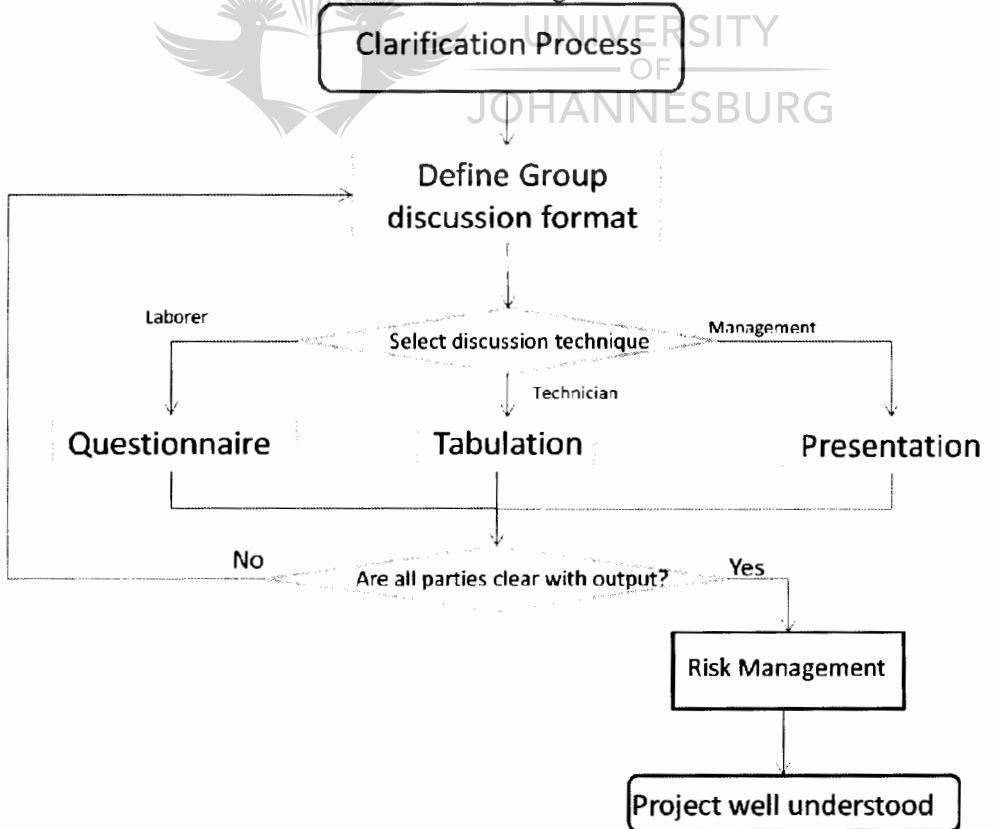
• Control Procedure-How



• Control Procedure-When



• Commissioning Process-How



### 5.3 OPERATIONAL PROCESS OF FRAMEWORK FOR CONSTRUCTION

There are many factors that need to be considered which may affect the inner city construction project, such as a melt down of the economy. For the purpose of completing the research study with reasonable and measurable solutions within the time constraints, it is only reasonable to deal with only direct internal factors to the project. However, since the inner city construction project is based in a developing country (Republic of South Africa), there will be some external factors considered as well.

Therefore in attempting to control the scope and implementing the Zachman Framework for Construction only direct material resources, physical resources, financial resources, internal risks and only political and economic external risks will be considered for this inner city construction project case study.

#### 5.3.1 Project Team-How (Planning Process)

##### a) Developing Work Break Down Structure-

By analysing the building plan drawings approved by municipality in figure 5.2, the layout of the 8<sup>th</sup> floor in the building allows a concise WBS to be implemented.



**Figure 5.4: 8<sup>th</sup> Floor WBS**

##### b) Select Scheduling Tool-

As this inner city construction project in the JHB CBD is a common project, it is neither unique in nature nor is it unique to the construction company. Therefore this leads to selecting CPM as a scheduling tool to be used. Through CPM the WBS is assessed into activities that are critical and non-critical.

The activities are the following:

1. Clearing floor (Demolishing and removal of waste)
2. Bricklaying (include door frames)
3. Plastering
4. Ceiling
5. Painting
6. Tiling (include floor and wall)

7. Plumbing (1<sup>st</sup> and 2<sup>nd</sup>)
8. Build in Cardboard (include kitchen units)
9. Electrical Installations (1<sup>st</sup>, 2<sup>nd</sup> and stove)
10. Ceramic Installations (toilets, basins, baths and showers)
11. Doors Installation
12. Cleaning (1<sup>st</sup> and 2<sup>nd</sup>)
13. Commissioning (electrical, fire escape and habitation)

A software tool common to all project managers to establish which activities are critical, Microsoft (MS) Office Project 2003 is used. At this point, a non technical investigation into the project is made in order to produce a Gantt chart on the Office Project. The non technical investigation includes questionnaire interviews with senior management about the labour pricing, manpower and materials required.

Through the interviews the following are noted:

1. Brick Laying- 110m<sup>2</sup> of double wall/day
    - 55m<sup>2</sup> of single wall/day
    - 100 bricks/brick layer/day
  2. Plastering- has a 3 days delay after bricking
    - 45m<sup>2</sup>/day
  3. Ceiling- 35m<sup>2</sup>/day
  4. Painting- has a 5 days delay after bricking/ceiling
    - 3 coats required for quality finish
    - 50m<sup>2</sup>/day
  5. Tiling- 45m<sup>2</sup>/day
  6. Plumbing- Outsourced
  7. Electrical Installations- Outsourced
  8. Commissioning Certificates- Outsourced
  9. Complete wet tasks first before other tasks
- c) Risk Assessing Techniques-

From the developed WBS, interviews and the selected scheduling tool together with the inner city construction project scope; the relevant risk techniques to be used to asses risk in the project are the following:

1. Expert interview
 

Again senior management of the project are interviewed regarding the risks involved with an inner city construction project. From the interviews the following risk were identified and qualified by using risk matrix in Chapter 3, figure 3.4:

  - Drawing risk (low probability, moderate impact: 2) - The drawing layout of the floor sometimes does not correspond with the bricklaying to be done.

- Power risk (moderate probability, high impact: 12) – The country is currently going through an energy crisis, therefore the lack of adequate power supply will impact on the project and therefore the schedule will be highly affected.
- Heritage risk (low probability, high impact: 6) – Since the building is a heritage site, government building regulations need to be adhered to.
- Supplier and resource risk (moderate probability, moderate impact: 6) – As a developing country, the inflation and country currency tend to be volatile with regards to the markets therefore affecting costs in a project. As well as some resources that might not be available in the country.
- Outsourcing risk (moderate probability, high impact: 12) – By outsourcing some activities, a positive or negative advantage may accrue on the schedule of the project.

## 2. Plan evaluation

Having done the Gantt chart on MS Project, the plan evaluation technique is implemented to analyse WBS elements, specifications and work to be done. From the evaluation the following risk(s) are identified and qualified by using risk matrix:

- Critical activities risk (moderate probability, high impact: 12) – If any of the critical activities are not completed on time, this affects the entire schedule
- Wet activities risk (low probability, moderate impact: 3) – All wet activities have delays on them, by starting or ending one late may result in an increase in delays.
- Commission activities risk (low probability, high impact: 6) – Activities such as fire and habitation not approved may have negative impact on entire project being completed.

Once all identified risks have been assessed using the techniques, they can be now classified into the following sections:

- Financial- critical, wet and commission activities
- Organization- outsourcing
- Technical- design (drawings)
- Policy- heritage
- Economy- supplier and resource
- Political- energy

The final stage in the risk assessing in the cell is to select a risk model for the inner city construction project. The standard risk model is selected as the project is not unique to the company and it can also be implemented in a risk matrix from.

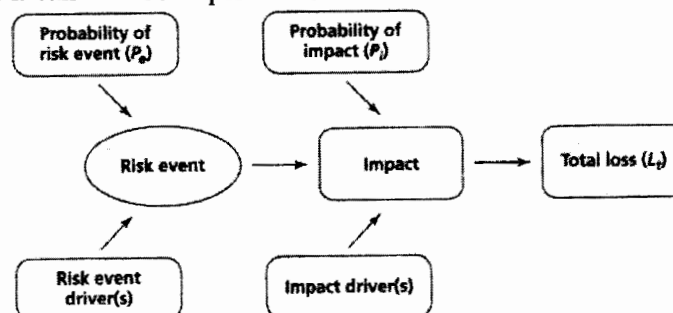


Figure 5.5: Standard Risk Model [13]



d) Preliminary Approval-

At this stage the project team has a good idea of the kind of work required to be done in the building and the risk events and drivers of the expected losses. This is a where pre-tendering is determined. If none of the parties agree at this point then Stage 1 of this cell is repeated until the last stage.

Once all project investors have come to an agreement on the estimated plan then it is preliminarily approved.

5.3.2 Project Team- When (Estimation Process)

a) Estimate accurate project resources-

With all activities well defined, it is important using MS Project to estimate and define resources to be controlled and monitored. From the WBS and schedule developed it can be seen the following resources are required:

- |   |  |
|---|--|
| <ul style="list-style-type: none"><li>• <b>Material:</b></li><li>Wall and floor tiles</li><li>Bricks</li><li>Cement bags</li><li>Paint</li><li>Taps</li><li>Sinks</li><li>Basins</li><li>Baths&gt;Showers</li><li>Electrical Fittings</li><li>Toilets</li><li>Electrical External/Internal Distribution</li><li>Stoves</li><li>Ceiling</li><li>Cardboards</li><li>Doors and window frames</li><li>Doors and handles</li><li>Mirrors</li><li>Smoke detectors</li><li>Fire escape signs</li><li>Security installation</li></ul> | <ul style="list-style-type: none"><li><b>Human:</b></li><li>Maximum of 18 workers/floor</li><li>Skilled bricklayers</li><li>Non-skilled bricklayer</li><li>Painter</li><li>Plumber</li><li>Electrician</li><li>Carpenter</li><li>Tiler</li><li>Plasterer</li><li>Supervisor</li><li>Senior Engineer</li><li>Project Manager</li><li>Non skilled worker</li></ul> |
|---|--|

Physical and material resources are depended on the finance available, it is imperative that cost is estimated as accurately as possible. Therefore a cost estimating tool is to be selected.

b) Selecting cost estimation tool-

As the project has been defined through WBS and using the Zachman graphical representation, Work-Element (WE) cost estimation is selected. Using the stated activities in the MS Project and the drawing plans, the following WE cost estimation is produced on a Microsoft Excel Worksheet on page 80.

**Table 5: Cost Estimation of a floor in the inner city construction project**

	No. of units/floor 3								
<u>Material</u>	<u>Total number</u>	<u>m<sup>2</sup></u>	<u>Rand/m<sup>2</sup></u>	<u>Rand/item</u>	<u>Rand/floor</u>	<u>Rand/unit</u>	<u>Tasks</u>	<u>Total Rand costs</u>	
Bricks	3055	280		R 1.00	R 3,054.55		Critical	R 379,934.82	
Ceiling (incl. Labour)		447	R 150.00		R 67,050.00		Material	R 403,846.82	
Tiles floor		432	R 120.00		R 51,840.00		Wet	R 207,134.82	
Tiles wall		385	R 100.00		R 38,500.00		Supplier	R 129,033.00	
Carbits					R 24,000.00	R 8,000.00	Commission	R 27,900.00	
Cement bags (bricking)	31			R 50.00	R 1,527.27				
Cement bags (plastering)		280	R 5.00		R 1,400.00				
Door (inside+handle)	11			R 400.00	R 4,400.00				
Doors(outside+handle)	3			R 600.00	R 1,800.00				
Paint (ceiling)		447	R 25.00		R 11,175.00				
Paint (walls)		280	R 25.00		R 7,000.00				
Bath	3				R 3,000.00	R 1,000.00			
Shower	3				R 7,500.00	R 2,500.00			
Taps	24				R 7,500.00	R 2,500.00			
Basins	6				R 6,000.00	R 2,000.00			
Stove (incl. Fan)					R 90,000.00	R 30,000.00			
Sink	3				R 3,600.00	R 1,200.00			
Toilet	8			R 1,000.00	R 8,000.00				
Elec. Fittings					R 24,000.00	R 8,000.00			
Elec. External/distribution					R 8,000.00				
Hole cutting Machine	5			R 2,300.00	R 10,000.00				
Security					R 10,000.00				
Smoke detectors					R 12,500.00				
Escape routes signs					R 2,000.00				
Pump	2			R 3,500.00	R 7,000.00				
Door Frames	20			R 125.00	R 2,500.00				
<u>Labour</u>			<u>Rand/m<sup>2</sup></u>	<u>Rand/day</u>		<u>Rand/person</u>	<u>No.people/team</u>	<u>Rand/floor/team</u>	
Bricky (skilled)				R 150.00		R 1,500.00	2	R 3,000.00	
Bricky (non-skilled)				R 95.00		R 950.00	4	R 3,800.00	
Elec. (external & internal)				R 225.00		R 2,925.00	1	R 2,925.00	
Plumber (All plumbing tasks)				R 200.00		R 4,400.00	3	R 13,200.00	
Tiler (floor & walls)			R 35.00			R 28,595.00	2	R 57,190.00	
Plaster			R 20.00			R 5,600.00	2	R 11,200.00	
painter (ceiling & walls)			R 12.00			R 8,724.00	2	R 17,448.00	
Driller				R 400.00		R 1,200.00	1	R 1,200.00	
Certificates					R 1,000.00				
Fire installation				R 800.00				R 2,400.00	
Cleaning crew (non-skilled)				R 95.00		R 570.00	1	R 570.00	
Carpenter				R 175.00		R 2,800.00	2	R 5,600.00	
						<u>Cost/Floor</u>			
						<u>Total</u>		R 532,879.82	
						<u>Cost/m<sup>2</sup>/Floor</u>			
						<u>Total</u>		R 1,233.52	

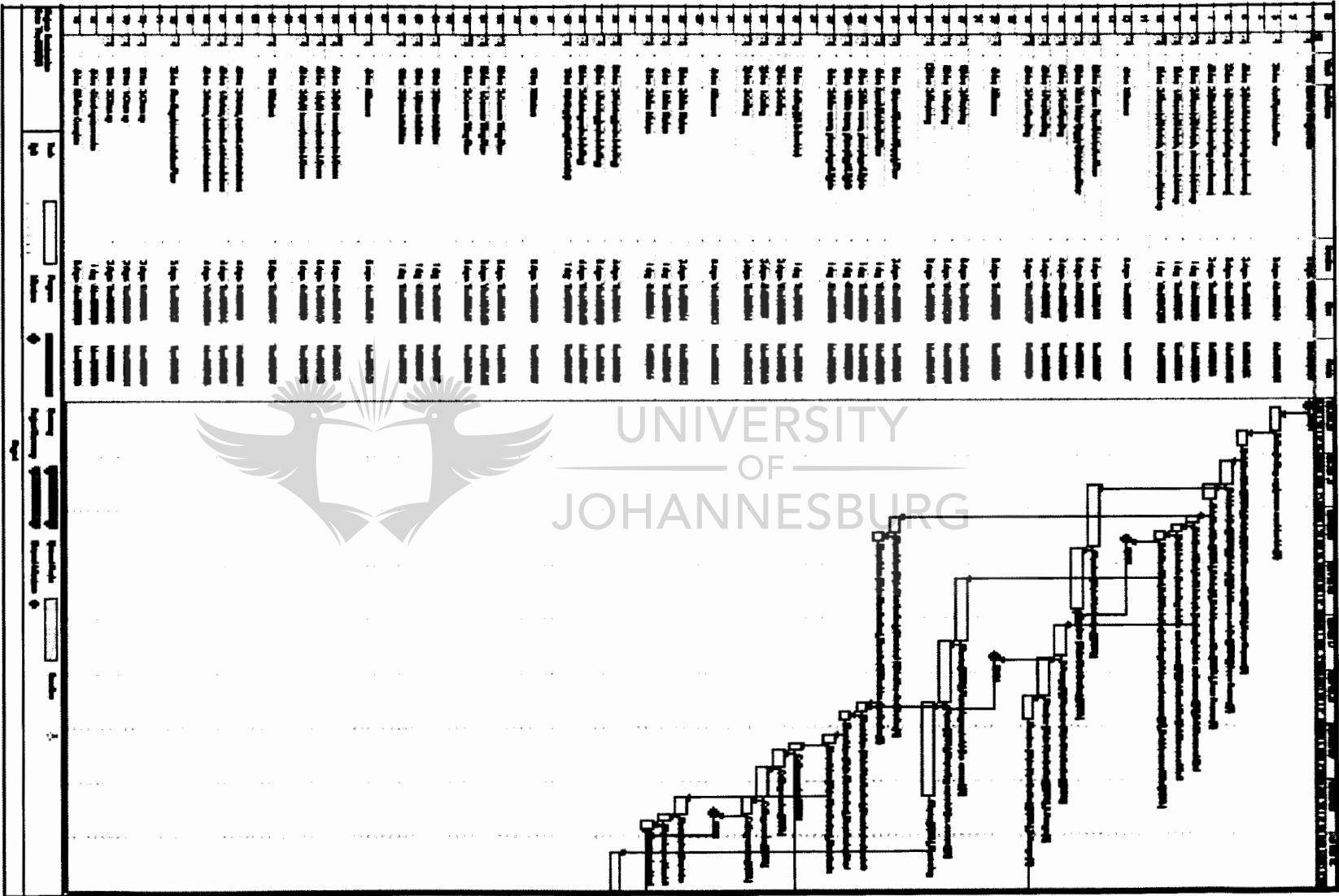
**a) Select Resource allocation method-**

With all direct resources well defined and cost estimated, the next important factor to be considered in the cell is the allocation of physical (human) resource to each activity. At this stage resource allocation heuristic resource method is selected and implemented to allocate resources to each activity. This method allows the shortest activities, the critical activities and minimum slack activities respectively to be levelled accordingly.

