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RISK SIMULATION IN A PORTFOLIO OF PORT AND RAIL CAPITAL PROJECTS

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A thesis submitted in partial fulfilment of the requirements for the degree of

PHILOSOPHIAE DOCTOR

in the

**GRADUATE SCHOOL OF TECHNOLOGY MANAGEMENT,
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY,**

UNIVERSITY OF PRETORIA

30 October 2015

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Stating the obvious using simulation: "What matters most are controllable risks."

"I am not concerned about the risks that we don't know about but about the ones that we know about and ignore."

ABSTRACT

RISK SIMULATION IN A PORTFOLIO OF PORT AND RAIL CAPITAL PROJECTS

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There are some advantages of using quantitative risk assessment methods over more traditional qualitative risk assessment methods. The cost and schedule impacts of project risks can be better described when using quantitative methods. This in turn allows contingency calculations to be more scientific than when using more traditional methods. In many cases, these quantitative risk registers are stand-alone MS Excel based entities. This represents a problem in that it is difficult and impractical to use these separate risk registers to do a concurrent Monte Carlo simulation. This thesis therefore presents a model which uses the Monte Carlo method to quantify certain risk and project categories in a portfolio of 86 port and rail capital projects. The purpose of the model is to provide a portfolio-wide view of risks to answer the questions “What matters most?” and “Where should the focus be regarding risk treatment plans?”. The answers to these questions should then be used to identify policies and procedures which need to be changed to improve the project delivery and execution process.

The model was based on the principles of the ISO31000:2009 risk management process, MS Excel spreadsheets and @Risk simulation software to generate output distributions which are ranked using various methodologies. The risk and project categories which were used in the model included the following:

- Project type: Each of the 86 projects in the project portfolio was assigned to one of 15 different project categories. The initial expectation was that certain risk names in the project portfolio would cause the most uncertainty.

- Risk type: This refers to the control the project owner and the project team have over influencing the likelihood and consequences which are associated with specific risks. Five different types were used: External uncontrollable, External Influencable, Internal Owner Requirement, Internal Operational and Internal Project Processes.
- Risk name: A total of 165 risk names were used to describe 1063 different risks which belonged to the 86 projects.
- Project start delays: Certain risks delay the execution start of projects and therefore caused the escalation of project cost due to inflation.
- Risks associated with programmes: The model classified each risk in terms of three types defined by Aritua (2011, 311): Generic Project Risks, risks which are Amplified in Programmes and risks which are Common to Programmes.

The initial assumption that certain risk names drive uncertainty in the project portfolio was disproved using the unique risk simulation approach developed in this thesis. It was also shown in a unique manner, using various risk categories, that uncertainty in the project portfolio was driven by eight large, complex, multi-stakeholder projects. The next risk category which caused the most uncertainty was controllable risks, followed by start delay risks, planning risks and lastly policy related risks.

The main contributions of the thesis are identified as:

- **Amount and quality of the unique data which was gathered for this research.** Limited information was available regarding risk simulation in a portfolio or program of projects, especially for a large, complex portfolio. A total of 165 different risk names were identified during the research. Each of the risks were assigned to various risk categories in a unique manner as part of a detailed risk analysis to determine “What Matters most/” and “Where to focus?”.
- **The way in which the simulation model and accompanied framework was developed.** The literature review identified a gap in how simulation models related to the ranking of risks in portfolios of projects can be developed and which questions to ask during the risk analysis process. This gap was filled by a detailed description of how such a model can be built and how risk aggregation

can take place in a project portfolio, using unique combinations of functions in spreadsheets and risk simulation software standards MS Excel and @Risk functions.

- **Some of the specialised representations and analysis of the risk simulation results**. During this research, various graphical representation and analysis techniques were developed. These include methods on (i) how to use regression coefficients in a tree structure to compare various categories in a risk breakdown structure with each other and (ii) how to combine various risk categories in a single simulation table to enable enhanced comparison of various sets of simulation results.

The process of developing such a simulation model was described in great detail in Chapter 4 and applied in various forms in Chapter 5. The contribution is discussed in terms of the following aspects:

- Using risk classification to determine “What matters most?” and “Where to focus?”
- How the initial Research Roadmap changed into a Risk Simulation Framework.
- The research fills a gap regarding quantitative risk analysis on port and rail capital projects. It provides a unique view of the some important risks and risk categories related to port and rail capital projects.
- Since the methodologies and language used in this research project is based on ISO31000:2009, and PMBoK, it implies that the methods developed to aggregate and analyse the risks in the portfolio of projects may not be restricted to port and rail capital projects, but the extent to which this type of quantitative risk assessment approach and framework using dedicated focus group techniques can be beneficial in for example R&D projects remain a topic for further research
- The thesis also supports the idea that using the Monte Carlo method is a valid research methodology and can be beneficial in at least the extensive set of unique port and rail capital projects considered in this research.

Key words: programme management, project portfolio management, project risk management, risk simulation, Monte Carlo method, port project, rail project.

Opgedra aan Willie, Elize, Mannie en Johannes.

ACKNOWLEDGEMENTS

Since I am an engineer, the acknowledgements are in chronological order:

- My husband Werner, who is greatly relieved that this project is now complete. *Tu che le vanità conoscesti del mondo,* Verdi, Don Carlo, Act 5. I couldn't have completed this without your support.
- Moira Moses and Tanya Jeffrey which gave me the opportunity to delve into project risk management. A further thanks for giving me a new career.
- Gerhard Bierman and Charl Möller from Transnet SoC Ltd. for allowing me to use the quantified risks registers used in this research. Without this permission, the development of the model and the risk simulation results would not have been possible.
- Professor Leon Pretorius in helping me putting this together. I enjoyed the thinking together and was privileged to have had such an experienced supervisor.
- Transnet colleagues Rudie Basson, Gerhard Bierman, Dave Budler, Satish Ganesh and Eddie Lindeque which helped answer all my annoying questions. My years (2007 – 2014) as an employee of Transnet Capital Projects was made so much richer having had colleagues like you.
- The people which helped to find gaps in thesis: Graham Atwood, Gerhard Bierman, Neville Eve, Mark Gilfillan, Francois Heyns, Graham Jones, Connie Lesch, Moira Moses, Pascal Mabelo, Sheldon Morris, Doug Oldfield, Dalene Rohde, Martin Snyman, Alicia Swart, Quinton van Eden and the many helpful people at the Palisade helpdesk.
- My sister Elna Budgen who had the dreadful task of going through the final document, correcting all kinds of language and grammar issues.

Shere, October 2015

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LIST OF TERMS AND ACRONYMS

ACRONYM	DESCRIPTION
Billion	10^9
Control	Risk treatment plan which has been implemented
ERM	Enterprise Risk Management
OD	Operating Division
CRR	Combined Risk Register
MDS	Market Demand Strategy
OHTE	Overhead Traction Equipment
Portfolio	Group of related programmes
Programme	Group of related projects
PROM	Project Risk and Opportunity Management
RBS	Risk Breakdown Structure
RIMS	Risk Information Management System
Risk Register	Record of information of identified risks
RRT	Risk Register Template
TCP	Transnet Capital Projects
TFR	Transnet Freight Rail
TNPA	Transnet National Port Authority
TPT	Transnet Port Terminals

1. INTRODUCTION

1.1 Problem Statement Context

This thesis is about risk simulation in a portfolio of capital projects related to rail and port projects. This section sets the context in which the research was conducted by further discussing the concepts (and some supporting ones) used in the thesis title.

The section therefore contains information regarding the following concepts and definitions:

- Port and Rail Capital Projects. This sets the context in which the research was done.
- Projects, Programmes and Portfolios. These terms are described as defined in Project Management Body of Knowledge (PMBoK) (Project Management Institute, 2013, pp. 8-9) and a discussion on project complexity is included.
- Risk Simulation.

The section concludes by discussing the Language used, Problem Statement, Research Objectives, Research Contributions and Thesis Boundaries and a Research Roadmap. The latter is a schematic view of the steps which were followed during this this research.

It also contains a short section on what the Microsoft Excel (MS Excel) and @Risk (MS Excel plug-in which allows stochastic modelling) requirements are, should someone want to replicate a similar simulation model as described in Chapter 4. This enhances the reliability of the research results presented in this thesis.

1.2 Setting the Context: A complex project and organizational environment

This research is conducted in the context of a case study of a complex project and organisational environment specifically related to the development and execution of capital projects related to port and rail infrastructure.

Transnet gave permission for the use of the data analysed in this research and the research process and results have been shared with Transnet throughout the research process. The author collected most of the data himself and was also fully in charge of data collection while being employed at Transnet from August 2007 to April 2014.

Some data on the organisation may also be found in public documentation referred to in the main body of this thesis. It should be noted however, that the simulation model and the principles which was applied in the model, is not dependent on the Transnet data but can be used with any set of quantified risk registers.

1.2.1 Transnet and Port and Rail Capital Projects

The case study organisation is wholly owned by the Government of the Republic of South Africa. It is a freight transport and logistics company and is the custodian of South Africa's freight railway, ports and pipelines infrastructure (Transnet SoC Ltd., 2013, p. 6). Transnet's revenue for the year ended 31 March 2015 grew 8% to R61,2 billion, which was driven by a 7,7% increase in rail volumes, predominantly with regards to iron ore and manganese, coal and mineral mining and chrome exports (Transport World Africa, 2015). The iron ore is mostly mined in Sishen and exported at Saldanha, the manganese at Port Elizabeth and coal at Richards Bay.

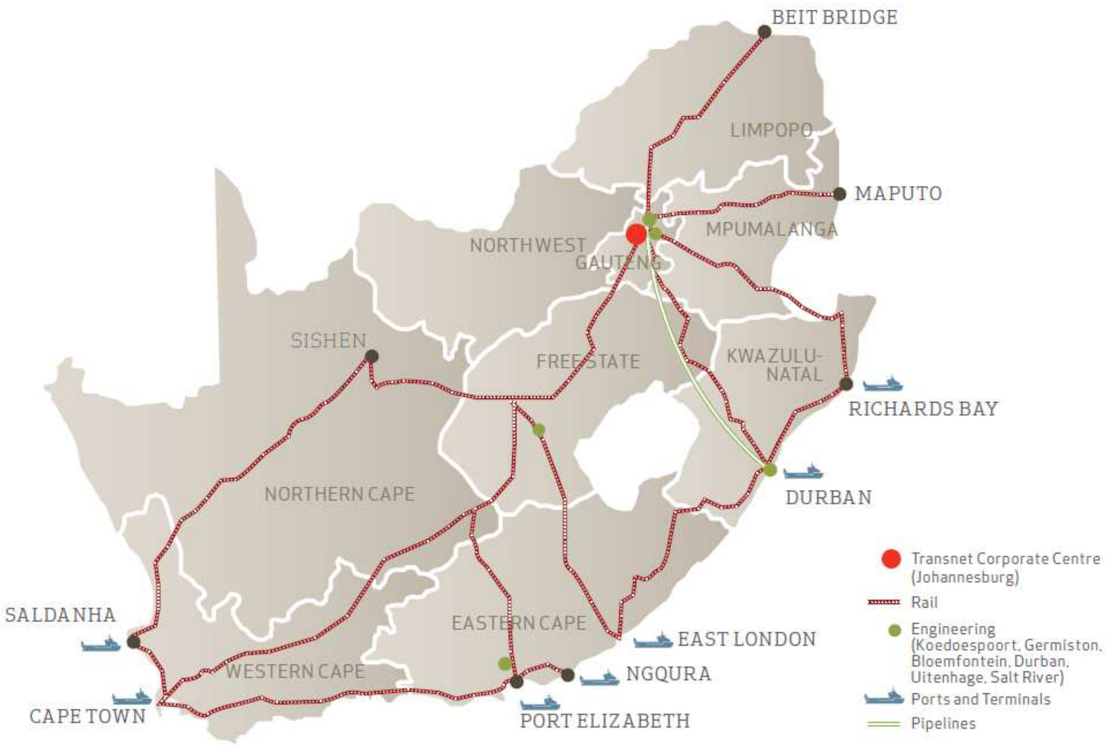


Figure 1-1: Graphical location of the Transnet Corporate Centre and Operating Divisions (Transnet SoC Ltd., 2014, p. 4)

The company has five Operating Divisions (OD), each with a specific purpose, as described in Table 1-1:

OPERATING DIVISION	PURPOSE AND PRIMARY ASSETS
Transnet National Port Authority (TNPA)	Owns and operates 8 commercial ports.
Transnet Port Terminals (TPT)	Owns and operates 5 container terminals, 3 automotive terminals, 3 bulk terminals and 5 break-bulk terminals.
Transnet Pipelines (TPL)	Owns and operates 3 800 km pipelines for petroleum, crude oil, jet fuel and gas.
Transnet Freight Rail (TFR)	Owns and operates 20 500 km railway, 2 255 locomotives and 71 036 wagons.
Transnet Engineering (TE)	132 Depots and 7 Factories.

Table 1-1: Overview of Transnet's operating divisions (Transnet SoC Ltd., 2013, pp. 11 - 12)

The role TNPA plays in the South Africa economy is important when taking into consideration that approximately 31% of South Africa's GDP is derived from export and around 33% of GDP is derived from imports and that TNPA facilitates 98% of South Africa's global trade and services the shipping feeder network connecting the west and east coasts of Africa. At the end of 2014, the company had in excess of 55 000 employees. This then emphasises the extent of the impact this research on risk management has for the region at least.

During the next few years a significant amount of money will be spent in Southern Africa on port and rail projects. Transnet's Market Demand Strategy (MDS) requires that capital investment of R307.5 billion be made between 2013 and 2020. Other regional developments include the 1 500 km, R100 billion Trans-Kalahari railway (Botswana to Walvis Bay) rail project (New Era, 2014) and a 525 km, R55 billion (Tete province to Macuse) rail and port development project in Mozambique (Business Day, 2013).

The MDS is aimed at expanding South Africa's rail, port and pipelines infrastructure, resulting in a significant increase in freight volumes, especially in commodities such as iron ore, coal and manganese. The main objective of the strategy is for Transnet to invest in developing capacity to meet validated market demand that will enable economic growth (Transnet, 2012). Nearly 50% of the investment is related to the procurement of new locomotives and rolling stock.

Transnet Capital Projects (TCP) is one of three specialists units within Transnet and is responsible for the development and execution of capital projects related to port, rail and pipeline infrastructure.

Capital projects are undertakings which require the use of notable amounts of capital, both financial and labour, to start and complete. These projects are often defined by their large scale and large cost relative to other investments requiring less planning and resources (Investopedia, 2014; Dartmouth College, 2015).

The 86 projects which were the focus of this research, are spread over the entire South Africa and the completed assets will be owned by the OD as indicated in Table 1-2:

OPERATING DIVISION	CAPE TOWN	PORT ELIZABETH	DURBAN	CONTAINER FREIGHT (DURBAN)	RICHARDS BAY	COAL (ERMELO TO RICHARDS BAY)	GRAND TOTAL
TFR	1		3	2	2	31	39
TNPA	1	3	10	2	1		17
TPT	1	1	2	2	16		22
Buildings	2		2	4			8
TOTAL	**5**	**4**	**17**	**10**	**19**	**31**	**86**

Table 1-2: TCP Projects per location

The variety of projects required by the Operating Divisions is wide but is related to the ODs core business, as described in Table 1-3:

OPERATING DIVISION	TYPICAL PROJECTS	PROJECT NAMES
TFR	Projects related to the rehabilitation and developing of railway lines and related infrastructure (overhead traction equipment, signaling and electrical supply).	• Black hill Combination yard refurbishment • Tunnel 7 Realignment • Sheepmore substation construction • Matlabas Loop Lengthening • Dumbe slip repair
TNPA	Projects related to port infrastructure which do not relate to materials handling equipment. This includes infrastructure such as road upgrades, berth deepening, new quay walls and the repair of quay walls and berths.	• Berth Deepening 203 - 205 • East London Foreshore refurbishment • Maydon Wharf refurbishment • Permanent Sand Bypass construction • Pier 1 Phase 2 construction
TPT	Projects related to the repair, removal and installation of materials handling equipment - conveyors, ship loaders, tipplers as well as the creation and repair of stacking and lay-down areas.	• Export Trippers, Port of Richards Bay construction • Weigh Bridges construction • Dust suppression Rail Wagons installation • Saldanha Tippler construction • Dust control K 24 tunnel, Conveyor transfers and compressed air reticulation system construction

Table 1-3: Variety of projects

1.2.2 Projects, Programmes, Portfolios and Complexity

PMBoK (Project Management Institute, 2013, p. 8) defines a project hierarchy where projects roll up into programs and programs up into portfolios. This view is shared by Hillson (2009, p. 80) and Chapman & Ward (2011, p. 8) and the best solution for managing risk is a project portfolio, is to adopt a portfolio-wide approach (Teller, 2013, p. 36). This is important because the simulation model which is newly developed in Chapter 4 needs to be able to aggregate risks on a project, programme and portfolio level and form a core contribution in this research. This in turn should provide programme and portfolio managers with information regarding where to focus their risk treatment plans. This is important because certain risks might not be solvable on a project or programme level (Hillson, 2009, p. 81).

By their nature, programmes and portfolios are more complex to manage than single projects and compared to matured disciplines like project management, there is little literature available to accurately describe programme management, its nature and practice. Programme management is also not the same as project management, but rather an integrated approach that should streamline the effective delivery of projects (Shehu & Akintoye, 2009, p. 203). Baccarini (1996, p. 202) proposes that project complexity is defined as “Consisting of many varied interrelated parts” and that it can be operationalised in terms of differentiation and interdependency. Aritua et al. (2009, p. 76) also discussed inter-relationships as one of the characteristics of a complex, multi-project (for example programmes) construction environment.

The projects TCP execute take place in an organisationally complex environment for the following reasons:

- Construction projects are typically characterised by the engagement of several separate and diverse organisations (ODs, TCP, contractors, and consultants) over a project’s lifecycle.

When looking at the 86 projects which form the core of this research data and thus providing the input to this research, TCP can be differentiated into 86 temporary multi-organisational structures to manage the development and execution of projects.

- The case study environment considered in this research is organisationally complex because it is vertically differentiated into many levels and horizontally differentiated into the various operating divisions (TCP, TFR, TNPA, TPT, and TPL). Organisational complexity is further increased by the degree of operational reciprocal interdependencies and interactions (or lack thereof) between TCP and the ODs, specifically in multiple OD projects. The latter presents the highest level of project complexity (Baccarini, 1996).
- The case study organisation is horizontally differentiated in terms of a task structure where each specialization presents a distinct area of knowledge which is typically founded on education and/or training. In construction management this can include the different knowledge areas as described in the PMBoK (Project Management Institute, 2013, p. iii). This type of specialisation is common in the construction industry as a result of the wide variety of different services required to execute a construction project.
- The task structure is further differentiated according to location (for example Engineering Departments in Durban and Johannesburg, centralised functions such as Project Risk Management and Legal Services) and different requirements during the phases in the project lifecycle (Baccarini, 1996, p. 202).

In addition to the above, the projects being executed in an environment where there are significant risks regarding revenue and volume growth, energy security, funding and liquidity, regulatory uncertainty as well as human resources capability (Transnet SoC Ltd., 2013, p. 16), significant project complexity also exist.

Some of the attributes contributing to the organisational complexity appear in Table 1-4.

VARIABLE	RANGE FROM	RANGE TO
Engineering	No or limited in-house design required.	In-house managed, outsourced specialist/Original Equipment Manufacturer design.
Timescale	6 months.	More than 5 years.
Procurement	In-house procurement (standard or Original Equipment Manufacturer specifications).	In-house managed, outsourced procurement (standard or Original Equipment Manufacturer specification + 3rd party specialist specification).
Commissioning and Handover	Simple handover to Operations.	In-house managed, outsourced 3rd specialist commissioning and project handover to Operations.
Stakeholder impact	No stakeholder impact.	Multiple external stakeholders (including customers)/strategic multiple Operating Division impact.
Team Size	< 5 people	> 50

Table 1-4: Project Complexity (Transnet, 2011)

The above all fits into a model which was proposed by Evaristo & Van Fenema (1999, p. 277) in which projects take place inside a programme, in multiple distributed locations (Figure 1-2, right left corner). Problems identified with these types of projects include difficulties with communication, sharing resources and difficulties in scheduling of projects (and their related emergencies).

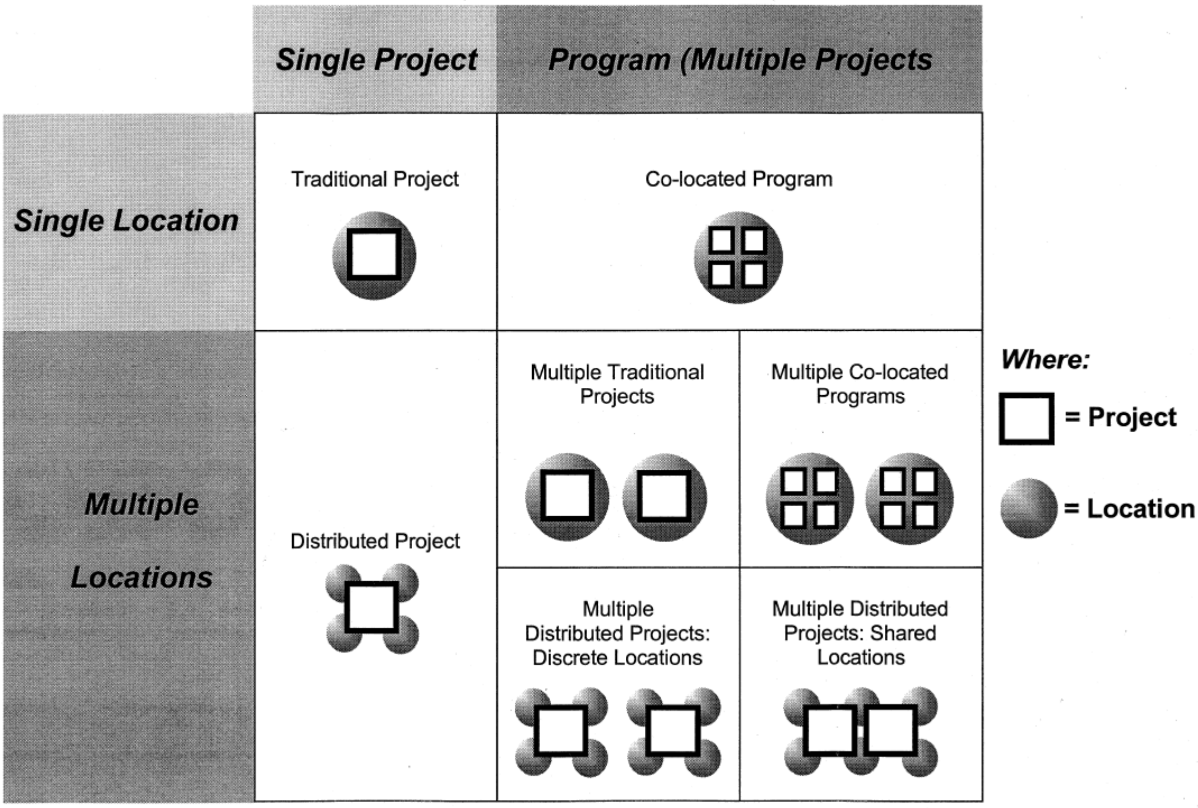


Figure 1-2: Project Management Typology (Evaristo & van Fenema, 1999)

1.2.3 Section Summary

It can therefore be concluded that in the context of this research, projects are executed in a complex organisational environment. The complexity is further exacerbated by the difference in complexity of the various projects. They can range from a like-for-like replacement, requiring a team of 3 people for one OD, to a multiple stakeholder, R6 billion berth deepening project, involving 150 people, requiring complex engineering with different suppliers, complex multi-contract procurement which can take 5 years to complete.

1.3 Risk Simulation and the Roll-out of Project Risk and Opportunity Management at Transnet Capital Projects

Up to 2010, TCP (the case study environment) used a joint venture, HMG (Hatch, Mott McDonald, Goba) as an EPCM consultant. HMG employees conducted quantitative risk analysis on a project by project basis since there was no internal Capacity at TCP.

When the relationship with HMG ended, internal project risk management capacity was created at TCP and the unique set of data used in this research was gathered during the roll-out of a quantitative Project Risk and Opportunity Management (PROM) approach at TCP.

It was the first time in South Africa's history that this type of approach was rolled out on part of a *port and rail capital investment programme*/portfolio and not individual projects. This also means that the amount quality and extent of data which was collected during this process is unique in a South African context.

There were two primary reasons for the roll-out of PROM in the case study organisation. This first was that the Enterprise Risk Management (ERM) approach could not handle project complexity and that the project reserve/contingency guidelines were found to be insufficient.

1.3.1 ERM and handling complexity

The Transnet ERM methodology could not fulfil the risk modelling requirements of complex projects. The methodology followed a risk qualification approach. This process ranked risks for further analysis or action by assessing and combining their probability of occurrence and consequence (International Organization for Standardization, 2009, p. 273) but did not provide for quantitative analysis of the effect of identified risks on overall project objectives. A quantitative approach fulfils this requirement and had to be able to model risks of the following complexity:

- "Risk XYZ is a multiple occurrence risk, which can happen 4 times over the duration of the project, has a time delay of up to 4 weeks, with a weekly cost of R250 000 and additional capital cost of between R30 and R60 million".

The unique methodology developed as part of the research presented in this thesis therefore had to be able to model single or multiple occurrence risks, time delays, time variable cost and additional capital cost.

1.3.2 Contingency guidelines not accurate

The contingency guidelines provided by the TCP Project Lifecycle Process (PLP) used percentage values to calculate project contingency. This meant that for a project in execution phase, a standard 10% was applied. A more accurate approach was required and was developed during this thesis. PROM therefore had to provide for the following:

- The calculation, testing and tracking of project contingency/reserves. These provisions in the project estimate to be used in the mitigation of cost and/or schedule risk (Project Management Institute, 2013, p. 445) estimate project management plan.
- The integration of a risk register with the Project Estimate and Project Schedule to provide a risk loaded Final Project Cost and Completion Date. A risk register is a document used to identify, analyse and evaluate risks (International Organization for Standardization, 2009).

1.3.3 Development of Risk Register Template

As per Cooper, et al. (2005, p. 258), Hillson (2009, p. 36) a Risk Register Template (RRT) was therefore developed for use in the TCP project environment with unique risk data, using the Monte Carlo method and @Risk software. The Monte Carlo method is a computerized mathematical technique that allows for the calculation of risk in quantitative analysis and decision making (Hillson, 2009 p. 41; Palisade, 2014). It is used to aggregate variation in a system resulting from variations in the system, for a number of inputs, where each input has a defined distribution and the inputs are related to the output via defined relationships ISO31010 describes it as one of the three statistical methods to do risk assessments (American Society of Safety Engineers, 2011, p. 30). Hillson (2009, p. 40) also states that there are various quantitative risk analysis techniques available and that Monte Carlo is the most popular because it uses simple statistics, is can use existing project data as baseline and that there are many good software tools to support it.

@RISK uses the Monte Carlo method to identify, measure, and root out the causes of variability in the risk register (Palisade Corporation, 2014, p. 843). In the context of simulation software, Palisade Corporation defines risk as referring to uncertainty or variability in the outcome of some event or decision. Vose uses the same definition (Vose, 2008, p. 4).

The Monte Carlo method can be used to perform risk analysis by developing models of possible results by substituting a range of values, in the form a probability distribution, for any factor in a project that has inherent uncertainty (Palisade Corporation, 2014; Cooper et al., 2005, p. 258). In the context of project management, these factors include variables such as project delays, time variable cost and additional capital requirements for risk treatment. The simulation then calculates results repeatedly, each time using a different set of random values from the probability distribution functions. After executing up to tens of thousands of iterations, a Monte Carlo simulation produces distributions of possible outcome values (Palisade Corporation, 2014, American Society of Safety Engineers, 2011, p. 89).

In practical terms, it produces a number in conjunction with a likelihood, for example: "There is an 80% likelihood that the project will be completed on 4 April 2015" instead of "on 4 April 2015". Other advantages of a Monte Carlo simulation over a deterministic or "single-point" estimate analysis includes, amongst others, the following:

- It enables sensitivity analysis which identifies which inputs have the biggest effect on the results and allows scenario analysis to take place (Palisade Corporation, 2014).
- It can provide a measure of the accuracy of the result and the software is readily available and relatively inexpensive (American Society of Safety Engineers, 2011, p. 92).

It was attempted to roll out a quantified approach in all of TCP's projects. This was not fully possible since in some projects, there simply wasn't enough information available in the early project phases to complete a quantified project risk register. Of the 106 projects uploaded in the Risk Management Information System (RIMS), 86 were quantified.

1.3.4 Section Summary

A qualified ERM methodology could not fulfil the requirements of risk modelling in a complex port and rail capital project environment. An approach using a MS Excel based risk register template and simulation software (@Risk) was rolled out on 106 projects. Of these 106, 86 were quantified.

The extant and quality of data collected during this process contributes to the uniqueness of this research. It is the first time in the case study organisation's (and South Africa's) history that data of this nature (quantity quality and scope related to port and rail projects) is available for further analysis and this therefore also represents a unique contribution of this research.

1.3.5 Language: ISO31000:2009

The language used in ISO 31000:2009 was used extensively during the creation of the project risk management procedures at TCP. Therefore, their definition of *risk* as the "effect of uncertainty on objectives" was used during the writing of these procedures. The other risk related terms and definitions used in this thesis also stems from ISO31000:2009.

ISO31000:2009 provides principles and generic guidelines on risk management. It can be used by any public, private or community enterprise, association, group or individual and is applicable to any type or risk. ISO31000:2009 can be applied throughout the life of an organisation, and to a wide range of activities, including project management (Dali, 2013; Purdy, 2010). It was also adapted as the national risk management standard for South Africa by the South African Bureau of Standards (South African Bureau of Standards, 2014, p. 1).

When implemented and maintained in accordance with ISO31000:2009, the management of risk enables an organisation to, amongst other outcomes:

- Increase the likelihood of achieving objectives.
- Encourage proactive management.
- Increase the awareness of the need to identify and treat risk throughout the organisation.
- Improve the identification of opportunities and threats.
- Improve stakeholder confidence and trust (South African Bureau of Standards, 2014, p. i).

As defined by ISO31000:2009, Risk Analysis, together with Risk Identification and Risk Evaluation, enables Risk assessment to take place. It is by definition a dynamic process because it requires a process to start by establishing the context and continues throughout the other steps until the project is complete.

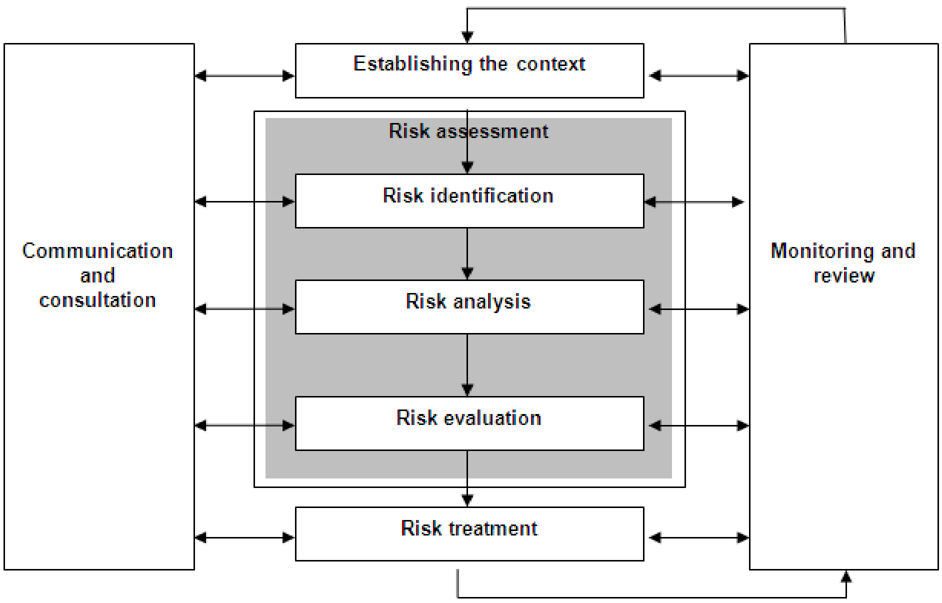


Figure 1-3: Risk Management Process (South African Bureau of Standards, 2014, p. 14)

Risk Analysis is a process to comprehend the nature of risk and to determine the Level of Risk. The Level of Risk is the magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood (South African Bureau of Standards, 2014, p. 6). After the Level of Risk has been determined, it is compared to risk criteria to determine if the level of risk is acceptable or not.