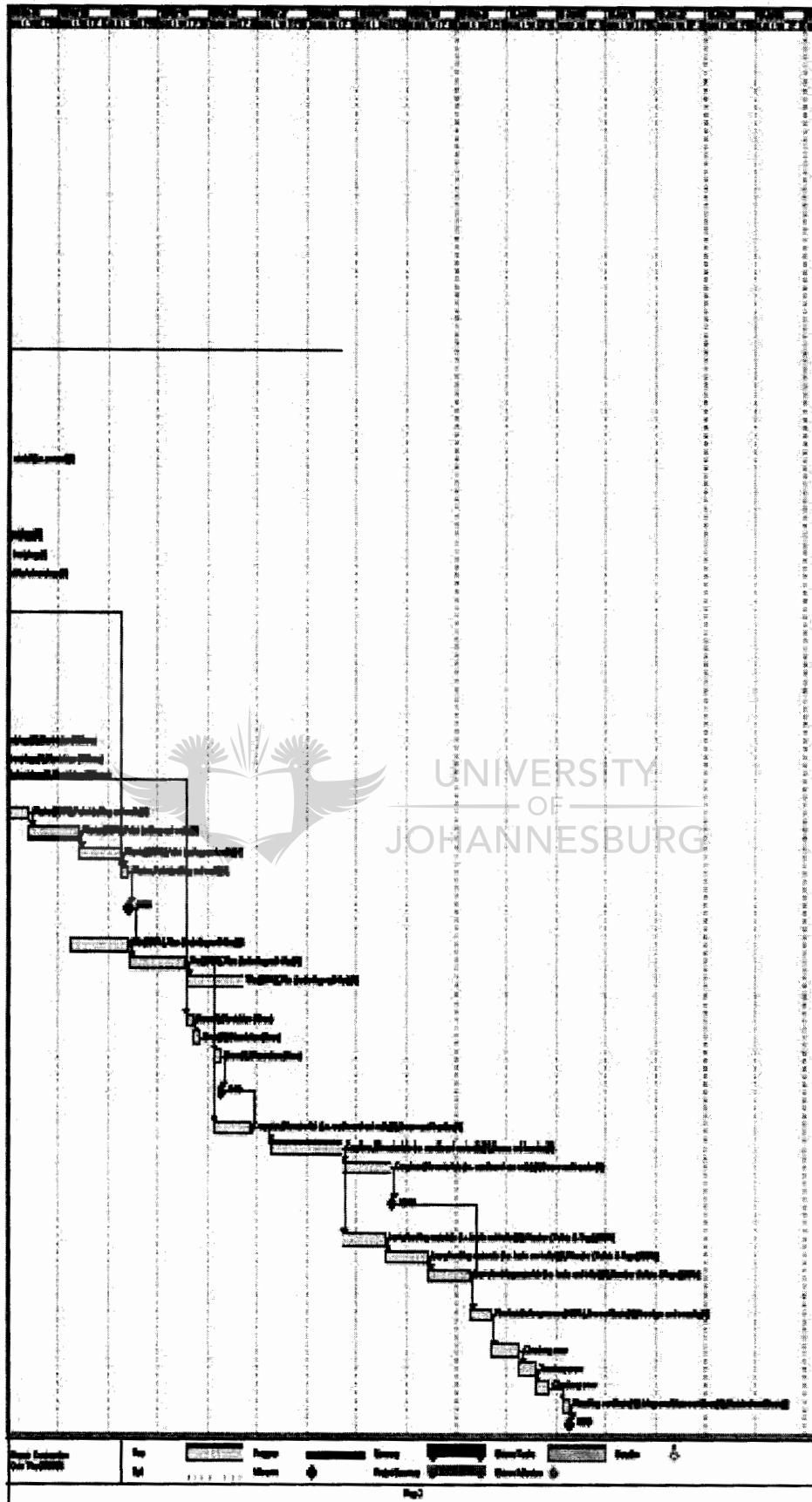
The method also allows each activity not to be allocated the same human resource name; as it is separated according to the WBS. What this means is that although you have one electrician for the entire inner city construction project, he is allocated to different activities on different days. This means that when allocating the human resource name it should be different for each activity. For example; the human resource name allocated to power distribution activity is electrician (main distribution) and stove connection activity is allocated as electrician (stove). This procedure allows fewer errors and minimum resource confusion when tracking a project throughout its project lifecycle.

The allocation method together with the fact that only 15 workers/floor has an effect on each activity's time frame constraints. Therefore allocating resources allows a more accurate ideal scheduling of the inner city construction project as seen on the MS Project Grant chart provided on the following page.





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Please see attached CD for MS Project Plan

a) Resource Estimation Approval-

Estimations are just that, estimations. They have errors that should be carefully considered especially when it comes to finance. At this stage of the inner city construction project, all investors are to agree on estimated resources and cost required for each activity in order for approval to be granted but it is imperative that contingency plan(s) are put into place first.

*Contingency Plan 1- Materials and Subcontractors:*

With a wide variety of material suppliers available on the market, a contingency plan has to have a flexible supply chain. By not being in agreement with one supplier and/or subcontractor, the budget can be manipulated if there is a need to do so.

*Contingency Plan 2- Energy Crisis:*

Due to that the country is currently in an energy crisis, it is important to have a contingency plan regarding this factor as power supply lifts are used to transport resources up and down the building. By having a dedicated individual tasked to monitor the load shedding time schedule, it is possible to control when and where to transport important resources through the building; thus decreasing the impact of the energy crisis on the schedule of the project.

b) Risk Estimations-

The estimation risk in this cell allows monitoring of financial and economic risks through a ranking matrix to establish the expected losses in the inner city construction project by using the standard risk model since its risk response can only be acceptance and mitigation.

**Table 6: Risk Matrix of Inner City Construction Project**

Financial Risks	Identified risk	Probability Impact	Probability event	Likelihood	Total Loss (days)	Total Loss (costs)	Expected Loss (days)	Expected Loss (costs)
1	Critical	1.0	0.7	0.67	103	R 379,934.82	68.7	R 25,4556.33
2	Wet	0.5	0.3	0.17	39	R 207,134.82	6.5	R 35,212.92
3	Commission	1.0	0.3	0.33	3	R 27,900.00	1.0	R 9,207.00
Economic Risks								
1	Suppliers	0.5	0.7	0.33	156	R 129,033.00	52.0	R 42,580.89
2	Resources	0.5	0.7	0.33	176	R 403,846.82	58.7	R 13,3269.45
Ranking	Identified risk	Probability Impact	Probability event	Likelihood	Total Loss (days)	Total Loss (costs)	Expected Loss (days)	Expected Loss (costs)
1	Critical	1.0	0.7	0.67	103	R 379,934.82	68.7	R 25,4556.33
2	Resources	0.5	0.7	0.33	176	R 403,846.82	58.7	R 13,3269.45
3	Suppliers	0.5	0.7	0.33	156	R 129,033.00	52.0	R 42,580.89
4	Wet	0.5	0.3	0.17	39	R 207,134.82	6.5	R 35,212.92
5	Commission	1.0	0.3	0.33	3	R 27,900.00	1.0	R 9,207.00

Therefore this amount of probability impact and event of both financial and economic risks will be monitored and measured throughout the project lifecycle by the project team. This information is to be handed in together with project team documents for approval of plan by project sponsor.

### 5.3.3. Project Sponsor Owner- When (Project Constraints)

#### a) Define project restrictions-

It is important that restrictions of the project after planning are discussed with the project owner. At this stage the project owner is presented with ideal total cost, time scope of the project and then the owner must define only one out of the three. With the one defined it is possible to determine either how far the budget, scope and/or time can be stretched. Unfortunately quality output can never be compromised so it is only defined by project manager.

The estimation of the ideal total cost, time and scope of the project is the following:

- Time- Six months and two weeks (as shown in MS Project Grant Chart)
- Scope- Eighth floor only, three units/floor
- Cost – R 532,879.82
- Quality- High finish residential apartments

#### b) Owner defines one constraint-

The project owner has chosen to define cost as the primary variable to control. Therefore the cost constraint is R730 000/floor as stipulated by the project owner. This constraint excludes indirect costs.

#### c) Constraint risk realistic-

Due to client defining constraint, this affects the time and performance in the inner city construction project. Therefore it is imperative that the project team model the thresholds of the probabilities thoroughly to be monitored through risk qualification.

**Table 7: Risk Matrix of Inner City Project Constraints**

Constraints (Triangle Rule)	Identified risk	Probability Impact	Probability event	Likelihood	Calc. Constraints	Expected added Costs	Expected added Scope	Expected added Time
1	Client (financial)	0.83	0.40	0.32	R 532,879.82	R 170 521.54		
2	Scope	0.72	0.50	0.36	100%		35%	
3	Time Frame	0.78	0.50	0.47	15-Jul			20-Oct

With the total direct expected added cost being under the estimated defined cost constraint which is given by owner, all project constraints are now authorised by all parties involved and monitored together with the plan evaluation technique in the previous row.

### 5.3.4. Consultant-What (Technical Process)

#### a) Segment project problem technically-

Segmenting and assigning the project activities into different engineering disciplines allows a simpler approach by tackling the project technically. The developed WBS activities from the previous row are segmented into the following disciplines:

- **Mechanical activities:**  
Pump system installation activities  
Gas system installation activities  
Generator installation activities
- **Electrical activities:**  
External electrical system distribution activities  
Internal electrical system distribution activities  
Generator installation activities
- **Civil activities:**  
Building process activities  
Resource management activities  
Fire system activities
- **Other disciplines activities:**  
Outsourced activities  
Commissioning activities

b) Representation of disciplines in WBS-

It is important that the disciplines cover all activities mentioned in the project WBS. If not, then they fall under other disciplines until each activity is represented by some form of engineering discipline.

When looking at the inner city construction project, we see that all activities have been placed in their respective discipline. This makes the next step of identifying technical risks easier as each discipline has their own professional input.

c) Engineering risk data according to discipline-

- Risk identified in Mechanical discipline to be compared to SABS:  
Site risk identified- Gas system safety data (leakage of gas into apartments)
  - Generator system safety data (maintenance and leakage of fumes into atmosphere)
  - Pump system safety data (maintenance)
- Risk identified in Electrical discipline to be compared to SABS:  
Site risk identified- Installation system safety data (cable theft and earth leakage)
- Risk identified in Civil discipline to be compared to SABS:  
Site risk identified- Security of the area (equipment and labour safety)
  - Implementation (maximum labour/floor, protective clothing, behaviour)
- Risk identified in Other disciplines to be compared to SABS:  
Subcontractor risk identified- Contractor's capability (history of successful inner city projects data)
  - Quality assurance (benchmark final product)
  - OHSA

Once all activities have been represented by their specific discipline together with their identified risk data, it can be safely assumed that engineering implementation process can take place.



### 5.3.5 Consult-How (Technical Methodologies)

#### a) Develop detail design of project-

The detail design approach to the project is done according WBS. When analysing the inner city construction project, the following approach is taken for drawings and calculations:

- **Drawings:**  
Architecture discipline  
Medium complexity  
Methodology selected to be computerized  
Output figure 5.2
- **Calculations:**  
Mechanical discipline (Pump calculations and Gas calculations)  
Civil discipline (Structure calculations)  
Electrical discipline (Generator and wiring calculations)  
Other discipline (Other calculations)  
Historical data available  
Methodology selected to be logical

#### b) Detail design risk likelihood affecting project constraints-

It is crucial that all calculations and drawings of the detail design support and fall within all project constraints. Therefore relevant risk technique to be used to qualify risk in the design stage of each discipline is the risk matrix technique (figure 3.4) through expert interviews and documentation reviews.

Mechanical design risk matrix:

- Gas risk (low probability, high impact) – 6
- Generator risk (low probability, moderate impact) – 3
- Pump risk (low probability, low impact) – 1

Electrical design risk matrix:

- Installation risk (low probability, high impact) – 6

Civil design risk matrix:

- Security risk (moderate probability, high impact) – 6
- Implementation risk (low probability, moderate impact) – 3

Other design risk matrix:

- Capability risk (moderate probability, moderate impact) – 6
- Quality risk (moderate probability, high impact) – 12

As the design risks qualifications influence on the project disciplines are completed successfully, the construction detail drawings and calculations are signed off.

### 5.3.6 Consult- Where (Ecological Impact)

#### a) Discuss ecological structure-

With every project, the ecological aspects have to be satisfactory. A social, environmental and economical look is discussed in this cell concerning the inner city construction project's ecological outputs in the location it is based at.

- **Social impact of project:**  
Job creation for the people of JHB CBD  
Better living conditions  
City rejuvenation
- **Environmental impact of project:**  
Less energy used by building's electricity  
Use solar heating to reduce electricity as well as gas to reduce dependence  
No landscape changes, building structure remains the same  
Heritage value retained
- **Economical impact of project:**  
Increases value of the property in JHB CBD  
Contribution to the revenue services of the country

#### b) Ecological risk to be monitored-

Due to the fact that the inner city construction project is based on the inhabitants, its negative environmental impact needs to be as minimal as possible and in this case a certificate of habitation will not be issued if the project does not comply with the standards.

Therefore the environmental risks to be monitored during the inner city construction project are health and pollution risks. According to the historical data in Table 4 of Chapter 3.6, the likelihood of such environmental risks is at 0.026% of the value to the construction project, complying with the codes of standards within the country.

#### c) Ecological report approved-

As the social, positive environmental and economical impacts outweigh the negative outputs then an ecological approval is granted towards building the project as long as it remains within the agreed environmental standards.

### 5.3.7. Consult-Who (Engineering disciplines)

#### a) Roles and responsibility of professionals in project-

With every project the roles should be well defined in order to know who is responsible for an activity's progression and to avoid confusion. The following professional roles and responsibility for the inner city construction project are noted below:

- **Mechanical professional:**  
Model pump and gas systems  
Graphically represent model and functions to team  
Delegate and monitor progress of system implementation
- **Electrical professional:**  
Model internal and external electrical systems  
Graphically represent model and functions to the team  
Delegate and monitor progress of system implementation
- **Civil professional:**  
Model building and resource management processes  
Graphically represent model and functions to the team  
Delegate and monitor progress
- **Other disciplines professional:**  
Model other discipline professional starting and ending timeframe(s) in the project  
Define and monitor accountability according contract

b) Defining risk response process and techniques according to roles-

With each specified roles and responsibility of the inner city construction project, there must be a modelled process of responding to identified risk occurrence. Therefore each discipline defines its own response techniques to its roles in the following manner to the inner city construction project organization:

- **Mechanical risk response:**  
Risk avoidance- expert interviews and planning techniques  
Risk alternative- brainstorming and swot techniques
- **Electrical risk response:**  
Risk avoidance- expert interviews and planning techniques  
Risk alternative- brainstorming and swot techniques
- **Civil risk response:**  
Risk active acceptance- network analysis technique  
Risk mitigation- response matrix and contingency plan techniques
- **Other disciplines risk response:**  
Risk mitigation- response matrix and contingency plan techniques

This stage of the cell provides an overview of all roles and responsibilities which exist in the project team together with response techniques defined according to WBS. This makes it simpler to approve the roles of the professionals.

### 5.3.8. Consult-When (Project technical fault life cycle)

#### a) Fault occurrence in project life cycle-

Throughout the project life cycle, errors will occur and this cell puts mechanisms as to how engineering disciplines will deal with those errors. Depending on the complexity of the fault and the complexity of the project, either re-engineering or upgrading system techniques could be selected.

Since the current project is low in complexity, it is eminent that only system upgrading technique will be used.

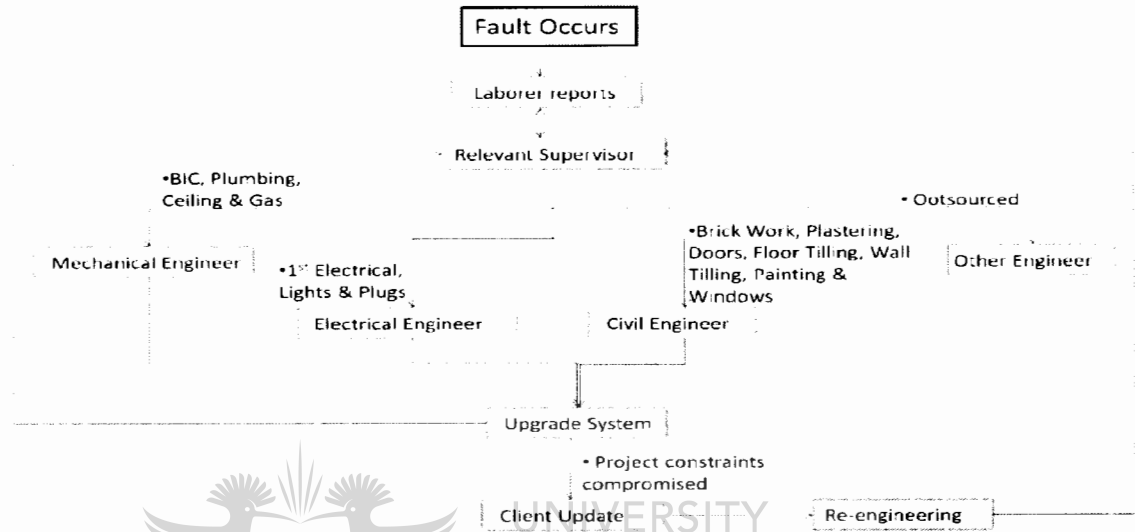


Figure 5.7: Fault Occurrence Model

#### b) Project risk fault monitoring and control process according to discipline-

During the system upgrade, project constraints will be possibly compromised, then re-engineering will take place and client will be contacted. However, if the risk techniques used to monitor and control the upgrades is defined according to its discipline, then clients tend to want to redefine some constraints in the inner city construction project.

- **Mechanical risk monitoring and control:**  
Plan evaluation and project templates techniques
- **Electrical risk monitoring and control:**  
Plan evaluation and project templates techniques
- **Civil risk monitoring and control:**  
Performance tracking technique
- **Other disciplines risk monitoring and control:**  
Contract documentation reviews technique

Once the project fault is resolved using the cell's processes and techniques; the construction in the inner city project is implemented.

### 5.3.9 Contractor-What (Project Implementation)

#### a) Develop material resource management structure-

In order project not to be delayed, material resources need to be organised and co-ordinated effectively according to their specific activities. A project manager organises the material and the supervisor co-ordinates the material, making sure it is available at the right place and time. The structure shows what material needs to be co-ordinated:

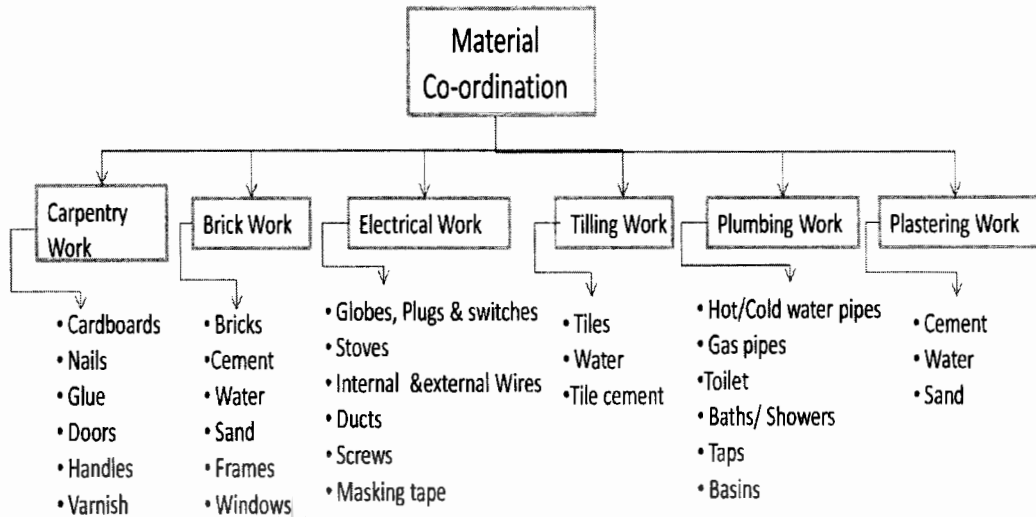


Figure 5.8: Material WBS

#### b) Selection of resource levelling method-

Given that the inner city construction project is segment according to WBS activity and it is a repetitive project, heuristic resource levelling method is selected. The following MS Project resource graph shows an example of how skilled bricklayer activity resources are levelled in the project:

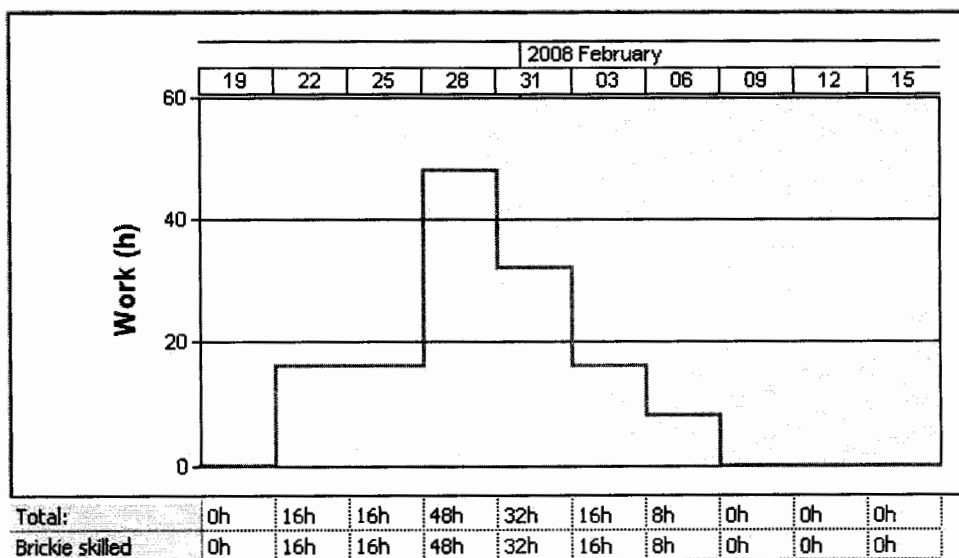


Figure 5.9: Skilled Brickie MS Project Resource Graph

c) Identifying availability in material risks-

Any levelling method of materials in the inner city construction project introduces risk within the contractor models due to material availability when required. Therefore the techniques used to store data required to identify material risk for the contractor are as follows:

1. Plan Evaluation- stores data that represents required materials within each WBS (timing of delivery of materials)
  - Stoves, basins, baths to be delivered on exact specified time frame otherwise a delay in the project will occur as well as storage space will not be available is delivered sooner or later.
2. Documentation reviews- stores data that determines sufficiency of material at each review (timing of completion of materials)
  - Sufficient material is required at all times otherwise a cost is incurred in standing labour rates.