1.4 Problem Statement

Although the 86 projects as part of empirical research conducted in this thesis were all quantified, each risk register was a separate entity and a mathematically correct view of the various risks spread over project portfolio did not exist. All the risk registers were captured in the RIMS and the only available methodology was to export all the data to MS Excel and perform aggregation of the P80 values of each individual risk description. In practical terms, if the risk "Industrial Action" appeared 5 times, each time with a different P80 value, these values were simply summed, as shown in Figure 1-4:

Figure 1-4: Risks aggregation

This is mathematically incorrect but at least provided some idea of which risks had the biggest potential consequence.

The purpose of this thesis is to develop a mathematically correct way of aggregating risks from various risk registers and the research problem statement therefore is as follows:

How can individual Risk Registers and the Monte Carlo method be used to identify focus areas in a project portfolio?

This means that Figure 1-4 changes to what is presented in Figure 1-5:

Figure 1-5: Risk aggregation using Monte Carlo Method

1.4.1 Research Objectives and Research Questions

Based on the Problem Statement, the Research Objectives and Research Questions addressed in this thesis are summarised in Table 1-5.

	RESEARCH OBJECTIVE	RESEARCH QUESTION
1.	Establish what is available in the literature regarding risk simulation and programmes/portfolios in a port and rail project environment.	What is available in the literature to provide guidelines in answering the problem statement?
2.	Present a methodology on how to develop a model which can run a concurrent Monte Carlo simulation on a programme/project portfolio.	How does one develop a model to enable a quantified portfolio view of risk in a set of projects?

	RESEARCH OBJECTIVE	RESEARCH QUESTION
3.	When simulating the risks in a project portfolio, establish where the focus areas are when taking the programmes and the Risk Breakdown Structure (RBS) into consideration.	How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?
4.	When simulating the risks in a project portfolio, establish where the focus areas are when taking the ability to control risks and the RBS into consideration.	When simulating the risks in a portfolio of programmes, are controllable risks material in causing uncertainty?
5.	When simulating the risks in a project portfolio, establish where the focus areas are when taking the ability to control risks, the RBS and project start delay risks into consideration.	When simulating controllable project execution start delay risks, where should the focus area be?
6.	When simulating the risks in a project portfolio, establish if risks related to programmes are material causing uncertainty.	When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?
7.	When simulating the risks in the project portfolio, establish which of the categories defined in Research Questions 3, 4 and 5 have the most influence on uncertainty in the project portfolio.	When simulating various risk categories, which of the categories have the most influence on uncertainty in the project portfolio?

	RESEARCH OBJECTIVE	RESEARCH QUESTION
8.	When estimating contingency, establish the difference between the simple aggregation of P80 values compared to a concurrent simulation of a portfolio of programmes when estimating contingency and ranking risks.	How does the contingency requirement in a portfolio of programmes compare to the contingency requirement of the sum of the individual project's requirements?
9	When estimating contingency, establish how simulation results compare to using "rules of thumb", e.g. "Contingency is equal to 10 % to estimate contingency requirements.	How does the simulated contingency requirements compare when using rules of thumb?

Table 1-5: Research Objectives and Research Questions

1.4.2 Research objective summary

The contents from Table 1-5 can be summarised as follows:

The simulation model should assist decision making on a programme and portfolio level by identifying which risks really matter and which ones can be controlled. The result of this should be used as an input to the case study organisation's ERM processes to ensure that systemic risks are treated in an appropriate manner.

1.4.3 Research Contributions

When looking at the research objectives and questions, as mentioned in the previous section, several research contributions can be derived. This includes the following and will be discussed a much more detail in the final chapter of this thesis:

- A unique risk simulation methodology which can be used in a portfolio of programmes.
- Presenting and discussing the unique simulation results in terms of "What matters most?" and "Where to focus?".

1.4.4 A unique risk simulation in a portfolio of programmes

A great number of project risk management related texts (Cooper, et al., 2005, Project Management Institute, 2013, Chapman & Ward, 2011, Edwards & Bowen, 2005, Jahangirian, et al., 2010) touches on the uses of risk quantification and the Monte Carlo method, but does not give details of the "how" on developing models capable of simulating risks in a project portfolio. As shown in the Literature Review in Section 2 much has been written regarding various topics related to risk simulation, risks in capital projects, risks related to port and rail projects, but very little which specifically relates to this topic.

Due to the gap identified in the previous paragraph, the documentation of a method to develop such a model should provide a further research contribution. This research covers this in great depth and provides detail to enable project risk practitioners, with a good understanding of spreadsheet and risk simulation software such as MS Excel and @Risk, to develop similar models. This also adds to the reliability and validity of the research results presented later in this thesis.

1.4.5 The risk simulation results: "What matters most?" and "Where to focus?"

This unique contribution is a direct result of the risk simulation results. The case study organisation (and by implication - South Africa and this Southern African region) has never had the opportunity to have a quantified portfolio view of risks across the capital projects being executed by TCP. Based on the scale of the case study organisation's investment, the number of projects and the importance of these projects to South Africa's economic growth, the results of a risk simulation across 86 quantified projects are relevant and should provide input into at least the case study organisation's ERM activities.

The outcomes of the second half of the second research question "Where are the focus areas in the RBS when taking project execution start delay risks into consideration?" and the rest of the research questions should provide the case study organisation with empirical results to identify where the focus should be, on a portfolio and programme level, during the implementing risk treatment plans. But the organisation, being such a major player in the South African context as shown in previous section, should also supply some indications for similar sectors.

The unique risk simulation results can also provide useful information to similar regional projects, such as the Trans-Kalahari railway and Tete province to Macuse rail and port project (Section 1.2).

1.5 Thesis Boundaries

The boundaries for this thesis are briefly discussed in terms of the following:

- Scope limited to port and rail capital projects
- Implementation of the risk management process.
- Business case for project risk management.
- Integration of project risk register into cost estimates and schedule
- Opportunities.
- Parts of ISO31000:2009 Risk Management process.
- Transnet Pipelines.
- Causes and treatment plans for the risks identified after simulation results.
- Use of MS Excel and @Risk functions.
- Correlation.

1.5.1 Scope limited to port and rail capital projects

The scope of this thesis was limited to port and rail capital projects for the reason that data related to these projects could be accessed and, as mentioned earlier, collected by the author while employed at Transnet Capital Projects. The majority of the data collection was done by the author himself over a four year period and he was essentially in charge of the entire collection process

1.5.2 Implementation of risk management process

The thesis assumes that the risk management policies, frameworks, procedures and templates used during the implementation of PROM at TCP are in order and does not make any judgments regarding how the process could have been improved and on the effectiveness of the implemented risk management process.

1.5.3 Business case for project risk management

Although the reasons for TCP implementing a Quantified Risk Management approach are mentioned in Section 1.3, this research is not about the business case for project risk management. This has been eloquently described by Hillson (2009), Chapman and Ward (2011), Kendrick (2003) and the Project Management Institute (2008). The research also does not cover the creation of project risk management policies and procedures and practices.

1.5.4 Integration of project risk registers into cost estimate and schedule

The research only covers the risk analysis and simulation of the risk register and excludes the integration of the identified risks into each project's estimate and schedule for any kind of uncertainty modelling. It also excludes discussions regarding cost uncertainty and the developing of models relating to executing a concurrent Monte Carlo simulation on all the individual projects' estimates and schedules.

1.5.5 Opportunities

Work done related to the *Opportunity* part of PROM is excluded, mainly because the risk identification process followed during the risk management process did not include the identification of opportunities, a common shortfall as identified by Hillson (2009), Chapman & Ward (2011) and Krane & Johansen (2014).

1.5.6 Parts of ISO31000:2009 Risk Management process

The risk register used to collect the data, included the following parts of the ISO31000:2009 process:

- Establish the context.
- Risk Identification.
- Risk Analysis.
- Risk Evaluation.
- Risk Treatment.

The following two sections are not described in this research since they were not part of the Risk Identification process:

- Monitor and Review.
- Communicate and Consultation.

1.5.7 Transnet Pipelines

This research excludes risk register related to work done by TCP on the New Multi Product Pipeline (NMPP). The main reason for this is that this research focusses on port and rail projects, and not complex bulk liquid transport projects, such as the NMPP.

1.5.8 Causes and treatment plans for the risks identified after simulation results

In the discussions regarding the impact of the risk simulation results on project management in Chapter 5, some potential causes and treatment plans for various risks are mentioned. These are incidental since this thesis deals with risk simulation and not the identification of systemic risk causes and treatment plans for the case study organisation. The latter forms part of future research.

1.5.9 Use of MS Excel and @Risk functions

This research is not a textbook on how the MS Excel and @Risk functions which are used in the simulation model work and how they are used. Therefore, when the simulation model is presented in Chapter 4, none of the more complex functions (De-duplication, Named Ranges, and Pivot Tables etc.) are described in detail. For further information regarding these, please refer to the MS Excel Help function (Microsoft, 2013).

1.5.10 Correlation

Simulation models normally require that risks should be correlated with each other before executing simulation results (Palisade Corporation, 2014, p. 26; Smith, et al., 2006, p. 95). The simulation model developed and presented in this research contains 1063 different risks from 86 different projects. This means that a 1063 by 1063 correlation matrix needs to be created to enable the incorporation of correlation into the simulation model.

Due to the complexity and dynamic nature of such a matrix, it was assumed at this stage of the research that all the risks were independent, which excluded the use of any correlation matrix. There is also evidence that when considering large numbers of items, realistic correlation modelling is rarely practiced (Broadleaf Capital International Pty. Ltd., 2014, p. 11).

1.6 Research Roadmap

This research is broken up into six parts, as shown in Figure 1-6 and the description of the steps in Table 1-6. This research roadmap is used throughout this thesis and is further broken down in Chapters 4 and 5.

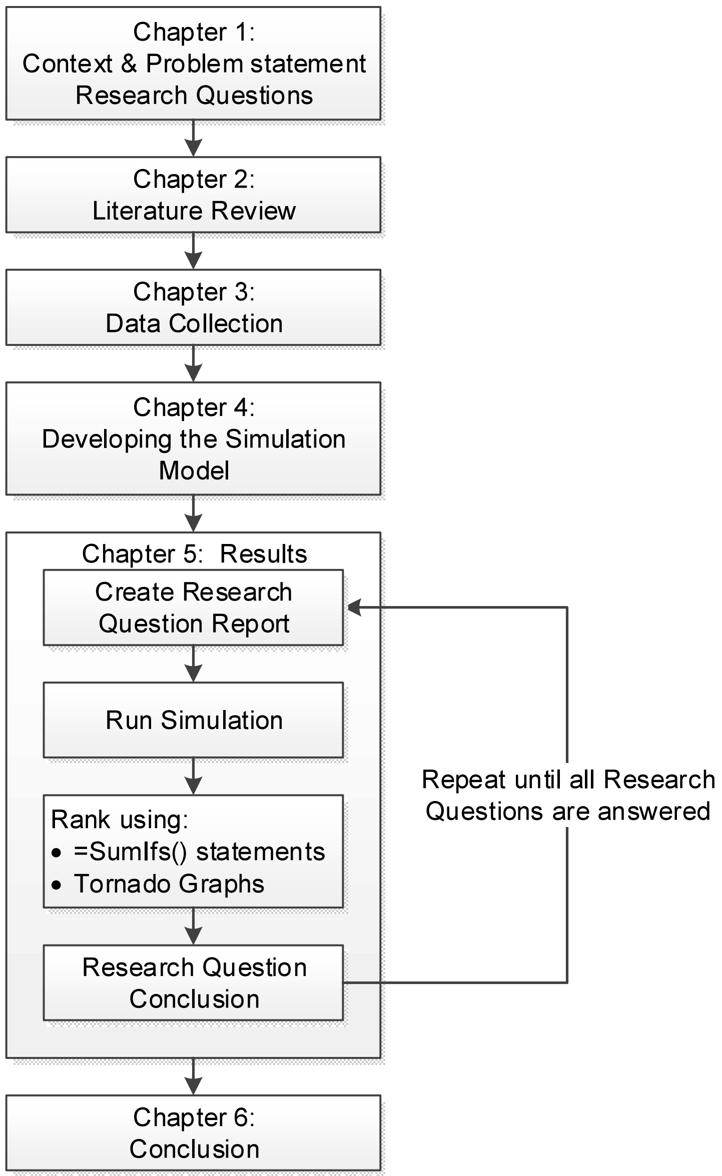


Figure 1-6: Research Roadmap

CHAPTER	CONTENTS
Chapter 1: Introduction	• Contains the context, Problem statement, Research Objectives and Questions, Research Contributions and Thesis Boundaries.
Chapter 2: Literature Review	• Discusses the appropriateness of simulation as a research methodology. • Gives an overview of what literature is available regarding risk simulation in a portfolio and the risks found on port and rail projects.
Chapter 3: Data Collection	• This describes the tools and techniques used during the data collection. It focusses on the risk analysis part of the risk register. • It includes detail on how likelihood and consequence were modelled using @Risk. • It concludes with a short section on lessons learned during this process.
Chapter 4: Developing the Simulation Model	• This describes step-by-step on how the individual risk registers were taken and integrated into a single MS Excel based model. • It describes how the reports were created and how they function. • It concludes with executing the simulation and some techniques to resolve simulation errors.
Chapter 5: Results	• A report is created in MS Excel for each research question, a simulation is executed and the risks are ranked using *=SumIfs()* statements and Tornado graphs.
Chapter 6: Conclusion	• This Section includes a discussion on the research results, academic contributions and recommendations.

Table 1-6: Section overview

1.7 Requirements for replication of methodology

In addition to knowledge on project risk management, project management, construction management, Monte Carlo simulations and spreadsheets, the following are required to replicate the simulation model described in this thesis and thereby increase the reliability of the research results presented:

- MS Excel and @Risk were used in the creation of the individual risk registers and also in the development of the simulation model described in this research.
- Detailed knowledge of MS Excel and the ability to use the following functions:
    - =If().
    - =Sum().
    - =VLookup().
    - =SumIf() and =SumIfs().
    - =IfError().
    - Data validation - Lists.
    - Deduplication.
    - Pivot Tables.
    - Named ranges and the use of these in equations.
    - Conditional formatting.
- Detailed knowledge of @Risk and the ability to use the following functions:
    - =RiskBinomial().
    - =RiskPoisson().
    - =RiskPertAlt().
    - =RiskLognormAlt().
    - =RiskOutput().
    - =RiskMakeInput().
    - =RiskSimtable().

The functions and distributions described above are generic and should other software packages be used to develop similar models, the steps described in Chapter 4 should be generic enough to enable the replication in other software environments. No knowledge of Visual Basic (VBA) is required.

The functions described above are fairly standard and appear in other comparable software such as Modelrisk and Crystal Ball. One particular reason for using @Risk for this research was that it was the software standard for Case Study organisation where the research was mainly focussed and the author has extensive knowledge of theoretical and practical issues related to simulation using @Risk.

1.8 Chapter Summary

This chapter set the context in which the 86 project risk registers as part of the research and process discussed in this thesis were created for port and rail infrastructure capital projects. It proposes seven different research questions and discusses the research contribution in terms of the following:

- A literature study on what is available regarding the developing of simulation models for programmes related to port and rail capital projects.
- Documenting how a simulation model, which is able to simulate risks in a programme and portfolio environment, can be developed.
- Using the risk simulation results to answer the questions “What Matters Most?” and “What can be controlled?”.

The Chapter concluded by stating thesis boundaries which mainly deals with the exclusion of certain parts of the ISO31000:2009 risk management process. It then gives an overview of the rest of this thesis and concludes with a list of requirements; should a risk practitioner be tasked to replicate the developing of the simulation model.

In Chapter 2, a literature review is presented which shows that little has been published regarding the development of risk simulation models related to port and rail capital projects.

2. LITERATURE REVIEW

This Chapter is in essence the answer to Research Question 1 where a literature review is conducted and it relates to the other research questions by identifying gaps in the literature and provides grounds for the uniqueness of the outcomes of the research questions.

The purposes of a literature review is to (i) establish the context of the problem by referencing previous work, (ii) discussing theories and ideas related to the problem, (iii) showing the reader what work has been done previously and (iv) which theories have been applied in solving the research problem (Blumberg, et al., 2008, pp. 106-107). Taking this and the research questions into consideration, this chapter provides answers to the following questions:

1. What is the relationship between programme management, project management, project risk management and risk simulation?
2. Which sources are available showing the structure and functioning of a simulation model which produces a quantified view of a project portfolio?
3. What research has been published regarding the quantification of risks for capital projects such as port and rail infrastructure?
4. What has been published regarding simulation as research methodology?

To provide the above answers, the chapter is divided into the following parts:

- Research method employed.
- Outcome of literature review.
- Summary.

It should also be noted that the research questions which were defined in Chapter 1 were not the result of a literature review, as may be the case in some research projects. In this case, the literature review is used to determine what has already been published regarding a set of research questions, where these questions were in turn based on a practical, engineering management problem.

2.1 Research Method

For the 1st of the questions mentioned in the introduction above, the following approach was followed:

1. Are there textbooks available to allude to the relationship between programme management, project management, project risk management and risk simulation?

For the 2nd to 4th questions mentioned in the introduction above, the methodology followed to do this review is broadly the following:

1. The thesis title as representative of the broad research goal was broken down into the following parts:
   - Simulation Models and a quantified view of a project portfolio.
   - Risks in Port and Rail Capital Projects
   - Simulation as Research Methodology.
2. Each of these parts were then investigated in terms of the following:
   - Are there any international standards which can be used to provide answers to the research questions?
   - Are there authoritative textbooks available to provide answers to the research questions?
     Are there any appropriate journal articles or conference proceedings available which can provide answers to the research questions?

The following sources were used in the above investigation:

- University of Pretoria and author's personal library.
- Online databases such as Knovel, Sage Knowledge, ScienceDirect e-Books, Taylor & Francis eBooks, Wiley Online Library.
- Google Scholar where appropriate.
- Posting questions in publics forums such as LinkedIn's group "Project Risk Management Online".

Most, if not all of the sources cited were typically checked to be reasonably cited, properly peer reviewed and supported from frequently used and well known publishing entities such as the *International Journal of Project Management*.

2.2 Outcome of literature review

As mentioned earlier, this section is divided into the following four parts:

- Programmes, Projects, Project risk management and Risk Simulation.
- Simulation Models and a quantified view of a project portfolio.
- Risks in Port and Rail Capital Projects.
- Simulation as Research Methodology.

2.2.1 Programmes, Projects, Project Risk Management and Risk Simulation

This section deals with searches in textbooks, conference proceedings and journal articles to establish what has been written regarding the relationship between programmes, projects, risk management and risk simulation.

Textbooks on risk simulation

When writing about risk simulation, it is important to link risk simulation back to the broader literature base related to project management and project risk management. This is important because it directly influences the application of the work done in this research project. Although the data which will be used in the project relates to port and rail capital projects, the principles applied should still relate to risk management and its' position within project management as a discipline.

Portfolio management refers to the centralised management of one or more portfolios which includes identifying, prioritising, authorising, management and controlling projects, programs and other related work, to achieve specific strategy business objectives (Project Management Institute, 2013, p. 9). PMBoK therefor creates a hierarchy (from large to small) in the form of Portfolio, Program, Project, similar to what is displayed in Figure 1-4. The opinion is shared by Chapman & Ward (Chapman & Ward, 2011, p. 9).

In addition to this, there are several sources which place project risk management inside the sphere of project management activities. PMBoK states that it is one of the 12 project management knowledge areas (Project Management Institute, 2013, p. 43). The simple fact that there are books specifically related to project risk management that confirm this. Examples of the latter are by Chapman & Ward (2011), Cooper et al., (2005), Hillson (2009) and Flyvbjerg et al. (2003).

PMBoK then includes “Perform Quantitative Risk Analysis” as one of the six project risk management processes under which “Quantitative risk analysis and modelling techniques” are included. (Project Management Institute, 2013, p. 274). Risk simulation forms part of “Quantitative risk analysis and modelling techniques”.

The implication of this hierarchy implies that the research conducted in this thesis should be applicable to the entire project management discipline. This is to some extent confirmed by the journal articles and conference proceedings mentioned in the rest of this chapter.

Section Summary

The researched text shows the relationship between programmes, projects, risk management and risk simulation and implies that the research conducted in this thesis is applicable to the entire project management discipline.

2.2.2 Simulation models and a quantified view of a project portfolio

This section starts with a short discussion of the advantages of quantitative risk assessments (Monte Carlo simulations) over qualitative risk assessments (probability-impact grids / heat maps). It then discusses the results from a literature review in terms of searches in textbooks, conference proceedings and journal articles to establish what has been written regarding the simulation of risks in a portfolio of programmes.

Quantitative vs. Qualitative risk assessments

The use of qualitative and quantitative risk assessment methods are described in texts by The Project Management Institute, (2009), Chapman & Ward (2011), Cooper et al. (2005), and Hillson (2009). Qualitative methods use likelihood and consequence ratings to plot risks on probability-impact grids (PIG) (also called heat maps) as described by Cooper et al. (2005, p. 53) and Hillson (2009, p. 38). Hillson (2009, p. 39), Cox (2008) as well as Chapman and Ward (2011, p. 49) presents some criticisms on the use of such matrices, mainly related to their simplicity not being able to support complex decision making as well as their focus on *risk* and the exclusion of *opportunities*.

Cox (2008, p. 510) further states that results from the matrices have limited ability to correctly reproduce the risk ratings implied by quantitative models, especially when the frequency and the severity of a risk are negatively correlated. Cox (2008, p. 510) is also of the that effective risk management decisions cannot in general be based on mapping ordered categorical ratings of frequency and severity into recommended risk management decisions or priorities, as optimal resource allocation may depend on other quantitative information, such as budget constraints, the costs of different treatment plans, and the risk reductions that they achieve.

There are several advantages of these qualitative methods. They are in general, simple to implement and use. There are limitations associated with these methods which are treated by the use of quantitative risk assessment methods, such as Monte Carlo simulation. These limitations include the following:

- These methods cannot be used to estimate project contingency.
- These methods don't make provision for multiple occurrence risks.
- These methods don't use variability to state which of the risk cause the most uncertainty in the project. @RISK uses the Monte Carlo method to identify, measure, and root out the causes of variability in the risk register (Palisade Corporation, 2014).

- In the context of simulation software, Palisade Corporation defines risk as referring to the variability (or spread) in the outcome of some event or decision. Vose uses the same definition (2008, p. 4). This is important because qualitative methods such as probability-impact grids are unable to produce variability in a set of data.

The next step is therefore to determine what a literature review would produce in terms of how these quantitative methods work and how a simulation could be conducted on a portfolio of projects.

Risk Management Standards

- The International Organisation for Standarization (2014) defines "standard" as follows: "A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose."

As a general comment, standards such as ISO31000:2009 (International Organization for Standardization, 2009), PMBoK (Project Management Institute, 2013), their Practice Standard for Risk Management (Project Management Institute, 2009) do not provide the "how to" part on risk simulation and also do not contain lists of risks which might realise on port and rail capital projects.

It is therefore not expected that these standard type documents will provide any knowledge regarding the types of risks which one may expect in projects.

Textbooks on risk analysis

In this regard, the book "Risk Analysis - a Quantitative Guide" (Vose, 2008) was helpful in that it gave a thorough overview on how to develop a model. Vose devoted a short section of the text (2008, pp. 486-487) to "Portfolios of risks" and refers the reader to the help file of *ModelRisk*, a programme similar to @Risk and also a MS Excel add-in. As with the @Risk help file (Palisade Corporation, 2014, p. 502), Vose used the term "portfolio" largely as something related to find an optimal portfolio of investments (Vose Software, 2014, p. 355). Nothing in these texts specifically referred to the simulation modelling of a portfolio of capital projects.

Journal articles and Conference proceedings

When searching online libraries for the terms *monte* + *carlo*, a great number of articles appear and it is possible to group some of the results.

The article by (Kwak & Ingall, 2007) conceptually explores **various applications of the Monte Carlo method** for managing project risks and uncertainties. This includes the quantification of the effects of risk and uncertainty in project schedules and budgets, which gives the project manager a statistical indicator of project performance such as target project completion date and budget.

A large quantity of articles referred to the use of the Monte Carlo method in **project schedule simulation**, including those by Elshaer (2013), Trietsch & Baker (2012) and Zammori et al. (2009). The paper by Jahangirian et al. (2010) contained a review of simulation applications published in peer-reviewed literature between 1997 and 2006 in manufacturing and business, and found that Monte Carlo simulations were mostly used to solve numerical problems with a stochastic nature, such as property valuation and risk management (Jahangirian, et al., 2010, p. 8).

Fuzzy Sets Theory also featured frequently, as in Carr & Tah (2001), Kuo & Lu (2013) and Zeng et al. (2007). Several articles related to **Public-Private Partnerships (PPP)** appeared which includes those of Tang et al. (2010), Kwak et al. (2009), and Cruz & Marquez (2013). **Cost estimation and cost risk analysis** were also covered in great detail by authors such as Pugh & Soden (1996), Chapman & Ward (2000), Chou (2011), Sato & Hirao (2013) and Khodakarami & Abdi (2014).

- The search for **multi-project** and **programme** also yielded some interesting results. Lytvyn & Rishnyak (2014) presented a decision making algorithm which can be used when the multi-project environment influences a project. This is outside the scope of this research since it does not attempt to simulate and identify risks on a portfolio or programme level.

- There were a limited number of articles discussing risks **common to programmes and/multi-project** environments, such as the MDS.

- Shehu & Akintoye (2010) did not discuss any specific risks but gave an overview of the challenges experienced in the United Kingdom with the successful practice of programme management. This is important in the current research context since some of the challenges might be related to the risks as presented in Section 0. Regarding risks in multi-project environments, Aritua et al. (2011, p. 308) differentiated between three types of risks:

- Risks which are *Common to Programme*s. These risks related to the function of managing multiple projects and aligning them to the organisation's strategy and policies. It included the following risks:
    - Linking strategy and projects.
    - Challenges in procurement.
    - Competition for contractors.
    - Stakeholder expectation management.

- Risks which were amplified in programmes. These risks are simple to deal with but exacerbated as a result of the multi-project environment. They included:
    - Reputational risk.
    - Fraud.
    - Cash flow and funding problems.
    - Changes in government policy.

- Risks which were generic to endeavours in project environments.

This distinction is similar to that proposed by Hillson (2009, pp. 81-82) and will be used in categorising risks in Chapter 4.

Taroun (2014) conducted a literature review of **which tools were being used in construction risk assessments** and concluded that simple analytical tools which used risk cost as a common scale and utilised professional experience would be a viable option to facilitate closing the gap between theory and practice of risk assessment.

Section Summary

Much has been written regarding various aspects of risk simulation but very little on the simulation of risks in a portfolio of programmes. The latter is especially true when looking for information regarding risk simulation in a portfolio of rail and port programmes.

2.2.3 Risks on port and rail capital projects

This section starts with a discussion on the validity of checklists as a risk identification technique. It then continues by presenting the outcome from searches in textbooks, conference proceedings and journal articles to find which risks might appear on port and rail capital projects. There were no Standards found. The chapter therefor concludes with a short discussion on the advantages of using quantitative methods, such as Monte Carlo simulations.

Checklists as a valid Risk Identification technique

The American Society of Safety Engineers' publication "Risk Assessment Techniques" is a National adaption of ISO31010:2009 (American Society of Safety Engineers, 2011, p. 4) and identifies six different types of risk assessment tools. These include the following:

- Lookup Methods: checklists, preliminary hazard analysis.
- Supporting Methods: structured interviews and brainstorming.
- Scenario Analysis: root cause analysis, fault tree analysis.
- Function analysis: FMEA, HAZOP.
- Controls assessment: Layers of Protection Analysis, Bow Tie Analysis.
- Statistical techniques: Markov analysis, Monte Carlo Analysis.

A total of 31 tools and techniques are described for these six different types of risk assessment tools, each discussed in terms of its application in Risk Identification, Likelihood and Consequence Estimation, Level of Risk and Risk Evaluation (American Society of Safety Engineers, 2011, p. 27). Lookup methods such as checklists are useful because they may be used by non-experts and can help ensure that common problems are not forgotten. Limitations include that they tend to limit imagination and have the potential to ignore “unknown unknowns”.

Checklist are most useful when applied to check that all the important aspects have been covered by more imaginative techniques (American Society of Safety Engineers, 2011). Lyons & Skitmore (2004) and (Chapman, 1998) have also identified checklists as risk identification tools. Chapman also discusses the use of checklists in an article dealing with the effectiveness of working group risk identification and assessment techniques (Chapman, 1998). This supports the use of a literature review in an attempt to create a checklist of risks related to port and rail capital projects.

Textbooks on project risk management

Flyvbjerg et al. (2003) dealt with a wide variety of **mega projects** (including a large number of **public-private partnerships**) such as the Channel Tunnel, the Concorde, the Sydney Opera House and the German MAGLEV train between Berlin and Hamburg.

He discussed problems with these projects such as how misinformation was used to justify project implementation and how inaccurate estimates contributed significantly to project overruns (Flyvbjerg, et al., 2003, p. 14).

Other books contained lists of potential risks. Cooper et al. (2005, p. 357) included a section called “Examples of Risks and their Treatments” which was obtained from a “wide range of projects”. Kendrick (2003, p. 337) concluded his book with a list, although not as exhaustive as that provided by Cooper et al.

Journal articles and Conference Proceedings

There has been several survey based articles on the **types of risks found in construction** projects. This include those by Zou et al. (2006), Zou et al. (2007), Akintoye & MacLeon (1996) and Aritua et al. (2011). Although Lam's article (1999) mentions a "sectoral review of risks associated with major infrastructure projects", it does not refer to the port and rail sectors in any detail. When searching for journal articles using search terms *railway* + *risk*, the following types of references appear:

- The articles tend to refer to the management of **safety, health, the environment and quality**, as demonstrated by Albert & Hallowell (2013), Fang et al. (2011) and Sousa et al. (2015).
- There is a plethora of articles related to **tunnel construction**, such as those by Rehbock-Sander (2004), Lin et al. (2006) and Huang (2006).

There are similarities with the search *rail* + *risk* when searching for *port* + *risk*:

- Articles tend to focus on **port operational safety**, like those by Alises et al. (2014), Kim & Kim (2009) and Yang & Ng (2014).
- There are some articles related to **environmental risk** and **investment risk**. Examples of the former is Zheng et al. (2011) and Kakimoto & Seneviratne (2000) of the latter.

Risk identification techniques found during literature review

When looking at the literature mentioned in this section, various techniques were used by the authors to identify and rank risks, as contained in Table 2-1. The table is important for the following reasons:

- Research has been published regarding risks in construction project.
- Various techniques (surveys, literature reviews, case studies) were used in creating potential checklists which could be used during risk identification.
- It does not contain any information regarding the use of risk workshops, Monte Carlo Simulation to create a list of ranked risks. This is important because it identifies a gap in the literature and supports the contributions made by this thesis.

AUTHOR	PURPOSE	DATA COLLECTION METHOD	RANKING METHOD
Zou et al. (2006)	Determine significance of risk in relation to project objectives.	Survey	Formula based on product between likelihood and impact.
Karim et al. (2012)	Determine significant risk factors.	Survey	Frequency of response.
Rezakhani (2012)	Classifying risk factors.	Literature review	Constructed a risk breakdown structure.
Lam et al. (2007)	Methods on the allocation of risk.	Survey	Fuzzy set theory.
Lam (1999)	List of lessons learned.	Case study	Literature review.
Chan et al. (2011)	Produce a list of ranked risks in construction project	Survey	Descriptive statistics, Kendall's concordance test, Spearman's rank correlation test Mann-Whitney U test.