An approval of the construction is granted once risk within material resources are well levelled to its activity and not hindering the processes and performance of the contractor's models.

5.3.10 Contractor- How (People skills)

a) Develop technical communication structure-

Clear communication is the key to a successful project. It is important that delegation, staffing and motivational structures are well defined. In this cell, the project communication structure is established as line/staff structure communication and the motivation technique as sideways technique. This communication flow is as follows:

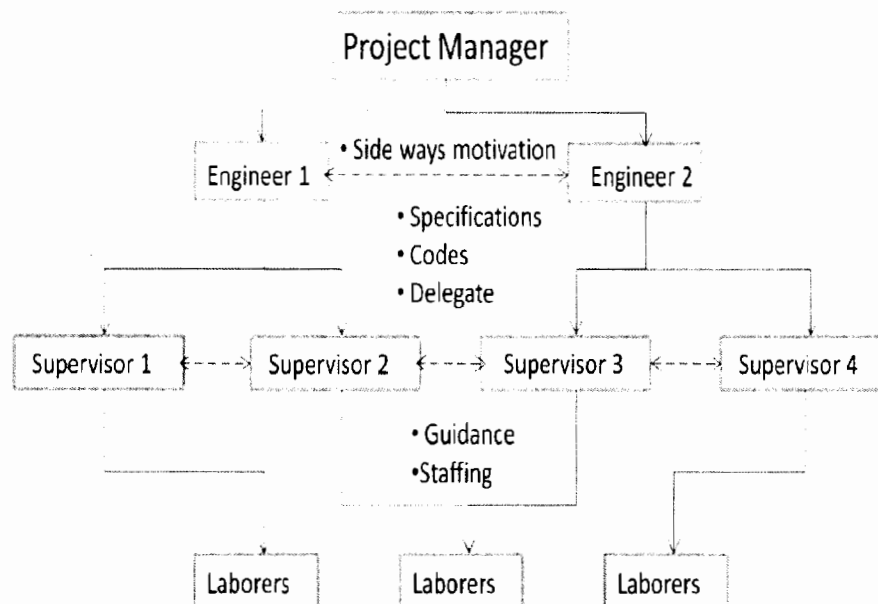


Figure 5.10: Communication Flow Structure

b) Technical risk techniques assessment-

It is important that the technical communication structure allows a development of technical skills during the inner city construction project as changes in technology may have an impact of project objectives. This is highly dependent on the labour standards and levels within the country of construction.

To assess the probability and impact of such risks, a risk rating matrix technique is selected together with analogy comparison and expert interviews:

- Technological development in RSA construction (moderate probability, low impact)- 2
- Skills development in RSA construction (low probability, high impact)- 6

By the assessment of technical and skill development amongst the labourers, the contractor is able to offer motivation thresholds to the inner city construction project.

5.3.11 Contractor-Where (Regulatory Governance)

a) Discuss regulatory situations-

It is important that all regulatory situations are known beforehand the site in order to improve working conditions and prevent compromising project constraints. The regulatory situations to the project are as follows:

- **On Site situation:**  
Heritage of building to be maintained  
Labour law to be adhered to  
Exterior Quality finish
- **Resources and Technology situation:**  
South African human resource to be employed  
BEE candidates to be considered  
SABS codes of standard followed  
Certified equipment only  
OHSa regulations

b) Monitoring and controlling risks in trading resources-

The regulatory situations are likely to affect the project constraints and impact on resources of the inner city construction project. By monitoring and controlling labour law and trading risks through a selected risk monitoring and controlling technique(s) the project manager is able to minimise the effect.

- **Labour and trading law monitoring and controlling risk:**  
Workers union documentation reviews  
Department of trading documentation reviews

With the inner city construction project all resources required for completion of project are locally available. Thus export trading risk can be ignored when it comes to documentation reviews.

### 5.3.12 Contractor-Who (Authorised Duties)

#### a) Discussion of duty structure-

In order to avoid any conflict during the inner city construction project, clear authorities need to be well defined towards the project team in this cell.

- **Project Manager:**  
Organises and monitors the all the resources of the project, especially finance  
Develops and controls the activities  
Communicates with the engineer  
Reports to project owner on a monthly bases
- **Engineer:**  
Designs all the technical requirements of the project  
Makes sure that the project stays in budget  
Monitors and controls the activities  
Communicates with supervisor
- **Supervisor:**  
Makes sure that all the specifications are followed so that quality is not compromised  
Controls the resources of the project, especially material  
Communicates with the engineer
- **Labourer:**  
Does the actual work of the activities  
Uses the resources available  
Communicates with supervisor

#### b) Site and human error risk response process-

With the specified duties outlined of the inner city construction project, there must be modelled specified process for each duty in responding to identified risk occurrence due to site and human error.

- **Project manager risk response:**  
Risk alternative- brainstorming and SWOT techniques  
Risk mitigation- response matrix and contingency plan techniques
- **Engineer risk response:**  
Risk alternative- brainstorming and SWOT techniques  
Risk mitigation- response matrix and contingency plan techniques
- **Supervisor risk response:**  
Risk active acceptance- network analysis technique  
Risk transfer- expert interview technique
- **Labourer risk response:**  
Risk transfer- expert interview technique



By selecting response techniques to the human and site errors that the OHS Act as applied to the inner city construction project not to be compromised when execution of activities takes place.

#### 5.3.13 Contractor- When (Project Timeframe)

##### a) Define project milestones-

Milestones signify stages in the project where the project manager checks if project constraints are being compromised or are still on track. It is important to select a technique according to deadline of project.

The technique selected for the project is start-end because residential projects such as the inner city construction project are not catastrophic if the deadline is missed however it should be always noted that it may cause the company a huge deficit in its budget.

##### b) Milestone risk monitoring and control process-

It is important that at all milestones are accurately used to analyse all activities through a monitoring process. This is the point when a project manager considers the implications of a contingency plan(s) on the financial risks.

- **Financial milestone monitoring and controlling risk:**  
Checklist process on improper estimation on current state of project  
Project evaluation process according to contingency plan(s)

Through adding the financial risk monitoring processes that need to be considered at each milestone of the inner city construction project, it provides information for the project team in making decisions on contingency plan(s) for the finance.

#### 5.3.14 Control Procedure-How (Monitoring & Control)

##### a) Develop and selecting monitoring and control systems-

Monitoring and control systems have to be put in place to observe the project output and compare it with the ideal states. These systems provide a process to the project manager in deciding if it is necessary to take any action accordingly.

- Monitoring system selected- Routine System according to WBS due to that the project is not unique and done on regular bases.
- Control system selected- Go/No Go System according to WBS due to that early deviation on project will minimize impact on project schedule.

##### b) Reassess internal risk-

It is important to reassess the risk involved in the inner city construction project in case new risks have developed. Therefore a risk technique(s) is required to be selected in order to continuously analyse risk and justify the actions of the project manager.

- **Reassessment risk technique:**  
Risk review selected- Identifies risk through WBS, qualify previous and new risk and reassesses responses  
Brainstorming on a regular basis

Through monitoring and control system in place together with reviewing risk, the inner city construction project objectives can be noted to either being ahead or behind schedule therefore any action process can be justified by the current situation.

### 5.3.15 Control Procedure-When (Closed Loop Report)

#### a) Define feedback system and report-

Feedback provides an on-going evaluation of time constraints to the project. By using feedback system of the data obtained from monitoring a timeline a report correction is determined. Since the inner city construction project is standard to the project team then a minimum of two weeks timeline is selected.

- **Report questionnaires for team leaders (i.e. supervisors) every two weeks:**  
How much of material and human resources used (i.e. bricks and brickie)?  
What is the duration that one took to complete the previous activity?  
What is the problem(s) that one is encountering if any?  
Recommend solution to problem.  
Discuss the steps one will be taking in the next activity.  
Estimate completion of next activity.

#### b) Risk in report documenting-

Incorrect documenting of a report may cause the project team be unaware of the new risks within the inner city construction project. Therefore a systematic procedure of risk monitoring and controlling of documenting in routine reports has to exist in the inner city construction project and is as follows:

1. Appoint a technical individual who understand risk to collect information
2. Establish a clear, open and easy excess risk communication forum
3. Develop a filling system for each activity exposed to risk separately
4. Provide performance tracking charts
5. Reward excellent risk documenting of activities

By feeding back accurate and controlled information tabulated in reports to the inner city construction project objectives, the negative impact on correction evaluation procedures is reduced.

### 5.3.16 Commissioning/Closure Process-How (Clarification Process)

#### a) Define group discussion format-

The discussion format is significant with all projects as it provides a platform of a learning process by clarifying any errors that have occurred. A questionnaire format for the labourers is used; tabulation for engineers and a presentation format is used for project managers.

- **Questionnaire:**  
Which activity did you enjoy?  
What did you enjoy about it?  
Which activity was your biggest problem during the project?  
What was the problem and was it recognised on time?  
When did the problem occur?  
How did you and your supervisor solve the problem?
- **Tabulation:**  
Cost Data  
Time Data  
Performance Data
- **Presentation:**  
Project objectives  
Project constraints  
Project achievements

b) Clearance of inner city construction project-

It is important that the final product of the inner city construction project is at a high quality and all activities together with their risks if any are audited properly. If this is not done correctly, it could result in clearance being denied therefore hindering the success of the project.

**To minimise clearance risk, a technique(s) is selected for this procedure:**

Risk Auditing technique- audit all risks throughout the project specifically environmental clearance risk.

It is vital that all parties involved in the project together with project owner are clear and satisfied with the objective outputs of the inner city construction project during group discussions and auditing.

## 5.4 CONCLUSION

Through the developed Zachman Framework for Construction, the inner city construction project management phases and risk management phases have been dissected into simpler applications. The framework has also provided a critical way to examine the case study without ignoring continues risk assessment and risk technique(s) selection according to related activities of the chosen framework cell. Therefore resulting in processes such as interviewing, communication and scheduling of activities easier to recognise, analyse and implement.

Although one can argue that the Zachman Framework for Construction has done this very well, the framework does not satisfy one of the objectives of the research study. This is to graphically represent and achieve risk quantification at each cell, making it easier to thoroughly reduce the degree of uncertainty involved with each activity and sum up risks through all columns or rows. However this may only be possible through an integrated tool that combines the framework with project activity constraints and its development is discussed in detail in the following chapter.

## CHAPTER 6

### AN INTEGRATED FRAMEWORK RISK MANAGEMENT TOOL

#### 6.1 INRODUCTION

When managing a project together with its risks involved, there will always be an existence of a certain amount of uncertainty. This uncertainty cannot be eliminated but however reduced by introducing and increasing project confidence [13]. Risk quantification is the application of risk management which introduces project confidence by numerically assessing identified risks within the project as mentioned in Chapter 3.3.3 through simulation techniques.

Since WBS has been used in analysing the inner city construction project therefore it is only appropriate to select a risk quantification technique that allows project simulation according to the WBS. Noted in Chapter 3.3.3, the most popular simulation technique used to estimate the uncertainty and risk in each element of the WBS is the Monte Carlo technique.

In this Chapter, the Monte Carlo simulation technique is selected to be the integrated framework risk management tool which links the Zachman Framework of Construction with MS Project Gantt chart. This is done in order to graphically represent the confidence in each project activity constrain according to its identified risk(s) within its selected framework cell.

#### 6.2 INTEGRATED TOOL FUNCTIONALITY FLOW CHART

The developed integrated risk management tool should be simple to use and understand by most if not all users. It should be designed around frequently used programmes that are found in the every day life of a student, home user, office user and project manager. Therefore figure 6.1 below shows the functionality flow chart of a simple to use integrated tool.

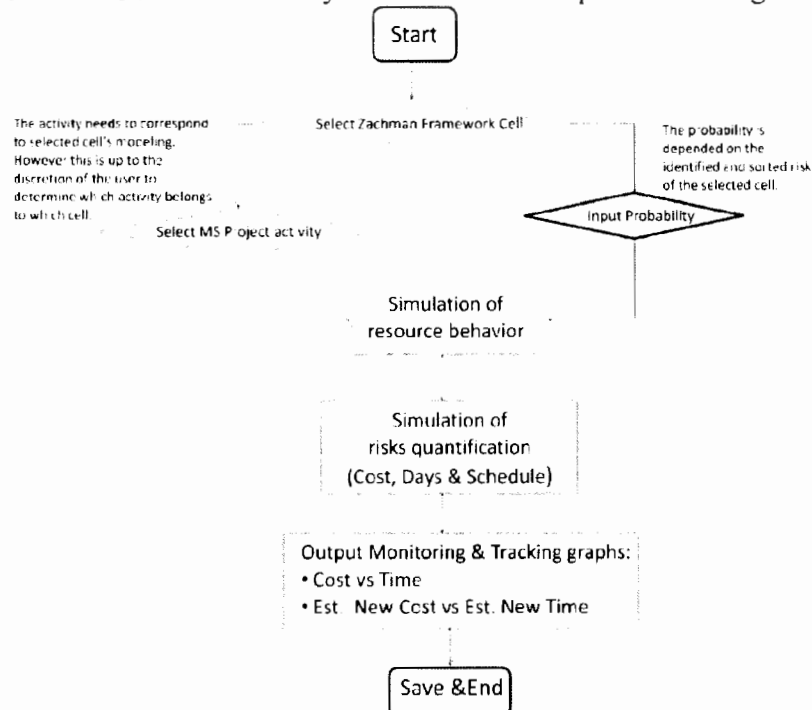


Figure 6.1: Functionality Flow Chart

### 6.3 DEVELOPING A USER FRIENDLY INTERFACE

#### 6.3.1 Selecting a common ground

In order to integrate the Zachman Framework for Construction and the MS Project, Visual Basic (VB) is selected as the common ground tool. VB is a software tool that is common in all MS Office programmes such as the Excel programme. These MS Office software programmes are easily available and present in most homes, offices and projects therefore satisfying the above statement of everyday use.

However, what makes VB the ideal tool is that it is a Windows application tool that creates, tests and runs programmes within other MS Window programmes. This then creates interfaces between the Window applications a lot simpler [25] therefore making VB an unquestionable selection. It also uses common English words and phrases while supporting the same features such as C++ and J++, making it a language that is not too difficult to understand for programmers.

#### 6.3.2 Representing Framework in Windows application

To link the framework to the MS Project plan, the framework must be represented in a Windows program where the VB tool is present and can operate in. MS Office Excel is selected to represent the reduced Zachman Framework for Construction. This is because Excel has mathematical and statistical functions that are already programmed in VB and will be necessary in the later stage when simulating graphical risk outputs. The representation of the reduced Zachman Framework for Construction in Excel sheet is shown in the following Table 8 below:

**Table 8: Reduced Zachman Framework for Construction Excel**

Project Values into Framework	MS Project Inputs				
<b>Zachman Framework (Row-Coulomb)</b>					
Project Team/Management -How					
Project Team/Management -When					
Project Sponsor -When					
Architecture/Consultant -What					
Architecture/Consultant -How					
Architecture/Consultant -Where					
Architecture/Consultant -Who					
Architecture/Consultant -When					
Contractor -What					
Contractor -How					
Contractor -Where					
Contractor -Who					
Contractor -When					
Control Procedure -How					
Control Procedure -When					

### 6.3.3 Represent MS Project in Excel Sheet

Due to the fact that the MS Project software program is a windows application; its data can be represented and saved as an Excel worksheet in order to make the interface to VB much more user friendly. To do this, the data of the activities and resources in the MS Project Gantt chart of the inner city construction project must be saved as an .xls file.

The risk to be simulated and quantified through the integrated tool is the Cost, Time and Performance (Scheduled) as seen in the functionality flow chart. Therefore the following data is required from each MS Project Gantt Chart activities respectively:

1. Resource/Activity Name
2. Maximum Unit (physical resource)
3. Standard Rate/day (currency)
4. Baseline Cost (currency)
5. BCWS (currency)
6. BCWP (currency)
7. Actual Cost (currency)
8. Start Date (days)
9. Finish Date (days)
10. Total Duration (days)
11. Task Duration (days)

The above required data is to be saved as a Microsoft Excel Workbook file name "**construction.xls**". The following Table 9 below shows where the MS Project data will be inserted by the user into the MS Office Excel framework screen respectively.

**Table 9: Framework and MS Project Input data Screen**

Project Values into Framework	MS Project Inputs										
Zachman Framework (Row-Coulomb)	Resource Name	Max. Unit	Standard Rate/Day	Baseline Cost	BCWS	BCWP	Actual Cost	Start Date	Finish Date	Total Duration	Task Duration
Project Team/Management -How											
Project Team/Management -When											
Project Sponsor -When											
Architecture/Consultant-What											
Architecture/Consultant-How											
Architecture/Consultant-Where											
Architecture/Consultant-Who											
Architecture/Consultant-When											
Contractor-What											
Contractor-How											
Contractor-Where											
Contractor-Who											
Contractor-When											
Control Procedure-How											
Control Procedure-When											
Closure/Commissioning Process-How											

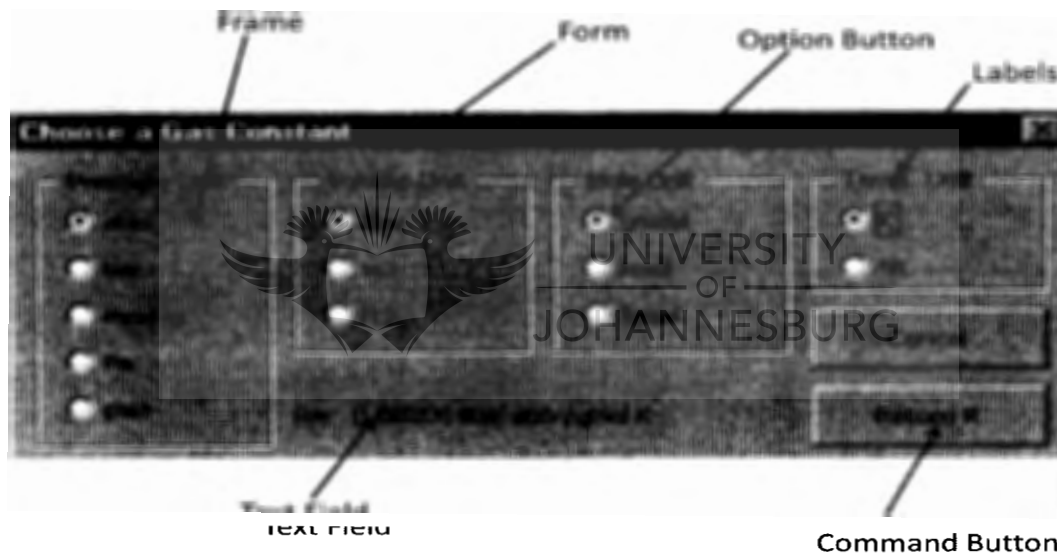
Appendix G: How to use MS Project on saving data as an .xls file.

#### 6.3.4 Linking framework to MS project for simulation

For the framework risk management integrated tool to interact with the user, allowing the user to link Zachman Framework for Construction and MS Project Gantt Chart for simulation, a dialog box needs to be developed. VB allows the development of a dialog box by creating a form which contains programming objects which interacts with the user [26].

According to Larsen [26], “a form makes a multiple step task easier and less error prone”. Figure 6.2 below shows an example of a form created for the user to choose a gas constant using programming objects such as the following:

- Frames (collecting objects)
- Labels (display text)
- Option Buttons (user chooses)
- List Boxes
- Check Boxes
- Text Fields (display and data entry)
- Command Buttons (program simulation)



**Figure 6.2:** Choosing a Gas Constant Form [26]

From the functionality flow chart, we see that the probability input from Zachman Framework for Construction is required and inputs from MS Project Gantt chart of the inner city construction project for are also required to simulate risk quantification using Monte Carlo.

Therefore, “two” forms have to be created for the user to link their desired values for simulation. However, the probability “form” will be an input box. An input box is mostly used to ask the user a question and retrieve an answer; in this case the question being the probability of the selected framework cell. Therefore it can be argued that the integrated tool is designed with one form making the interface much easier to use so that there is only one main frame for the user to interact with.

Figures 6.3 and 6.4 on the following page the Probability Input Box and the Project Form created for the interface between Zachman Framework for Construction and MS Project Gantt chart where the command button the “Enter” key is where risk simulation of the project will be programmed.

Figure 6.3: Input Project Values Form

Figure 6.4: Input Probability Form

### 6.3.5 Selecting tasks for simulation

In order to determine which task(s) belongs to which cell in the framework for simulation purposes, the MS Project task(s) are linked to the Zachman Framework for Construction in correlation to similar if not the same framework cell objectives. For example, the planning of the inner city construction task can be linked to the Project Team/How cell (Planning process) as the cell and the task have the same output which is to plan.

Therefore all the tasks in the MS Project Gantt Chart are correlated the following in to the Zachman Framework for Construction cells:

- Column
  1. Project Team How- Planning task
  2. Consultant/How- Technical tasks (Electrical supply and Main Plumbing)
  3. Contractor/How- Wet tasks (Bricking, Plastering and Painting)
  4. Control Procedure/How- Critical tasks (Tiler, Carpenter, Toilet, Stove, Basin and Sink)
  5. Commissioning Process- Certification tasks (Fire, Electrical, Habitation and Water)
- Row
  1. Contractor What- Coordinate task
  2. Contractor/Where- Non skilled tasks (Cleaning, Bricking non skilled)
  3. Contractor/Who- Fully outsourced tasks (Ceiling and Drilling)
  4. Contractor/When- Milestone tasks



However it should be noted that in the programmed MS Project Gantt Chart, page 82, there are no planning and coordinating tasks therefore their risk quantification simulation respectively are assumed as 50 percent certainty results.

## 6.4 STATISTICAL SIMULATION PROGRAMMING

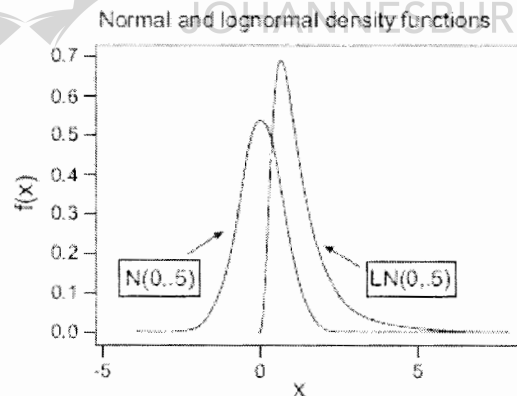
### 6.4.1 Resource Behaviour

In order to establish the possible behavioural scenarios that may occur throughout the lifecycle of a project resource behaviour is simulated. This provides a more accurate estimated risk quantification of the project as random probability density scenarios will be sampled according to the Monte Carlo technique.

To simulate the behaviour distribution of a resource throughout the project or an activity, a statistical analysis approach is taken. The most commonly used statistical modelling is the Normal Distribution attributed from continuous distribution of normal curves of errors [28].

However, all project resources are a function of time and thus making the distribution of project time positively skewed. Therefore the project resource behaviour distribution is modelled using Log Normal Distribution therefore keeping positive time. According to Johnson, “the occurrence of a lognormal distribution happens whenever a random variable is met such that its logarithm has a normal distribution” [27].

The figure 6.5 below demonstrates this logarithm variable difference between Normal and Log Normal distribution graphs where the density functions mean ( $\mu$ ) is 0 and standard deviation ( $\sigma^2$ ) is 0.5.



**Figure 6.5:** Normal & Lognormal distribution graphs [28]

Where probability density functions  $f(x)$  of the Normal and Lognormal distribution are represented by the following standard formulas [27, 28]:

- Normal Distribution:  $f(x; \mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(x-\mu)^2/2\sigma^2} \quad -\infty < x < \infty$  (6.1)

$$\sigma^2 - \text{Standard deviation} = \frac{\sum_{i=1}^N (x_i - \mu)^2}{N} \quad (6.2)$$

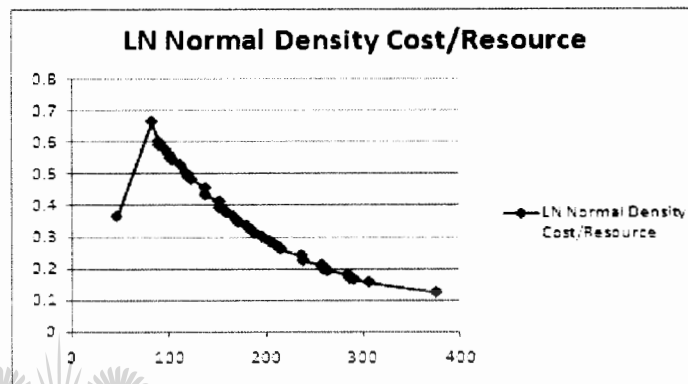
$$\mu - \text{Mean} = \frac{\sum_{i=1}^N x_i}{N} \quad (6.3)$$

- Lognormal Distribution:  $f(x) = \left\{ \frac{1}{\sqrt{2\pi\beta}} x^{-1} e^{-(\ln x - \alpha)^2 / 2\beta^2} \right.$  for  $x > 0, \beta > 0$  (6.4)

$$\sigma^2 - \text{Variance of lognormal} = e^{\alpha + \beta^2/2} \quad (6.5)$$

$$\mu - \text{Mean of log normal} = e^{2\alpha + \beta^2} (e^{\beta^2} - 1) \quad (6.6)$$

The following figure 6.6 shows an example of the resource simulation lognormal behavior of a skilled bricklayer in the inner city development construction project using lognormal distribution from the developed integrated risk management tool.



*Figure 6.6: Behaviour of skilled bricklayer in inner city project*

#### 6.4.2 The Monte Carlo simulation

To simulate the Monte Carlo technique in the project the same four steps noted in Chapter 3.3.3 are followed with additional steps to develop graphs for analyses:

- Step 1: Probability Density distribution of each task according to selected framework cell is defined by the lognormal resource behaviour distribution, figure 6.6.
- Step 2: Select random values from lognormal distribution within a specified range that is given by the probability density range which is inserted by the user. The probability density range will be inserted by using VB Probability Input box and this depends on the selected framework cell.

From the expert interviews and the risk matrix modelling done in Chapter 5, we are able to determine the probability density range within each framework cell as shown in the following Table 10 on the next page:

**Table 10: Zachman Framework for Construction Probability Density Range**

		Risk identification	Risk quantification & qualification	Risk monitoring & control	Risk response	Risk monitoring & control	Risk identification
		Strategic		Logistics	Logistics	Logistics	Strategic
	(Zachman Framework)	What/Data	How/Function	Where/Network	Who/People	When/Time	Why/Motivation/Constraints
Management Issues	(Contextual/Planner) Project Team/Management		[17%-33%]			[33%-67%]	
People Elements	(Conceptual/Owner) Project sponsor/owner					[30%-40%]	
Physical Properties	(Logical/Designer) Architecture/Consultant	[10%-17%]	[17%-56%]	[13%-26%]	56%-67%	[67%-98%]	
Action Process	(Physical/Builder) Contractor	[10%-25%]	[25%-95%]	[11%-33%]	25%-90%	[30%-90%]	
Action Process	(As built) Control Procedure		[17%-90%]			[37%-41%]	
People Elements	(Functioning) Closure/Commissioning Process		[15%-35%]				

- Step 3: Values from resource and random values selected from lognormal resource behaviour distribution are used to calculate and simulate the risk graphs to be analysed.

Risk quantification result, resource cost, in the task is calculated by using the following formula:

$$Cost_1 = (\text{Random resource cost/day sample}_1) \times (\text{Number of resources/day}_1) \times \text{day}_1$$

Therefore Total cost risk quantification of the entire task is calculated the following:

$$C_T = \sum_{i=1}^N C_i \quad (6.7)$$

Where  $C_T$ - Total resource cost risk quantification (currency)

$C_i$ - Resource cost risk quantification/day<sub>i</sub>

$N$ - Total number of resources/activity

- Step 4: Repeat Step 2 and Step 3 multiple times depending on the accuracy and confidence required. In this project case study a hundred iterations are assumed and considered to be sufficient.

Once there are a hundred results, they are sorted from the lowest total to the highest total and plotted against calculated cumulative probability and the sample count similar to Figure 3.6.

The following graph shows an example a skilled bricklayer cost distribution in the inner city development construction project using the developed integrated Monte Carlo risk management tool up to step 4:

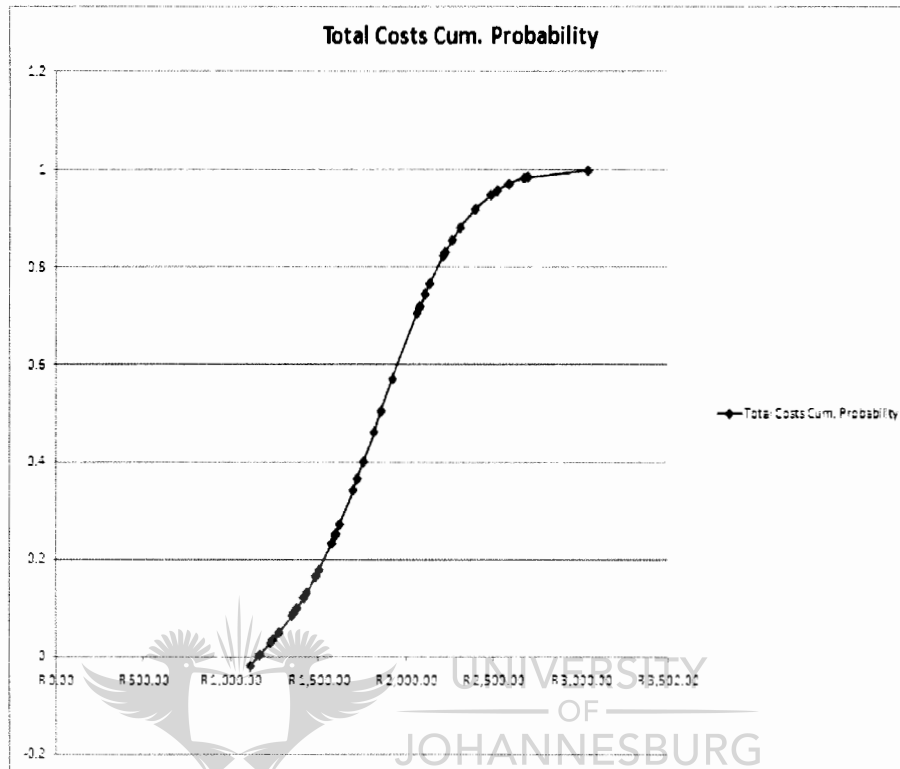


Figure 6.7: Resource Cost Distribution of a skilled bricklayer

- Step 5: Repeat step 1-2 and step 4 for total resource duration risk quantification (days). However step 3 has the following different formula:

$$\text{Duration}_1 = (\text{Random lognormal distribution sample}_1) \times \text{Total Duration of task}$$

Therefore total duration risk quantification of the entire task is calculated the following:

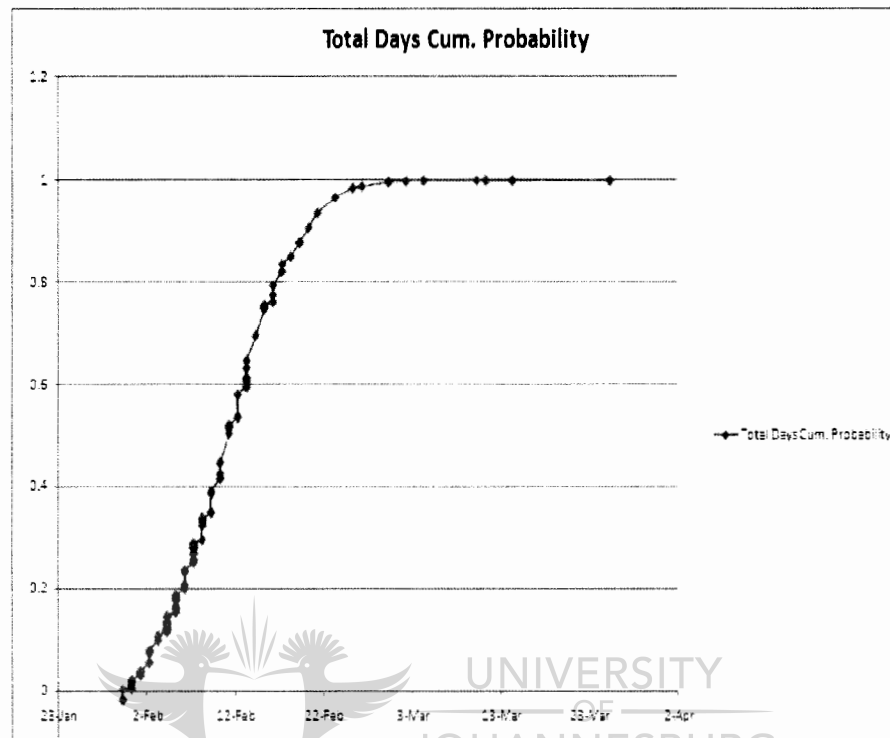
$$D_T = \sum_{i=1}^N (D_i + \text{Start Date of task}) \quad (6.8)$$

Where  $D_T$ - Total resource duration risk quantification (days)

$D_i$ - Resource duration sample<sub>1</sub>

$N$ - Total number of random lognormal distribution samples

The following graph shows an example a skilled bricklayer time distribution in the inner city development construction project using the developed integrated Monte Carlo risk management tool up to step 5:



*Figure 6.8: Resource Time Distribution of a skilled bricklayer*

- Step 6: Plot resource time cumulative distribution against resource cost cumulative distribution. This allows a graphical representation of predicting and tracking costs according to a status date of each task within its selected framework cell. This will therefore decrease the uncertainty amongst the project team.

In order to have an accurate predicting and tracking simulation processes, a similar Monte Carlo simulation approach is taken to calculate, Estimated New Cost and Performance risk quantifications of each task within its selected framework cell.

The following steps and formulas are used to simulate estimated cost and performance when it comes to predicting whether task will be on time and on budget:

- B<sub>T</sub>- Total resource estimated cost risk quantification (currency)

To review and quantify the risk contained within a resource's budget, one needs to determine whether the task is on track in terms of cost. If resource cost is not on track whether it is under or over budget on a status date, this provides a way to estimate/predict the total cost of resource up to status date according to the cost variance.

Therefore reducing the uncertainty of total estimated cost required to complete task recorded up to the status date.

Steps 1-2 and Steps 4 are the same as in page 102-103.

Step 3: Estimated cost risk quantification calculation has the following formula:

$$\text{Cost variance}_i = (\text{Random lognormal distribution sample}_i) \times (\text{AC} - \text{BCWP})$$

Where AC is the actual resource cost spent up the status date,  
BCWP is how much of the budget should have been spent on a resource up to the status date [1].

Therefore Estimated Total Cost risk quantification of the entire task up to status date is calculated the following:

$$B_T = \sum_{i=1}^N (\text{Cost variance}_i + C_i) \quad (6.9)$$

Where  $B_T$ - Estimated total cost risk quantification up to status date (currency)

$C_i$ - Resource cost cumulative distribution sample<sub>i</sub>

N- Total number of random lognormal distribution samples

- $S_T$ - Total resource schedule performance risk quantification (time)

To review whether the resource is ahead, behind or on schedule in terms of cost and time, it is required to determine if there is a schedule variance. This provides a way to track the performance of the resource in terms of cost and time as it measures the difference in planned and scheduled up to the status date.

Thus it can be concluded that resource schedule is equal to resource performance up to status date. Therefore reducing the uncertainty of the resource performance recorded up to the status date.

Steps 1-2 and Steps 4 are the same as in page 102-103.

Step 3: Performance risk quantification calculation has the following formula:

$$\text{Schedule variance}_i = (\text{Random lognormal distribution sample}_i) \times (\text{WS} - \text{WP})$$

Where WS is how much of the resource work is scheduled up to the status date [1],

Therefore performance (schedule) risk quantification of the entire task up to status date is calculated the following:

$$P_T = \sum_{i=1}^N (\text{Schedule variance}_i + D_i) \quad (6.10)$$

Where  $P_T$ - Performance risk quantification up to status date (time)

$D_i$ - Resource date cumulative distribution sample<sub>i</sub>

N- Total number of random lognormal distribution samples

The following graph shows an example of a skilled bricklayer cost against time distribution in the inner city development construction project using the developed integrated Monte Carlo risk management tool (on provided CD) up to step 6:

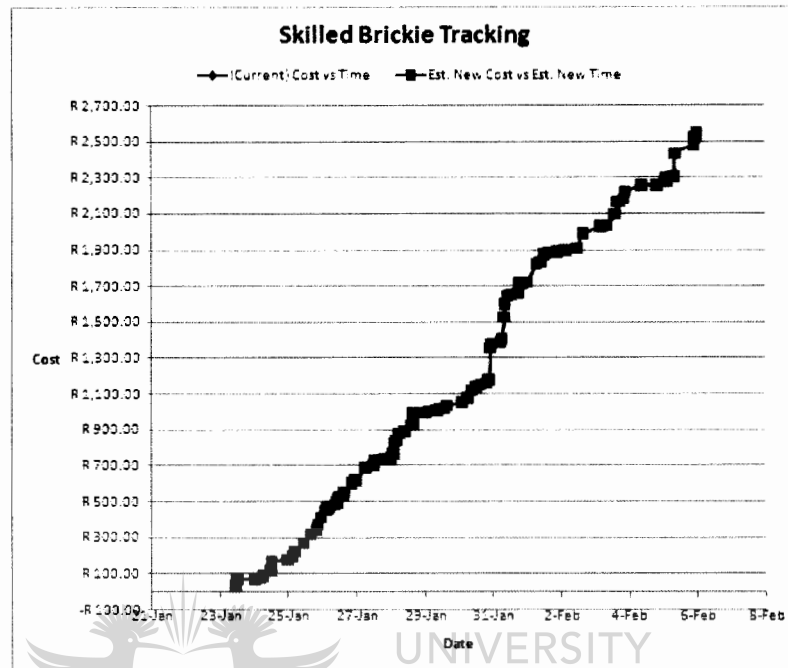


Figure 6.9: Cost vs. Time Distribution of a skilled bricklayer

#### 6.4.3 Analysing Predicted and Tracked Resource Time and Cost

It can be seen from figure 6.9 above that the estimated and current graphs are equal to one another. This means that the task is on time and on budget at the given status date. This is shown by the red dot on figure 6.10 below meaning that the other four quadrants are possible outcomes that can be estimated through a project lifecycle.