Table 2-1: Risk identification methods identified

Section Summary

There are several papers dealing with which risks one could expect on capital projects. Various techniques (surveys, literature reviews, case studies) were used in creating potential checklists which could be used during risk identification. Risks related to port and rail projects are mainly confined to investment decisions, operational safety and environmental compliance. No evidence could be found regarding the use of risk workshops (and by implication risk registers) and Monte Carlo Simulation to create a list of ranked risks. This is important because it identifies a gap in the literature and supports the contributions made by this thesis. Simulation as research methodology is therefor discussed in the next section.

2.2.4 Simulation as Research Methodology

This section deals with searches in textbooks, conference proceedings and journal articles to find which risks might appear on simulation as research methodology. There were no Standards found.

Textbooks on Simulation as Research Methodology

Blumberg et al. (2008, p. 45) defines “model” as a representation of a system which is constructed to study some aspect of the system or the system as a whole.

Simulation, together with *Description* and *Explication*, are the three major functions of modelling and each of these functions is appropriate to applied research or theory developing.

Simulation models clarify structural relationships between concepts and attempt to reveal the process relationships among them according to Blumberg et al. (2008, p. 46).

Simulations also resemble induction in that relationships among variables may be inferred from analysing the output data, for example: “The consequence of risks related to environmental approval delays are twice that of risks related to objections to environmental approvals”.

Axelrod (1997) identified three research purposes of simulation models:

- Prediction - The analysis reveals relationships among variables, for example: “For new projects, it can be expected that the contingency requirements for Rail projects will be half that of Port projects”. The outcome of the research is applied on future projects.
- Proof - A simulation can show that it is possible for the simulation modelled processes to produce certain types of behaviour, for example: “The simulation model supplies evidence that the biggest risks are associated with Scope Definition”. The outcome of the research is compared to an expected outcome.

- Discovery - Simulations can be used to discover unexpected consequences of the interaction of simple processes, for example: "When run at the same time, the combined consequence of 34 instances of Risk A across the project portfolio of 86 projects is bigger than the consequence of 2 instances of Risk B" or "The risks category with the highest P80 value is Category XYZ". The outcome of the research is new.

A discussion on all the research questions and Prediction, Proof and Discovery appears in Chapter 6.

Journal articles on Simulation as Research Methodology

Several studies showed the use of simulation in the **management studies**. Harrison et al. (2007, p. 1231) state that although some simulation studies were published in major management journals in the 1980s, simulation-based work did not begin to appear in management and social science journals with any regularity until the 1990s. It was particularly found in disciplines related to Management, Sociology, Psychology, Economics and Political science. This view was confirmed by Berends & Romme (1999, p. 576). The conclusion of Harrison et al.'s (2007, p. 1243) started with "Computer simulation can be a powerful way to do science" and concluded with "…computer simulation promises to play a major role in the future…".

Harrison et al. (2007, p. 1231) also stated that, together with theoretical analysis (deduction) and empirical analysis (induction), computer simulation is now a recognised way of doing science.

Deduction requires absolute proof, for example:

- I am human.
- All humans die.
- Therefore, I will die.

Induction requires strong evidence (92% of projects contain risk related to safety, therefore it is likely that my project will contain risks related to safety) and not absolute proof.

Simulation resembles deduction in that the outcomes follow directly from the assumptions for example: "A high likelihood input will produce a high likelihood output distribution".

Issues with simulation research

Harrison, et al. (2007) state that there are some limitations to using simulation as research methodology. This includes issues related to complexity and independent verification.

Complexity

Simulation models can be too complex and it is suggested that the simpler the simulation model, the easier it is to gain insight into causal relationships (Axelrod, 1997). The principle of developing models as simple as possible is shared by Vose (2008, p. 7) and Marsh (2013). The simulation model presented in Chapter 4 is fairly simple in that it avoids long, complex equations, does not use any macros and is contained in one single worksheet.

When models are not presented in sufficient detail on how it actually functions, it becomes difficult to evaluate and to independently verify the outcome of the risk simulation results (Harrison, et al., 2007, p. 124) therefore reducing the reliability of the research results. The simplicity and manner in which the simulation model is described in Chapter 4 should overcome this shortcoming.

Model description and independent verification

Simulation experiments are artificial in that they are based on computer models and the data are generated by a computer programme (Harrison, et al., 2007, p. 1241). When looking at Monte Carlo simulations and this research, the data which were generated was based information which were supplied by subject matter experts. Eppen et al. (1988, p. 2) calls a model a "selective abstraction of reality". This brings up the problem of how the simulation model relates to real world behaviour.

This shortcoming can be remedied by comparing the outcome of the simulation with empirical work (as will be attempted in this research thesis), and to base some of the simulation model's parts on empirical work. Both Vose (2008, p. 5) and Cooper et al. (2005, p. 259) included validation as part of developing a quantitative model. The steps involved in this process include the following:

- Removal of spreadsheet model errors.
- Checking model behaviour.
- Comparing predictions against reality.

The following was validated by the Palisade, the developers of @Risk:

- Original risk register and methodology (Prabhakar, 2012).
- The methodology to produce output distributions based on various criteria as described in Section 4.2 (Prabhakar, 2014).

The simulation model developed in this thesis is further validated and this is discussed in detail in Section 5.10.

Section Summary

Although there are some issues with simulation related to complexity and independent verification, it is an acceptable way of doing research. Issues related to model complexity were addressed in developing the simulation model. The simulation model was also independently verified.

2.3 Chapter Summary

In the beginning of this chapter, three questions related to available literature were presented. The answers to these questions are summarised in Table 2-2:

QUESTIONS ASKED	OUTCOME OF LITERATURE REVIEW
What is the relationship between programme management, project management, project risk management and risk simulation?	The researched text shows the relationship between programmes, projects, risk management and risk simulation and implies that the research conducted in this thesis is applicable to the entire project management discipline.
What has been written regarding simulation as research methodology?	Although there are some issues with simulation related to complexity and independent verification, it is an acceptable way of doing research. Issues related to model complexity were addressed in developing the simulation model. The simulation model was also independently verified.
Which sources are available showing the structure and functioning of a simulation model which produces a quantified view of a project portfolio?	Much has been written regarding various aspects of risk simulation but very little on the simulation of risks in a portfolio of programmes. The latter is especially true when looking for information regarding risk simulation in a portfolio of rail and port programmes.
What research has been done regarding the quantification of risks for capital projects such as port and rail infrastructure?	There are several papers dealing with which risks one could expect on capital projects. Risks related to port and rail projects are mainly confined to investment decisions, operational safety and environmental compliance.

Table 2-2: Outcome of literature review

From this it can be concluded that although some topics related to these questions have been answered, very little in the literature actually directly refers to answering these three questions. This clearly identifies a gap in the literature which this research will attempt to address. Chapter 3 presents the research methodology as well as the way in which the data used in this research was captured.

3. DATA COLLECTION

3.1 Purpose and Outline of the Section

This chapter describes the methodology and tools used in the process which was used to gather the case study data for the eventually produced 86 risk registers. The tools and techniques include the following:

- ISO31000:2009 risk management process. The language in this chapter leans heavily on the ISO31000:2009 vocabulary since it was used extensively during the creation of the TCP risk management procedures and templates.
- MS Excel based Risk Register Template (RRT). As mentioned in Section 1.5.6, although the template covered the entire risk management process, focus will be placed on the risk assessment (which includes Identification, Analysis and Evaluation) aspect. The MS Excel functions are not described in this chapter since they are covered in detail when presenting the simulation model in Chapter 4.
- Structured risk workshops. Each of the risk registers was the result of a workshop during which subject matter experts and other stakeholders were present. The risk workshops were attended by between 2 and 20 people.
- The RRT was used during the entire risk management process, not only during the initial risk workshop.

3.2 Risk Register Template

This section describes the layout of the RRT which was used during the data collection process. The RRT made provision for two risk registers. The “Base” risk register is completed during the project’s first risk workshop. At the beginning of the second risk workshop, this is copied over to the “Live Risk Register”. It provides a baseline against which risk management for the project is measured. The fields and calculations are exactly the same for both these registers. The ISO31000:2009 Risk Management Process step “Monitor and Review” takes place in this sheet.

Both the sheets followed the ISO31000:2009 Risk Management Process and captured the information required in two MS Excel sheets, as described in Table 3-1:

ISO31000:2009 RISK MANAGEMENT PROCESS STEPS	MS EXCEL SHEET
Establish the context	Establishing the context
Risk Identification Risk Analysis Risk Evaluation	Base Risk Register
Risk Identification Risk Analysis Risk Evaluation Monitor and Review	Live Risk Register

Table 3-1: ISO31000:2009 steps and the Risk Register Template

Each of these are discussed in this section. Although the RTT also contained sheets with reports and graphs, these are not discussed since they are not relevant in answering the research questions posed in this thesis.

3.2.1 Establish the context

This is where the external and internal parameters, which needed to be taken into account when managing risk, are defined.

The external context refers to the external environment in which the project seeks to achieve its objectives. It includes aspects such as the cultural, social, political, legal, regulatory, financial, technological, economical etc. environment (International Organization for Standardization, 2009, p. 11). Its purpose it to describe the organization and the project environment in which the risk assessment takes place, specifies the main objectives and describes the criteria against which the consequences of the identified risks can be measured (Cooper, et al., 2005, p. 15).

The internal context refers to issues which can include project scope, objectives (cost, duration and other) assumptions and constraints. The RRT also focussed on the internal context and captured the information as presented in Table 3-2. The example is an extract from an actual project called "Berth Deepening Port of Durban".

TERM	EXAMPLE
Client Name	TPT, TNPA, TFR or a combination.
Project Title	Berth Deepening Port of Durban.
Scope	Deepening of berths to -19m CD
Objectives (Total capital cost, including contingencies)	R4.5 billion.
Additional Cost Objectives	R30 million must be spent in this financial year.
Total Duration	150 weeks.
Additional Schedule Objectives	The environmental approval must be obtained by 15 January 2019.
General	• Project must not interfere with shipping in the port. • Limit harm to people, the environment and property.
Assumptions	No environmental approval required since the project takes place inside the rail reserve.
Constraints	Laydown area for imported sheet piles far from place of installation.
Contractor Names or Type	The RRT made provision for the capturing of 5 contractor names together with their weekly rates. This is used when calculating time variable cost should the risk realise.

Table 3-2: Establishing the context data fields

3.2.2 Risk Identification

This is the process of finding, recognising and describing risks (International Organization for Standardization, 2009, p. 13). It involves the identification of risk sources, risk events, their causes and potential consequences. The terms presented in Table 3-3 were used during the risk identification part of the RRT.

TERM	DESCRIPTION
Risk Source	Element which alone, or in combination, has the potential to give rise to a risk.
Risk Event	Change of a particular set of circumstances.
Short Risk Name	Short name used in reporting. This is also convenient when naming risks in @Risk.
Consequence on Project	Outcome of a risk event affecting project objectives.
Risk Treatment	Process to modify a risk by removing, reducing likelihood, reducing the consequences.
Controls	Measures which modify risk - can be in place or be planned.
Can the risk be quantified?	Certain risks needs to be on the risk register but cannot be quantified. A "No" indicated that the risk was important to capture but will not be quantified and ranked.
Trigger Date	Date by which risk treatment should be in place.
Schedule Activity Number Affected	Line number in schedule affected by risk should it realise.
Single or Multiple Occurrence Risk?	Either a "Once" or a "More than once". The RRT selected a Binomial distribution if "Once" was selected and a Poisson distribution in case of "More than once". This is described in more detail in the next section.

Table 3-3: Terms used during risk identification (International Organization for Standardization, 2009)

These terms in Table 3-3 correspond largely with research conducted by Patterson & Neailey (2002, p. 367) regarding the fields normally used in risk registers.

3.2.3 Risk Analysis

The process is there to comprehend the nature of risk and to determine the level of risk (International Organization for Standardization, 2009, p. 6) and is described in terms of the following:

- The way in which likelihood (chance of occurring) is modelled for both once-off and multiple occurrence risks. A risk can either be described as a once-of or multiple occurrence risk and not as both.
- Various types of consequence (outcomes of the risk event) are modelled. These include time variable cost as well as direct capital cost. Risks which only have a time delay but no associated cost falls outside the boundaries of the research (see Section 1.5.4) and are not included.
- Level of risk (magnitude of a risk, expressed in terms of the combination of likelihood and consequences).

Likelihood - Single occurrence risks

For single occurrence risks, Table 3-4 describes the probability values used in the RRT. These values are values selected from the likelihood ranges prescribed by the case study organisation’s ERM policy since @Risk used requires a discrete value to run a simulation.

CATEGORY	QUALITATIVE DESCRIPTION	CRITERIA	LIKELIHOOD
A	Rare	Occurrence requires exceptional circumstances, exceptionally unlikely; even in the long term future; only occur as a "100 year event".	1.0%
B	Unlikely	May occur but not anticipated, or could occur in "years to decades".	20.0%
C	Moderate	May occur shortly but a distinct probability it won't, or could occur within "months to years".	45.0%
D	Likely	Balance of probability will occur, or could occur within "weeks to months".	80.0%
E	Almost Certain	Consequence is occurring now, or could occur within "days to weeks".	95.0%

Table 3-4: Risk Probability Category

A binomial distribution was used to model this. RiskBinomial(*n, p*) specifies a binomial distribution with *n* number of trials and *p* probability of success (as defined in Table 3-4) on each trial. The number of trials is often referred to as the number of draws or samples made.

The binomial distribution is a discrete distribution returning only integer values greater than or equal to zero (Palisade Corporation, 2014, Vose Software, 2014).

If the following is modelled: "There is a likelihood of 80% that the risk can realise", the equation looked like this:

$$Likelihood = RiskBinomial(1{,}0.8)$$

The associated distribution is as follows:

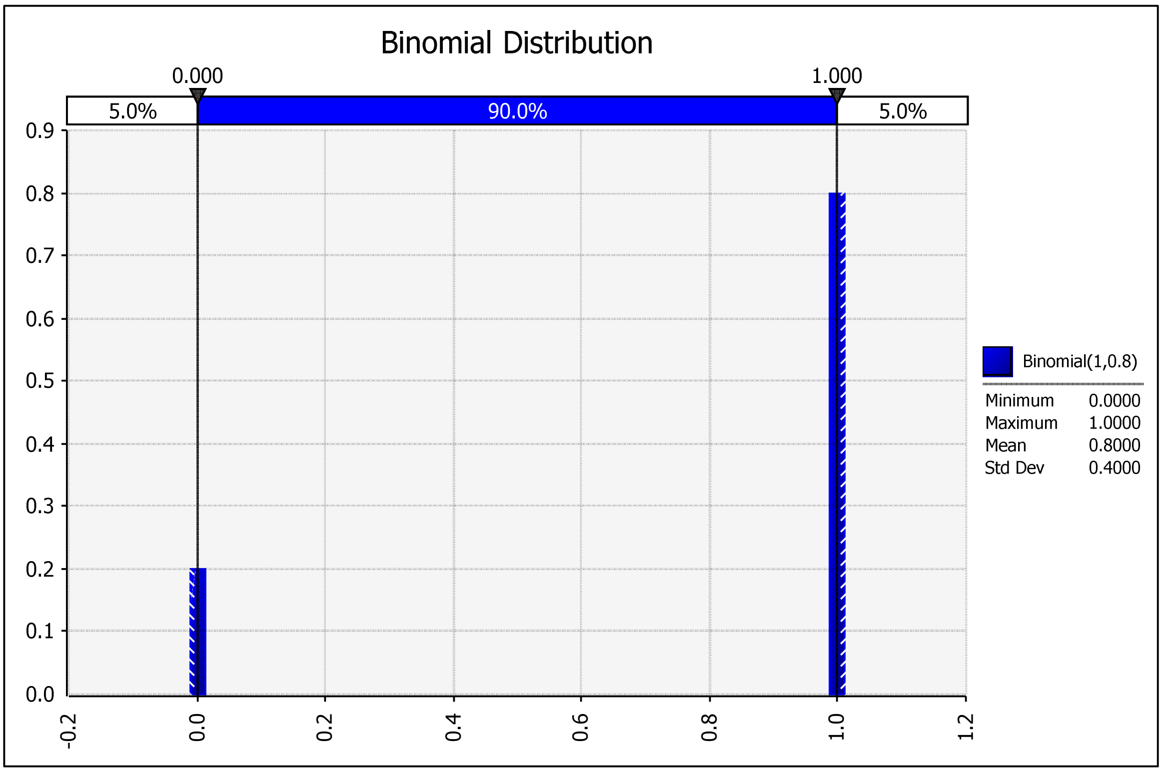


Figure 3-1: Binomial Distribution

Likelihood - Multiple occurrence risks

Risk such as *Industrial Action*, *Inclement Weather* and *Material Deliveries* can realise more than once on a project and should be modelled as such. A Poisson distribution is used to model the frequency of these type of risks.

RiskPoisson(λ) specifies a Poisson distribution where *λ* is the same as the mean of the Poisson distribution. The Poisson distribution is a discrete distribution returning only integer values greater than or equal to zero (Palisade Corporation, 2014, Vose Software, 2014).

If the following was modelled, "The risk can happen on average 5 times over the project lifecycle", the equation looked like this:

$$Likelihood = RiskPoisson(5)$$

The associated distribution is as follows with a mean of 5:

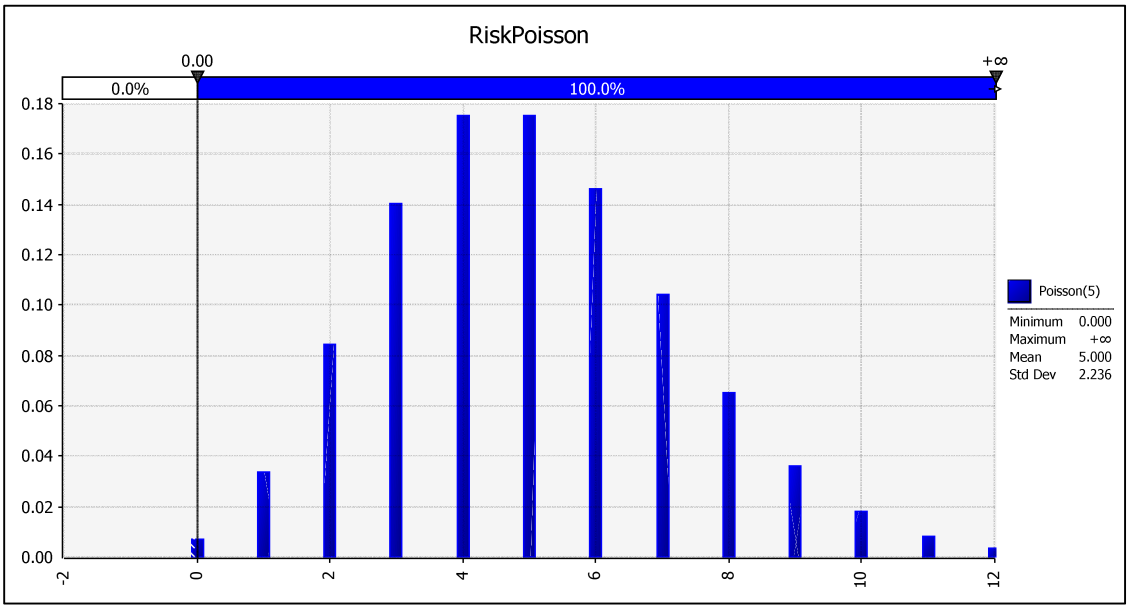


Figure 3-2: Poisson distribution

Types of consequence

The RRT went through 3 iterations and the final version was able to model the following types of risks, as illustrated by using examples:

RISK TYPE	TIME DELAY	TIME VARIABLE COST	ADDITIONAL CAPITAL COST
Time delay only	The late arrival of replacement equipment will delay the completion of the project by 4 weeks.	None, since the contractor is only paid for installation and will have no standing time.	None
Time variable cost	The delay will be between 1 and 2 weeks due to inclement weather.	R250 000 per week for additional labour.	None
Time variable cost + Additional Capital Cost	The delay will be between 8 and 16 weeks due to additional dredging.	R500 000 per week.	Cost of between R30 and R40 million will be incurred for additional rocks for scour protection
Additional Capital Cost	None	None	Two more pumps will be required each costing between R1.1 and R1.7 million.

Table 3-5: Types of risks modelled

Three-point estimate distributions used

To model *Time Variable Cost* and *Additional Capital Cost*, @Risk functions using three-point estimates were selected. In three-point estimation, three figures are produced initially for every distribution that is required, based on prior experience or best-guesses where

- Minimum = the best-case estimate.
- Most Likely = the most likely estimate.
- Maximum = the worst-case estimate.

Functions which are modelled using three-point estimates were used because it is simple to apply and get estimates for those numbers. When facilitating a workshop, it is easier to get opinions using three-point estimates than asking "What do you believe that standard deviation for this distribution is if the average delay for this risk is 4 weeks?". The ease of using three-point estimates are included in the research by Rao Tummala, et al. (1997).

There are two types of three-point estimate distributions used in the RRT:

RiskPertAlt:

=RiskPertAlt(*arg1type,arg1value,arg2type,arg2value,arg3type,arg3value*) specifies a PERT distribution with three arguments of the type *arg1type* to *arg3type*. These arguments can be either a *percentile* between 0 and 1 or *Min, Most likely* or *Max (Palisade Corporation, 2014, Vose Software, 2014).*

The function *=RiskPertAlt(0.05,2,0.5,5,0.95,11)* specifies a Pert distribution with P5=2, P50=5, and P95=11.

RiskLognormAlt: *=RiskLognormAlt(0.05,2,0.5,5,0.95,11)* is similar to RiskPertAlt but uses a Lognormal distribution.

The RRT automatically made the time delay more conservative when $(Max - Most\ likely) \geq 2 \times (Most\ likely - Min)$. This was done to ensure that sampling takes place in tail end of risks which are more uncertain. For example, a *=RiskLognormAlt(0.05,2,0.5,5,0.95,11)* and *=RiskPertAlt(0.05,2,0.5,5,0.95,11)* are compared in Figure 3-3. The main difference between these two distributions is that the maximum of the *=RiskPertAlt()* is 19.215 (for this simulation) and ∞for the *=RiskLognormAlt()*.

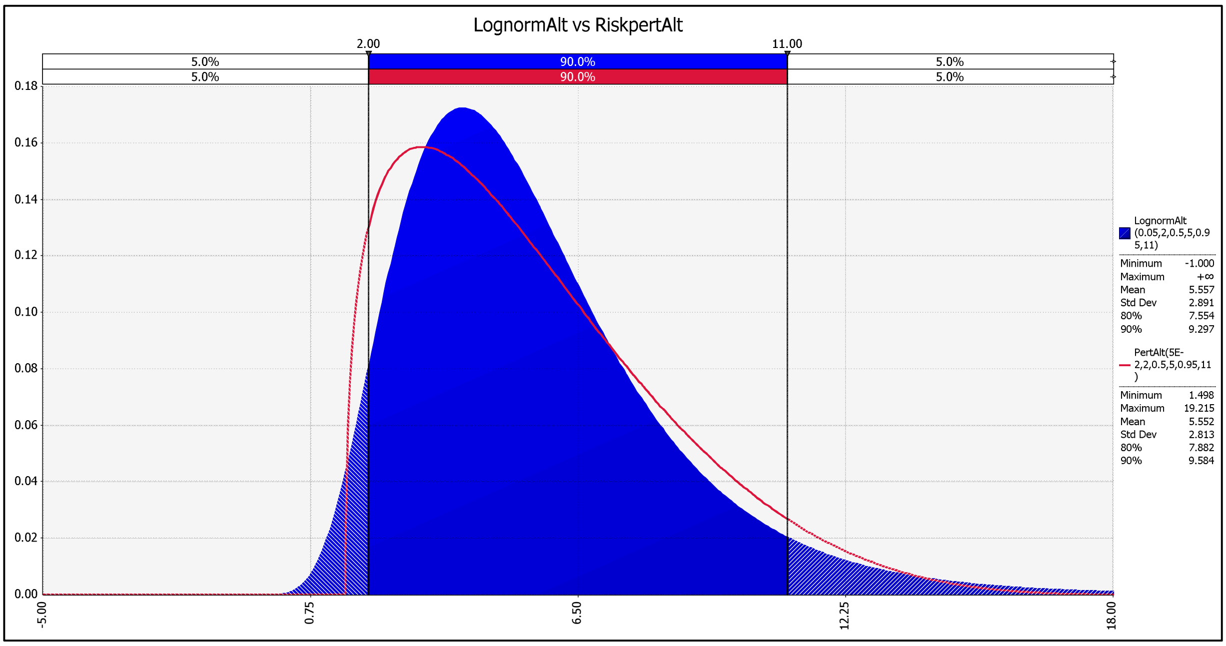


Figure 3-3: Comparison between RiskLognormAlt and RiskPertAlt

Modelling of consequence

The cost impact was modelled in the following manner for open risks and is shown in Figure 3-4 and Figure 3-5.

$$Total\ Cost = Time\ Variable\ Cost + Additional\ Capital\ Cost$$

Where

$$Time\ Variable\ Cost = Time\ Delay_{3\ Point\ Estimate} \times Weekly\ Weighted\ Average\ Cost$$

And

$$Additional\ Capital\ Cost = Additional\ Capital\ Cost_{3\ Point\ Estimate}$$

Where

$$Time\ Delay_{3\ Point\ Estimate} = RiskPertAlt(0.05, Min, 0.5, Most\ likely, 0.95, Max)$$

or

$$Time\ Delay_{3\ Point\ Estimate} = RiskLognormAlt(0.05, Min, 0.5, Most\ likeliy, 0.95, Max)$$

When

$$(Max - Most\ likely) \geq 2 \times (Most\ likely - Min)$$

Figure 3-4: Equations for modelling of consequence

$$Weekly\ Weighted\ Average\ Cost = \sum_{k=1}^{5} Supplier\ Weekly\ Rate_k \times Consequence\ (\%)_k$$

Figure 3-5: Equation for estimating Weekly Weighted Average Cost

To illustrate the above, the following is considered:

A project has two contractors, Contractor A with a weekly average rate of R50 000 and Contractor B with a weekly average rate of R100 000. During the risk workshop it was established that should a specific risk occur, Contractor A will have a 100% loss and Contractor B a 25% loss.

The Weekly Weighted Average Cost would therefore be as follows:

$$Weekly\ Weighted\ \ Average\ Cost = R50\,000 * 100\% + R100\,000 * 25\%$$

$$= R75\,000$$

Special cases

There were two types of risks which required special treatment. The first had to do with risks which delay the start of project execution. These risks are specifically pertinent in multi-year, high capital cost projects. If a project has a total cost of R1 billion, and would be delayed by one year, inflation (assume 7%) would increase project cost by at least 7% (R70 million), should the scope and schedule remain the same. An accelerated schedule would require more resources to deliver the project in the original schedule and would therefore increase the cost with a rate higher than inflation.

The second dealt with risks for which no provision could be made for in project contingency. The calculation of project contingency using Monte Carlo simulations was one of the reasons for the roll-out of PROM at TCP. Project contingency however, cannot provide for certain types of risks. If a project would cause volume loss due to a project being late, it would be illogical to expect the project to pay for the loss, w*hen the project owner is executing the project themselves*. Solutions to both these cases are presented in this section.

Risks which delay the start of project execution

There were two variables used in determining if this type of modelling could be required. The first was project duration and the second project cost. If a project would have a duration of less than one year, the escalation of project cost due to delayed project execution start would not be taken into consideration.

When the project context would be established, the RRT made provision for 5 Contractors and each of their respective weekly costs. Should a project be a R50 million, multi-year project, the weekly cost would be estimated as the following and a contractor called "Escalation" would be added.

The simulation model assumes the following:

- This "Escalation" does not replace any provision in the project estimate for cost escalation in multi-year projects but is in addition to the provisions already made.
- Project cost flow does not get compressed to complete the project earlier.
- Monthly project cost flow is distributed evenly over the project lifecycle. If the project would have a duration of 3 years and a total cost of R36 million, it assumes a monthly cost flow of R1 million.

Because the simulation model does not use a compound calculation in estimating the weekly cost, it can be argued that the weekly cost would be under-estimated. As mentioned above, it is assumed that the project has cost flow which is distributed evenly over the project lifecycle. When the risk is modelled, the weekly impact would be 100%.

$$Weekly\ cost = \frac{Project\ Cost\ \times Inflation}{52}$$

$$= R50\ 000\ 000 * \frac{0.07}{52}$$

Risks which don't have an impact on project contingency

The implication of this problem is that certain risks are part of risk ranking but not part of any contingency calculation. To resolve this issue, two columns were created in the model. The first column was a contingency calculation and the second one used to provide a distribution which would be used to calculate the risk's P80 value which in turn would be one of the methods used to rank the risks. For risks which don't have an impact on contingency, the equations in the contingency calculation cell was simply deleted.

Complete risk quantification model

The complete risk quantification model used during risk simulation is presented in Figure 3-6. It is broken down into five steps and the logic branches are displayed where required. The appropriate @Risk equations are also shown.

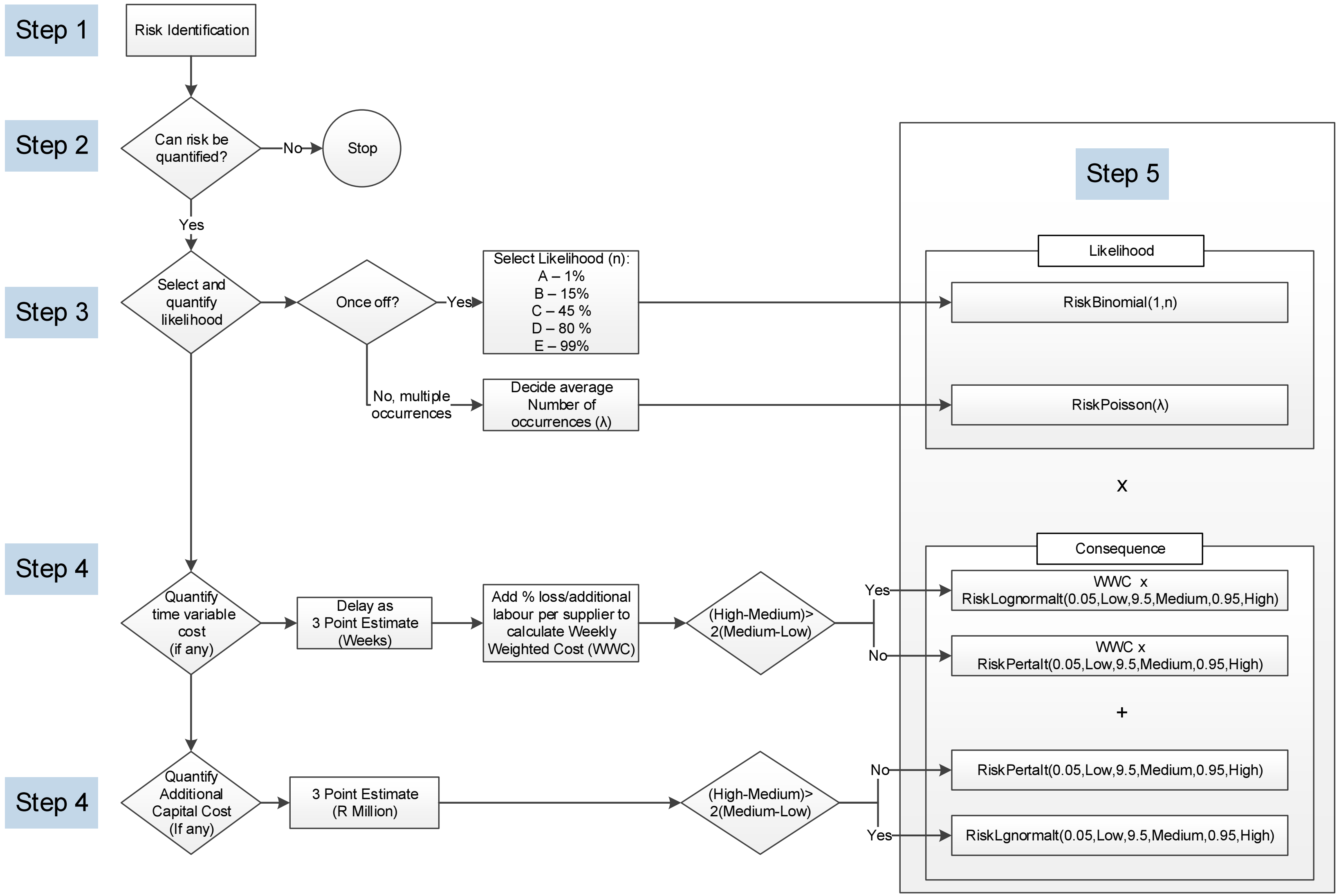


Figure 3-6: Overview of simulation logic

3.2.4 Risk evaluation

The purpose of risk evaluation is to assist in making decisions, based on the outcomes of the risk analysis process, about which risks need treatment and the priority for treatment implementation (International Organization for Standardization, 2009, p. 25). It compares the results of risk analysis with risk criteria to determine whether the risk and or magnitude is acceptable or tolerable (American Society of Safety Engineers, 2011, p. 12).