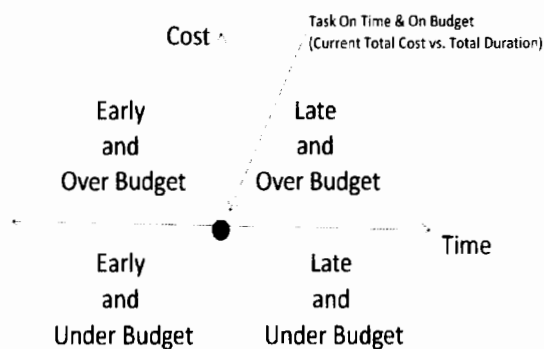


Figure 6.10: Four Possible Outcomes

The following two graphs are examples produced by the developed integrated risk management tool (on provided CD) of a skilled brickie tracking. The task estimates being under budget but late as well as over budget but early:

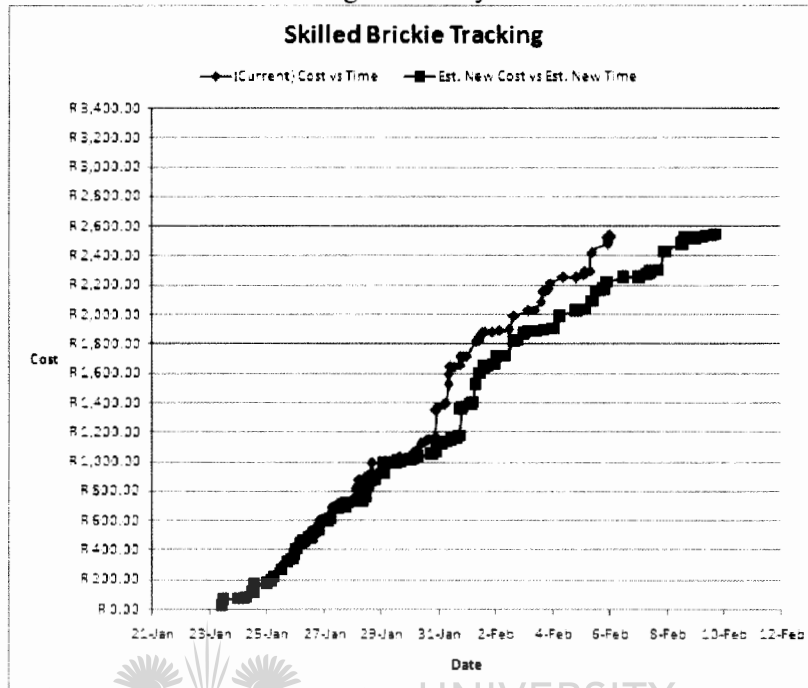


Figure 6.11: Under Budget but Late

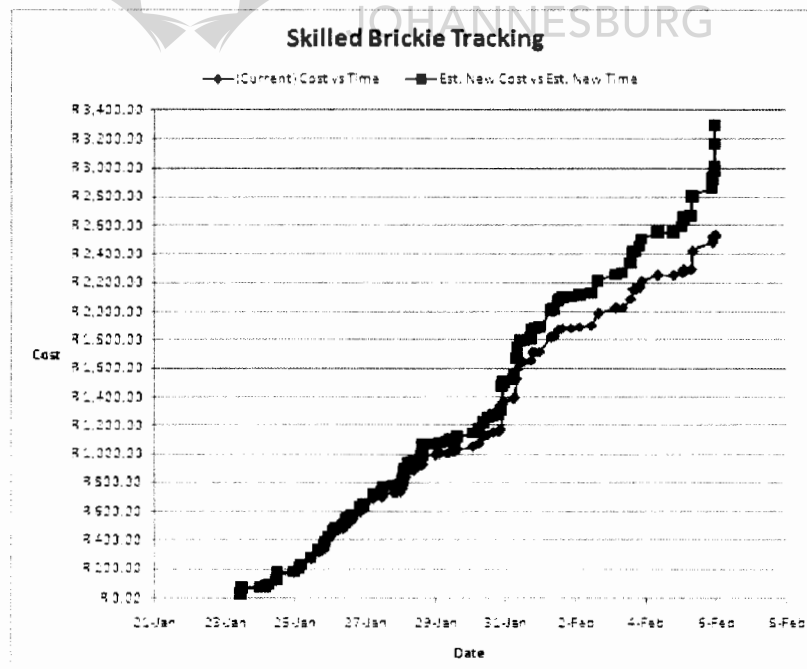


Figure 6.12: Over Budget but Early

From the graphs above it is easy to track the change in time and/or cost risk(s) of a task when comparing current graph versus the estimated graph according to the status date.

All the statistical resource behaviour and Monte Carlo simulations are programmed in VB and simulated when the user clicks the command button (Enter key) on the Project form. The program code can be seen in Appendix I on provided CD.



## 6.5 TRACKING OF PROJECT AND RISK BEHAVIOUR

Now that an integrated risk management tool that links with the Zachman Framework has been developed and tested, it is possible to visually track the inner city construction constraints and risk behaviour cell by cell throughout its project lifecycle.

To show how this is possible, three inner city construction project tasks have been selected which are placed in three different framework cells; a wet task, critical task and a technical task; and tracked at the same status dates throughout the project lifecycle.

### 6.5.1 Wet Task-Contractor/How: Skilled brickie

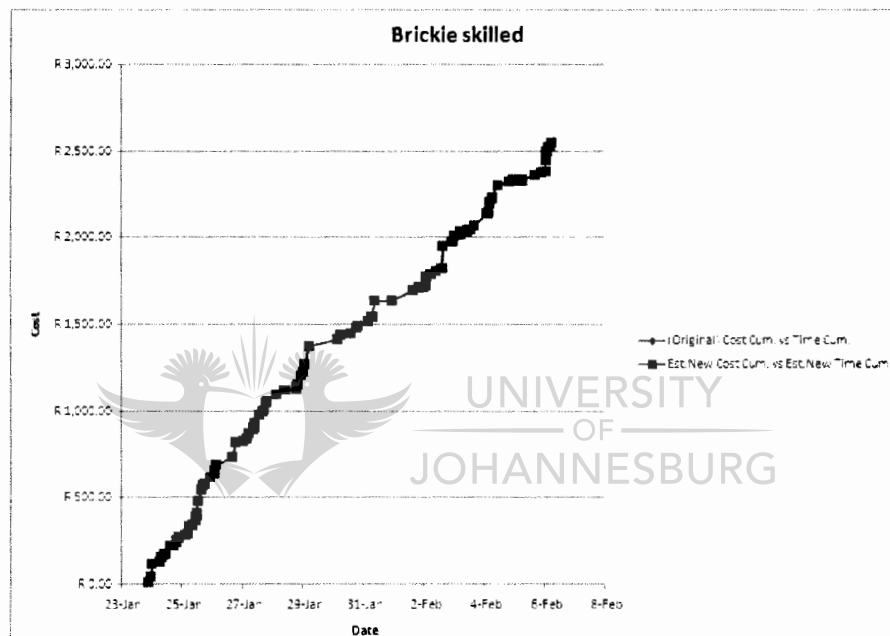


Figure 6.13: Tracking of skilled brickie- 21 Jan 08 (start date of task)

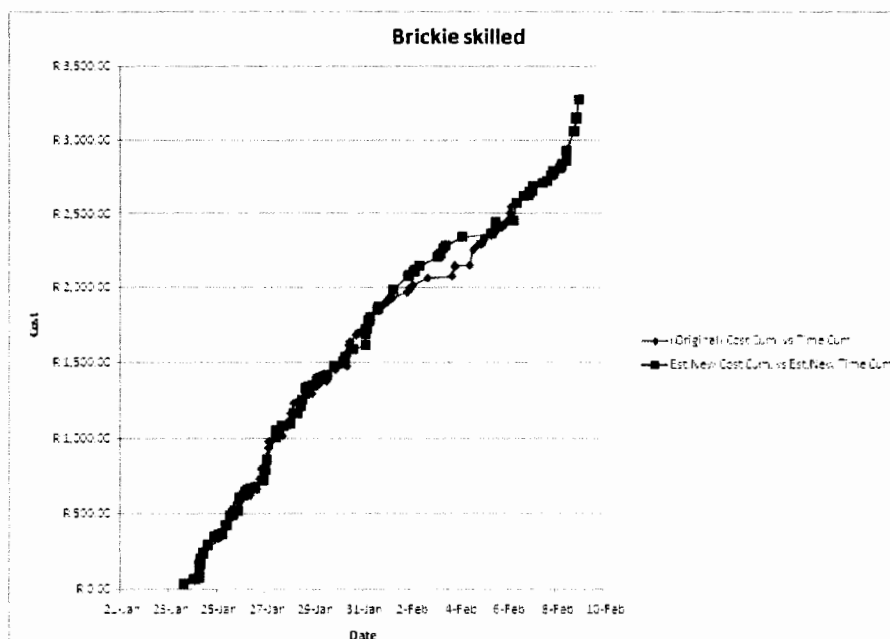


Figure 6.14: Tracking of skilled brickie- 31 Jan 08

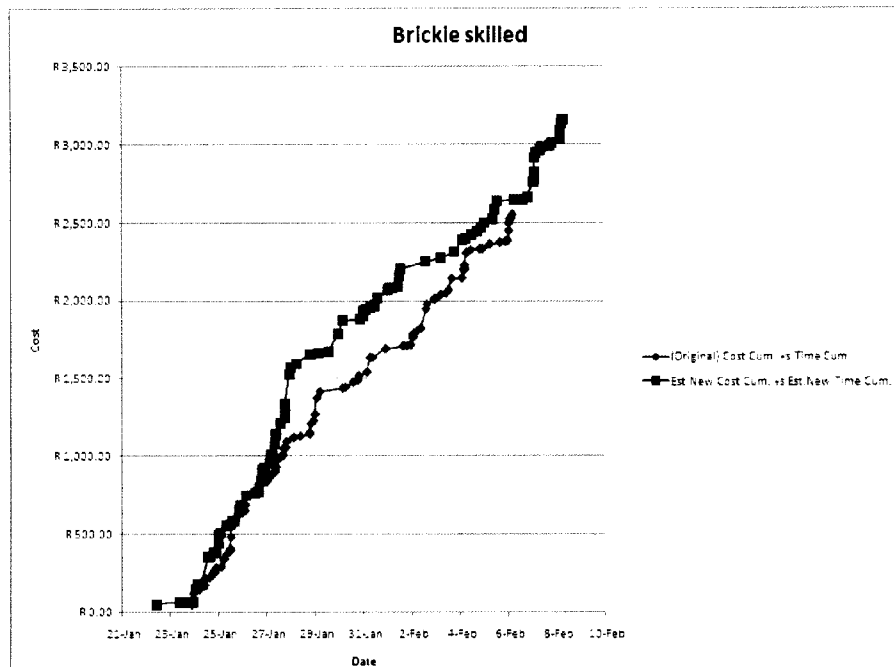


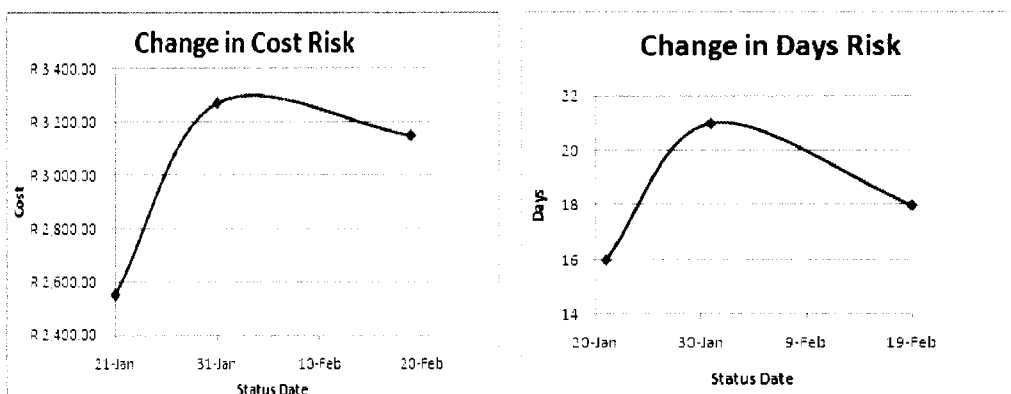
Figure 6.15: Tracking of skilled brickie- 19 Feb 08 (End date of task)

When analysing the wet trades above from the initial status date (start date of task), figure 6.13, it is estimated that the task will be on time and on budget the change in risk is zero. However when collecting data two weeks later on the 31<sup>st</sup> of January, figure 6.14 according to developed framework, it is seen that the wet trade tracked and estimated by the tool is to be over budget and late, therefore change in cost and time risk occurs.

From all the figures above of the wet trades throughout the project lifecycle (start date of trade-end date of trade), at different status dates, collected data and estimated data are tabulated as seen below in order to graphically represent change in risks occurred if any.

Table 11: Collected skill brickie data throughout project lifecycle

Skilled Brickie	Status Date	Original		Tracked		(Tracked-Original)+Original	
		Cost	Date	Cost	Date	Days	Cost
		25%-95%					
Start	21-Jan	R 2,550.00	6-Feb	R 2,550.00	06-Feb	16	R 2,550.00
	31-Jan	R 2,550.00	06-Feb	R 3,272.89	11-Feb	21	R 3,272.89
End	19-Feb	R 2,550.00	06-Feb	R 3,150.00	08-Feb	18	R 3,150.00



The following comments can be made about the wet trades analyses:

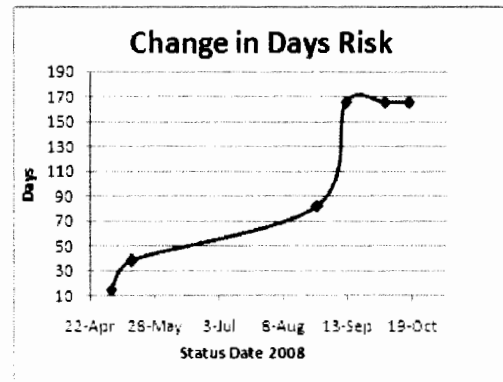
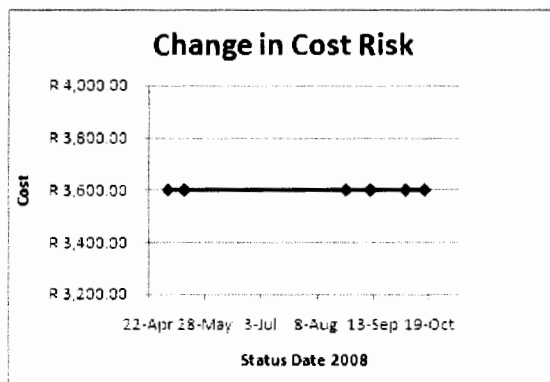
- Although the integrated tool has over estimated the final cost and date of the wet task, it has accurately predicted that it will be over budget and late. It has done this with a confidence of 96%.
- The change in cost and time risk occurred is clearly represented graphically and can be seen where the maximum, the contingency plan implemented, is and how throughout the project lifecycle it behaved.

### 6.5.2 Critical-Control Procedure/How: Plumber toilet

The same approach is taken when analysing the critical plumber task and the following table of data is produced.

**Table 12: Collected plumber data throughout project lifecycle**

Plumber 17%-90%	Status Date	Original		Tracked		(Tracked-Original)+Original	
		Cost	Date	Cost	Date	Days	Cost
Start	4-May	R 3,600.00	19-May	R 3,600.00	19-May	15	R 3,600.00
	15-May	R 3,600.00	19-May	R 3,600.00	11-Jun	38	R 3,600.00
	27-Aug	R 3,600.00	19-May	R 3,600.00	25-Jul	82	R 3,600.00
	12-Sep	R 3,600.00	19-May	R 3,600.00	17-Oct	166	R 3,600.00
	4-Oct	R 3,600.00	19-May	R 3,600.00	17-Oct	166	R 3,600.00
End	17-Oct	R 3,600.00	19-May	R 3,600.00	17-Oct	166	R 3,600.00



The following comments can be made about the critical task analyses:

- The integrated tool has accurately predicted the behaviour of the critical task cost and time with a confidence of 99%.
- The change in cost and time risk which occurred is clearly represented graphically and can be seen how it behaved throughout the project lifecycle.
- Although changes in time risk increased drastically there was no reason to implement a contingency plan towards it as this was not caused by itself. This was due to other previous tasks within the project lifecycle such as the main distribution plumbing task.

- However it can still be argued that there has been some sought of change in final project cost constraint due to equation 1.1 in Chapter 2.3.1. This can also be seen through analysing and graphically representing cost of the human resources versus time of the entire inner city construction project as shown on the following figure 6.16:

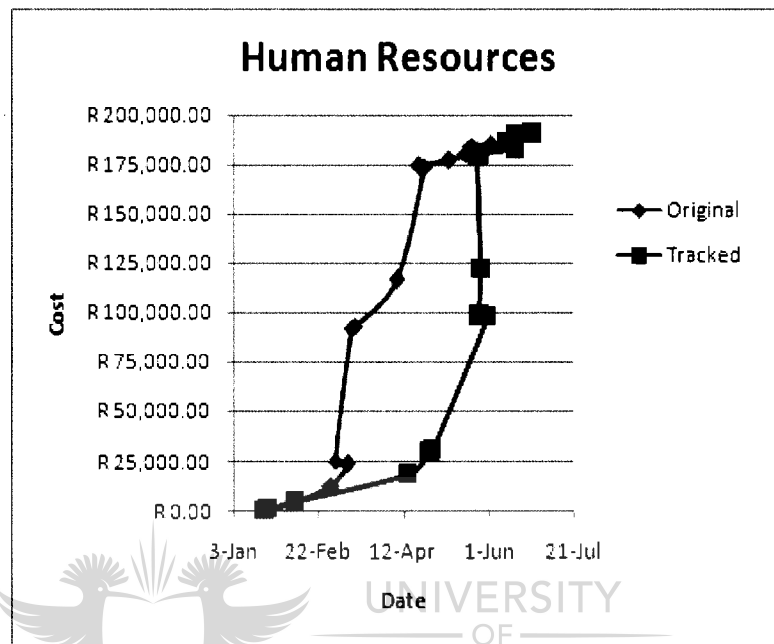


Figure 6.16: Tracking of Human Resources- 15 May 08

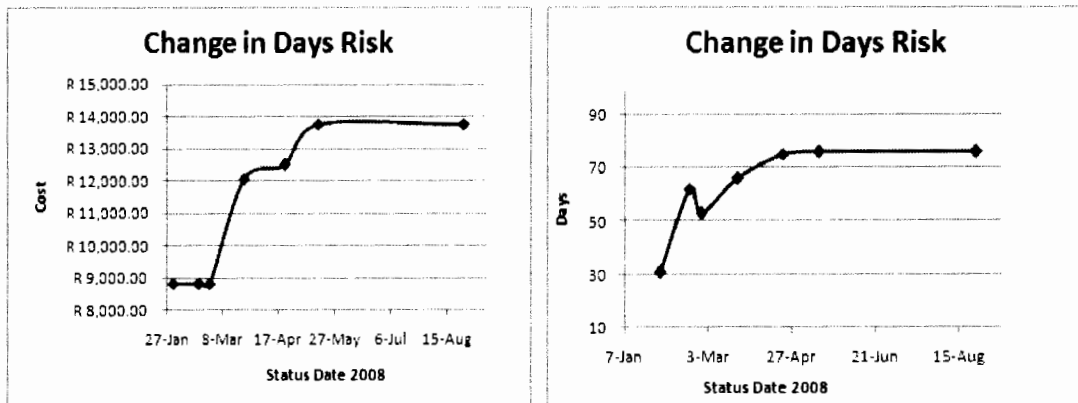
- With figure 6.16 above, we can comment that the entire project is late and over budget at the current status date.