The three methods which were used to rank the risks in the risk register are described in this section:

- Risk Urgency.
- Sensitivity Analysis (Tornado graphs).
- P80 Values of Risk Simulation Results.

Risk Urgency

Risks requiring near-term responses may be considered more urgent to address (Project Management Institute, 2013, p. 333). This relates to how far the risk is in the future and a column called “Trigger Date” appeared in the RRT. This date refers to when the treatment plan for the risk should be implemented to reduce the likelihood and/or potential consequences of the risk, should it realise (Gilfillan, 2012).

Sensitivity Analysis

Tornado graphs are used to show the influence an input distribution has on the change in value of the output (Vose, 2008, p. 83). The bars are ranked to the regression coefficients of the output simulations. Longer bars at the top representing the most significant input variables (Palisade Corporation, 2014, Vose Software, 2014). For example Figure 3-7, the variable “Project” is the most influential input parameter in changing the value of the output. It therefore contains the most risk.

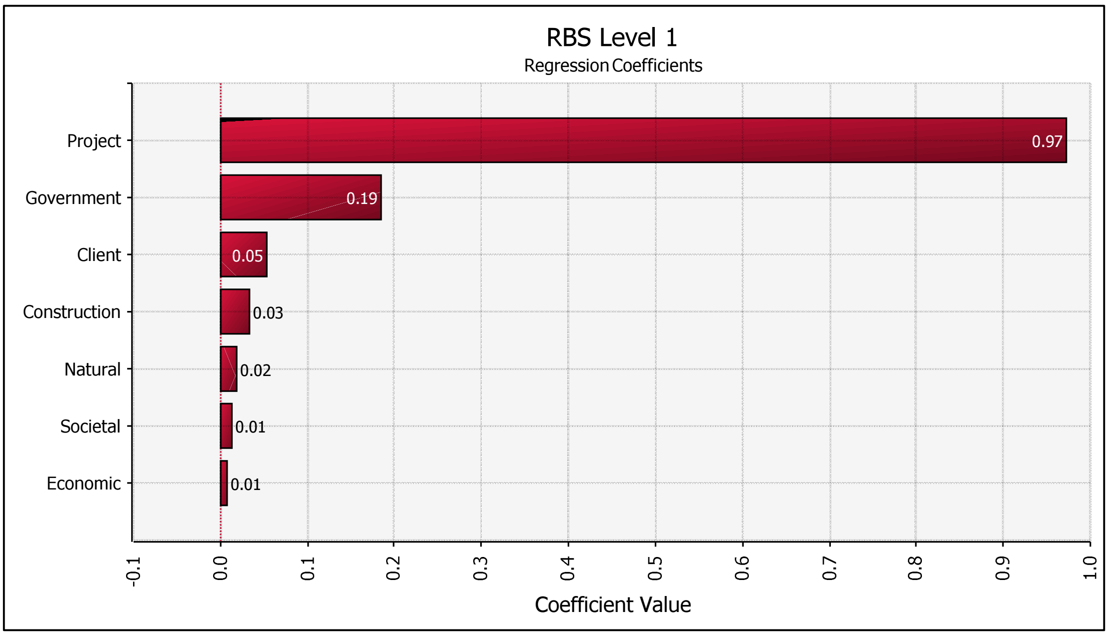


Figure 3-7: Sensitivity analysis using a tornado graph

P80 values of risk simulation results

Although tornado graphs present which input factors cause the most uncertainty in the output distribution, they do not present uncertainty in terms of potential losses. The RRT sorted out this problem by ranking the risks according to a tornado graph as well as presenting the results in terms of the P80 values of the individual risk's output distributions. It was interpreted in the following manner:

"Unknown construction methodology", for example, causes the most uncertainty in the project and there is an 80% chance that it can cost the project up to R5.12 million."

Risk Rank	Risk Description	Risk Attrributes	
		Risk Number	Risk to Project (P80)
1	Unknown construction methodology	1	5.12
2	Inexperienced contractors	3	2.23
3	Intimidation	5	0.59
4	Material & Plant delivery	6	0.51
5	Excavations collapsing	7	0.27
6	Safety	4	0.14
7	Site access	2	0.12

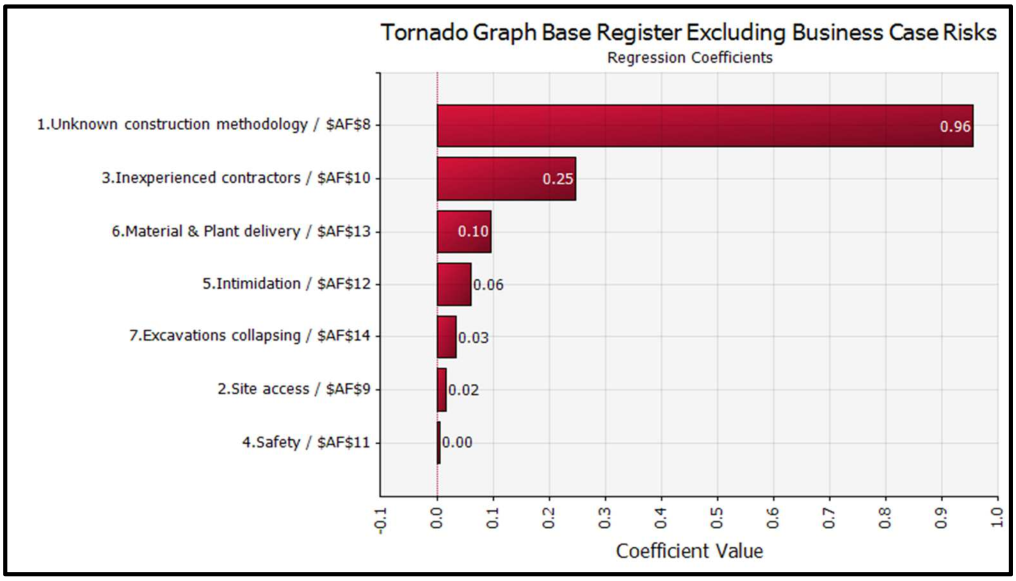


Figure 3-8: Tornado graph in conjunction with P80 values of individual risks

3.2.5 Risk Treatment

Risk Treatment involves selecting one or more options for modifying risks and implementing these options (International Organization for Standardization, 2009, p. 26). It is also called the process of modifying risk (American Society of Safety Engineers, 2011, p. 12). The RRT made provision for the capturing of the data as contained in Table 3-6:

<table>
<tr><th>TERM</th><th>DESCRIPTION</th></tr>
<tr><td>Risk Status</td><td>The following options were available:
• Emerging: Risk identified.
• Active: Risk realised.
• Closed: Risk closed and cannot realise any longer.</td></tr>
<tr><td>Response type</td><td>The following options were available:
• Accept - Informed decision to take a particular risk.
• Mitigate: Removing the risk source/changing the likelihood/changing the consequences.
• Transfer: Risk is shared with other parties.
• Avoid: Informed decision not to be involved in or withdrawing from an activity in order not to be exposed to a particular risk. (American Society of Safety Engineers, 2011, pp. 12-13)</td></tr>
<tr><td>Response Progress Status</td><td rowspan="2">The following options were available:
• Not started
• In progress
• Completed</td></tr>
<tr><td>Completed Action Plans</td></tr>
<tr><td>Cost Estimate</td><td>Cost estimate of action plan.</td></tr>
<tr><td>Action plan completion %</td><td>% of action plan completed.</td></tr>
<tr><td>Responsible</td><td>Risk owner.</td></tr>
<tr><td>Calculation Assumption</td><td>Any assumptions which were made and needed to be documented.</td></tr>
<tr><td>Due Date</td><td>Due date of treatment plan implementation</td></tr>
<tr><td>Opened by</td><td>Name of person which opened risk.</td></tr>
<tr><td>Comments</td><td>Comment column.</td></tr>
<tr><td>Closed By</td><td>Name of person which closed risk.</td></tr>
</table>

Table 3-6: Fields related to Risk Treatment

3.3 Risk workshops

At least 273 different risk workshops took place during the data collection phase of the research. The author himself facilitated the majority of the risk workshops himself. A small percentage of the risk workshops were conducted by graduate trainees, and mostly under supervision by the author. The projects which these graduate trainees managed were also simpler projects, such as the installation of septic tanks and pedestrian bridges. The techniques as described in Table 3-7 were used during the risk identification for the 86 risk registers:

TECHNIQUE	HOW IT WAS USED
Brainstorming	Initial risk workshop: • Each participant was asked to identify 5 risks (with their sources, consequences and treatment plans). • Each participant gave one risk which was then discussed by the team and then captured in the risk register. • The next participant then volunteered his/her risk. • The process was repeated until all the risks were captured. Follow-up risk workshop: • After the risk register was reviewed, each participant got an opportunity to add risks to the risk register.
Checklists	The following checklists were used: • Risk Breakdown Structure. • Risk Registers from similar projects. • List of critical controls and their associated risks.

Table 3-7: Techniques used during risk workshops

The risk workshops were attended by between 2 and 20 people. Attendees included representatives of the various engineering disciplines - project controls, engineering, health and safety, project management, etc. These techniques are described in more detail by Barkley, (2004), Chapman & Ward (2011), Cooper et al. (2005), and Hillson (2009).

3.4 Lessons learned

This short section contains some lessons which were learned during the data collection process which was followed as part of the research. The common factor between all the lessons is that they all placed constraints on the data collection process. These lessons are as follows:

- Over simplified risk model.
- Level of understanding of quantitative risk analysis.
- Availability of skilled risk managers able to do quantitative risk analysis.

Each of these lessons are discussed below.

3.4.1 Over simplified risk model

The initial model was developed in conjunction with an external consultant and after implementation required some improvements, mainly because the simulation model couldn't model some of the risks which were identified during the risk workshops. These improvement included the following:

- Accommodate the simulation modelling of multiple occurrence risks
- Accommodate both time variable cost as well as additional capital cost.

The implication of this is that 25 out of 86 risk registers do not make provision for these risks and model and therefore might be underestimating the output distributions for these particular projects and the related risk categories. These 25 projects represents 249 (27.0%) out of a total of 921 open risks.

Of these 249, 198 are individual risks (representing 42 risk names) which, in the rest of the sample, are treated as multiple-occurrence risks. This issue was corrected in October 2012 and all subsequent projects were modelled used the new methodology.

To improve the validity of the simulation model, other risk practitioners could have been consulted during the development phase of the initial model.

3.4.2 Level of understanding regarding quantitative risk analysis

This problem was encountered during the initial phases of the roll-out of a quantitative risk analysis approach at TCP. It was treated by always including some training at the beginning of the risk workshops.

3.4.3 Availability of skilled risk managers able to do quantitative risk analysis

This was the most significant problem encountered during the roll-out of a quantitative risk analysis approach at TCP. It limited the number of projects which could form part of the programme and limited the number of follow-up meetings which could take place.

The following combination of knowledge and skills is required to use the RRT:

- Project Management.
- Technical knowledge of port and rail projects.
- Risk Management.
- Excel.
- @Risk.
- Quantitative methods.

As an initial attempt, two graduate trainees with a financial modelling background were appointed. They took nearly a year to be able to facilitate risk workshops of simple projects under the guidance of the researcher. A later appointment with a BTech Mechanical degree was able to operate independently after 3 months.

The lesson was that it is easier to teach technical people quantitative methods and @Risk than it was teaching financial people technical projects.

3.5 Chapter Summary

This chapter described the various tools and techniques used during data collection. This included how the ISO31000:2009 process was used together with MS Excel and @Risk to create the RRT which was used capture the 86 risk registers. A short discussion on how the risk workshops were conducted is also included. The chapter concluded with some lessons learned which placed some constraints on the data collection process.

Chapter 4 discusses how the model was developed and illustrates the process by using process flow charts and MS Excel screenshots.

4. DEVELOPING THE SIMULATION MODEL

4.1 Purpose and outline

"Unfortunately, there are no easy rules of automatic methods for model developing. Model developing involves art and imagination as well as technical know-how." (Eppen, et al., 1988, p. 8).

To start this chapter, it is perhaps prudent to remind the reader on the purpose of this thesis, as described in Section 1.4 where it is stated that the purpose of this thesis is to develop a mathematically correct way of aggregating risks from various risk, i.e. existing project risk data. The corresponding problem statement was "*How can individual Risk Registers and the Monte Carlo method be used to identify focus areas in a project portfolio?"*

This chapter therefore describes how the simulation model (and related reports) was developed to enable a concurrent Monte Carlo simulation to be executed on all the existing quantified risk registers to answer the various research questions. It is also prudent to re-state the main research purpose of the risk simulation results produced by the simulation model:

The simulation model should assist decision making on a programme and portfolio level by identifying which risks really matter and which ones can be controlled. The result of this should be used as an input to the case study organisation's ERM processes to ensure that systemic risks are treated in an appropriate manner.

The following is therefore described in detail in this chapter:

- The methodology used to develop and populate a Combined Risk Register (CRR) and associated sheets. This refers to Research Question 2.
- The methodology which was used to develop the reports. These reports were used to answer Research Questions 3 to 9.

Each step of the developing of the simulation model is discussed in terms of the following:

- The purpose.
- Flow diagrams are shown when the process involves more than 5 steps and/or contains possible rework.
- Steps, giving detailed instructions on how to complete each step.
- MS Excel Figures of the simulation model which illustrate each step.

Please note the following:

- As the simulation model is developed, the MS Excel cell references will change as new columns are introduced. Therefore, please use the latest Figures as reference.
- When developing such a model, it is good practice to regularly save the simulation model under a new name. It has two purposes - it keeps track of how the work was done and keeps a record of the last version should the current version get corrupted or fail during the simulation - something which is known to occur.

4.2 Section flow diagram

Taking the above methodology as input, this Section covers the first five blocks in Figure 4-1: Section flow diagram, which is similar to that proposed by Vose (2008, p. 5) and Cooper, et al. (2005, p. 260). The last three steps are covered in Chapter 5.

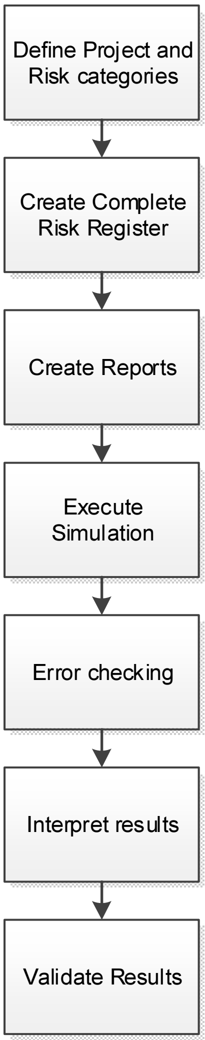


Figure 4-1: Section flow diagram

4.3 Define Project and Risk Categories

Before the simulation model could be developed, certain Project and Risk categories were defined. Two types of categories were defined in the simulation model to produce the answers to the research questions:

- Project.
- Risk.

Both these categories are discussed in the next sub-section.

4.3.1 Project Categories

Projects have many characteristics and attributes of projects which can be used as criteria to categorize them. These characteristics, are summarized for instance, by (Crawford, et al., 2004) are as follows:

- Application area or product.
- Stage of life-cycle.
- Grouped or single.
- Strategic importance.
- Strategic driver.
- Geography.
- Scope.
- Timing.
- Uncertainty.
- Risk.
- Complexity.
- Customer.
- Ownership.
- Contractual.

There were two reasons why Scope was selected as the criterion for categorization in this research:

- The Transnet Operating Divisions, on which this case study is based, have specific types of projects (Table 1-3: Variety of projects) and would require this research to provide feedback on their projects.
- Research Question 7 specifically refers to the use of rules of thumb (for example use a 10% contingency for the project budget during the execution phase) to estimate contingency. When selecting scope, one could, for example, test a hypothesis that "Port Bulk handling equipment" requires a 15% contingency".

PROJECT TYPE	RAIL	PORT	
	TFR	TNPA	TPT
Buildings	X	X	X
Safety and Security	X	X	X
Equipment	X		X
Earthworks	X		
Tunnels and Bridges	X		
Earthworks and OHTE	X		
Power Supply	X		
Signaling	X		
Environmental Clean-up		X	
Marine Infrastructure		X	
Road Infrastructure		X	
Bulk Handling Equipment			X
Liquid Handling Equipment			X
Stacking and Laydown Areas			X

Table 4-1: Project type and Operating Division

Because all the projects from the various OD's fell into the above 15 categories, the following 15 project categories were defined:

- Port Bulk Handling Equipment.
- Port Environmental Clean-up.
- Port Equipment.
- Port Liquid Handling Equipment.
- Port Marine Infrastructure.
- Port Stacking and Laydown Areas.
- Port and Rail Buildings.
- Port and Rail Safety and Security.
- Port Road Infrastructure.
- Rail Earthworks.
- Rail Earthworks & Overhead Traction Equipment (OHTE).

- Rail Equipment.
- Rail Power Supply.
- Rail Signalling.
- Rail Tunnels and Bridges.

The above list will be used later in this research to categorise each of the projects in the simulation model.

4.3.2 Risk Categories

Table 4-2 contains Research Questions 3, 4 and 5 as well as the Categories which needed to be defined to answer them during this research. It is best illustrated using two examples:

- For Research Question 1 "How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?", risk breakdown structure needed to be defined.
- For Research Question 2, a risk category dealing with the level of control which various stakeholders have over the likelihood and consequences of a risk on a project, needed to be defined.

	RESEARCH OBJECTIVE	RESEARCH QUESTION	CATEGORIES REQUIRED
3.	When simulating the risks in a project portfolio, establish where the focus areas are when taking the programmes and the Risk Breakdown Structure (RBS) into consideration.	How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?	RBS
4.	When simulating the risks in a project portfolio, establish where the focus areas are when taking the ability to control risks and the RBS into consideration.	When simulating controllable and not controllable risks, where should the focus area be?	Risk Category RBS
5.	When simulating the risks in a project portfolio, establish where the focus areas are when taking the ability to control risks, the RBS and project start delay risks into consideration.	When simulating controllable project execution start delay risks, where should the focus area be?	Risk Category RBS Start Delay Risks
6.	When simulating the risks in a project portfolio, establish if risks related to programmes are material causing uncertainty.	When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?	Programme Type

	RESEARCH OBJECTIVE	RESEARCH QUESTION	CATEGORIES REQUIRED
7.	When simulating the risks in the project portfolio, establish which of the categories defined in Research Questions 3, 4 and 5 have the most influence on uncertainty in the project portfolio.	When simulating various risk categories, which of the categories have the most influence on uncertainty in the project portfolio?	As defined in research questions 3, 4 and 5.
8.	When estimating contingency, establish the difference between the simple aggregation of P80 values compared to a concurrent simulation of a portfolio of programmes when estimating contingency and ranking risks.	How does the contingency requirement in a portfolio of programmes compare to the contingency requirement of the sum of the individual project's requirements?	None.
9	When estimating contingency, establish how simulation results compare to using "rules of thumb", e.g. "Contingency is equal to 10 % to estimate contingency requirements.	How does the simulated contingency requirements compare when using "rules of thumb"?	None.

Table 4-2: Risk Categories and the answers to Research Questions

To answer these research questions, each of the risks were categorised in terms of the following:

- Risk Type.
- Delay Execution Start.
- Risk Breakdown Structure.
- Programme Type.

As displayed in Figure 4-2, each of these categories (and their descriptions in the green blocks) were used to answer the research questions (numbers in ovals refer to research question):

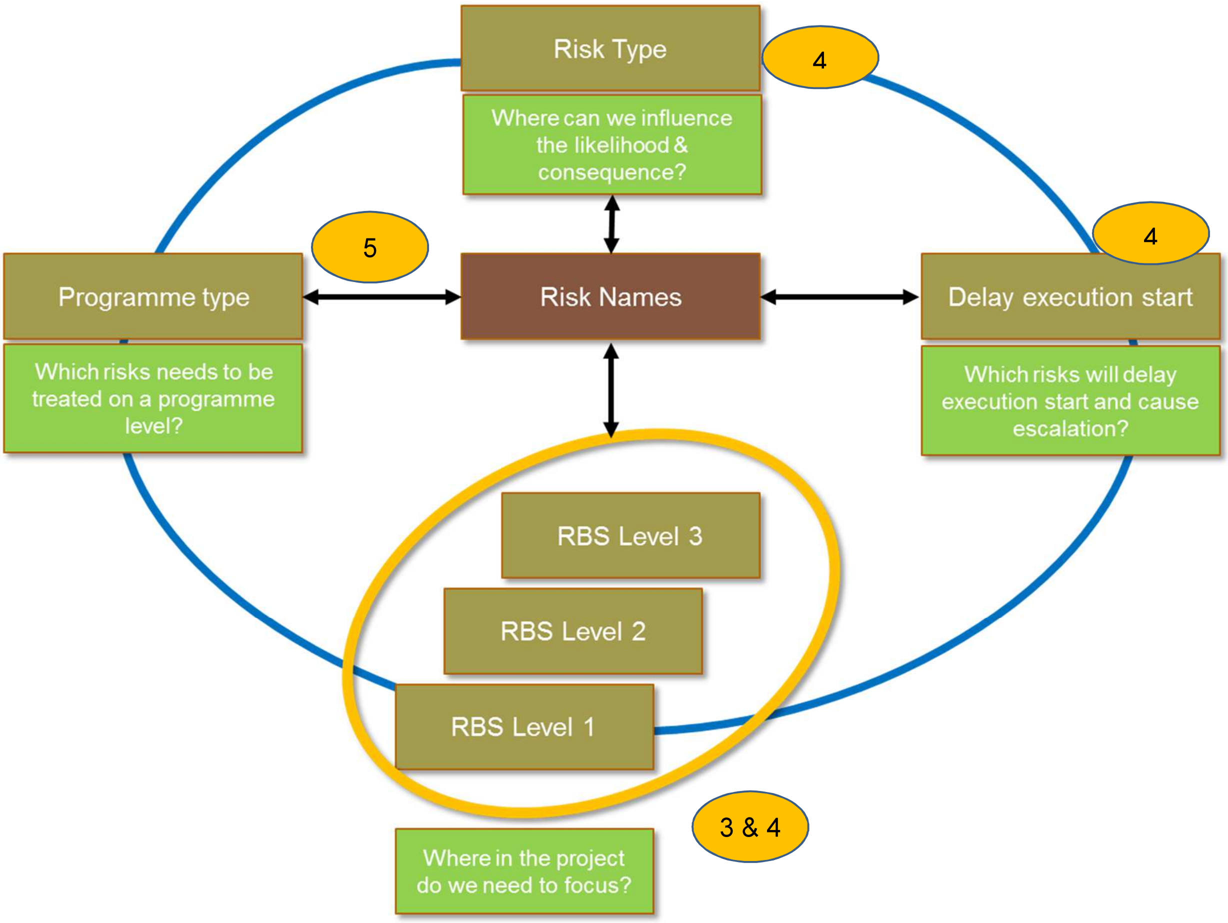


Figure 4-2: Risk Categories and Research Questions

Category: "Risk Type"

The category "Risk Type" refers to the extent to which the project manager/project team has control over the likelihood and consequences of a risk. The following options are available, as in Table 4-3.

- External - Uncontrollable.
- External - Influencable.
- Internal - Owner Requirement.
- Internal - Operational.
- Internal - Project Processes.

RISK CATEGORY	RISK SOURCE	SOURCE CHARACTERISTICS	RESPONSE CHARACTERISTICS
External - Uncontrollable	Event occurs due to circumstances outside of the project's control.	Client and project team have no control over the event occurring or its impact.	Provide contingencies to cater for the impact of the event should it occur.
External - Influencable	Event occurs due to circumstances outside of the project's control.	Client and/or project team have a degree of influence over the probability of the event occurring and its impact.	Plan actions to influence the probability of the event occurring. Provide contingencies to cater for the residual impact of the event should it occur.
Internal - Owner Requirement	Event occurs due to actions(s) taken by the client organisation.	The client has control over the probability of the event occurring. The project team has no influence over the probability of the event occurring or its impact.	The project team draws the client's attention to the ramifications of planned or implemented actions. The project team plans actions to reduce the impact of the event. The project team defines contingencies to cater for the residual impact of the event should it occur.
Internal - Operational	Event occurs due to actions(s) taken by the client and the project team.	Client and the project team have joint control over the probability of the event occurring. The client has control over the impact of the event.	Plan actions for the client and project team to implement that reduces the probability of the event occurring and its impact. Provide contingencies to cater for the residual impact of the event should it occur.
Internal - Project Processes	Event occurs due to actions(s) taken by the project team.	The project team has control over the probability of the event occurring. The project team has control over the impact of the event.	Plan actions for the project team to implement that reduces the probability of the event occurring and its impact. Provide contingencies to cater for the residual impact of the event should it occur.

Table 4-3: Risk types

Category: "Delay Project Execution"

This is used in answering Research Question 4. The following two options are available since a risk can either delay project execution start or not:

- Yes, the risk delays project execution start.
- No, the risk does not delay project execution start.

This category is important because, the risk simulation results might (refer Section 2.2) reveal that:

- Prediction (relationships among variables), for example: "The uncertainty related to Risks which delay project execution start is double that of risks which do not delay project execution start".
- Proof - (certain types of behaviour), for example: "The simulation model supplies evidence that more attention needs to be given to risks which delay project execution start".
- Discovery - (discover unexpected consequences of the interaction of simple processes) for example: "When combining the Risk Type with Delay Project Execution, it was discovered that the most uncertainty is caused by External Influencable risks which delay project execution start".

Category: "RBS"

This category is used to obtain answers to Research Question 4 and the entire RBS appears as APPENDIX A: RISK BREAKDOWN STRUCTURE. As can be seen in APPENDIX A, the risk breakdown structure has 3 levels. More detail on how this risk breakdown structure functions can be found in Section 9.5 (Create "RBS" sheet).

For the sake of this explanation, only the RBS Level 1 categories are included as follows:

- Client Environment.
- Construction Environment.
- Economic Environment.
- Government Environment.
- Natural Environment.
- Project Environment.
- Societal Environment.

Category: "Programme Type"

This category is used to answer Research Question 5 and refers back to Section 2.2.1 where the following options were presented:

- Risks which are *Amplified* in programmes/portfolios.
- Risks which are Common to Programmes.
- Risks which are *Generic* Project risks.

4.4 Complete Risk Register

This entire section is described in APPENDIX B: CREATE COMPLETE RISK REGISTER AND ASSOCIATED SHEETS. It shows how the "CRR" Sheet and associated sheets were developed and populated, as displayed in Figure 4-3 (Programme Type column hidden):

-

									Likelihood	Time Delay	Time Variable Cost	Additional Capital Cost	
Line Number	Project name	Project type	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name	Likelihood simulation	Delay simulation	Weighted weekly cost (R million)	Extra capital simulation	Simulation Result
1	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	Natural	Natural : Weather	Natural : Weather - Extreme weather	External - Uncontrollable	No	Inclement weather	1.00	1.73	R 0.12	R -	R 0.21
2	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	Construction	Construction : Industrial Relations	Construction : Industrial Relations - Industrial unrest	External - Uncontrollable	No	Labour unrest	0.00	0.35	R 0.16	R -	R -
3	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	Project	Project : Procurement	Project : Procurement - Availability/ lead times	Internal - Project Processes	No	Long lead items	0.00	0.55	R 0.04	R -	R -
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	Project	Project : Plans	Project : Plans - Scope definition	Internal - Project Processes	Yes	Scope definition	1.00	0.00	R -	R 0.22	R 0.22
5	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	Project	Project : Safety	Project : Safety - Worker injury	Internal - Project Processes	No	Safety non-compliance	0.00	0.39	R 0.11	R -	R -

Figure 4-3: Complete "CRR" Sheet

Of the initial 106 risk registers, 86 were consolidated into the CRR. A total of 15 different programmes/project types were created. A total of 1063 individual risks, representing 165 individual risks, were copied into the "CRR" sheet. Each of the risk names were put into various categories. The process (in green) appears in Figure 4-4.

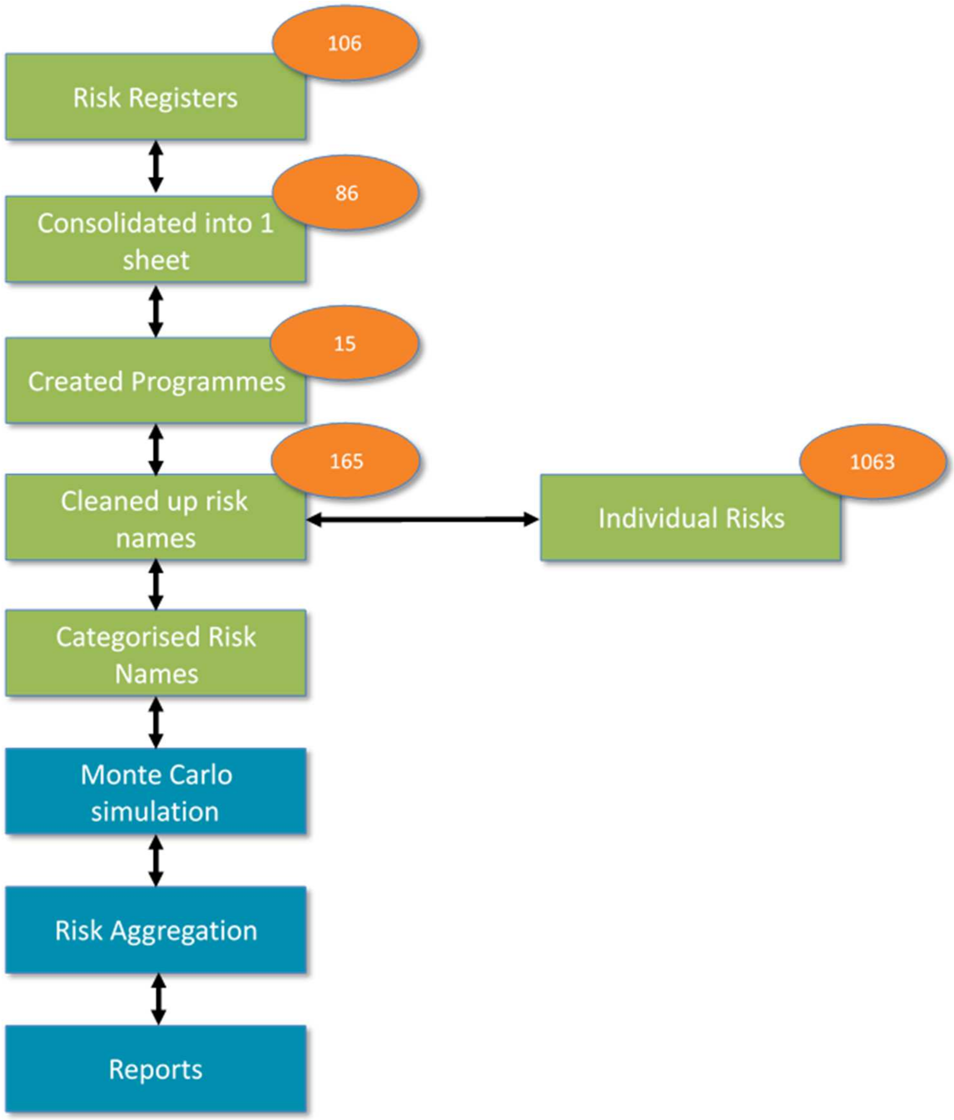


Figure 4-4: Summary in developing "CRR" Sheet

The "CRR" Sheet will be used to produce the various output distributions, as described in the next section.