### 6.5.3 Technical- Consultant/How: Plumber main distribution

The same approach is taken when analysing the technical plumber main distribution task and the following table of data is produced.

Table 13: Collected electrical main distribution data throughout project lifecycle

Plumber Main	Status Date	Original		Tracked		(Tracked-Original)+Original	
		Cost	Date	Cost	Date	Change in Risk	
						Days	Cost
	21-Jan	R 8,800.00	28-Feb	R 8,800.00	28-Feb	0	R -
<b>Start</b>	31-Jan	R 8,800.00	28-Feb	R 8,800.00	03-Mar	31	R 8,800.00
	19-Feb	R 8,800.00	28-Feb	R 8,800.00	31-Mar	62	R 8,800.00
	27-Feb	R 8,800.00	28-Feb	R 8,800.00	22-Mar	53	R 8,800.00
	23-Mar	R 8,800.00	28-Feb	R 12,058.98	04-Apr	66	R 12,058.98
	21-Apr	R 8,800.00	28-Feb	R 12,496.57	13-Apr	75	R 12,496.57
	15-May	R 8,800.00	28-Feb	R 13,744.74	14-Apr	76	R 13,744.74
<b>End</b>	27-Aug	R 8,800.00	28-Feb	R 13,744.74	14-Apr	76	R 13,744.74



The following comments can be made about the technical task analyses:

- The integrated tool has accurately predicted the behaviour of the technical task cost with a confidence of 89% and time with confidence of 82%.
- The change in cost and time risk which occurred is clearly represented graphically and can be seen how it has behaved throughout the project lifecycle.
- When comparing the change in time risk to cost risk, it is seen that time risk is smoother than cost risk and is kept almost constant, especially from the end of March status date.
- However the change in cost risk increases dramatically, this is because more human resources were added to the task mid March in order to finish the task within its time constraint. This decision was hugely contributed by the energy crisis which had started affecting the critical tasks.

#### 6.5.4 Final Project Constraints Tracking

Once all tasks have been tracked together with their risk behaviour throughout the inner city construction project life according to its selected framework cells, it is now possible to add risk(s) row by row and column by column. This is done in order to conclude on how accurate through the framework the project team has been able to estimate the expected added losses due to financial and economical risks.

This can be seen by graphically analysing and graphically representing the cost of the human resources versus time of the entire inner city construction project at the end of the project lifecycle as shown on the following figure 6.17 in the next page.

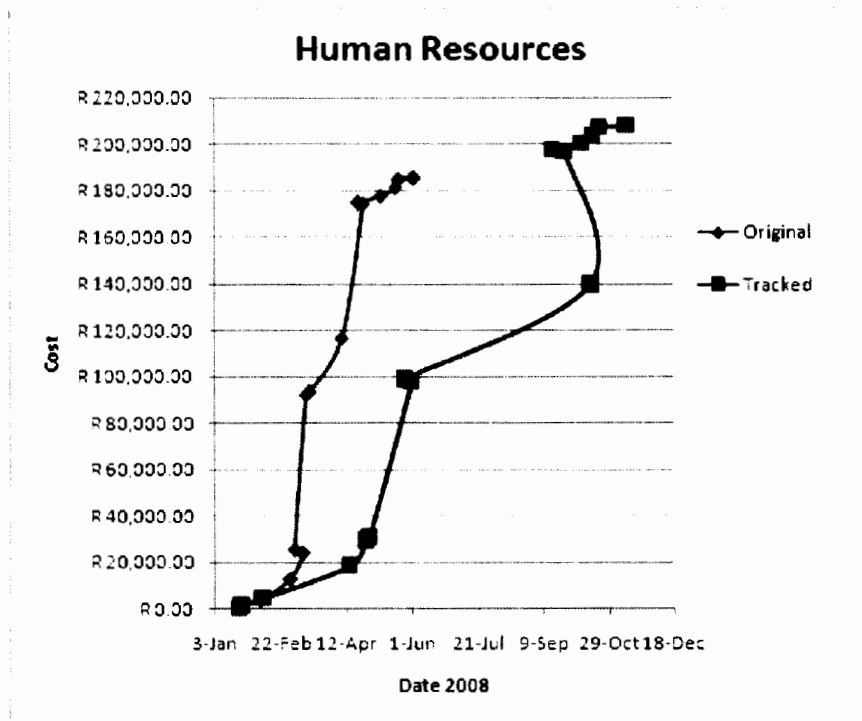


Figure 6.17: Tracking of Human Resources- End of Project Lifecycle

This can also be seen by analysing and comparing initial project financial, scope and time constraints to final project financial project financial, scope and time as shown in Table 14 below.

Table 14: Comparison of expected total output to final output

Constraints (Triangle Rule)	Identified risk	Probability Impact	Probability event	Likelihood	End of Project		
					Final added	Final added	Final added
1	Client (financial)	0.80	0.40	0.32	R 532,879.82	R 170 521.54	R 197 155.53
2	Scope	0.72	0.50	0.36	100%	36%	30%
3	Time Frame	0.78	0.60	0.47	18-Jul	20-Oct	11-Nov

From the table above, it can be commented that through the Zachman Framework for Construction, a confidence of 87% is reached in the financial constraint, while a confidence of 81% is reached in the time frame constraint and a confidence of 80% is reached in the scope constraint.

Due to the assumptions made at the beginning of the research study with regards to all floors being similar, the above results can be duplicated throughout the entire building resulting in an aggregated risk estimator for the entire inner city construction project.

## 6.6 CONCLUSION

Tracking of the inner city construction project using the developed integrated risk management tool to the framework not only allows accurate possible estimates of the task(s) constraints outcome(s) but has provided a way to visualise and aggregate risk(s) behaviour throughout the project cycle according to its specific framework cell. This enabled project managers and their team to determine when and in which area should developed contingency plans be applied.

With the inner city construction project floor in completion and results tabulated, it is possible to discuss the success of the research study.



## **CHAPTER 7 DISCUSSION AND RECOMMENDATIONS**

### **7.1 DISCUSSION**

It is commonly accepted that project and risk management are problematic fields on their own and together present a challenge. However it can be safely concluded that by adopting the Zachman Framework for Construction the magnitude of the challenge can be decreased drastically, even though not all cells within the framework need be implemented as hypothesised in Chapter 1. This is due to the fact that for a Zachman Framework cell to exist, it is highly dependent on the environment in which the framework is used, as seen in many other Zachman Framework research studies.

Despite this situation the framework was able to break down the complexity of project and risk management processes while each row and/or column defined a complete phase(s) in both project and risk management. Therefore clearer strategies, parameters, techniques, roles, responsibilities and requirements in the applied case study (inner city construction project) were obtained, easily applied and confidently met.

As with any framework, the Zachman Framework rules are rigid to its specific industry and had not been hypothesised. This being one of the weaknesses in the framework mentioned by Fatolahi, Ylimakia and other studies [18, 19] in utilizing the framework, it is limited by the graphical interconnection representation between the cells. Therefore rules of the Zachman Framework were modified to suite the construction industry as well as to have the framework amenable for project managers graphically.

This allowed tracking and monitoring of each constraint within its specified framework cell by introducing and developing an integrated risk management framework tool however not allowing risk controlling as hypothesised. In order to achieve this, only a change in risk cost and risk time had to be summed instead of all risk areas, drivers and factors as predicted.

Therefore the tool provided a more controllable approach towards the framework cell(s) requirements thus resulting in easy visualization of risk and the ability to respond to aggregate risk(s) in cost and time at a given status date within the applied case study. From this it can be concluded that a reduction in risk ignorance has been accomplished successfully.

There is no doubt that through the adapted Zachman Framework for Construction and the developed integrated risk management tool, the above findings supported by the case study, the conclusions support what was hypothesised in the beginning of the research. However more work still needs to be done in the field as not all goals have been achieved.

### **7.2 RECOMMENDATIONS**

In order to increase the success rate of the Zachman Framework for Construction and establish its limitations, it has to be applied to more case studies that have different elements and surroundings. One case study only provides an introduction to a possible solution to the project and risk management field. Otherwise the framework will end up as a mentioned methodology and not being implemented in the real world.



Although the Zachman Framework for Construction stipulates the *when* column through the project, stricter measures and more emphasis need to be taken in beginning a task(s) on time. The Zachman Framework for Construction does not enforce this and this requires it to be investigated in more detail.

Feedback stages in the framework throughout the project lifecycle are very important and this is seen during the project lifecycle as when data collection was skipped, communication and assessment errors increased. To avoid this, it is recommended that in the continuation of the research each cell within the framework has a designated individual(s) to it who takes full responsibility.

When looking at the developed integrated risk management tool, more work needs to be done with regards to its interface with the MS Project. It would be ideal if the integrated tool were to function as an Add-In option to the MS Project toolbox.

To achieve a complete low error functional Zachman Framework for Construction for the entire project and risk management field, it is with believe that if the framework were to be implemented by a more experienced researcher in the construction field and as well as all its cells are to be applied and implemented successfully, an increased ability to manage project outputs against identified risk(s) would be achieved.



## REFERENCES

1. Lewis, J.P., 2001, *Fundamentals of Project Management: Developing core competencies to help outperform the competition*, 2<sup>nd</sup> ed, AMACOM, a division of American Management Association
2. Meredith, J.R., Mantel, S.J., 2000, *Project Management: A Managerial Approach*, 4<sup>th</sup> ed, John Wiley and Sons Ltd.
3. Kerzner, H., 1998, *Project Management: A Systems Approach*, 6<sup>th</sup> ed, John Wiley and Sons Ltd.
4. Rosenau, M.D. 1998, *Successful Project Management*, 3<sup>rd</sup> ed, John Wiley and Sons Ltd.
5. Knipe, A., Van Nierkerk, G., 2002, *Project Management for Success*, 1<sup>st</sup> ed, Heinemann Publishers (Pty) Ltd
6. Terblanche, M.C., 2003, *Risk Identification in Engineering Projects*, M Eng Dissertation, University of Johannesburg.
7. Gahlot, P.S., Dhir, B.M., 1996, *Construction: Planning and Management*, Technical Teachers' Training Institute Chandigarh, New Age International (P) Ltd.
8. Gould, F.E., 2002, *Managing the Construction Process: Estimating, scheduling and project control*, 2<sup>nd</sup> ed, Roger Williams University, Prentice-Hall International Ltd.
9. Jaynes, J., 2002, *Risk Management: 10 Principles*, 1<sup>st</sup> ed, Butterworth-Heinemann Publication.
10. Pritchard, C.L., 2001, *Risk Management: Concepts and Guidance*, 1<sup>st</sup> ed, Project Management Institute, Inc., ESI International
11. Thompson, P., Perry, J., 1992, *Engineering Construction Risks*, 1<sup>st</sup> ed, University of Manchester Institute of Science and Technology, Thomas Telford Services Ltd.
12. Changhua, L., 2006, *Risk Management in Residential Development*, D Eng Dissertation, University of Johannesburg.
13. Smith, P.G., Merritt, G.M., 2002, *Proactive Risk Management: Controlling uncertainty in product development*, 1<sup>st</sup> ed, Productivity Press Book.

14. Tah, J.H., Carr, V. 2001, *Knowledge-based approach to construction project risk management*, Journal of Computing in Civil Engineering 3<sup>rd</sup> July 2001, Vol. 15, pp.170-177, viewed 26 April 2007<<http://web.ebscohost.com.raulib.rau.ac.zaehostpdfvid=5&hid=120&sid=7a93f9f0-0745-4aa2-b2e0-d9f17fc7aea3%40sessionmgr104>>
15. Dey, P.K., *Quantitative Risk Management Aids refinery construction*, Hydrocarbon Processing March 2002, pp.85-95, viewed 26 April 2007<<http://web.ebscohost.com.raulib.rau.ac.zaehostpdfvid=5&hid=120&sid=7a93f9f0-0745-4aa2-b2e0-d9f17fc7aea3%40sessionmgr104>>
16. Ertaul, L., Sudarsanam, R, *Security Planning Using Zachman Framework for Enterprises*, California State University, Hayward, Hayward, Department of Mathematics and Computer Science, 2005 Issue , pp.153-162, viewed 19 February 2007, <[http://www.mcs.csuhayward.edu/~lertaul16\\_S039EL-S13.pdf](http://www.mcs.csuhayward.edu/~lertaul16_S039EL-S13.pdf)>
17. Dinner, W., Kolber, A.B., *Zachman, Basel II and Sarbanes-Oxley*, DM Review Magazine October 2005 Issue, viewed 19 February 2007<[http://www.dmreview.com/article\\_sub.cfm?articleId=1038091](http://www.dmreview.com/article_sub.cfm?articleId=1038091)>
18. Ylimakia, T., Halttunen, V., *A case of applying the Zachman framework in the context of small enterprise architecture oriented projects*, Information Knowledge systems Management 5 2005/2006, Information Technology Research Institute, University of Jyväskylä in Finland, pp.189-209, viewed 26 April 2007, ISBN 1389-1995/05/06, <<http://web.ebscohost.com.raulib.rau.ac.zaehostpdfvid=4&hid=117&sid=7c2e745b-81d5-477d-8e1d-200cc82c3b56%40sessionmgr108>>
19. Fatolahi, A., Shams, F., *An investigation into applying UML to the Zachman framework*, Information System Front 2006, Electrical and Computer Engineering Faculty, Shahid Beheshti University, pp.8: 133-143, viewed 26 April 2007, DOI 10.1007/s10796-006-7977-8, <<http://www.springerlink.com/content/x405x666351q3t67/fulltext.pdf>>
20. Zachman, J. A., Sowa, J. F., *Extending and Formalizing the Framework for Information Systems Architecture*, IBM Systems Journal 1992, vol. 31, No. 3: 590-616, viewed 22 December 2008, <<http://www.research.ibm.com/journals/j313sowa.pdf>>
21. Johannesburg City Council, *Inner City Regeneration Strategy: Business Plan for 2004 – 2007*, Business Plan 10 March 2004, viewed 12 March 2007, < [www.joburg-archive.co.za/udz04.doc](http://www.joburg-archive.co.za/udz04.doc)>

22. Johannesburg City Council, *Chapter 11: Inner City Regeneration*, Inner City Regeneration 2003, pp.11: 190-203, viewed 12 March 2007, <[http://www.joburg-archive.co.za/2006/pdfs/final\\_term/Chapter11.pdf](http://www.joburg-archive.co.za/2006/pdfs/final_term/Chapter11.pdf)>
23. CBD Development Article., *Reshaping Johannesburg's Inner City*, Official website of the City of Johannesburg, viewed 12 March 2007, <<http://www.joburg.org.za/business/cbd.stm>>
24. Schaefer, N., *Trafalgar Inner City Report 2006*, Trafalgar Property Investment Company, pp. 1-32, viewed 12 March 2007, <<http://www.trafalgar.co.za/cms/Downloads/InnerCityReport/Report-4.pdf>>
25. Perry, G., Hettihewa, S., 2000, *Teach Yourself Visual Basic 6 in 24 Hours*, 2<sup>nd</sup> ed, SAMS, a division of Macmillan Computer Publishing.
26. Larsen, R.W., 2005, *Engineering with Excel*, 2<sup>nd</sup> ed, Department of Chemical Engineering Montana State University-Bozeman, Pearson Prentice Hall.
27. Johnson, R.A., 2005, *Miller & Freund's Probability and Statistics for Engineers*, 7<sup>th</sup> ed, University of Wisconsin-Madison, Pearson Prentice Hall.
28. Singh, A.K., Singh, A., Engelhardt, M., *The Lognormal Distribution in Environmental Application*, EPA Technology Support Center Issue 1997, EPA/600/R-97/006: 1-19, viewed 25 September 2007, <<http://www.usepatechnologysupportcenter.pdf>>
29. Yager, S., *Top 10 Project Management Problems*, DSSResources.Com 2001, viewed 11 December 2008, <<http://dssresources.com/papers/features/yager10032001.htm>>
30. Zachman, J. A., *A Framework for Information System Architecture*, IBM Systems Journal 1987, vol. 26, No. 3: 276-292, viewed 18 November 2008, <<http://www.research.ibm.com/journals/>>

# **APPENDIX A**

## **Project Definitions**



a) *Project definitions* [3]

- a human endeavour that creates change, is limited in time and scope, has mixed goals and objectives, involves a variety of resources, and is unique
- a complex effort to achieve a specific objective within a schedule and budget target, which typically cuts across organisational lines, is unique, and is usually not repetitive within the organisation
- a one-time, unique endeavour by people to do something that has not been done that way before
- a unique effort to introduce or produce a new product or service conforming to certain specifications and applicable standards (Knutson & Bitz, 1991:1).