4.5 Create Reports

4.5.1 Purpose and outline

In the previous section, the CRR was prepared in such a manner that a concurrent Monte Carlo simulation could be executed using the 86 risk registers. This section describes the basic principle which was used to create reports, which in turn was utilised to answer the research questions. The method described (or slight variations thereof) was implemented in all the reports, as presented in the next chapter.

To illustrate how these report can be created, Research Question 3: "How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?" is used as an example.

4.5.2 Methodology to generate output distributions

The following methodology was used to generate the output distributions:

At the end of each iteration, *=SumIfs()* statements, in conjunction with either a *=RiskMakeInput()* or *=RiskOutput()* were used to generate output distributions based on various sets of simulation results (project type, risk name, RBS level etc.).

- Two different types of "collection of output" data methods were used in the simulation model.
- RiskOutput()
- RiskMakeInput()

Both were used and are discussed below, as illustrated.

Creating an output distribution using two input criteria

When a cell is added as a simulation output, a RiskOutput function is placed in the cell by adding it to the existing cell equation, that is to be a simulation output (Palisade Corporation, 2014, p. 715).

Using the above, the following syntax was produced:

=*SumIfs*(sum_range, criteria_range1, criteria1, [criteria_range2,criteria2], …)+=*RiskOutput()*

Example:

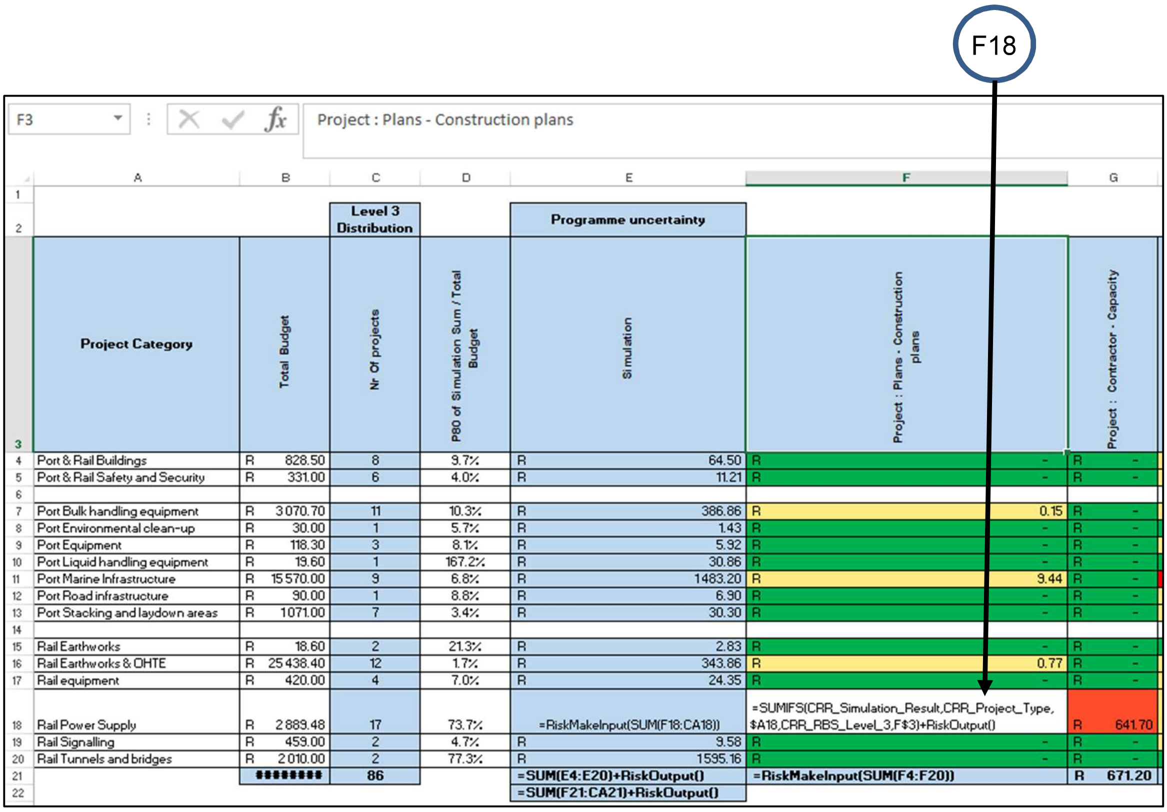
=*SumIfs*(Simulation_Result, Project_Type, ”Rail Power Supply”, RBS_Level_3,”Project : Project Plans - Construction plans”,) + *RiskOutput()*

Which means:

Produce an output distribution for all the “Simulation Results” where:

- Project type = “Rail Power Supply”
- Level 3 RBS = “Project : Project Plans - Construction plans”

It is similar to Figure 4-5 (Cell F18).



Row	Project Category	Total Budget	Nr Of projects	P80 of Simulation Sum / Total Budget	Simulation	Project : Plans - Construction plans	Project : Contractor - Capacity
2			Level 3 Distribution		Programme uncertainty		
4	Port & Rail Buildings	R 828.50	8	9.7%	R 64.50	R -	R -
5	Port & Rail Safety and Security	R 331.00	6	4.0%	R 11.21	R -	R -
6							
7	Port Bulk handling equipment	R 3 070.70	11	10.3%	R 386.86	R 0.15	R -
8	Port Environmental clean-up	R 30.00	1	5.7%	R 1.43	R -	R -
9	Port Equipment	R 118.30	3	8.1%	R 5.92	R -	R -
10	Port Liquid handling equipment	R 19.60	1	167.2%	R 30.86	R -	R -
11	Port Marine Infrastructure	R 15 570.00	9	6.8%	R 1483.20	R 9.44	R -
12	Port Road infrastructure	R 90.00	1	8.8%	R 6.90	R -	R -
13	Port Stacking and laydown areas	R 1071.00	7	3.4%	R 30.30	R -	R -
14							
15	Rail Earthworks	R 18.60	2	21.3%	R 2.83	R -	R -
16	Rail Earthworks & OHTE	R 25 438.40	12	1.7%	R 343.86	R 0.77	R -
17	Rail equipment	R 420.00	4	7.0%	R 24.35	R -	R -
18	Rail Power Supply	R 2 889.48	17	73.7%	=RiskMakeInput(SUM(F18:CA18))	=SUMIFS(CRR_Simulation_Result,CRR_Project_Type, $A18,CRR_RBS_Level_3,F$3)+RiskOutput()	R 641.70
19	Rail Signalling	R 459.00	2	4.7%	R 9.58	R -	R -
20	Rail Tunnels and bridges	R 2 010.00	2	77.3%	R 1595.16	R -	R -
21		########	86		=SUM(E4:E20)+RiskOutput()	=RiskMakeInput(SUM(F4:F20))	R 671.20
22					=SUM(F21:CA21)+RiskOutput()		

Figure 4-5: Example of =*SumIfs()* and =*RiskOutput()*

Note: The creation of the table is described in APPENDIX C: CREATION OF REPORTS. The following simulation output was produced:

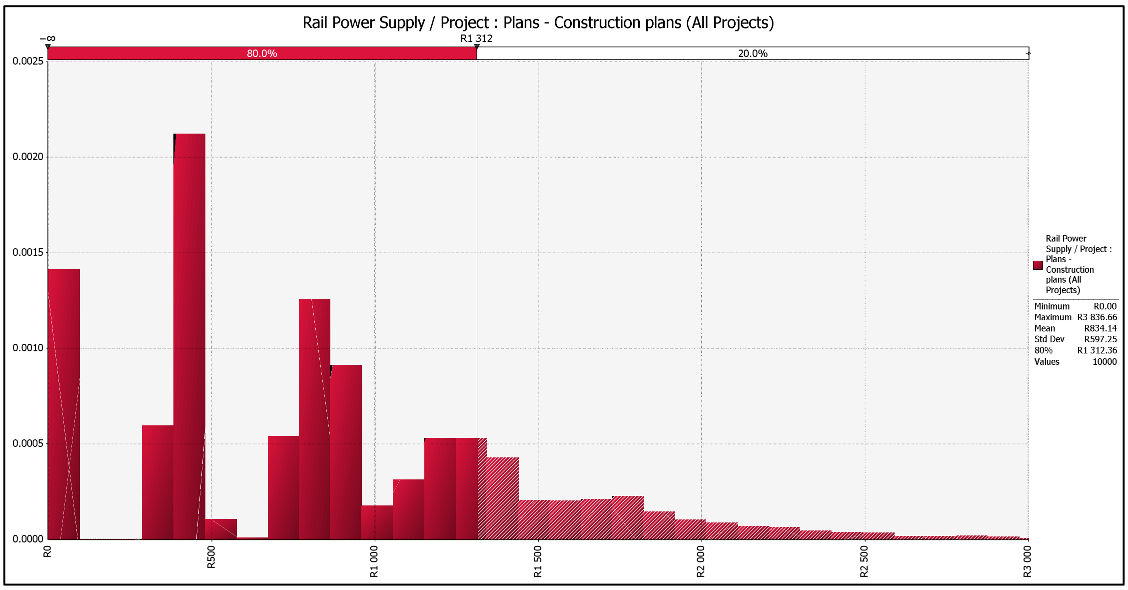


Figure 4-6: Example of output distribution using =*SumIfs()* and =*RiskOutput()*

The use of the above type of output is limited to comparing descriptive statistics such as Minimum, Maximum, Standard Deviation and P80 values of the various distributions.

The method remains the same for three and more input criteria.

Using the *=RiskOutput()* and *=RiskMakeInput()* to determine variability

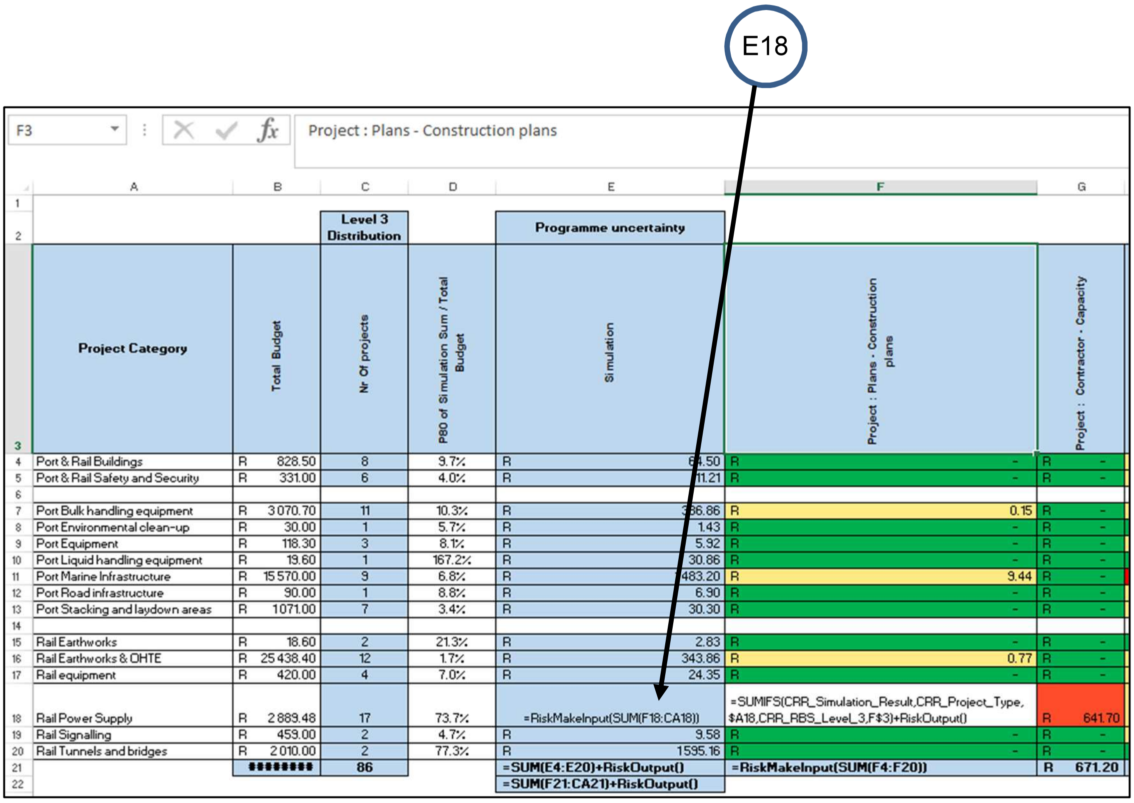
In the context of this research, *=RiskMakeInput()* is a more useful function as it uses the output distributions (as presented in the previous section) as inputs.

When all these output distributions puts are summed, tornado graphs could be produced. Tornado graphs from a sensitivity analysis, display a ranking of the input distributions which impact an output. Inputs that have the largest impact on the distribution of the output will have the longest bars in the Figure (Palisade Corporation, 2014, p. 254).

=RiskMakeInput() of specifies that the calculated value for equation will be treated as a simulation input, the same way as a distribution function. This function allows the results of Excel calculations (or a combination of distribution functions) to be treated as a single "input" in a sensitivity analysis (Palisade Corporation, 2014, p. 651).

To determine which of the Project Categories caused the most uncertainty, the following was used:

E18: *=RiskMakeInput(Sum(F18:AC18)*): This produced an output distribution for all the items in the RBS Level 3 which are related to the project category "Rail Power Supply".



	A	B	C	D	E	F	G
1							
2			Level 3 Distribution		Programme uncertainty		
3	Project Category	Total Budget	Nr Of projects	P80 of Simulation Sum / Total Budget	Simulation	Project : Plans - Construction plans	Project : Contractor - Capacity
4	Port & Rail Buildings	R 828.50	8	9.7%	R 64.50	R -	R -
5	Port & Rail Safety and Security	R 331.00	6	4.0%	R 11.21	R -	R -
6							
7	Port Bulk handling equipment	R 3 070.70	11	10.3%	R 386.86	R 0.15	R -
8	Port Environmental clean-up	R 30.00	1	5.7%	R 1.43	R -	R -
9	Port Equipment	R 118.30	3	8.1%	R 5.92	R -	R -
10	Port Liquid handling equipment	R 19.60	1	167.2%	R 30.86	R -	R -
11	Port Marine Infrastructure	R 15 570.00	9	6.8%	R 1 483.20	R 9.44	R -
12	Port Road infrastructure	R 90.00	1	8.8%	R 6.90	R -	R -
13	Port Stacking and laydown areas	R 1071.00	7	3.4%	R 30.30	R -	R -
14							
15	Rail Earthworks	R 18.60	2	21.3%	R 2.83	R -	R -
16	Rail Earthworks & OHTE	R 25 438.40	12	1.7%	R 343.86	R 0.77	R -
17	Rail equipment	R 420.00	4	7.0%	R 24.35	R -	R -
18	Rail Power Supply	R 2 889.48	17	73.7%	=RiskMakeInput(SUM(F18:CA18))	=SUMIFS(CRR_Simulation_Result,CRR_Project_Type, $A18,CRR_RBS_Level_3,F$3)+RiskOutput()	R 641.70
19	Rail Signalling	R 459.00	2	4.7%	R 9.58	R -	R -
20	Rail Tunnels and bridges	R 2 010.00	2	77.3%	R 1595.16	R -	R -
21		########	86		=SUM(E4:E20)+RiskOutput()	=RiskMakeInput(SUM(F4:F20))	R 671.20
22					=SUM(F21:CA21)+RiskOutput()		

Figure 4-7: Example of =*RiskOutput()*

This in turn, produced similar results to that in the previous section:

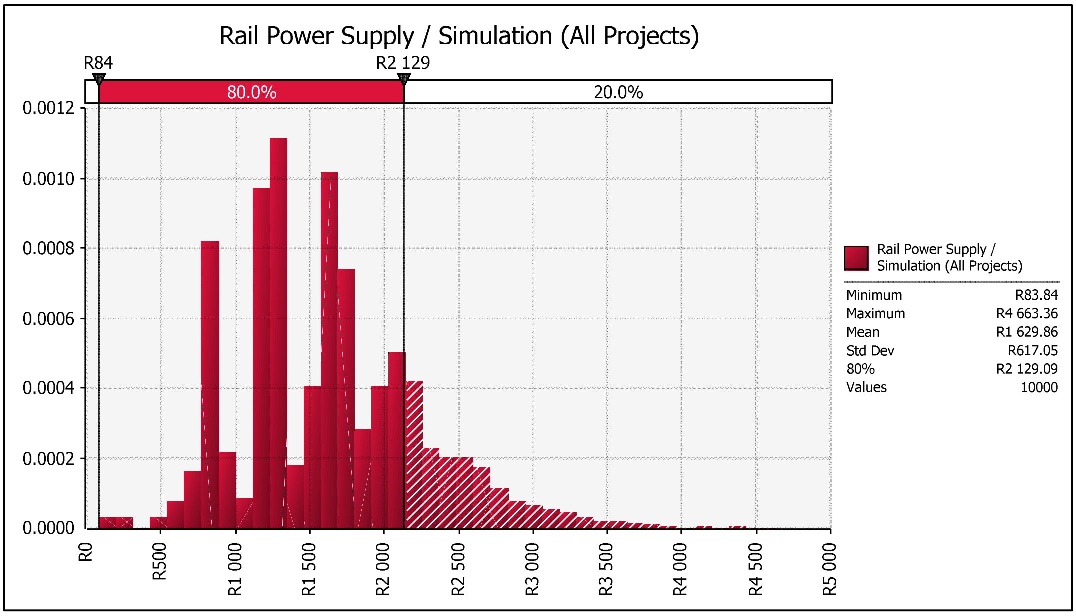
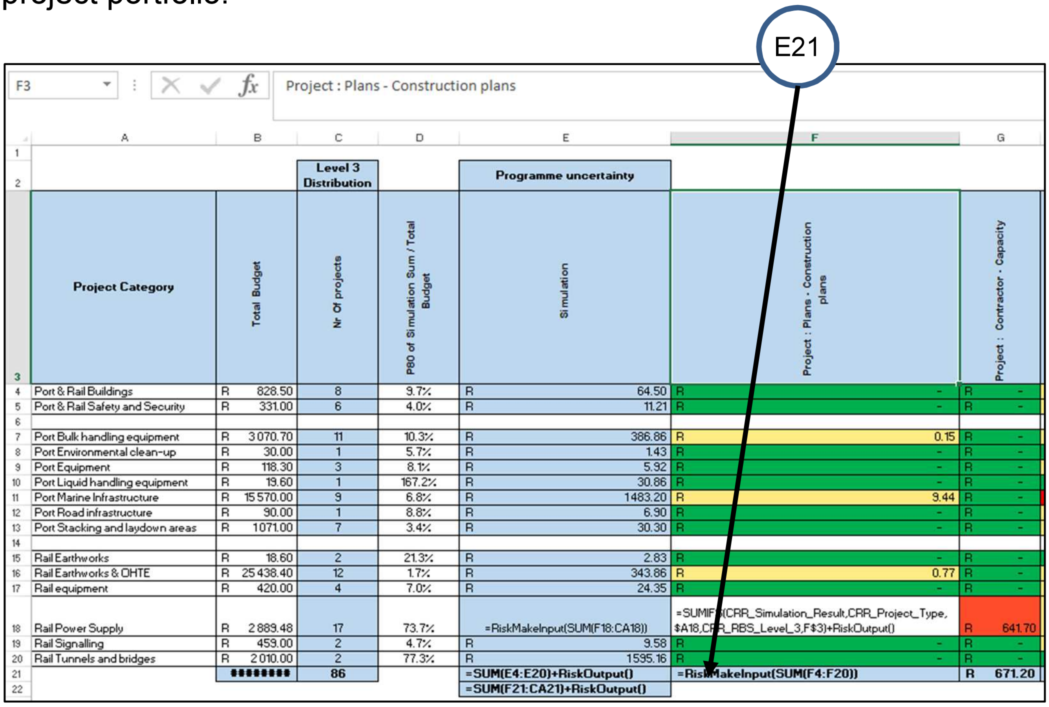


Figure 4-8: Sum of all Rail Power Supply inputs

The next step (E21) produced an output distribution using the input distributions of the various project categories. This allowed for a tornado graph to be produced which showed which project category had the biggest influence on the total project output distribution, for example that *Rail Power Supply* causes the most risk in the project portfolio.



F3 | Project : Plans - Construction plans

	A	B		C	D	E		F		G	
1											
2				Level 3 Distribution		Programme uncertainty					
3	Project Category	Total Budget		Nr Of projects	P80 of Simulation Sum / Total Budget	Simulation		Project : Plans - Construction plans		Project : Contractor - Capacity	
4	Port & Rail Buildings	R	828.50	8	9.7%	R	64.50	R	-	R	-
5	Port & Rail Safety and Security	R	331.00	6	4.0%	R	11.21	R	-	R	-
6											
7	Port Bulk handling equipment	R	3 070.70	11	10.3%	R	386.86	R	0.15	R	-
8	Port Environmental clean-up	R	30.00	1	5.7%	R	1.43	R	-	R	-
9	Port Equipment	R	118.30	3	8.1%	R	5.92	R	-	R	-
10	Port Liquid handling equipment	R	19.60	1	167.2%	R	30.86	R	-	R	-
11	Port Marine Infrastructure	R	15 570.00	9	6.8%	R	1483.20	R	9.44	R	-
12	Port Road infrastructure	R	90.00	1	8.8%	R	6.90	R	-	R	-
13	Port Stacking and laydown areas	R	1071.00	7	3.4%	R	30.30	R	-	R	-
14											
15	Rail Earthworks	R	18.60	2	21.3%	R	2.83	R	-	R	-
16	Rail Earthworks & OHTE	R	25 438.40	12	1.7%	R	343.86	R	0.77	R	-
17	Rail equipment	R	420.00	4	7.0%	R	24.35	R	-	R	-
18	Rail Power Supply	R	2 889.48	17	73.7%	=RiskMakeInput(SUM(F18:CA18))		=SUMIFS(CRR_Simulation_Result,CRR_Project_Type,$A18,CRR_RBS_Level_3,F$3)+RiskOutput()		R	641.70
19	Rail Signalling	R	459.00	2	4.7%	R	9.58	R	-	R	-
20	Rail Tunnels and bridges	R	2 010.00	2	77.3%	R	1595.16	R	-	R	-
21		########		86		=SUM(E4:E20)+RiskOutput()		=RiskMakeInput(SUM(F4:F20))		R	671.20
22						=SUM(F21:CA21)+RiskOutput()					

Figure 4-9: Example =Sum() and =*RiskOutput()*

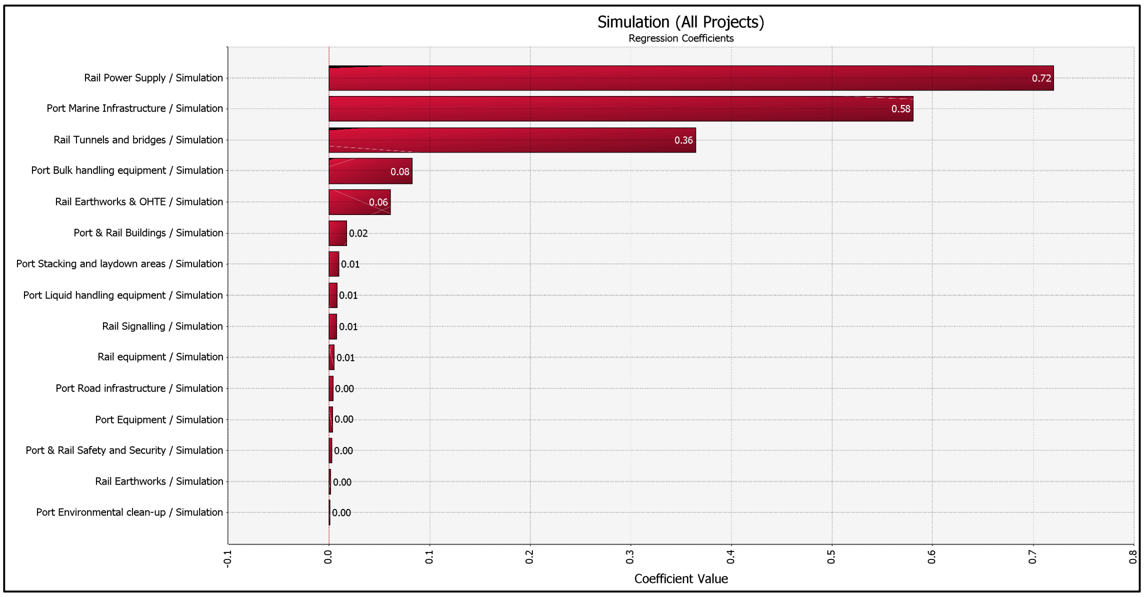


Figure 4-10: Tornado graph for Project Category

Similar to the above method, the functions in cells F21 and E22 were used to produce the following tornado graph:

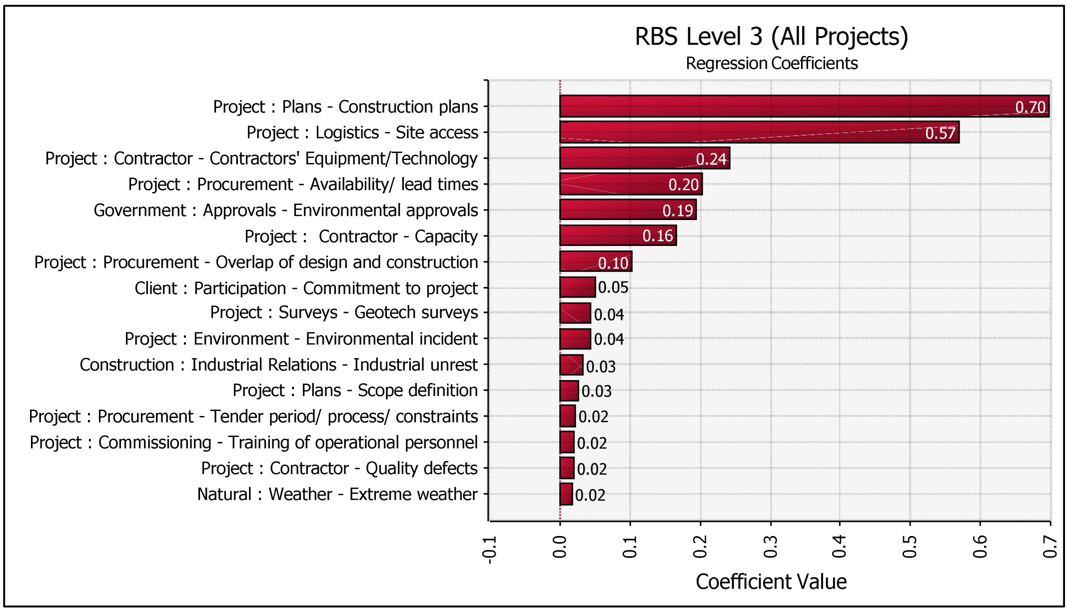


Figure 4-11: Tornado graph for RBS Level 3

From the above Figure, it was deduced that the most uncertainty in the project portfolio is caused by risks related to:

- Construction plans.
- Site access.
- Contractor's equipment/technology.

4.6 Execute simulation

After the reports were created, simulations were executed using the simulation model and @Risk software. Before this could be done, the @Risk simulation settings had to be changed and some error checking needs to take place.

Please note:

- Since simulation runs of 10 000 iterations might take more than 20 minutes to complete, it is suggested to have simulation runs of 500 iterations during the error checking phase.
- In case of MS Excel or @Risk malfunctioning during the simulation run, please save the workbook before the simulation run.

4.6.1 Flow diagram

This section uses the following process flow:

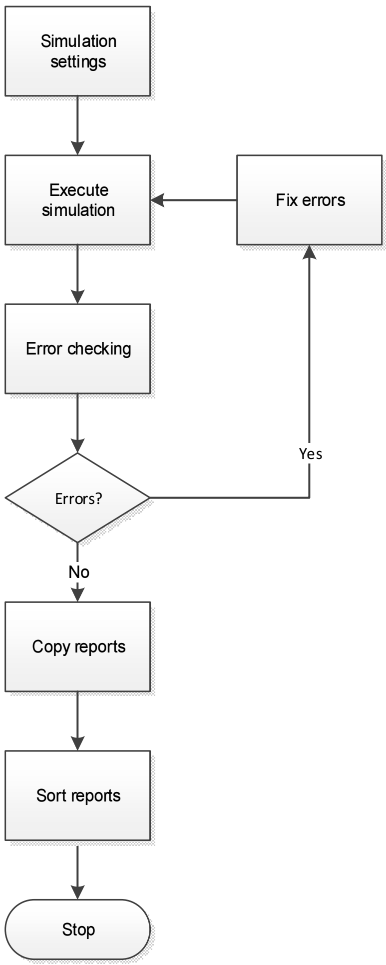


Figure 4-12: Simulation run flow diagram

4.6.2 Execute simulation

During this process, the following happens:

- All distribution functions are sampled.
- Sampled values are returned to the cells and equations of the worksheet.
- The worksheet is recalculated.
- Values calculated for output cells are collected from the worksheet and stored.
- Open @RISK Figures and reports are updated, if necessary (Palisade Corporation, 2014, p. 62).
- Run simulation of 500 iterations during error checking. After the errors have been corrected, run 10 000 iterations.

4.6.3 Simulation errors

During the developing of the simulation model, two types of errors related to the following occurred:

- The cells (or some cells) returned no results. The reason for this was that there were data mismatches between the values used in the =*SumIfs()* statements, for example: The named range might contain the RBS Level "Nature : Weather" and the heading which is used in the =*SumIfs()* statement in the report might be "Nature: Weather". In this case, the result of the =*SumIfs()* statement will be 0. This can be corrected by ensuring that there are no similar data mismatches.
- If #Value errors occur, it means that there are problems in the CRR_Simulation_Result named range where certain of the line items in the data range returns errors. Filters were used to sort and correct the data.

4.7 Chapter Summary

This Chapter answered Research Question 2:

"How does one develop a model to enable a quantified portfolio view of risk in a set of projects?"

The chapter showed how the following sheets were created and linked to each other, in effect creating a small relational database consisting of the following parts:

SHEET	CONTENTS
Table References	• All the information used in dropdown boxes throughout the model. This includes the following: • Likelihood Types (Once/More than once). • Binomial likelihood categories and descriptions (A - E). • Fifteen Project Types based on scope, for example Port Bulk handling equipment and Port Environmental clean-up. • Risk type which includes External - Uncontrollable, External - Influencable, Internal - Owner Requirement, Internal - Operational, Internal - Project Processes • Indicators like Yes and No. • Programme type (Common to Programmes/Amplified/Generic Project Risk).
Project Information	• Project information used in the CRR sheet: • Budgets. • Cost Structure. • Project location. • Client (TFR/TPT/TNPA). • Project Type.
RBS	• Contains RBS Levels 1 to 3.

SHEET	CONTENTS
All Risks	Contains risk name information used in the CRR and Reporting sheets: • Risk Name. • RBS dropdown box (Level 1 - Level 3). • Execution delay dropdown box able references sheet (Yes or No). • Type dropdown box from Table References sheet: External - Uncontrollable, External - Influencable, Internal - Owner Requirement, Internal - Operational, Internal - Project Processes. • Programme type dropdown box from Table references Sheet: Programme type (Common to Programmes/Amplified/Generic Project Risk).
CRR	Combines all the above information and creates the risk simulation results.
Reports	Takes the risk simulation results from the CRR sheet and creates various types of graphs to answer Research Questions 3 to 9.

Table 4-4: Parts of the Simulation Model

The database was set up in such a way that should information be changed in the following sheets, automatic updates would take place in the CRR:

- Project Information.
- RBS.
- All Risks.

To ensure that simulations could be executed successfully, error checking took place throughout the process. The next chapter will use the database and reporting methodology to answer Research Questions 3 to 9.

5. SIMULATION RESULTS

5.1 Chapter Purpose and Outline

Before continuing with this chapter, a summary on the tasks which have been completed in order to answer Research Questions 3 to 9 are presented. Referring to Figure 5-1, and starting at Chapter 1, a problem statement of "*How can individual Risk Registers and the Monte Carlo method be used to identify focus areas in a project portfolio?*" was defined after which a set of Research Questions were developed. After this, a Literature review was conducted.

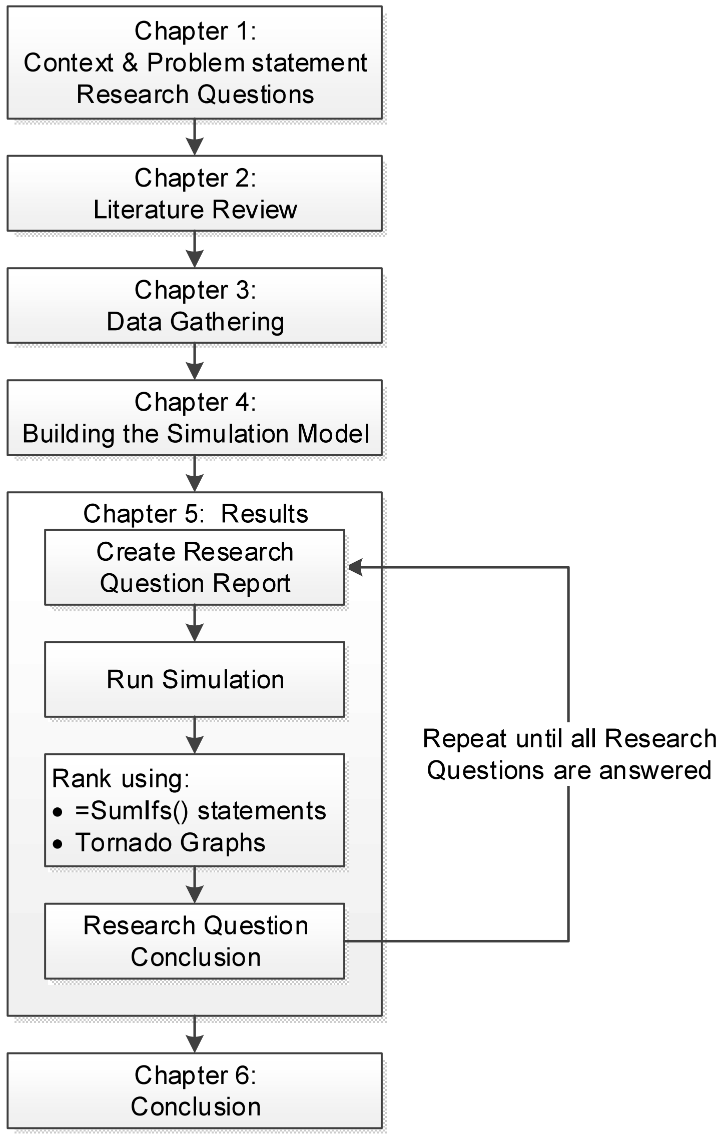


Figure 5-1: Research Roadmap

The following research questions still need to be answered:

3. How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?
4. When simulating the risks in a portfolio of programmes, are controllable risks material in causing uncertainty?
5. When simulating controllable project execution start delay risks, where should the focus area be?
6. When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?
7. When simulating various risk categories, which of the categories have the most influence on uncertainty in the project portfolio?
8. How does the contingency requirement in a portfolio of programmes compare to the contingency requirement of the sum of the individual project's requirements?
9. How does the simulated contingency requirements compare when using rules of thumb?

From the research questions, a simulation model was developed (and tested) in MS Excel which used the data from existing risk registers. The methodology used to execute simulations and generate reports was also discussed.

This chapter will therefore focus on answering the remaining research questions using the contents of Table 5-1 as reference and each section can be read as a separate fully contained section as well:

PARTS	PURPOSE
Simulation Model	• The chapter gives an overview of the input data. • It shows how the described simulation model was used as a basis to answer the research questions. • It demonstrates the flexibility of the simulation model by showing how it was adapted to answer additional questions which arose during the research.
Simulation Results	• Should provide the owner of the quantified risk registers with information regarding "What matters most?" and "Where to focus?". • The risk simulation results and their interpretation are presented. • Discusses the risk simulation results and their impact on project management.

Table 5-1: Purpose of Chapter

5.2 Steps in the process

For the rest of this chapter, the following structure is used when presenting the risk simulation results for Research Questions 3 to 9. For ease of reading and scientific validity each section is presented as a fully contained section. It is recognised that this chapter as a result of the extent and quality of the unique data set is quite long. Each of the ensuing paragraphs therefore contain a separate readable set of results based on the same logic for each of the research questions:

- **Description of data in the model:** This describes the data in the simulation model related to the research question using descriptive statistics. The purpose of this is to describe the basic features of the data and to provide some context regarding the importance of the related research question.

- **Simulation results:** For each of the risk simulation results, the MS Excel and @Risk functions which were used are shown. The risk simulation results themselves are presented in terms of tornado graphs (which show variability), probability density graphs as well as data tables.
- **Discussion of simulation results:** The results and their implication on the project portfolio and project management are discussed.

The chapter concludes with a summary of the essential answers to the research questions.

5.3 Research Question 3: When simulating controllable and not controllable risks, where should the focus area be?

This research question is important because it will highlight problem areas in the project portfolio in an attempt to provide some insight to the following questions:

- Which risks matter most?
- Where should the focus be during the implementation of risk treatment plans?

These questions are important because their answers can provide information regarding the ranking of risks in the project portfolio. The creation of tornado graphs for programme uncertainty as well as the uncertainty associated with RBS Level 1, RBS Level 2 and RBS Level 3 are described in this section, dealing with Research Question 3.

5.3.1 Description of data in the model

The data are described in terms of the projects as well as risks found in the simulation model.

Project data

As mentioned in Chapter 1, the simulation model contained data from 86 projects related to South African port and rail capital projects. These projects were spread all over South Africa. The majority of the projects belonged to TFR (53%) which also represented 61% of the total budget in the project portfolio. TNPA had the projects with the highest average budget (R999.6 million), followed by TFR (R694.4 million) and TPT (R184.6 million).

REGION	TFR	TNPA	TPT	TOTAL
Cape Town	2	1	2	5
Coal (Ermelo/Richards Bay)	31			31
Container Freight (Durban/Gauteng)	8		2	10
Durban	3	11	3	17
Port Elizabeth		3	1	4
Richards Bay	2	1	16	19
TOTAL	**46**	**16**	**24**	**86**
	53.5%	**18.6%**	**27.9%**	**100%**

Table 5-2: Number of Projects per Client per Region

REGION	INVESTMENT (MILLION)			
	TFR	TNPA	TPT	TOTAL
Cape Town	R16 450.0	R120.0	R1 612.0	R18 182.0
Coal (Ermelo/Richards Bay)	R12 848.9			R12 848.9
Container Freight (Durban/Gauteng)	R859.1		R 365.0	R1 224.1
Durban	R1 062.0	R13 150.0	R144.9	R14 356.9
Port Elizabeth		R2 660.0	R10.0	R2 670.0
Richards Bay	R722.0	R 63.0	R2 297.7	R3 082.7
TOTAL	**R31 942.0**	**R15 993.0**	**R4 429.6**	**R52 364.6**
	61.0%	**30.5%**	**8.5%**	**100%**

Table 5-3: Value of Projects per Client and Region

Risk data

A total of 1 063 individual risks were collected during risk workshops and appeared in the simulation model. Risks were classified according to whether they could still realise (open risks) or if they could not realise any longer (closed risks). Risks like *There is a risk of the late placement of orders* would typically be closed after the orders have been placed.

Of the 1 063 risks, 783 (73.7%) were open. The open risks were found throughout of the RBS. The closed risks were identified in the CRR by not having three-point estimates for either *Time Delay* or *Additional Capital Costs*. Open Risks represented 73.7% of the total number of risks of which Project related risks contributed 69.7%.

RBS LEVEL 1	CLOSED RISKS		OPEN RISKS		TOTAL	
Project	220	78.6%	546	69.7%	766	72.1%
Client	16	5.7%	68	8.7%	84	7.9%
Construction	11	3.9%	50	6.4%	61	5.7%
Societal	13	4.6%	44	5.6%	57	5.4%
Government	6	2.1%	37	4.7%	43	4.0%
Natural	7	2.5%	34	4.3%	41	3.9%
Economic	7	2.5%	4	0.5%	11	1.0%
TOTAL	**280**	**100%**	**783**	**100%**	**1063**	**100%**
	26.3%		**73.7%**		**100%**	

Table 5-4: RBS Level 1 and Risk Status

When sorting the risks data according to the project type and open risks, just over 80% of the open risks are found in the following seven categories: (i) Port Marine Infrastructure, (ii) Rail Earthworks and OHTE, (iii) Port Bulk handling equipment, (iv) Rail Power Supply, (v) Port and Rail Buildings, (vi) Port Stacking and laydown areas, (vii) Port and Rail Safety and Security (Table 5-6).

When looking at *Client* and *Open Risks* in the CRR (Table 5-5), TFR represented approximately half of all the risks (46.9%) with TNPA and TPT each representing a quarter (25.5% and 27.6%).

CLIENT	CLOSED RISKS		OPEN RISKS		TOTAL	
TFR	142	50.7%	367	46.9%	509	47.9%
TNPA	79	28.2%	200	25.5%	279	26.2%
TPT	59	21.1%	216	27.6%	275	25.9%
TOTAL	**280**	**100%**	**783**	**100%**	**1063**	**100%**
	26.3%		**73.7%**		**100%**	

Table 5-5: Client and Risk Status

To conclude, the project data considered in this research contained 1 063 risks of which 783 (73.3%) were open. TFR represented approximately 61% of the project budgets and the majority of the risks were in the project environment.

PROJECT TYPE	NUMBER OF PROJECTS	BUDGET (R MILLION)	CLOSED RISKS		OPEN RISKS		TOTAL	
Port Marine Infrastructure	9	R15 570.0	65	23.2%	151	19.3%	216	20.3%
Rail Earthworks and OHTE	12	R25 438.4	28	10.0%	136	17.4%	164	15.4%
Port Bulk Handling Equipment	11	R3 070.7	24	8.6%	93	11.9%	117	11.0%
Rail Power Supply	17	R2 889.5	66	23.6%	82	10.5%	148	13.9%
Port and Rail Buildings	8	R 828.5	14	5.0%	61	7.8%	75	7.1%
Port Stacking and Laydown Areas	7	R1 071.0	30	10.7%	60	7.7%	90	8.5%
Port and Rail Safety and Security	6	R 331.0	13	4.6%	55	7.0%	68	6.4%
Rail Equipment	4	R 420.0	22	7.9%	36	4.6%	58	5.5%
Port Liquid Handling Equipment	1	R19.6		0.0%	24	3.1%	24	2.3%
Port Equipment	3	R 118.3	5	1.8%	23	2.9%	28	2.6%
Rail Tunnels and Bridges	2	R2 010.0	5	1.8%	17	2.2%	22	2.1%
Rail Earthworks	2	R18.6		0.0%	15	1.9%	15	1.4%
Rail Signaling	2	R 459.0	7	2.5%	15	1.9%	22	2.1%
Port Road Infrastructure	1	R90.0	1	0.4%	11	1.4%	12	1.1%
Port Environmental Clean-up	1	R30.0		0.0%	4	0.5%	4	0.4%
TOTAL	**86**	**R52 364.6**	**280**	**100%**	**783**	**100%**	**1063**	**100%**
			26.3%		**73.7%**		**100%**	

Table 5-6: Descriptive Statistics on Project Type, Budget and Risk Status

5.3.2 Simulation results

The risk simulation results for answering this research question are presented in terms of the following two questions:

- Where in the RBS was the most uncertainty found?
- Which programmes/project types caused the most uncertainty in the project portfolio?

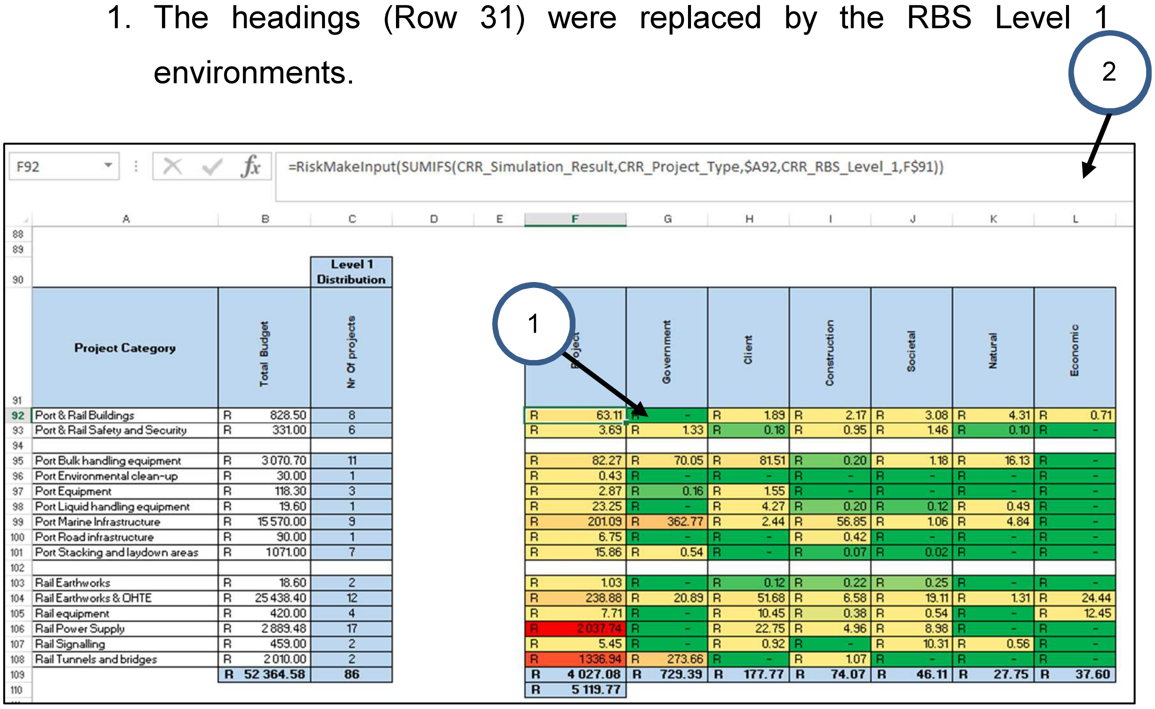
RBS and simulation results

Simulation results were produced for all three levels of the RBS, starting with the highest level and then drilling down.

Level 1 RBS

The output distribution as shown in Figure 5-2 was used in the risk simulation results for the Programmes and the Level 1 RBS. The purpose of this was to identify where in the Level 1 RBS and in which programme the most uncertainly could be found. There were two modifications from the example in the previous chapter:

1. The headings (Row 31) were replaced by the RBS Level 1 environments.



Project Category	Total Budget	Nr Of projects	Project	Government	Client	Construction	Societal	Natural	Economic
Port & Rail Buildings	R 828.50	8	R 63.11	R -	R 1.89	R 2.17	R 3.08	R 4.31	R 0.71
Port & Rail Safety and Security	R 331.00	6	R 3.69	R 1.33	R 0.18	R 0.95	R 1.46	R 0.10	R -
Port Bulk handling equipment	R 3 070.70	11	R 82.27	R 70.05	R 81.51	R 0.20	R 1.18	R 16.13	R -
Port Environmental clean-up	R 30.00	1	R 0.43	R -	R -	R -	R -	R -	R -
Port Equipment	R 118.30	3	R 2.87	R 0.16	R 1.55	R -	R -	R -	R -
Port Liquid handling equipment	R 19.60	1	R 23.25	R -	R 4.27	R 0.20	R 0.12	R 0.49	R -
Port Marine Infrastructure	R 15 570.00	9	R 201.09	R 362.77	R 2.44	R 56.85	R 1.06	R 4.84	R -
Port Road infrastructure	R 90.00	1	R 6.75	R -	R -	R 0.42	R -	R -	R -
Port Stacking and laydown areas	R 1071.00	7	R 15.86	R 0.54	R -	R 0.07	R 0.02	R -	R -
Rail Earthworks	R 18.60	2	R 1.03	R -	R 0.12	R 0.22	R 0.25	R -	R -
Rail Earthworks & OHTE	R 25 438.40	12	R 238.88	R 20.89	R 51.68	R 6.58	R 19.11	R 1.31	R 24.44
Rail equipment	R 420.00	4	R 7.71	R -	R 10.45	R 0.38	R 0.54	R -	R 12.45
Rail Power Supply	R 2 889.48	17	R 2 037.74	R -	R 22.75	R 4.96	R 8.98	R -	R -
Rail Signalling	R 459.00	2	R 5.45	R -	R 0.92	R -	R 10.31	R 0.56	R -
Rail Tunnels and bridges	R 2 010.00	2	R 1336.94	R 273.66	R -	R 1.07	R -	R -	R -
	R 52 364.58	**86**	**R 4 027.08**	**R 729.39**	**R 177.77**	**R 74.07**	**R 46.11**	**R 27.75**	**R 37.60**
			R 5 119.77						

Figure 5-2: RBS Level 1 Simulation set-up

2. The =*SumIfs()* statement was slightly modified to accommodate the Level 1 RBS from

=*RiskMakeInput*(=SumIfs(CRR_Simulation_Result,CRR_Project_Type,$A92,**CRR_RBS_Level_3**,F$91))

to:

=*RiskMakeInput*(=SumIfs(CRR_Simulation_Result,CRR_Project_Type,$A92,**CRR_RBS_Level_1**,F$91)).

The following tornado graph was produced where the RBS Level 1 Categories were ranked according to their regression coefficients:

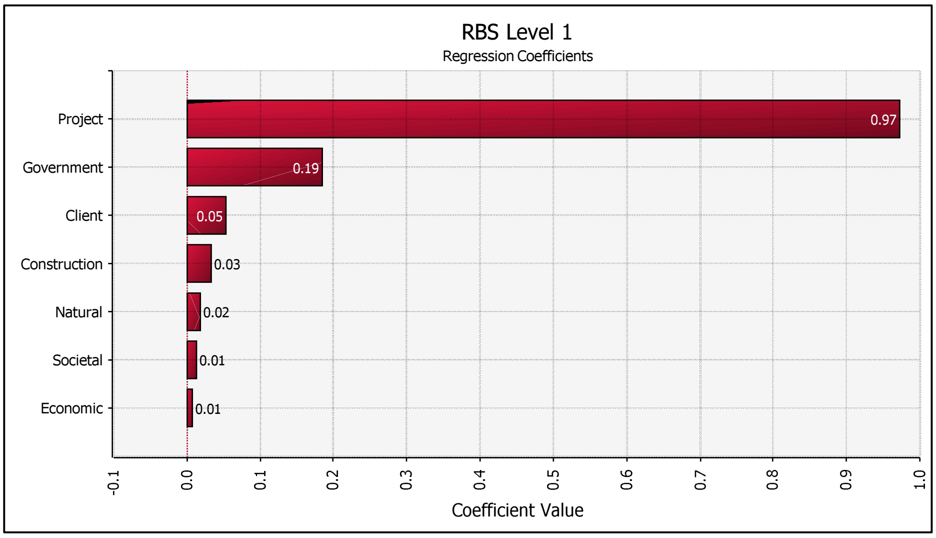


Figure 5-3: Tornado graph: Level 1 RBS

When looking at the seven environments found in RBS Level 1, the tornado graph shows that the most uncertainty relates to *Project Processes* and that *Government* related risks is the second most important.

Level 2 RBS

To create the RBS Level 2 simulation results, a similar method as was used as for RBS Level 1. A tornado graph in Figure 5-4 was produced:

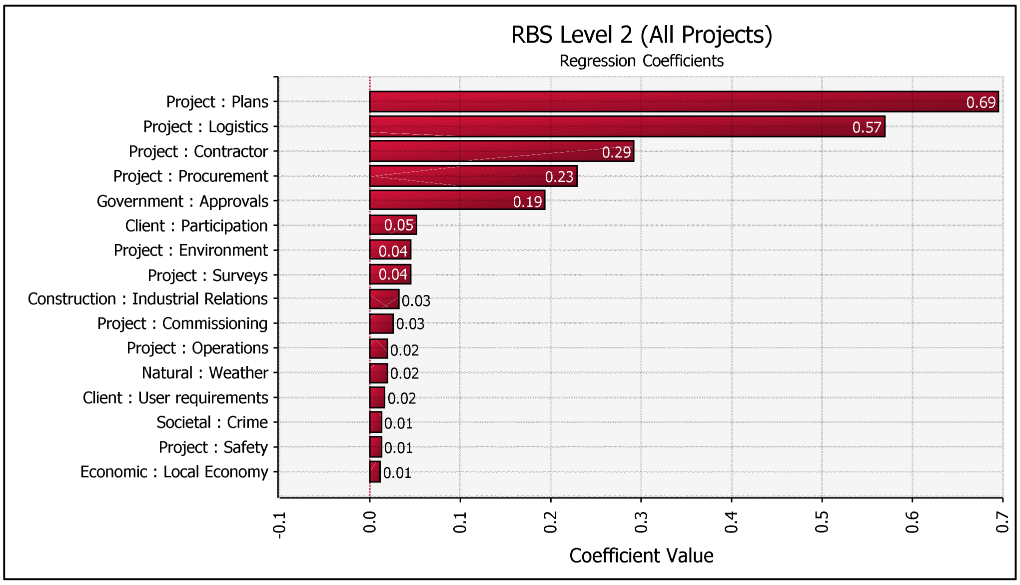


Figure 5-4: Tornado graph: Level 2 RBS

The tornado graphs shows that Project Environment risks are founds in related *Logistics*, *Plans*, *Contractors*, *Procurement* and *Operations*. *Government Approvals* also contributes significantly to uncertainty. It can be argued that the *Contractor* risks may be related to the *Procurement risks*, for example Procurement not appointing appropriate contractors.

Level 3 RBS

In this section, the regression coefficients which were produced in Figure 5-3 and Figure 5-4 are used together with a newly generated Figure 5-5 to generate Figure 5-6. Please note that the term *Project : Plans - Construction Plans* is interpreted in the following manner:

- RBS Level 1: *Project :*
- RBS Level 2: *Project :* Plans
- RBS Level 3: *Project :* Plans - Construction plans

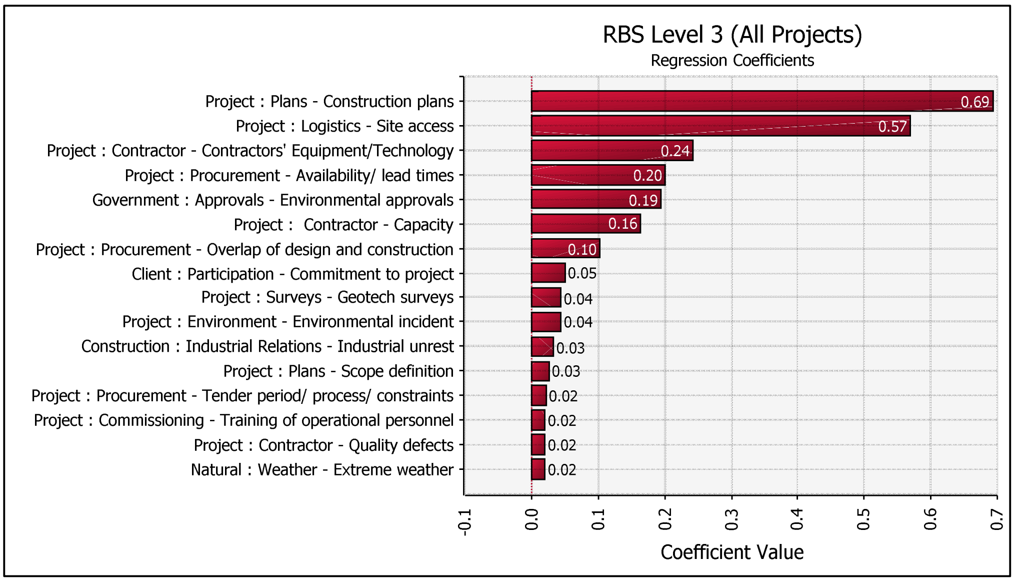


Figure 5-5: Tornado graph: Level 3 RBS

In the RBS Level 1 tornado graph, the Project Environment showed the most uncertainty. This is reflected in the Figure 5-5, where the following RBS Level 3 risks belong to the Project Environment:

- Construction Plans.
- Site Access.
- Contractor’s Equipment/Technology.
- Contractor Capacity.
- Procurement Availability/Lead times.
- Impact of the project on Existing Operations.
- Risks associated with the Overlap of Design and Construction.

When combining the results of the three sets of simulation results, Figure 5-6: Tornado graphs for RBS levels 1 to 3 combined (Figure 5-6) was produced. The figure is useful as it shows, on one diagram, where in the RBS the sources of risk can be found. The colour coding (Red, Orange and Green) used is based on bin sizes a third of the highest regression coefficient.

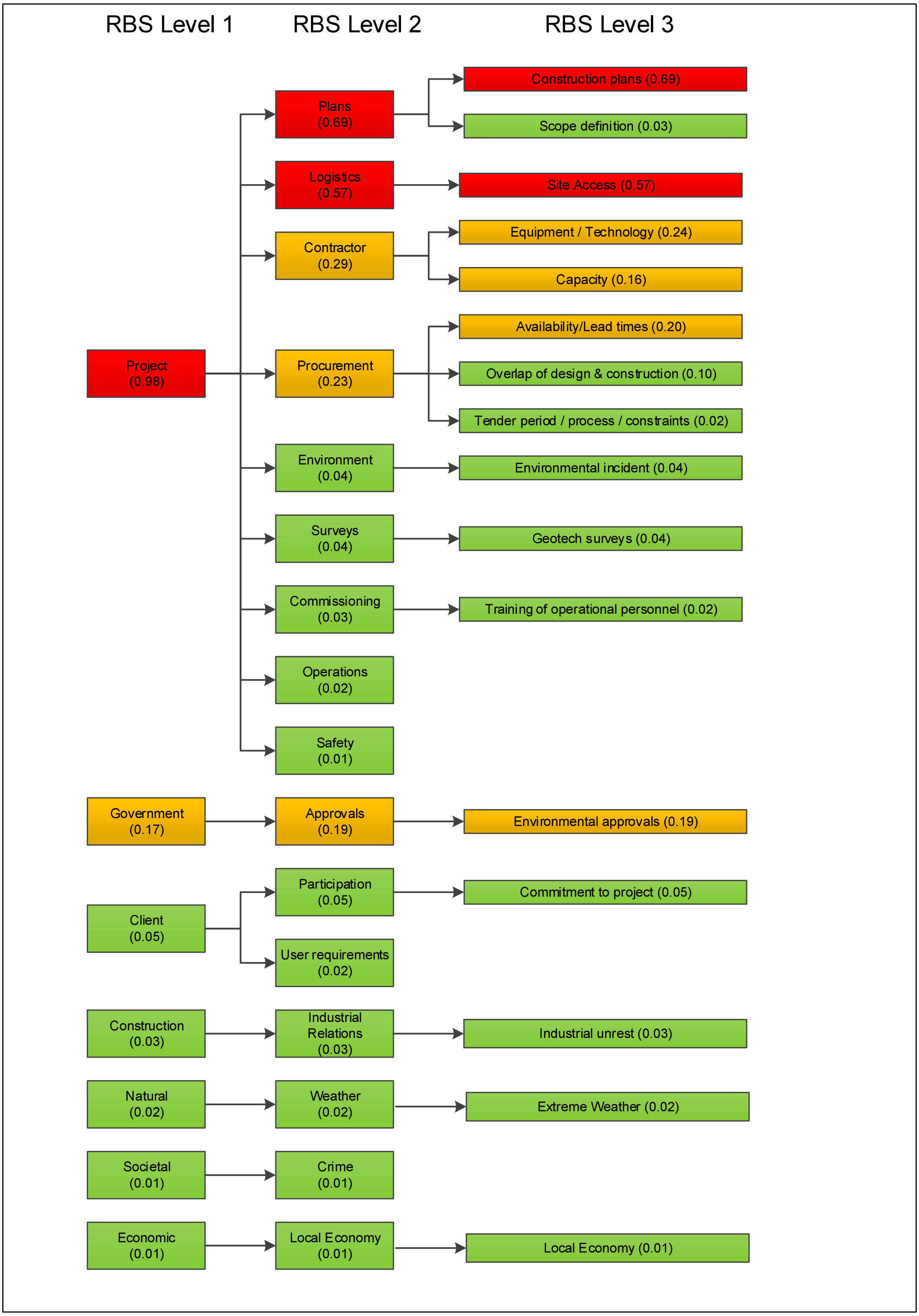


Figure 5-6: Tornado graphs for RBS levels 1 to 3 combined

Section Summary

When looking at the risk simulation results, the following can be concluded:

- The risks inside the project environment matters most because the most variance was found in this environment (Figure 5-3).
- The project environment risks which caused the most uncertainty had to do with (i) *Planning*, (ii) *Logistics*, (iii) *Contractors* and (iv) *Procurement. Environmental approvals*, part of *Government Appro*vals, also caused significant variance (Figure 5-4).
- The importance of treatment plans related to (i) *Construction Plans*, (ii) *Site Access*, (iii) *Contractor equipment*, (iv) *Contractor Capacity*, (v) *Procurement lead times* and (vi) *Environmental approvals* need to be communicated and built into project schedules (Figure 5-5).

Programmes and uncertainty

This simulation result (as described in Figure 4-10) produced a tornado graph which showed that the most uncertainty was related to the following project categories/programmes:

- Rail Power Supply.
- Port Marine Infrastructure.
- Rail Earthworks and OHTE.
- Rail Tunnels and Bridges.
- Port Bulk handling equipment.

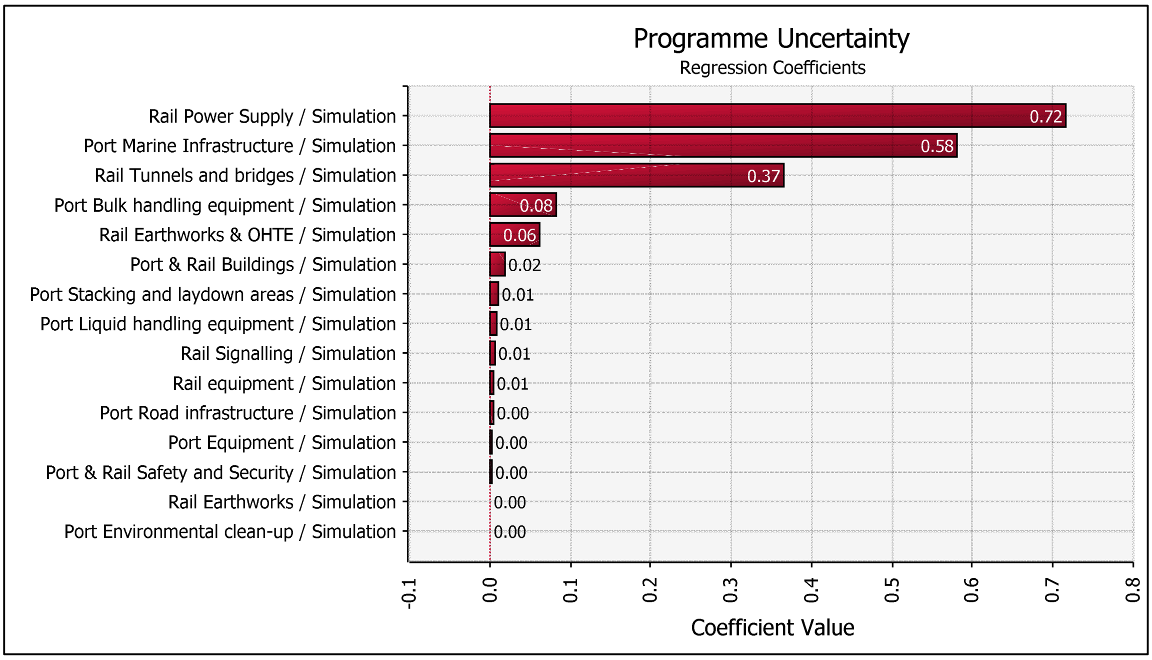


Figure 5-7: Tornado graph: All programmes

Projects driving the risks in the programmes

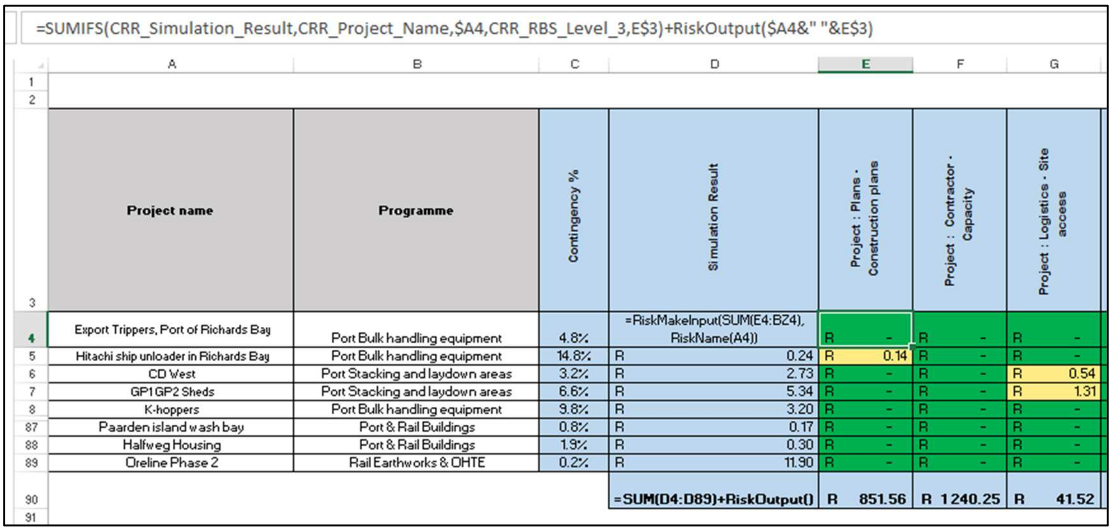
The simulation result from Figure 5-7 produced the question "*Is the uncertainty in the programmes driven by specific projects?"* This was an important question since it changed the research question from:

"How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?"

to

"How is the simulation model used to identify the projects which cause the most uncertainty?".