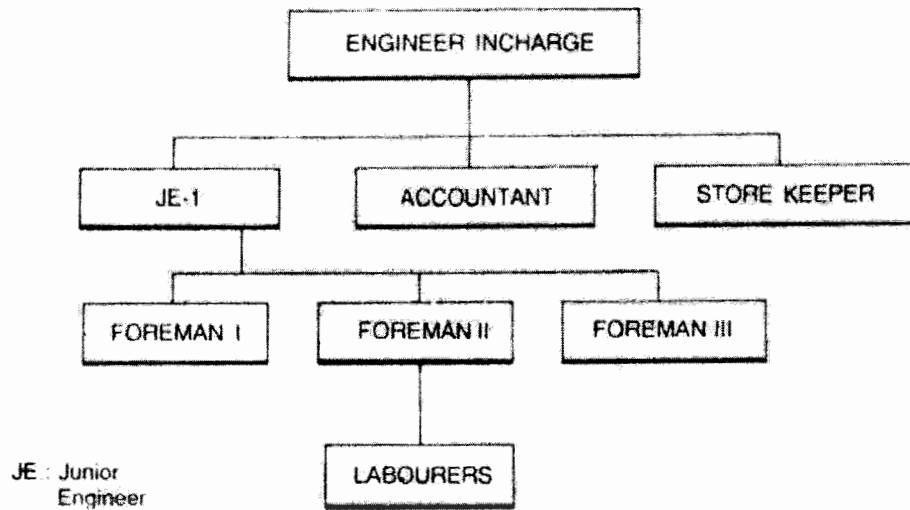


# **APPENDIX B**

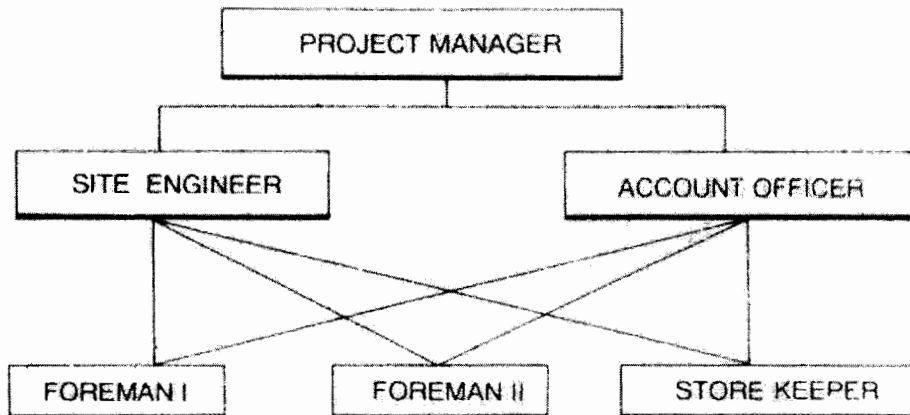
## **Organisational Structures**



a) *Line & Staff Structure diagram* [5]



b) *Functional Structure diagram* [5]



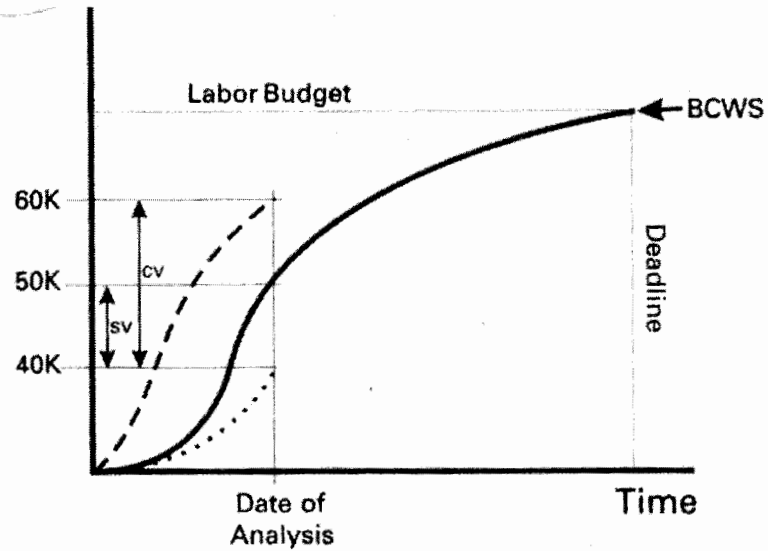


# **APPENDIX C**

## **Earned Value Charts**

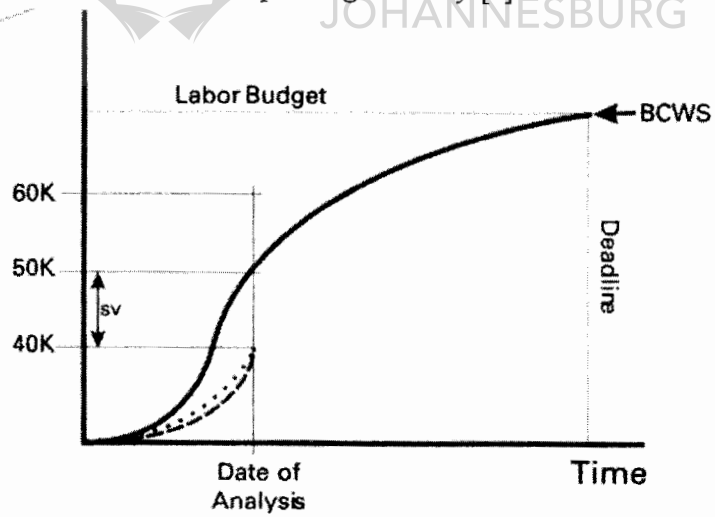


a) *Project behind schedule & overspent* [1]



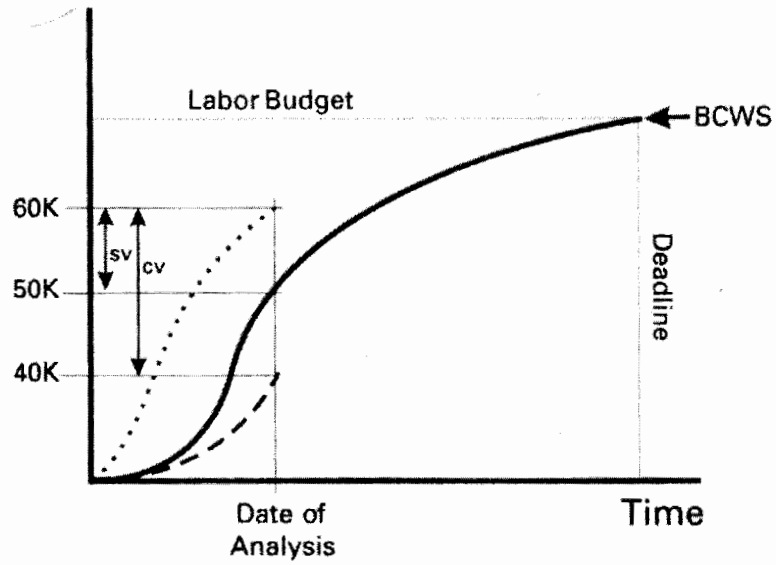
cv = cost variance      - - - - - ACWP  
 sv = schedule variance      ······ BCWP

b) *Project behind schedule but spending correctly* [1]



cv = cost variance      - - - - - ACWP  
 sv = schedule variance      ······ BCWP

c) *Project ahead schedule & under spent* [1]



cv = cost variance                      - - - - - ACWP  
 sv = schedule variance                ..... BCWP

d) *Project ahead schedule & overspent* [1]- Page 31, Figure 2.7

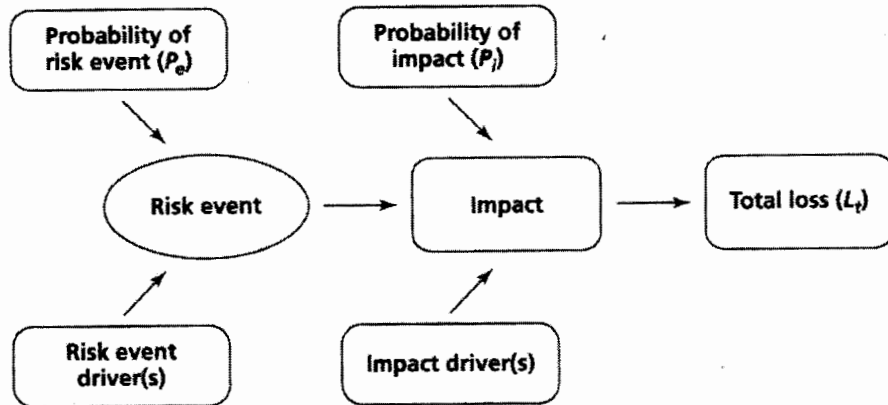


# **APPENDIX D**

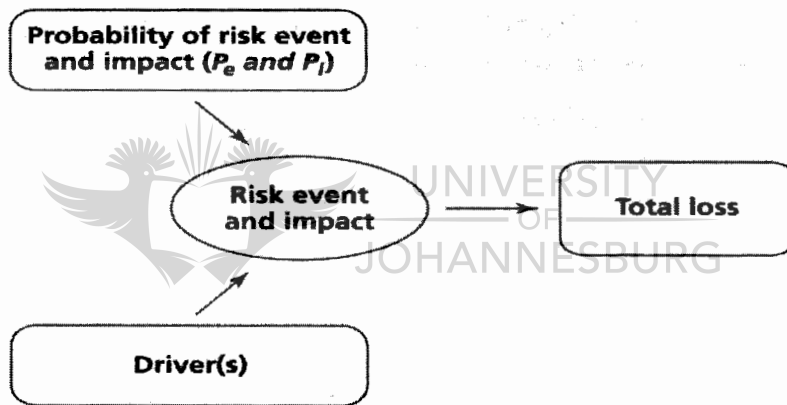
## **Risk Models**



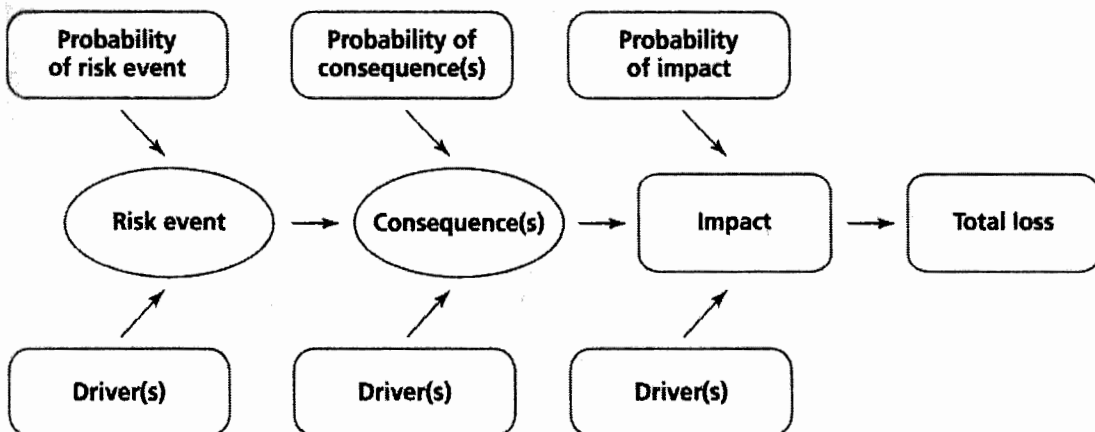
a) *Standard Risk Model* [13]



b) *Simple Risk Model* [13]



c) *Cascade Risk Model* [13]



d) Pros/Cons of Risk Models [13]

Risk Model	Pros	Cons
Standard	<ul style="list-style-type: none"> <li>• Model framework is easy to understand</li> <li>• Separate risk event reinforces the notion of prevention (being proactive)</li> <li>• Separate risk event and impact supports cause and effect concept</li> </ul>	<ul style="list-style-type: none"> <li>• Model allows a significant time span to lapse between the risk event and the impact</li> <li>• Model does not allow multiple risk events to converge on a single impact</li> </ul>
Simple	<ul style="list-style-type: none"> <li>• Model framework is easy to understand</li> </ul>	<ul style="list-style-type: none"> <li>• The risk event and impact are combined into a single entity, which obscures the notion of prevention</li> <li>• Model be can confusing when developing prevention and contingency due to risk event and impact being combined</li> <li>• Model does not allow multiple risk events to converge on a single impact</li> </ul>
Cascade	<ul style="list-style-type: none"> <li>• Very good representation of how risks occur on projects</li> <li>• Separate risk event reinforces the notion of prevention</li> <li>• Separate risk event and impact supports cause and effect concept</li> </ul>	<ul style="list-style-type: none"> <li>• Model framework can be complex</li> <li>• Probability calculations can be complex</li> </ul>
Ishikawa	<ul style="list-style-type: none"> <li>• Best representation of how risks occur on projects</li> <li>• Separate risk event reinforces the notion on prevention</li> <li>• Separate risk event and impact supports cause and effect concept</li> </ul>	<ul style="list-style-type: none"> <li>• Model framework can be very complex</li> <li>• Probability calculations can be very complex</li> <li>• Because risk events are divided into categories that may interact, it can be difficult to state a risk event cleanly</li> </ul>

\* Ishikawa model is not provided by Smith and Merit in their study

e) *Sample Risk Methodology [10]*

Step	Process Guidance	Timing	Special Considerations
Risk review	This step involves a thorough search of the <i>sample</i> database for past project experience with the same customer, product, or service. Outputs should be documented in the Risk-Review-Outputs directory of the PM office support folders	Prior to risk modeling and at any phase-gate reviews	Note that not all customers within a given business entity are the same. A different project sponsor may radically change the level of project risk and opportunity.
Risk modeling	The <i>sample</i> risk model should be scored by at least two project team members who should represent potentially competing interests within the organization. Scoring guidance is provided with the tool.	Prior to project acceptance and prior to risk contingency funding approval	The risk model is designed to provide relative scores on potential project risks. It is not intended to provide guidance on a risk-by-risk basis but instead to afford the organization a perspective on the general level of risk.
Risk identification	<i>Sample</i> prefers application of the Crawford Slip and brainstorming techniques, while other approaches, such as nominal group and the Delphi technique, may be appropriate. Identification should involve at least four team members, preferably including at least one from the customer organization.	Early in the concept phase, at phase-gate reviews, and any time the project undergoes significant change	Changes in personnel and requirements are frequently just as harmful to the project and generate as much risk as changes in external influences, such as technology or physical conditions. When in doubt as to the appropriateness of risk identification, it should be conducted.
Risk qualification	All identified risks should be evaluated according to the <i>sample</i> scales for impact and probability. These scores should be documented and logged in the project risk subdirectory in the project office repository. The scoring metrics reflect the organization's risk thresholds.	After risk identification and at regular intervals (at least once each quarter of the way through the project)	If the <i>sample</i> scale discounts risks that are obviously high probability or high impact, contact the project office to identify the shortcomings in the practice and any recommendations for metrics to overcome those shortcomings.
Risk quantification	All H-H risks (as identified in risk qualification) shall be quantified to establish the expected value ( <i>probability x impact</i> ) of the risks and any contingency funding appropriate to their application.	After risk qualification	Sources for impact and probability data should be thoroughly documented. If such data is the result of expert interviews or other nonquantitative techniques, validate the data to the degree possible by getting second (and third) opinions
Risk response development	At a minimum, strategies should be developed for the top 20 risks in the project. Strategies should be mapped against a strategy response matrix to ensure consistency and effectiveness of coverage.	After risk qualification and quantification	Those individuals or groups responsible for implementation should ideally develop strategies.
Lessons learned documentation	While most of this information will have been captured during the other stages in the risk process, it is important to close out the project with a comprehensive review of lessons learned. This should incorporate specific, actionable steps that can be pursued by other project managers on future efforts.	Regularly, as a component of the other steps, and at project termination	Lessons learned should capture a contact name, e-mail, and telephone number to ensure effective tracking.

# **APPENDIX E**

## **Risk Techniques**





a) Pros/Cons of Techniques [10]

Technique	Predominant/Secondary Use					
	Risk Management Planning	Risk Identification	Risk Qualification	Risk Quantification	Risk Response Planning	Risk Monitoring and Control
Expert interviews	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Planning meetings	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>	
Risk practice methodology	<input checked="" type="radio"/>		<input type="radio"/>	<input type="radio"/>		
Documentation reviews	<input type="radio"/>	<input checked="" type="radio"/>				<input type="radio"/>
Analogy comparisons		<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Plan evaluation		<input checked="" type="radio"/>				<input type="radio"/>
Delphi Technique	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Brainstorming		<input checked="" type="radio"/>			<input type="radio"/>	
Crawford Slip Method (CSM)		<input checked="" type="radio"/>			<input type="radio"/>	
SWOT analysis	<input type="radio"/>	<input checked="" type="radio"/>			<input type="radio"/>	
Checklists	<input type="radio"/>					<input checked="" type="radio"/>
Project templates	<input checked="" type="radio"/>		<input type="radio"/>			<input type="radio"/>
Assumptions analysis		<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>		
Decision analysis—Expected monetary value				<input checked="" type="radio"/>		
Estimating relationships	<input type="radio"/>			<input checked="" type="radio"/>		
Network analysis		<input type="radio"/>		<input checked="" type="radio"/>	<input type="radio"/>	
Program Evaluation and Review Technique (PERT)		<input type="radio"/>		<input checked="" type="radio"/>		
Other diagramming techniques				<input checked="" type="radio"/>		
Rating schemes	<input type="radio"/>		<input checked="" type="radio"/>	<input type="radio"/>		
Risk modeling	<input checked="" type="radio"/>		<input type="radio"/>			
Monte Carlo simulations				<input checked="" type="radio"/>		
Risk factors	<input type="radio"/>		<input checked="" type="radio"/>			
Risk response matrix	<input type="radio"/>				<input checked="" type="radio"/>	
Performance tracking	<input type="radio"/>					<input checked="" type="radio"/>
Risk reviews and audits	<input type="radio"/>					<input checked="" type="radio"/>

**Legend:**

- = Predominant use
- = Secondary use

# **APPENDIX F**

## **Construction Risk Factors**



a) Risk Rating Matrix [15]

Factors	Technical risk	Financial & economic risk	Organizational risk	Acts of God risk	Clearance risk	Likelihood risk
Technical risk	1	3	4	5	5	0.479
Financial & economic risk	½	1	2	4	3	0.228
Organizational risk	½	½	1	2	3	0.146
Acts of God risk	½	½	½	1	2	0.064
Clearance risk	½	½	½	½	1	0.083

Consistency ratio: 0.042. Hence acceptable.

b) Sub-Factors [15]

Subfactors	Instrumentation and control room		Process equipment and piping		Tank farm and pipelines		Power and utilities	
	LP	GP	LP	GP	LP	GP	LP	GP
Scope change	0.17	0.029	0.39	0.067	0.31	0.053	0.13	0.022
Technology selection	0.29	0.017	0.23	0.014	0.11	0.007	0.37	0.022
Implementation methodology	0.47	0.029	0.26	0.016	0.17	0.011	0.1	0.006
Equipment risk	0.33	0.012	0.21	0.007	0.28	0.013	0.18	0.006
Start-ups	0.17	0.007	0.35	0.013	0.25	0.010	0.22	0.008
Engg. and design change	0.37	0.041	0.33	0.037	0.13	0.015	0.17	0.019
Initiation	0.25	0.009	0.25	0.009	0.25	0.009	0.25	0.009
Fund	0.25	0.022	0.25	0.022	0.25	0.022	0.25	0.022
Local law	0.18	0.004	0.18	0.004	0.19	0.005	0.25	0.006
Policy	0.25	0.006	0.25	0.006	0.25	0.006	0.25	0.006
Estimate	0.43	0.025	0.43	0.025	0.17	0.010	0.08	0.005
Capability of owner's project group	0.33	0.005	0.3	0.005	0.27	0.004	0.1	0.002
Contractor's capability	0.37	0.015	0.33	0.014	0.22	0.009	0.08	0.003
Vendor's capability	0.21	0.014	0.29	0.019	0.4	0.026	0.1	0.007
Consultant capability	0.49	0.012	0.13	0.003	0.15	0.004	0.23	0.005
Calamity, normal	0.41	0.012	0.35	0.010	0.14	0.004	0.1	0.003
Calamity, abnormal	0.32	0.011	0.47	0.017	0.09	0.003	0.12	0.004
Environmental	0.25	0.005	0.25	0.005	0.25	0.005	0.25	0.005
Land acquisition	0.13	0.005	0.51	0.020	0.3	0.011	0.06	0.002
Explosive clearance	0.25	0.003	0.28	0.003	0.36	0.004	0.11	0.001
Other clearance	0.25	0.003	0.25	0.003	0.15	0.002	0.35	0.004
<b>Overall likelihood of failure</b>		<b>0.286</b>		<b>0.317</b>		<b>0.229</b>		<b>0.188</b>
<b>Rank</b>		<b>2</b>		<b>1</b>		<b>3</b>		<b>4</b>

LP - local percentage, GP - global percentage

**APPENDIX G**

**How to use MS Office**

**Project 2003**



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*a) Online Tutorials*

Online MS Office Project 2003 tutorials are available on Microsoft Office Website. These tutorials can provide good fundamentals on understanding how to use the software package for first time users.

**URL**

1. <http://office.microsoft.com/engb/project/FX100649021033.aspx?CTT=96&Origin=CL100627011033>
2. <http://office.microsoft.com/en-gb/training/CR061832711033.aspx>

*b) Package Tutorials*

Package tutorials are available with almost any software programme you buy and this is no different. Through these tutorials a first time user maybe able to grasp the usability of the software package. The following are some topics you may find in the package tutorial.