There were two possible ways to determine the answer to this question, both starting with the same set of simulation results. Instead of using the *Project type/Programme* as input, the *Project Name* is used, as illustrated in Figure 5-8:



=SUMIFS(CRR_Simulation_Result,CRR_Project_Name,$A4,CRR_RBS_Level_3,E$3)+RiskOutput($A4&" "&E$3)

	A	B	C	D	E	F	G
1							
2							
3	Project name	Programme	Contingency %	Simulation Result	Project : Plans - Construction plans	Project : Contractor - Capacity	Project : Logistics - Site access
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	4.8%	=RiskMakeInput(SUM(E4:BZ4), RiskName(A4))	R -	R -	R -
5	Hitachi ship unloader in Richards Bay	Port Bulk handling equipment	14.8%	R 0.24	R 0.14	R -	R -
6	CD West	Port Stacking and laydown areas	3.2%	R 2.73	R -	R -	R 0.54
7	GP1 GP2 Sheds	Port Stacking and laydown areas	6.6%	R 5.34	R -	R -	R 1.31
8	K-hoppers	Port Bulk handling equipment	9.8%	R 3.20	R -	R -	R -
87	Paarden island wash bay	Port & Rail Buildings	0.8%	R 0.17	R -	R -	R -
88	Halfweg Housing	Port & Rail Buildings	1.9%	R 0.30	R -	R -	R -
89	Oreline Phase 2	Rail Earthworks & OHTE	0.2%	R 11.90	R -	R -	R -
90				=SUM(D4:D89)+RiskOutput()	R 851.56	R 1 240.25	R 41.52
91							

Figure 5-8: Project uncertainty

Cell D90 in Figure 5-8 was used to create Figure 5-9, which is similar in shape and regression coefficient value to that of Programme uncertainty in Figure 5-7.

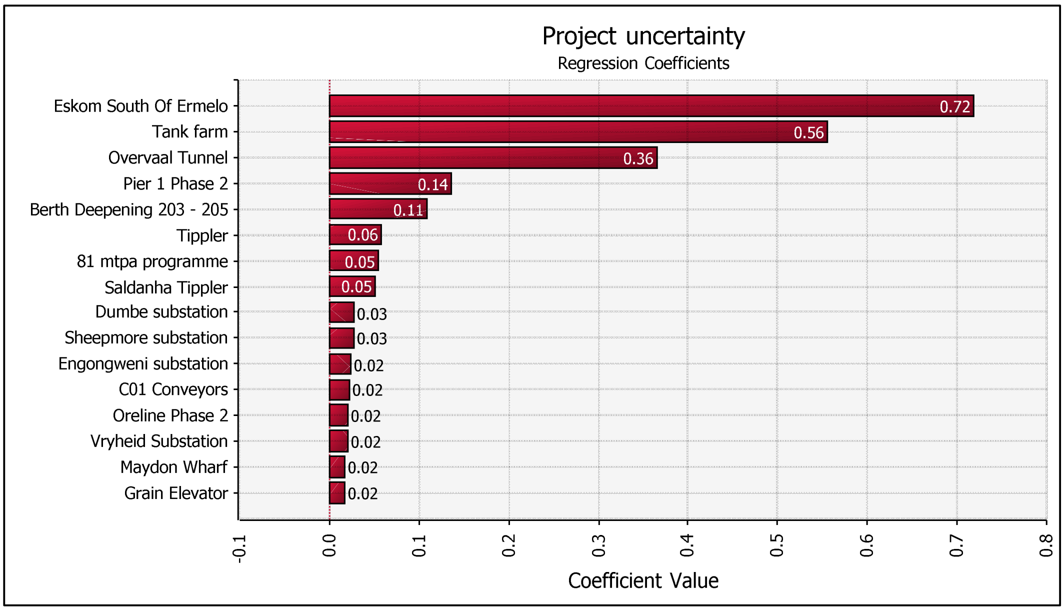


Figure 5-9: Comparing Simulation results from Programmes and Projects

The *Eight Projects* which had a Coefficient >0.03 are presented in Table 5-7, together with which project category they belonged to:

PROGRAMME	PROJECT WITH	REGRESSION COEFFICIENT
Rail Power Supply	Eskom South of Ermelo (TFR)	0.72
Port Marine Infrastructure	Tank Farm (TNPA) Pier 1 Phase 2 (TNPA) Berth Deepening (TNPA)	0.56 0.14 0.11
Rail Earthworks and OHTE	81 Mtpa Coal Export (TFR)	0.05
Rail Tunnels and Bridges	Overvaal Tunnel (TFR)	0.36
Port Bulk Handling Equipment	Tippler Richards Bay (TPT) Tippler Saldanha (TPT)	0.05 0.05

Table 5-7: Programmes and Projects mapped according to tornado graph results

For the rest of this research, the projects contained in Figure 5-7 will be called the *Eight Projects*.

Projects removed from the project portfolio

To determine the impact of these projects on the project portfolio, the *=RiskSimtable()* command was used as illustrated in Figure 5-10. To prepare for the simulation run, two columns were created. The first column, which contained all the risks from all the projects, was populated with a 1. In the second column, the 1 was removed for the risks which were related to the Eight Projects.

When executing the first simulation, the outcome of the risk simulation is multiplied by the contents of column CA. The second simulation run multiplied the simulation result with the contents of column CB, thus “turning off” all the risks related to the Eight Projects.

The simulation result is then used in the reports in conjunction with the appropriate *=SumIfs()* command.

=RiskMakeInput(AF157*(AJ157*AP157+AT157)*RiskSimtable(CA157:CB157))

	B	AU	BU	BY	BZ	CA	CB
2	Project name	Simulation Result	Eight			All Projects, All risks	8 Removed
157	Shiploader	R -	No			1.00	1.00
158	Shiploader	R 0.98	No			1.00	1.00
159	Shiploader	R -	No			1.00	1.00
160	Shiploader	R -	No			1.00	1.00
161	Shiploader	R -	No			1.00	1.00
162	Shiploader	R -	No			1.00	1.00
163	Tippler	R -	Yes			1.00	-
164	Tippler	R -	Yes			1.00	-
165	Tippler	R -	Yes			1.00	-
166	Tippler	R -	Yes			1.00	-

Figure 5-10: Use of the *=RiskSimtable()* function

The first simulation contained the 86 projects and the second one exclude the eight projects (called "Eight Projects") as in Figure 5-10. The Eight Projects contained 128 (16.3%) of the open risks 783 open risks. The risk simulation results from these two scenarios in Figure 5-11.

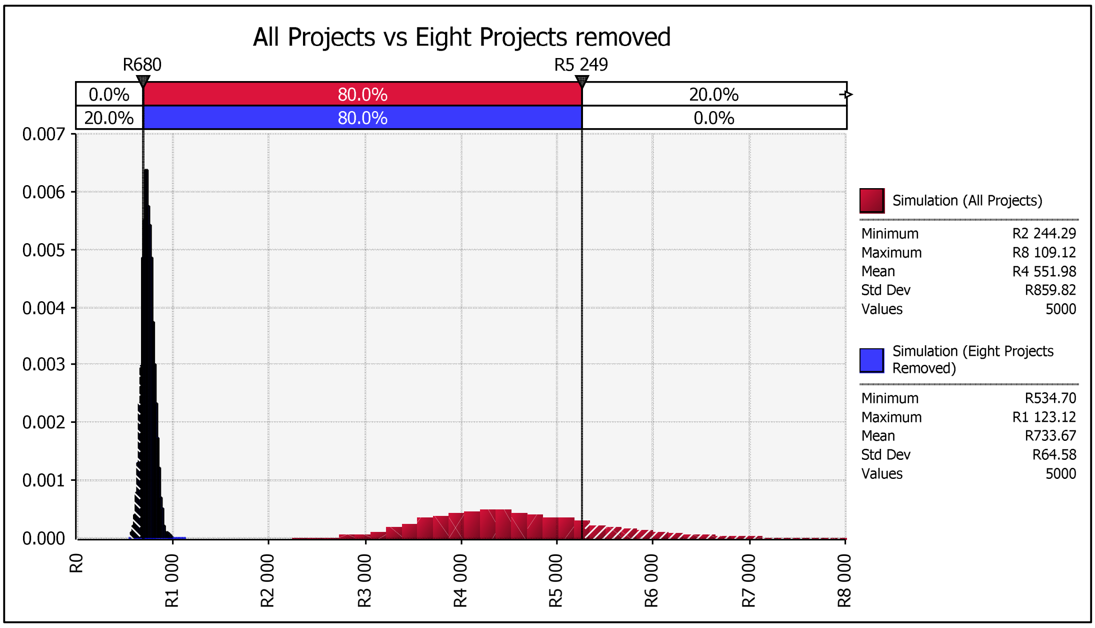


Figure 5-11: High uncertainty projects removed (R million)

From the output statistics on the Figure, (Maximum, Mean, Standard Deviation and P80) it was clear that the Eight Projects were causing the uncertainty in the project portfolio. To answer the *"What do these projects have in common?"*, Table 5-8 was created:

CATEGORY	DESCRIPTION
Governance and approvals	• Project approval delays due to governance requirements for projects with a cost higher than R1 billion. • Environmental approvals (including water use and borrow pit licenses). • Procurement eligibility requirements are often onerous, restricting the number of bids together with a complex and lengthy procurement process.

CATEGORY	DESCRIPTION
Physical project characteristics	• Complex, high capital cost, multi-disciplinary engineering projects. • Complex hydrogeological conditions (for example lots of water and rock). • Projects are not repeated regularly, for example comparing the following: • The same project team working for many years on various railway developing projects • A project team working on projects which after installation, have a 30 year lifecycle, such as a new quay wall with associated landside infrastructure, e.g. the Port of Ngqura. It implies limited institutional knowledge regarding high cost projects. • Large foreign content due to economics and/or skills available in South Africa. • The lead time from conception to commissioning is so long that the operational requirements, business models and operating models often change during the process, leading to scope changes and further delays.
Commercial	• The business cases are often difficult to quantify in order to satisfy investment committees. • Obtaining realistic construction estimates during study phases which stretch over many years. Study-based cost estimates are often not as realistic as planned and can only be adjusted once the bids start coming in, re-starting commercial approval processes.

CATEGORY	DESCRIPTION
Stakeholder issues	• Multiple, changing stakeholders with competing interests. • It is difficult to obtain stakeholder consensus on scope, and on design freeze. • Commitment to projects by Eskom. • Land acquisition or temporary land rights issues - land owners often demand excessive concessions/payments. • Multiple interfaces with other projects and business streams, complicating the authorisation and granting of necessary permits to execute project during operations.

Table 5-8: Project characteristics driving uncertainty

Changes in ranking: All Projects vs. Eight Projects Removed

After the removal of the projects, a new question came about: "*Does the removal of projects have a change in the ranking of risks?*" The answer to this question is important because it could show that different risk drivers are driving uncertainty in large complex projects when comparing them to smaller, less complex projects. The first step in answering this question was to create a similar diagram to that of Figure 5-6: Tornado graphs for RBS levels 1 to 3 combined and then comparing the diagrams with each other.

Figure 5-12: Risk driver comparison: All Projects vs Eight Project Removed

When combining the Top 10 of each of the previous RBS Level 3 tornado graphs, Table 5-9 was produced, using the regression coefficients:

NR.	RBS LEVEL 3	REGRESSION COEFFICIENTS	
		ALL PROJECTS	EIGHT PROJECTS REMOVED
1	Project : Plans - Construction Plans	0.70	
2	Project : Logistics - Site Access	0.57	0.14
3	Project : Contractor - Contractors' Equipment/Technology	0.24	
4	Project : Procurement - Availability/Lead Times	0.20	0.25
5	Government : Approvals - Environmental Approvals	0.19	0.27
6	Project : Contractor - Capacity	0.16	
7	Project : Procurement - Overlap of Design and Construction	0.10	
8	Client : Participation - Commitment to Project	0.05	0.68
9	Project : Surveys - Geotech Surveys	0.04	
10	Project : Environment - Environmental Incident	0.04	
11	Project : Commissioning - Acceptance by Operator		0.22
12	Project : Operations - Damage to Existing Facilities		0.22
13	Client : User requirements - User Requirement Definition		0.22
14	Client : Participation - Operations		0.18
15	Societal : Crime - Theft		0.17
16	Project : Plans - Scope Definition		0.15

Table 5-9: RBS Level 3 Regression coefficients compared

The RBS Level 3 risks were first ranked according to the regression coefficient found in the *All Projects* sample. These were then linked to the corresponding values in the *Eight Projects Removed* sample. The unmatched RBS Level 3 risks from the *Eight Projects Removed* sample was then ranked in descending order.

Although there were some matches between the two scenarios, as shown by:

- Project : Logistics - Site access,
- Project : Procurement - Availability/lead times,
- Government : Approvals - Environmental approvals and
- Client : Participation - Commitment to project,

the main drivers between the two scenarios shift from the Project environment for large complex project to the Client environment in the other, less complex projects.

5.3.3 Discussion of simulation results

The simulation model was used to demonstrate that certain project types cause the most uncertainty and that there is a difference in risk ranking between large complex projects and other projects. The two main findings are:

- Uncertainty is caused by large, complex projects with long lead times.
- There are different risk drivers when comparing large complex projects with smaller, less complex ones.

The risks causing the uncertainty will be discussed in terms of their impact on project management. The following risks are discussed in more detail:

- Client Participation - Commitment to project.
- Construction Plans.
- Contractor’s Capacity.
- Contractors' Equipment/Technology.
- Environmental approvals.

- Procurement - Availability/lead times.
- Procurement - Overlap of design and construction.
- Site Access.
- Client Participation – Operations.

Uncertainty is caused by large, complex projects with long lead times

From the tornado graphs in Section 5.3.2 it was clear that a set of eight projects drives uncertainty in the project portfolio. As mentioned in Section 4.3, the projects were placed into programmes based on the project scope. Since these projects fall into different project categories/programmes, it can be inferred that the uncertainty is not driven by the project scope but rather by scope *as well as* other project characteristics such as complexity, capital value, strategic importance etc.

Different risk drivers in large, complex projects

This observation goes hand-in-hand with the previous one. The risk simulation results (again Section 5.3.2) showed that there was a material difference in risk drivers when comparing the *Eight Projects* with the entire portfolio. The risk drivers of the Eight Project sat primarily in the *Project Environment*. In the simulation result where these projects were excluded, risks in the *Client Environment*, specifically related to *Commitment to the Project* and *User Requirement Definition* were causing the uncertainty in the project portfolio.

Impact on project management

Table 5-10 contains the risks discussed in this section, together with some of their causes and suggested treatment plans.

DESCRIPTION OF RBS LEVEL 3	IMPLICATIONS FOR PROJECT MANAGEMENT
Client Participation - Commitment to project	Client Participation and commitment to the project causes approval delays which in turn causes project cost escalation and delays in project completion. In some cases, this was driven by unclear owner requirement specifications and changes/lack of clarity in operational and business requirements. The lack of involvement in projects may cause a lack of understanding related to schedule and scope, which in turn might cause unrealistic expectations regarding cost and completion dates. Therefore: • Ensure early and regular engagement between ODs and Project Management to ensure that project objectives regarding scope and cost are clearly understood by all parties. • Ensure that the impact of time delays and cost increases related to these delays are clearly understood and documented.
Construction Plans	This relates primarily to executing projects in a brownfields environment where operational interruptions should be minimised because they might lead to revenue losses for Transnet. In some cases, the most optimal project construction sequences are not necessarily the most optimal solutions for an operational port or railway. Where different projects are executed by different contractors in the same area, interface risks (traffic, operations) also play a role. Therefore: • Ensure early and regular engagement between ODs and Project Management to ensure that project objectives regarding scope and cost are clearly understood by all parties.

DESCRIPTION OF RBS LEVEL 3	IMPLICATIONS FOR PROJECT MANAGEMENT
	• Ensure that the contracting strategy reduces the number of interfaces between contractors. For example, in a port project, there might be a civil contractor and a dredging contractor. By giving both contracts to a single contractor transfers the interface risks to the contractor.
Contractors' Equipment/Technology Contractor's Capacity	The source of these three risks relate to the appointment of inappropriate/inexperienced contractors, the availability of freight trains to deliver rail free issue material and the involvement of Eskom in executing parts of railway projects. The latter represented 20% of the risks in this category. Therefore: • During the procurement phase, ensure that the contract prices are realistic and that the work method statements are complete. • Discontinue the use of free-issue material in projects. • Regarding Eskom, ensure that the schedules are realistic.
Environmental approvals	The risks here relate to project plans not reflecting the entire legal process (which includes an appeal period) as well as inefficiencies at the Department of Environmental Affairs. Therefore: • It might be beneficial to start engagement with stakeholders earlier than the formal environmental approval process. • Ensure that project schedules make provision for the maximum approvals period.

DESCRIPTION OF RBS LEVEL 3	IMPLICATIONS FOR PROJECT MANAGEMENT
Procurement - Availability/lead times	It can be argued that the main source of risks in this category are related to Government and Transnet internal policies. Since Transnet is a state owned enterprise, government procurement policies are reflected in Transnet's own policies and procedures regarding Supplier Development and BBBEE procurement may add more stakeholders than would be required when comparing it with private companies. This forms part of the objectives of all the projects and has several implications which needs to be identified and managed. The implication of this is additional complexity and administration during the tender phase of the project due to additional stakeholders. In addition to the above, Transnet procurement governance requires that when projects go over certain capital cost thresholds, they have to go for Government Approvals which may add significant delays to the start of project execution and increase project cost due to the effect of inflation on delayed projects. Therefore: • Additional resources (time and cost) to ensure that the schedule makes provision for a longer tender period. • Ensure that project costing makes provision for the cost escalation due to longer approval periods. • Early engagement between project delivery teams, their planning, the availability of OD representatives as well as the related government departments to ensure that the dates agreed for project site work are reasonable and achievable.

DESCRIPTION OF RBS LEVEL 3	IMPLICATIONS FOR PROJECT MANAGEMENT
Procurement - Overlap of design and construction	This risk category involves procurement policies which requires that each project phase should go out on tender. This means that Contractor A can be contracted to do the engineering for a project and that the project execution may be awarded to Contractor B. The implication of this relates to time delays and associated cost escalation to validate designs and the potential that contractor B might completely reject the designs by Contractor A. Therefore: • These type of risks should be included in the risk registers during project development. • Transnet procedure should be reviewed to allow continuity between project development and execution phases, specifically when dealing with complex projects.
Site Access	There were two type of site access risks - site access due to geography (normally greenfields) and site access problems due to sites not made available by the OD due to operational and other requirements (normally brownfields). The consequence of this is that work cannot start as per the schedule. Therefore: • Better coordination between project delivery teams, their planning and OD representatives to ensure that the dates agreed for project site work is reasonable and achievable. • Early engagement between project management and commercial departments regarding realistic project delivery dates.

DESCRIPTION OF RBS LEVEL 3	IMPLICATIONS FOR PROJECT MANAGEMENT
Client Participation - Operations	The risk category deals with where client operational requirements would cause project work to be temporarily suspended and takes place in brown-fields environments. The general rule is that operations take priority over project work. Therefore: • The costs of these interruptions should be modelled to include standing time for both human resources as well as equipment. The costs of these interruptions should form part of the basis of estimate for these projects and can either be modelled deterministically or stochastically.

Table 5-10: Research Question 3: Impact on project management

5.4 Research Question 4: When simulating the risks in a portfolio of programmes, are controllable risks material in causing uncertainty?

This research question is directly related to the "*What matters most?*" and "*What can be controlled?*". The first question which need to be asked when looking at this research question, is "*Are controllable risks causing uncertainty?*". This question is important because the answer should indicate to the organisation whether the focus should be in attempting to implement treatment plans which are inside or outside the control of the organisation.

In Transnet's case, the project execution team and the project owners are part of the same organisation which puts a different slant on this research question.

The outcome of this research question will indicate two things:

- The extent to which the organisation (ODs and TCP) are exposed to internal or external project risks, and
- If the focus should be on implementing treatment plans on the internal and external risks.

Tornado graphs and RBS Level 3 are used to answer this research question.

5.4.1 Description of data in the model

As can be seen in Table 5-11, a total of 783 open risks were identified in the CRR of which 570 were classified as controllable. The risks are described in terms of what was defined in Table 4-3 where the amount of control the client and project team have over each of the risks. Nearly 60% of the open risks were identified as Internal Project processes.

The row heading *Not Controllable* is the sum of the following:

- External - Influencable.
- External - Uncontrollable.

The row heading *Controllable* the sum of the following:

- Internal - Operational.
- Internal - Owner Requirement
- Internal - Project Processes.

A new named range, CRR_Internal_External, was created where each risk was classified as either *Not Controllable* or *Controllable,* using the existing risk categories as input.

RISK CATEGORY	RISK STATUS				GRAND TOTAL	
	CLOSED		OPEN			
External - Influencable	46	16.4%	112	14.3%	158	14.9%
External - Uncontrollable	23	8.2%	101	12.9%	124	11.7%
Internal - Operational	17	6.1%	70	8.9%	87	8.2%
Internal - Owner Requirement	15	5.4%	35	4.5%	50	4.7%
Internal - Project Processes	179	63.9%	465	59.4%	644	60.6%
TOTAL	**280**		**783**		**1063**	
Not Controllable	69	24.6%	213	27.2%	282	26.5%
Controllable	211	75.4%	570	72.8%	781	73.5%
TOTAL	280	100.0%	783	100.0%	1 063	100.0%
	26.3%		73.76%			

Table 5-11: Controllable risks in the project portfolio

5.4.2 Simulation Results

The reports were set up as described in Figure 5-13 where Cells B4 and B5 were used to create the output distributions. Two simulations were run using the *=RiskSimtable()* function. The first was the *All Projects* sample and the second one, the *Eight Project Removed* sample.

	A	B	C	D	E	F
1						
2						
3	Client	Simulation	Project : Plans - Construction plans	Project : Contractor - Capacity	Project : Logistics - Site access	Government : Approvals - Environmental approvals
4	Not controllable	=SUM(C4:BX4)+RiskOutput()	=RiskMakeInput(SUMIFS(CRR_Simulation_Result,CRR_Internal_External,$A4,CRR_RBS_Level_3,C$3))	R -	R 12.23	R 473.46
5	Controllable	R 4 010.27	R 1 938.04	R 654.19	R 134.97	R -
6		**R 4 010.27**				
7						

Figure 5-13: RBS Level 3 and controllable risks

Controllable risks matter

The first finding is that controllable risks are material causing uncertainty in both the *All Projects* (Figure 5-14) and *Eight Projects Removed* (Figure 5-15) samples. When combining the descriptive statistic of these two simulation results, Table 5-12 was created. This table shows that the differences in the mean values are material in both samples (-75.5% and -57.6%). It can therefore be inferred that the classification of being *Controllable* has a material influence on the uncertainty in the project portfolio and that it by far outweighs the potential influence of *Not Controllable* risks.

RISK CATEGORY	MEAN (R MILLION)		CHANGE IN MEAN
	CONTROLLABLE	NOT CONTROLLABLE	
All Projects	R3 652.75	R891.62	-75.5%
Eight Projects Removed	R513.48	R217.55	-57.6%

Table 5-12: Controllable and Not Controllable risks compared

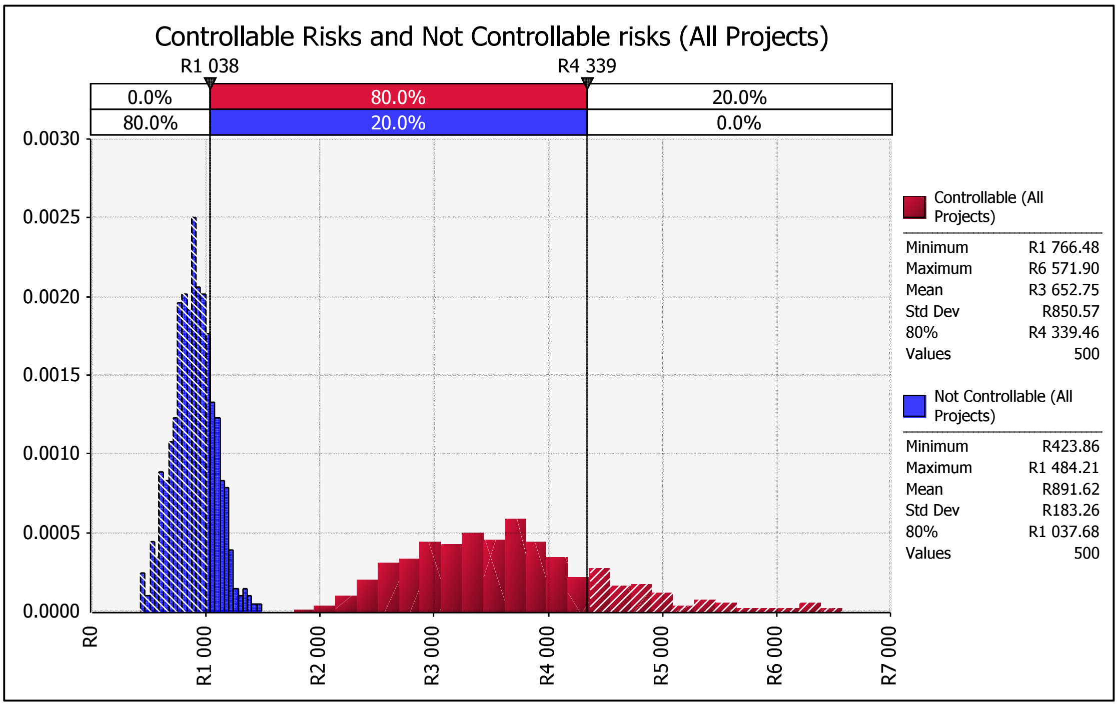


Figure 5-14: Controllable Risks: All Projects (R million)

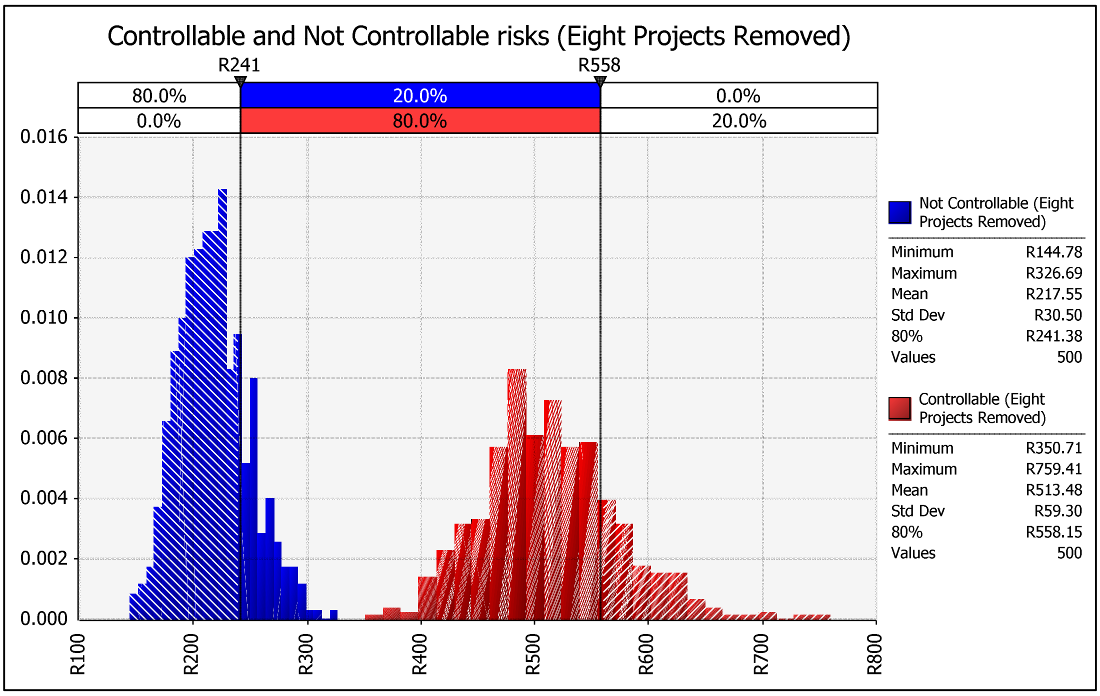


Figure 5-15: Controllable Risks: Eight Projects Removed (R million)

Section summary

When looking at the risk simulation results, the following can be concluded:

- Controllable risks are material causing uncertainty in the project portfolio (Table 5-12).
- The uncertainty caused by *Controllable risks* by far outweighs the uncertainty caused by *Not Controllable* risks (Table 5-12).

5.4.3 Further questions

From the risk simulation results presented in Section 0, further questions were asked to better understand the risk drivers in the project portfolio.

The questions were the following:

- Is there a difference in ranking for controllable risks between the *All Projects* and the *Eight Projects Removed* samples?
- Which controllable risks cause the uncertainty?

Tornado graphs and the CRR were used to answer these questions.

Changes in ranking of controllable risks

To answer these questions, the same report as set up in Figure 5-13 was used to create tornado graphs for both samples (Figure 5-16 and Figure 5-17) in which the risks were ranked according to their regression coefficients.

A comparison between these results appear in Table 5-13 which indicates that there are only 3 matches between the two samples which is evidence that the risk drivers in the two samples are different, similar to what was found in Section 5.3.3:

- Project : Logistics - Site access.
- Project : Procurement - Availability/lead times.
- Project : Plans - Scope definition.