1. Define the project
2. Define general working times
3. List the activities in the project
4. Organize activities into phases
5. Schedule activities
6. Link to or attach more activities information
7. Add columns of custom information
8. Set deadlines and constrain activities
9. Identify risks to the project
10. Add documents to the project
11. Specify people and equipment for the project
12. Specify the booking types for resources
13. Define working times for resources
14. Assign people and equipment to activities
15. Link to or attach more resource information
16. Add columns of custom information
17. Save a baseline plan to compare with later versions
18. Prepare to track the progress of your project
19. Incorporate progress information into the project
20. Check the progress of the project
21. Make changes to the project
22. Track risks and issues associated with this project

c) *How to save MS Project as an .xls file*

The following steps show how to save the data in MS Project as an .xls file in an order stated in section 5.4.2b of the case study:

1. Click File then Save as type Microsoft Excel Workbook
2. Type File name “**construction.xls**”
3. Click save then Export to Wizard box will appear, click next
4. Click Select own data to export, click next
5. Choose new map to create your data settings from scratch, click next
6. Click both Task, Assignment and Resource data to export including headers, click next
7. Export Wizard Task Mapping box will appear
8. Select Name, Duration Task, Start and Finish Date data inputs respectively, click next
9. Export Wizard Resource Mapping box will appear
10. Select Name, Max. Unit, Standard Rate, Baseline Cost, BCWS, BCWP, Actual Cost, ACWP and % Work Completed data inputs respectively, click next
11. Export Wizard Assignment Mapping box will appear
12. Select Task Name and Units data inputs respectively, click next
13. Click next and finished
14. Open “**construction.xls**”
15. Enable Macros, if not enabled select VBA Add-Ins options
16. Copy Units Column from Assignment\_Table1 to Task\_Table1 Column E (after Finish date column)
17. Make sure Units column correspond with Task
18. Save “**construction.xls**”
19. See page 138 of this Appendix to see example.

construction.xls [Compatibility Mode] - Microsoft Excel

	A	B	C	D	E	F	G	H	I
1	<b>Name</b>	<b>Max_Units</b>	<b>Standard_Rate</b>	<b>Baseline_Cost</b>	<b>BCWS</b>	<b>BCWP</b>	<b>Actual_Cost</b>	<b>ACWP</b>	<b>Percent_Work_Complete</b>
2	Driller	100%	\$400.00/day	\$1,200.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
3	Brickie skilled	200%	\$150.00/day	\$2,550.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
4	Brickie non-skilled	400%	\$95.00/day	\$950.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
5	Planter	200%	\$872.20/day	\$23,549.40	\$0.00	\$0.00	\$0.00	\$0.00	0%
6	Plaster	200%	\$280.00/day	\$11,200.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
7	Electrician	100%	\$225.00/day	\$2,925.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
8	Plumber	300%	\$200.00/day	\$12,400.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
9	Tiler	200%	\$1,588.70/day	\$57,193.20	\$0.00	\$0.00	\$0.00	\$0.00	0%
10	Carpenter	200%	\$175.00/day	\$2,800.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
11	Cleaning crew	100%	\$95.00/day	\$570.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
12	Ceiling worker	300%	\$4,790.00/day	\$67,060.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
13	Fire Installation personal	200%	\$800.00/day	\$3,600.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
14									
15	Drilling equipment machine hire		\$3,333.00	\$3,333.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
16	Bricks		\$1,100.00	\$3,300.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
17	Paint (ceiling and walls)		\$1,800.00	\$7,200.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
18	Tiles (including wall tiles)		\$30,200.00	\$90,600.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
19	Electrical cables/wires/plugs		\$4,000.00	\$24,000.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
20	Last plumbing materials (i.e. basin and toilet)		\$12,000.00	\$36,000.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
21	Build in bath (including bricks and cement)		\$1,800.00	\$5,400.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
22	Plastering material (i.e. cement)		\$1,000.00	\$3,000.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
23	Stove		\$30,000.00	\$90,000.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
24	Electrical DB/cables distribution		\$4,000.00	\$8,000.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
25	Doors and handles		\$2,100.00	\$6,300.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
26	Door Frames		\$834.00	\$2,502.00	\$0.00	\$0.00	\$0.00	\$0.00	0%
27	Fire signs and security		\$24,500.00	\$24,500.00	\$0.00	\$0.00	\$0.00	\$0.00	0%

construction.xls [Compatibility Mode] - Microsoft Excel

	A	B	C	D	E	F	G	H	I	J
1	<b>Name</b>	<b>Duration</b>	<b>Start_Date</b>	<b>Finish_Date</b>	<b>Units</b>					
2	8th Floor Project Plan	0 days	2008/01/21 08:00	2008/01/21 08:00						
3										
4	Cut Pipe Holes/Floor	3 days	2008/01/21 08:00	2008/01/23 17:00	100%					
5										
6	2-Brick Work (including door frames)	2 days	2008/01/24 08:00	2008/01/25 17:00	200%					
7	1-Brick Work (including door frames)	3 days	2008/01/28 08:00	2008/01/30 17:00	200%					
8	3-Brick Work (including door frames)	2 days	2008/01/31 08:00	2008/02/01 17:00	200%					
9	2-Place build in bath, shower & brick up	1 day	2008/02/04 08:00	2008/02/04 17:00	100%					
10	1-Place build in bath, shower & brick up	1 day	2008/02/05 08:00	2008/02/05 17:00	100%					
11	3-Place build in bath, shower and brick up	1 day	2008/02/06 08:00	2008/02/06 17:00	100%					
12										
13	Milestone	0 days	2008/02/07 08:00	2008/02/07 08:00						
14										
15	Sewer Pipes Distribution/Floor	6 days	2008/01/31 08:00	2008/02/07 17:00	200%					
16	Main Water Supply Distribution/Floor	6 days	2008/02/08 08:00	2008/02/13 17:00	200%					
17	2-First Plumbing	4 days	2008/02/18 08:00	2008/02/21 17:00	200%					
18	1-First Plumbing	3 days	2008/02/22 08:00	2008/02/26 17:00	200%					
19	3-First Plumbing	3 days	2008/02/27 08:00	2008/02/29 17:00	200%					
20										
21	Milestone	0 days	2008/02/21 17:00	2008/02/21 17:00						
22										
23	2-Plastering	6 days	2008/02/12 08:00	2008/02/19 17:00	200%					
24	1-Plastering	6 days	2008/02/20 08:00	2008/02/27 17:00	200%					
25	3-Plastering	8 days	2008/02/28 08:00	2008/03/10 17:00	200%					
26										
27	External Electrical Supply/Floor	2 days	2008/02/04 08:00	2008/02/05 17:00	100%					

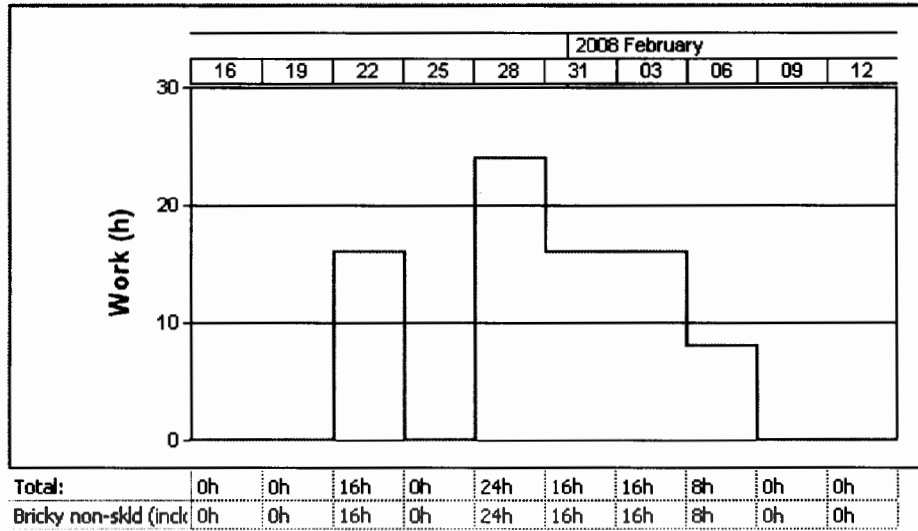
# **APPENDIX H**

## **MS Office Project Resources Ideal Stage**

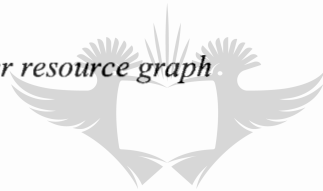




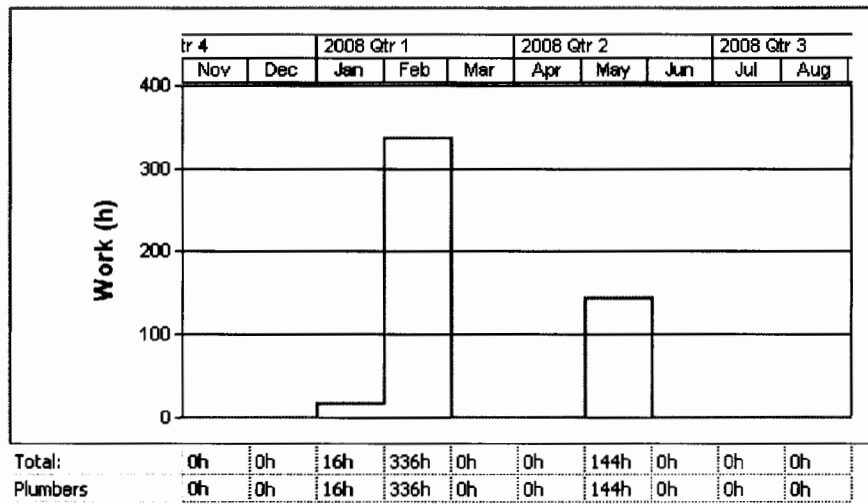
a) *Non-Skilled resource graph*



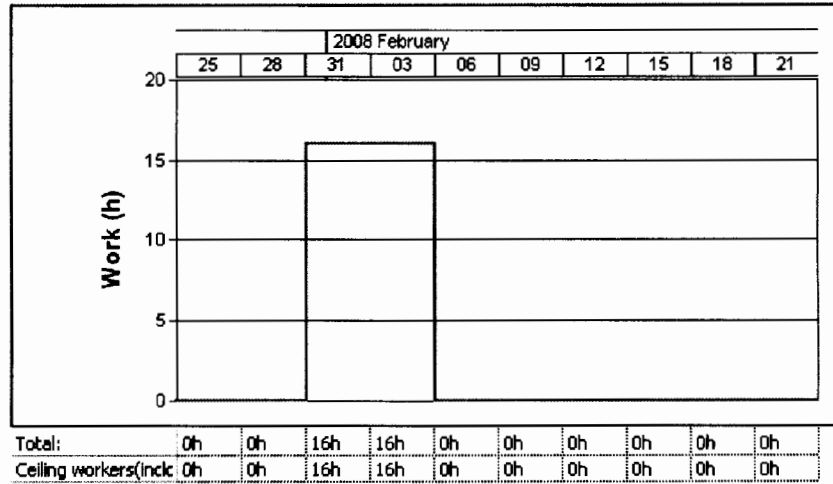
b) *Plumber resource graph*



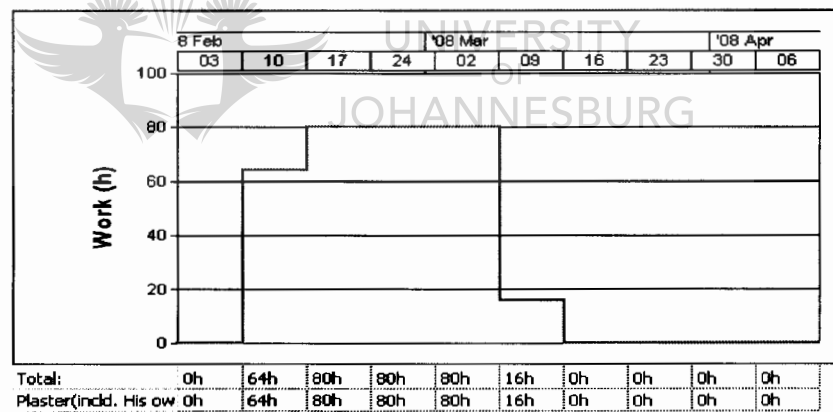
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JOHANNESBURG



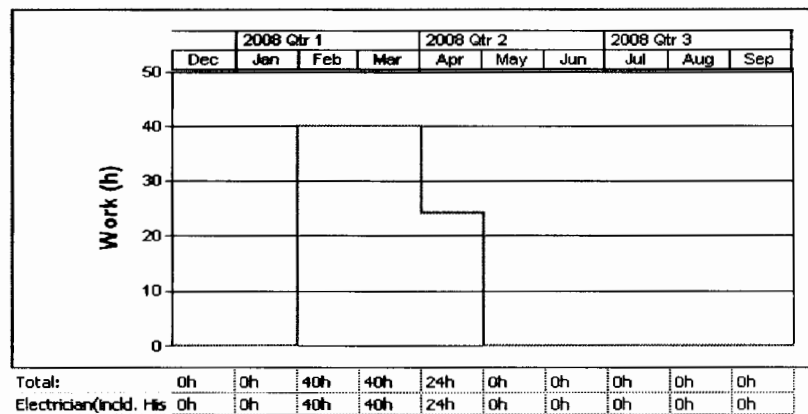
c) Ceiling resource graph



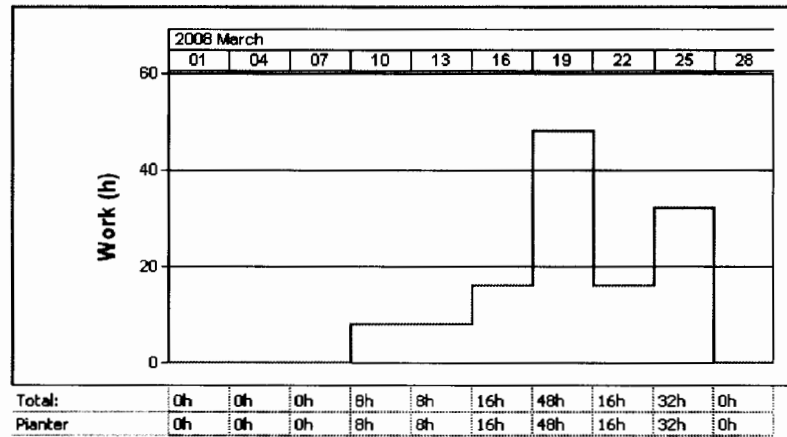
d) Plasterer resource graph



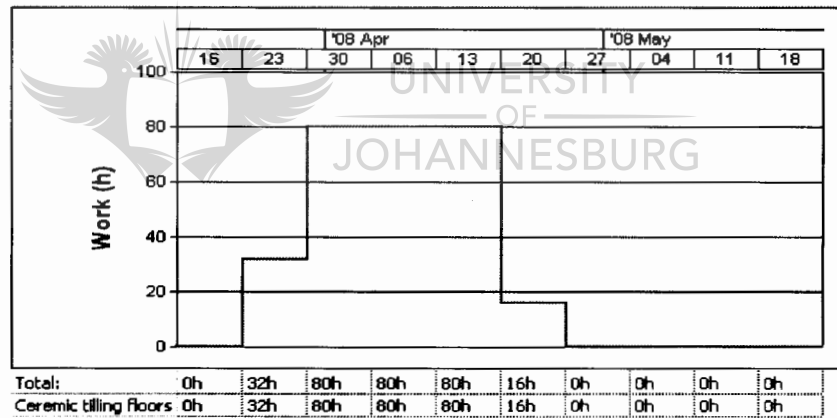
e) Electrician resource graph



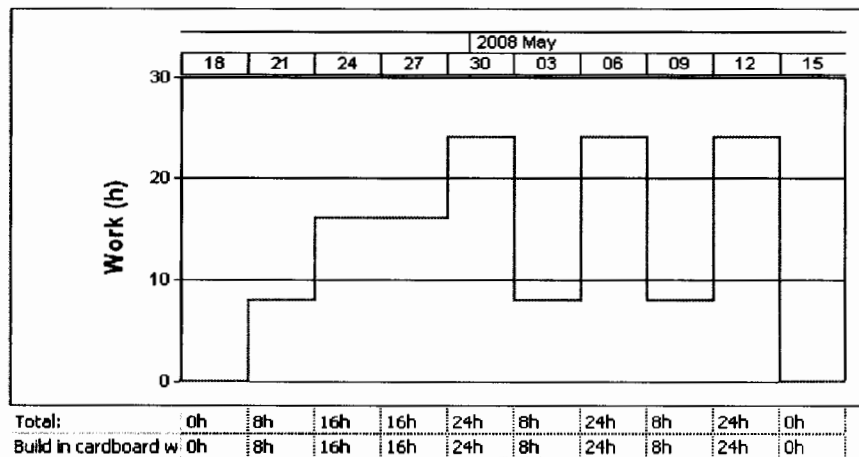
f) Painter resource graph



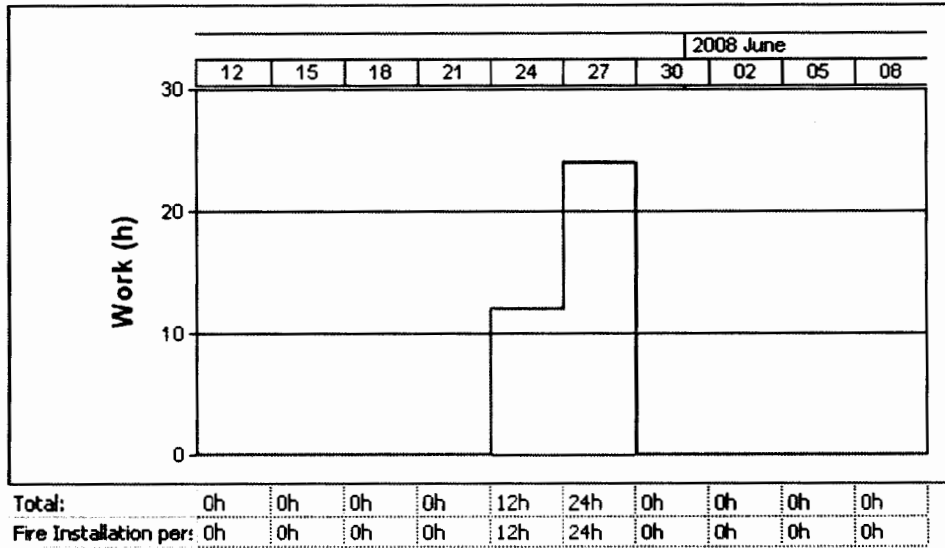
g) Tiling resource graph



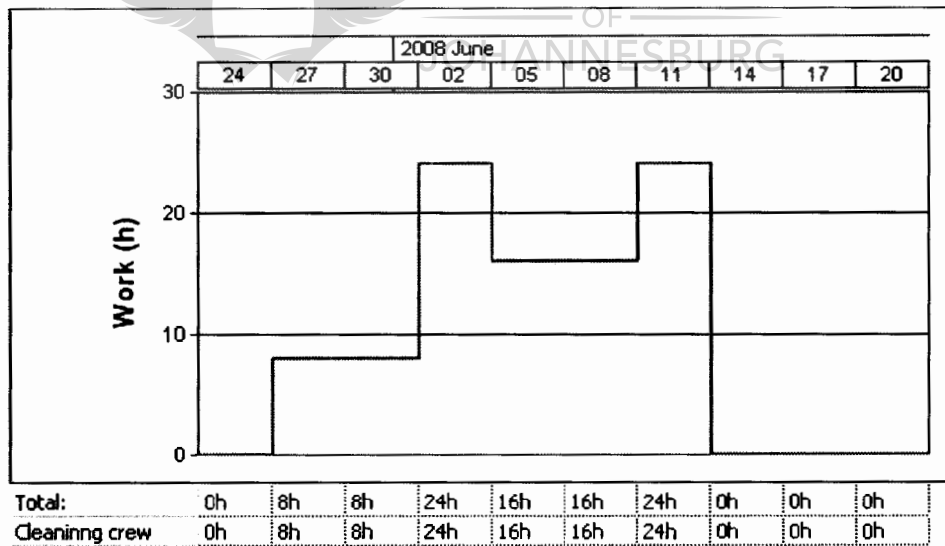
h) Carpenter resource graph



i) Fire installation resource graph



j) Cleaning crew resource graph



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