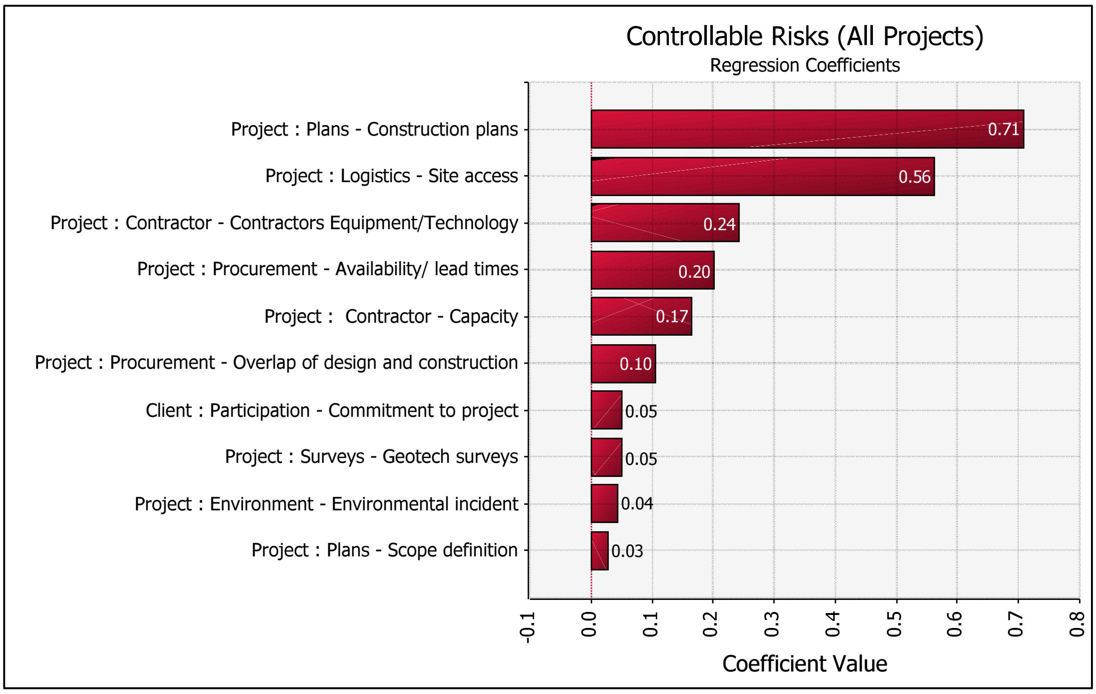


Figure 5-16: Controllable risks: *All Projects*

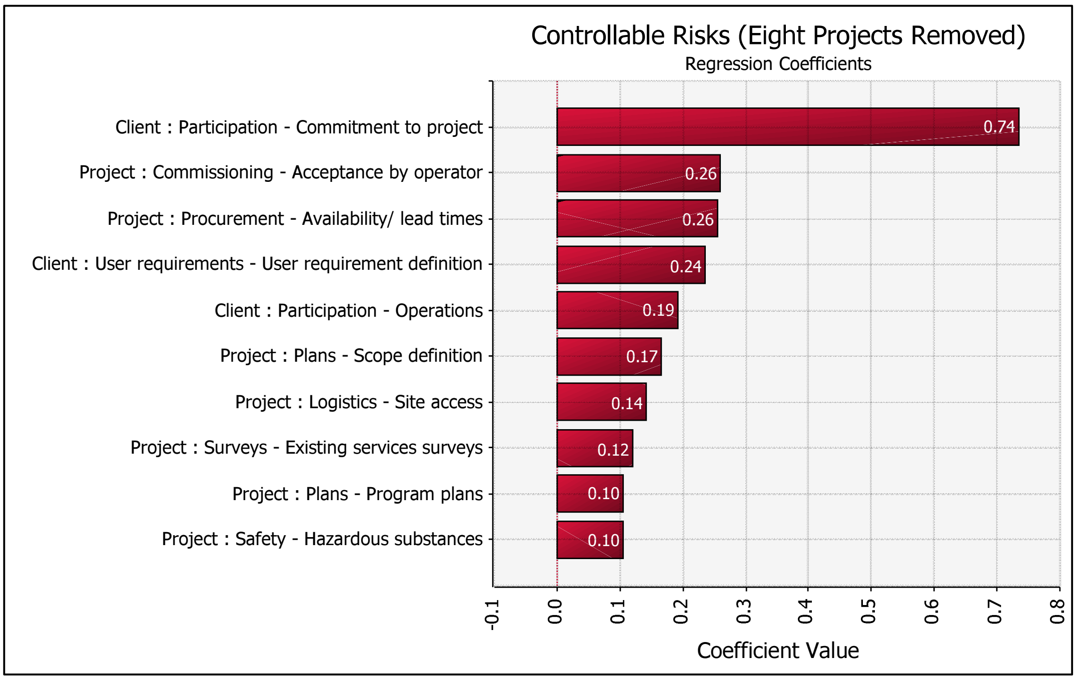


Figure 5-17: Controllable Risks: *Eight Projects Removed*

NR.	RBS LEVEL 3 START DELAYS	REGRESSION COEFFICIENTS	
		ALL PROJECTS	EIGHT PROJECTS REMOVED
1	Client : Participation - Commitment to Project		0.74
2	Project : Plans - Construction Plans	0.71	
3	Project : Logistics - Site Access	0.56	0.14
4	Project : Commissioning - Acceptance by Operator		0.26
5	Project : Contractor - Contractors Equipment/Technology	0.24	
6	Project : Procurement - Availability/Lead Times	0.20	0.26
7	Client : User requirements - User Requirement Definition		0.24
8	Client : Participation - Operations		0.19
9	Project : Contractor - Capacity	0.17	

NR.	RBS LEVEL 3 START DELAYS	REGRESSION COEFFICIENTS	
		ALL PROJECTS	EIGHT PROJECTS REMOVED
10	Project : Surveys - Existing Services Surveys		0.12
11	Project : Plans - Program Plans		0.10
12	Project - Safety - Hazardous Substances		0.10
13	Project : Procurement - Overlap of Design and Construction	0.10	
14	Client : Participation - Commitment to Project	0.05	
15	Project : Surveys - Geotech Surveys	0.05	
16	Project : Environment - Environmental Incident	0.04	
17	Project : Plans - Scope Definition	0.03	0.17

Table 5-13: Controllable and Not Controllable RBS level 3 risks compared

Section summary

When looking at the risk simulation results, the following can be concluded:

- There is a difference in ranking of controllable risks for both the *All Projects* and the *Eight Projects Removed* samples. It means that different treatment plans should be implemented for large complex projects when comparing them to smaller, less complex projects.

Which controllable risks cause the uncertainty?

This question follows directly from the one in the previous section. To answer it, the results from the tornado graphs (Table 5-13) were matched with Level 3 RBS in the CRR to identify the risk names associated with these findings. When applying the Pareto principle on these 218 risks, the following list was produced with *Environmental non-compliance*, *Scope definition, Long lead items, Geotech* and *Approval delays* making up the top 5. The list is limited to risks which contribute a total of 80% of the cumulative frequency.

The identification of the risk names when taking the outcomes of tornado graphs into consideration is a straight forward process and identified the related risks names are contained in Table 5-14

RISK NAME	FREQUENCY	%	CUMULATIVE %
Environmental Non-compliance	23	10.6%	11%
Scope Definition	23	10.6%	21%
Long Lead Items	19	8.7%	30%
Geotech	18	8.3%	38%
Approval Delays	12	5.5%	44%
Design Approvals	11	5.0%	49%
Site Congestion	10	4.6%	53%
Equipment Breakdown	10	4.6%	58%
Site access - Operational Requirements	9	4.1%	62%
Site Access	9	4.1%	66%
Late Order Placement	8	3.7%	70%
Traffic Congestion	7	3.2%	73%
Eskom	5	2.3%	75%
Unreliable Contractor	5	2.3%	78%
Equipment unavailable	5	2.3%	80%

Table 5-14: Risks causing project start delays

Section summary

When looking at the risk simulation results, the following can be concluded:

- By linking the tornado graphs with the CRR, the risks which cause the uncertainty were easy to identify. The risks appearing with the highest frequency in the project portfolio are *Environmental non-compliance*, *Scope definition, Long lead items, Geotech* and *Approval delays* (Table 5-14).

5.4.4 Discussion of simulation results

These results are discussed in terms of *"What matters most?"* and the impact of these findings on project management.

What matters most?

This answer to this research question clearly indicated that *"What matters most are controllable risks"*. This is further discussed in Section 5.6 which answers Research Question 6 which deals with different types of risks when taking programmes into consideration. As mentioned in section 1.2.2, Aritua et al. (2011, p. 308) differentiated between three types of risks:

- Risks which are *Common to Programme*s. These risks relate to the function of managing multiple projects and aligning them to the organisation's strategy and policies.
- Risks which are amplified in programmes. These risks are simple to deal with but exacerbated as a result of the multi-project environment.
- Risks which are generic to endeavours in project environments.

The implication of this argument is that certain types of risks cannot be solved in the project environment itself but requires intervention on a programme level.

Further important results relate to the difference in risks ranking when one compares large complex project with smaller, less complex projects. It means that different treatment plans should be implemented for large complex projects when comparing them to smaller, less complex projects.

Impact on project management

There is no specific discussion on the various risks which have been identified as being material causing uncertainty since the risks identified in this research question largely corresponds with the list of risks discussed under the same heading in the previous research question (0).

As mentioned in the opening chapter to this research question, the project execution team and the project owners are part of the same organisation. This brings along questions related to Transnet causing its own risks and would require the identification of risk treatment plans related to systemic risk. This topic is outside the boundaries of this research and may form part of future research.

5.5 Research Question 5: When simulating controllable project execution start delay risks, where should the focus area be?

In the previous research question is was established that controllable risks are material causing uncertainty in the project portfolio. The focus in Research Question 5 delves deeper into controllable risks and investigates the relationship between controllable risks and project execution start delay risks. To simplify this research question, it was broken into three parts:

- Are project execution start delays material in causing uncertainty?
- Which programmes/project types affected by start delays caused the most uncertainty in the project portfolio?
- Which controllable risks cause project start delays?

These questions are important for the following reasons:

- The risk *Skills & Resources* was identified as one of the risks contributing to variability in the project portfolio. When looking into the CRR, *Skills & Resources* appeared in 30 of the 86 risk registers. It would therefore be important to identify which risks can actually be controlled and which ones not as it doesn't make sense to assign resources to those risks which cannot be controlled.
- Cost increases due to project start delays were specifically modelled in high capital cost risk registers used in this research. The combined effect of these delays needed to be determined. This ties in with the results from the previous research question where *Client Participation/Commitment to the Project* was identified as a significant driver of risk in the project portfolio.

5.5.1 Description of data in the model

When looking at open risks, 149 (19%) of the risks are associated with project start delays (Table 5-15). The majority of the risks (12.6%) in this category are internal to Transnet and indicated on Table 5-15. The likelihood/frequency and consequences related to this sample will be the focus of this research question to determine where the focus areas should be regarding controllable project start delay risks.

RISK CATEGORY	RISK STATUS				GRAND TOTAL	
	CLOSED		OPEN			
DOES NOT CAUSE PROJECT START DELAYS	**227**	**81.1%**	**634**	**81.0%**	**861**	**81.0%**
External - Influencable	34	12.1%	68	8.7%	102	9.6%
External - Uncontrollable	23	8.2%	95	12.1%	118	11.1%
Internal - Operational	15	5.4%	60	7.7%	75	7.1%
Internal - Owner Requirement	5	1.8%	4	0.5%	9	0.8%
Internal - Project Processes	150	53.6%	407	52.0%	557	52.4%
CAUSES PROJECT START DELAYS	**53**	**18.9%**	**149**	**19.0%**	**202**	**19.0%**
External - Influencable	12	4.3%	44	5.6%	56	5.3%
External - Uncontrollable			6	0.8%	6	0.6%
Internal - Operational	2	0.7%	10	**1.3%**	12	1.1%
Internal - Owner Requirement	10	3.6%	31	**4.0%**	41	3.9%
Internal - Project Processes	29	10.4%	58	**7.4%**	87	8.2%
TOTAL	**280**	**100.0%**	**783**	**100.0%**	**1 063**	**100.0%**
	26.3%		**73.7%**			

Table 5-15: Descriptive statistics on project start delays and risk type

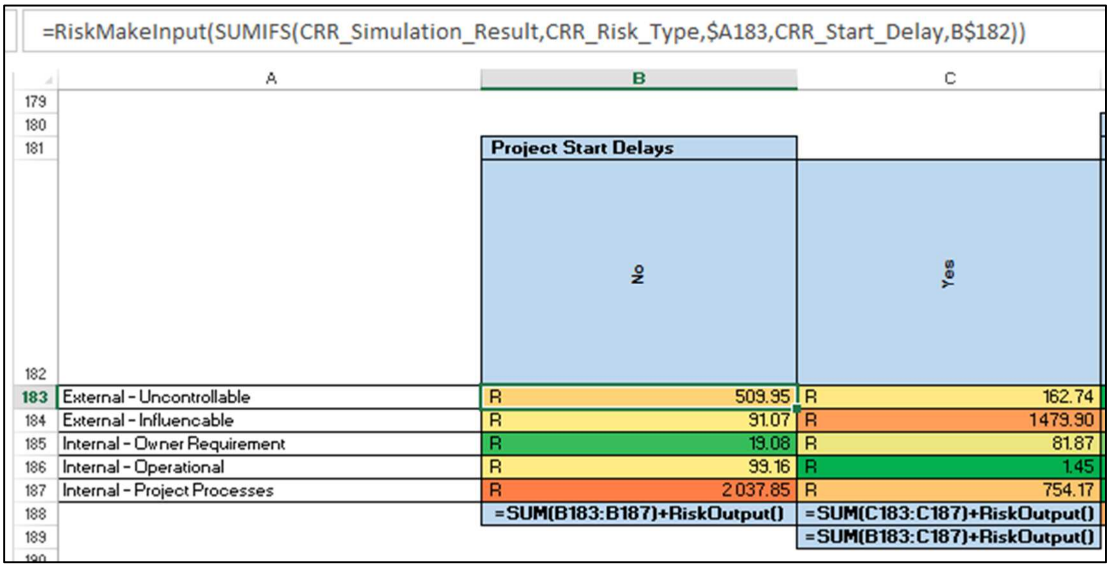
When applying the Pareto principle on these 149 risks, the following list was produced with *Scope Definition*, *Approval Delays*, *Design Approvals*, *Late Tender Documentation* and *Site Access* making up the top 5. The list is limited to those risks which contribute a total of 80% of the cumulative frequency.

RISK NAME	FREQUENCY	%	CUMULATIVE %
Scope Definition	23	15.4%	15.4%
Approval Delays	12	8.1%	23.5%
Design Approvals	11	7.4%	30.9%
Late Tender Documentation	10	6.7%	37.6%
Site Access	9	6.0%	43.6%
Site Access - Operational Requirements	9	6.0%	49.7%
Late Order Placement	8	5.4%	55.0%
Environmental Approval Delay	6	4.0%	59.1%
Stakeholder Commitment	5	3.4%	62.4%
Land Acquisition	5	3.4%	65.8%
Eskom	5	3.4%	69.1%
Procurement Delays	5	3.4%	72.5%
Environmental Approval Challenged	4	2.7%	75.2%
Environmental Approval Requirements Unknown	4	2.7%	77.9%
Water License	3	2.0%	79.9%

Table 5-16: Risks causing project start delays

5.5.2 Simulation results

Two simulation outputs were created. The simulation output used the Risk Type and Project Start Delay to create the output distribution. In Figure 5-18, cell E189 was used to collect data for the output distribution and Cell E188 produces the ranking of which type of risk causes the most uncertainty regarding project start delays.



=RiskMakeInput(SUMIFS(CRR_Simulation_Result,CRR_Risk_Type,$A183,CRR_Start_Delay,B$182))

	A	B	C
179			
180			
181		Project Start Delays	
182		No	Yes
183	External - Uncontrollable	R 509.95	R 162.74
184	External - Influencable	R 91.07	R 1479.90
185	Internal - Owner Requirement	R 19.08	R 81.87
186	Internal - Operational	R 99.16	R 1.45
187	Internal - Project Processes	R 2 037.85	R 754.17
188		=SUM(B183:B187)+RiskOutput()	=SUM(C183:C187)+RiskOutput()
189			=SUM(B183:C187)+RiskOutput()

Figure 5-18: Project Start Delays

Project Start Delays

The risk simulation results showed that project start delays were material causing uncertainty in the project portfolio. As shown in Figure 5-18, the "/Yes" or "/No" on the y-axis means "Yes, project start delays" and "No project start delays". The tornado graph showed that although *Internal Project Processes* which do not delay project execution start created the most uncertainty in the project portfolio, the next four risks (marked in red) - which all delay project execution start - showed high regression coefficients.

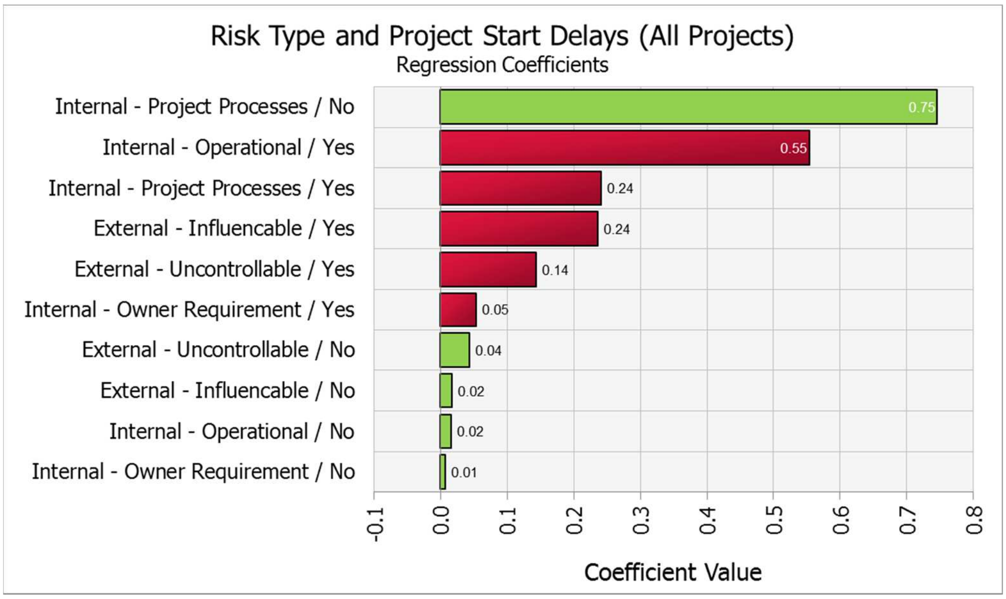


Figure 5-19: Risk Type and Project Start Delays

Projects driving Start Delays

As in the previous section, two simulations were executed where the first one included *All Projects* and the second one excluded the *Eight Projects*. Their probability density graphs were plotted together in Figure 5-20:

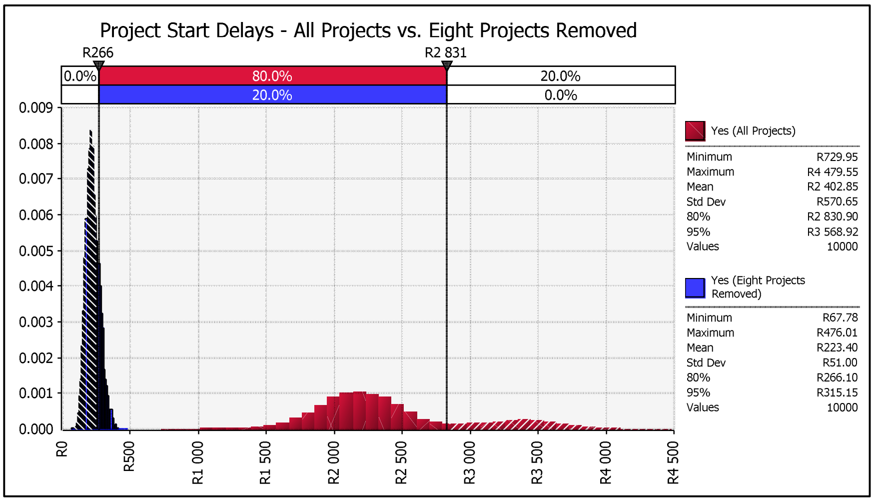


Figure 5-20: Project start delays (R million): *All projects* and *Eight Projects Removed*

From the result it was clear that the *Eight Projects* drive risks related to project start delays because when removing these projects, the mean reduced from R2 402.85 million to R233.4 million (-90.3%).

To determine the effect of start delay risks on the *Eight Projects*, two different simulation results were plotted together in Figure 5-21. The first simulation included all the risks and the second one excluded all the risks causing project cost escalation due to project start delays.

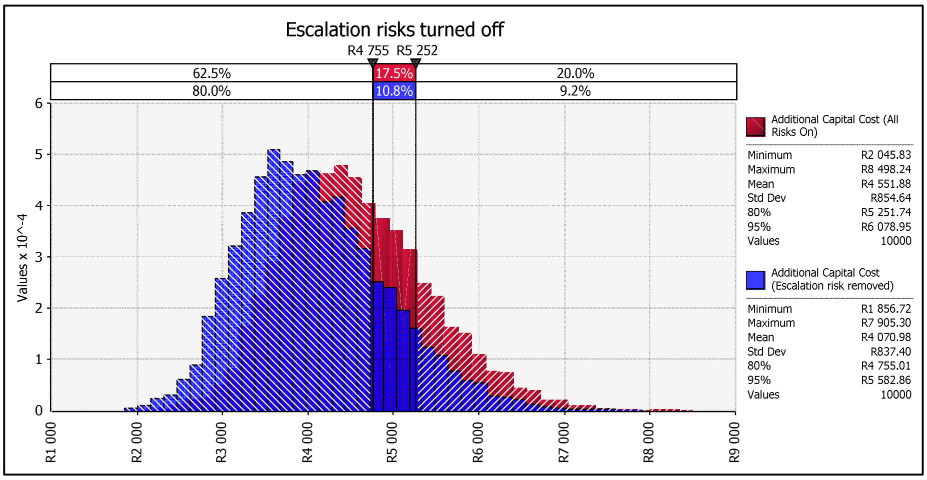


Figure 5-21: Output distribution with and without project start delays (R million)

The descriptive statistics (Maximum, Mean, P80) showed a reduction of approximately R500 million (-10%).

Section Summary

From the risk simulation results, the following summary is provided:

- When looking at the *All Projects* sample, project start delays are significant because five of the top six categories on the tornado graph are related to project start delays (Figure 5-19).
- Project start delay risks caused the most uncertainty in the Eight Projects (Figure 5-20).
- The removal of project start delays is material. When removing these from the *All Projects* sample, the mean of the output distribution reduced by approximately R500 million (-10%) (Figure 5-21). Another way to see this is that the provision for project start delay risks adds approximately 10% to the project portfolio contingency requirements.

Controllable Risks and Project Start Delays

The question which flowed from what was discussed in Section 0 was "*Which controllable risks are causing project start delays*?" The answer to this question can provide information to implement controls regarding internal, controllable processes which influence uncertainty in the project portfolio.

Table 5-21 reflects variables which enabled the creation of output simulations taking RBS Level 3, Project Start delays and Risk Type into consideration. To enable the ranking of *Start Delay* and *Non-start Delay* risks, separate output distributions were crated for the sum of all *Non-start Delay* Risks (cell F288) and *Start delay* risks (Cell K288).

A combined sum (Cell M288) allows for ranking of both type of risks to take place in one tornado graph. The output distribution in cell K288 was used to create the required output distribution.

=RiskMakeInput(SUMIFS(CRR_Simulation_Result,CRR_RBS_Level_3,$A213,CRR_Risk_Type,B$211,CRR_Start_Delay,B$212),RiskName($A213&", "&B$211&"No Start Delay)"))

	A	B	C	D	E	F	G	H	I	J	K	L	M
209		Distribution											
210		Does not delay project start					Delays project start						
211	Level 3 RBS	External – Uncontrollable	External – Influencable	Internal – Owner Requirement	Internal – Operational	Internal – Project Processes	External – Uncontrollable	External – Influencable	Internal – Owner Requirement	Internal – Operational	Internal – Project Processes		
212		No	No	No	No	No	Yes	Yes	Yes	Yes	Yes		
213	Project : Plans – Construction plans	R -	R -	R -	R -	R 851.56	R -	R -	R -	R -	R -		
214	Project : Contractor – Capacity	R -	R -	R -	R -	R -	R -	R 1240.25	R -	R -	R -		
215	Government : Approvals – Environmental approvals	R -	R -	R -	R -	R -	R 161.83	R 219.50	R -	R -	R -		
216	Project : Logistics – Material supply logistics	R -	R -	R -	R -	R 317.41	R -	R -	R -	R -	R -		
217	Project : Project Team – Project management Team Composit	R -	R -	R -	R -	R -	R -	R -	R -	R -	R -		
218	Project : Procurement – Availability/ lead times	R -	R -	R -	R -	R 124.57	R -	R -	R -	R -	R 344.29		
219	Project : Contractor – Contractors' Equipment/Technology	R -	R -	R -	R -	R 507.16	R -	R -	R -	R -	R -		
220	Project : Logistics – Site access	R -	R -	R -	R -	R 26.09	R -	R 12.64	R -	R 1.45	R 1.34		
221	Project : Operations – Existing operations	R 356.05	R -	R -	R 14.25	R -	R -	R -	R -	R -	R -		
222	Project : Procurement – Overlap of design and construction	R -	R -	R -	R -	R -	R -	R -	R -	R -	R 299.65		
266	Project : Technology – Project technology	R -	R -	R -	R -	R 0.08	R -	R -	R -	R -	R -		
267	Project : Resources – Resources Accommodation	R -	R -	R -	R -	R 0.10	R -	R -	R -	R -	R -		
287		R 509.95	R 91.07	R 19.08	R 99.16	R 2 037.85	R 162.74	R 1 479.90	R 81.87	R 1.45	R 754.17		
288						=SUM(B213:F286) +RiskOutput()					=SUM(G213:K286) +RiskOutput()		=SUM(B213:K286)+ RiskOutput()

Figure 5-22: Risk Category and Project Start Delay risks (R million)

Changes in Ranking: Controllable Start Delay Risks

As seen in Figure 5-23*, Site access*, as an *Internal - Operational Process*, is the risk source which has the biggest influence on uncertainty when looking at risks delaying project execution start. The tornado graph also shows that only six out of sixteen RBS Level 3 environments are External Influencable or Uncontrollable (marked in red). This result is important because it shows that the risks which are causing project delays could be reduced by implementing the appropriate treatment plans and controls.

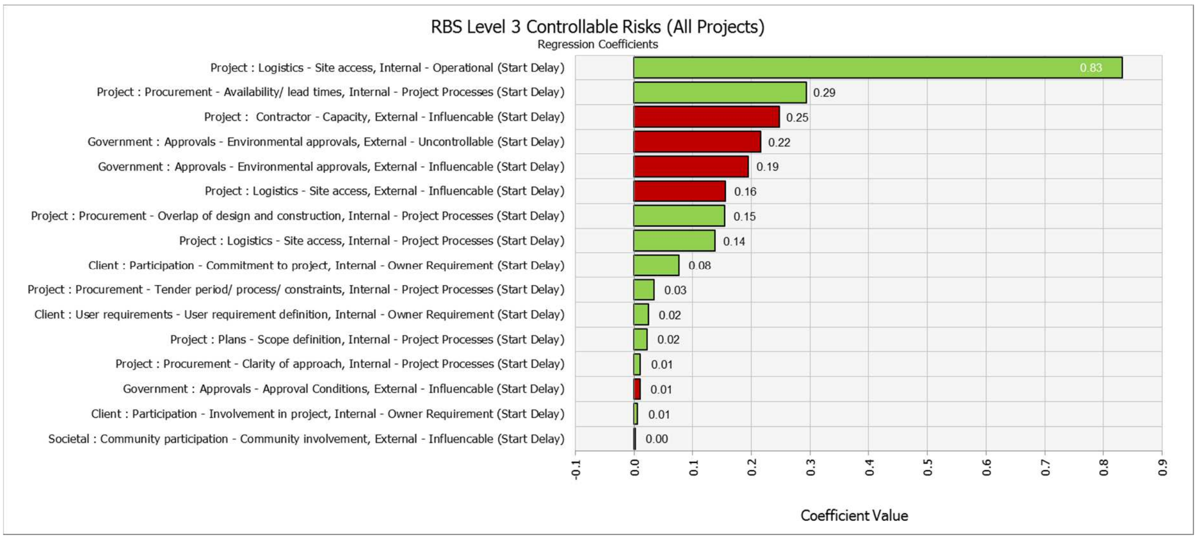


Figure 5-23: RBS Level 3 and Start Delays (*All Projects* included)

Figure 5-24 shows the coefficients for the project portfolio where the Eight Projects were removed. It shows again that Controllable risks are causing the uncertainty in this project portfolio with *Client Participation and Commitment*, *User Requirements* and *Scope Definition* having high coefficients.

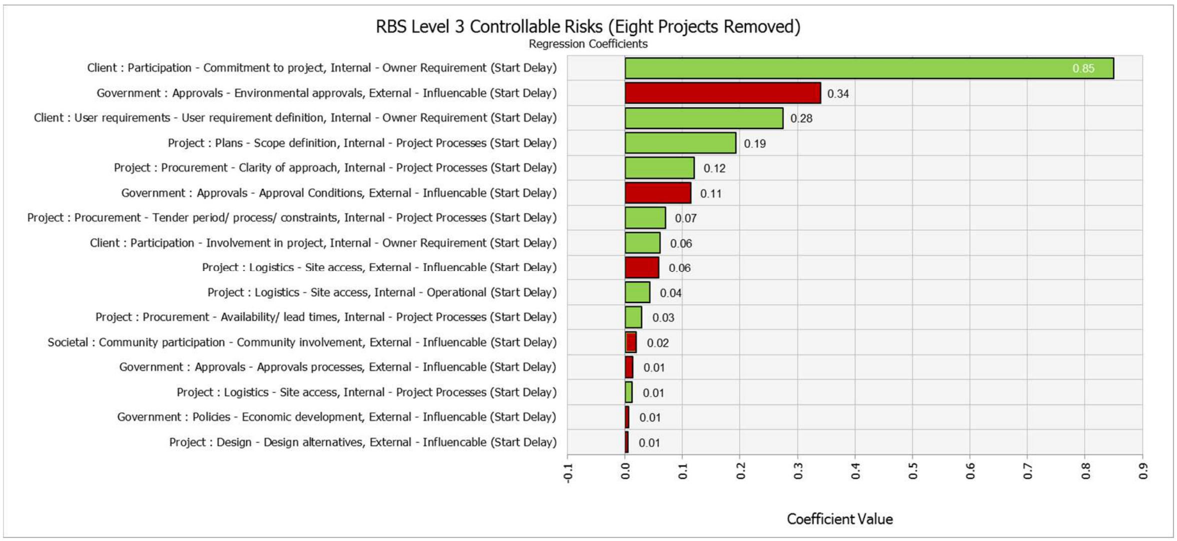


Figure 5-24: RBS Level 3 and Start Delays (*Eight Projects Removed*)

When comparing the Top 10 regression coefficients from the above two graphs, Table 5-17 was produced:

NR.	RBS LEVEL 3 START DELAYS	REGRESSION COEFFICIENTS	
		ALL PROJECTS	***EIGHT PROJECTS REMOVED***
1	Project : Logistics - Site access, Internal - Operational	0.83	0.04
2	Project : Procurement - Availability/Lead Times, Internal - Project Processes	0.29	
3	Project : Contractor - Capacity, External - Influencable	0.25	
4	Government : Approvals - Environmental approvals, External - Uncontrollable	0.22	0.34
5	Government : Approvals - Environmental approvals, External - Influencable	0.19	
6	Project : Logistics - Site Access, External - Influencable	0.16	0.06

NR.	RBS LEVEL 3 START DELAYS	REGRESSION COEFFICIENTS	
		ALL PROJECTS	***EIGHT PROJECTS REMOVED***
7	Project : Procurement - Overlap of Design and Construction, Internal - Project Processes	0.15	
8	Project : Logistics - Site access, Internal - Project Processes	0.14	
9	Client : Participation - Commitment to Project, Internal - Owner Requirement	0.08	
10	Project : Procurement - Tender period/process/constraints, Internal - Project Processes	0.03	0.07
11	Client : Participation - Commitment to project, Internal Owner Requirement		0.85
12	Client : User requirements - User Requirement Definition, Internal - Owner Requirement		0.28
13	Project : Plans - Scope definition, Internal - Project Processes		0.19
14	Project : Procurement - Clarity of approach, Internal - Project Processes		0.12
15	Government : Approvals - Approval Conditions, External - Influencable		0.11
16	Client : Participation - Involvement in project, Internal - Owner Requirement		0.06

Table 5-17: Controllable Risks: Regression coefficients compared

The controllable RBS Level 3 risks were first ranked according to the regression coefficient found in the *All Projects* sample. These were then linked to the corresponding values in the *Eight Projects Removed* sample. The unmatched RBS Level 3 risks from the *Eight Projects Removed* sample were then ranked in descending order to see which risks caused the most uncertainty.

There were only three risk categories which appeared in each sample featured in the Top 10 tornado graphs:

- Government : Approvals - Environmental Approvals, External - Uncontrollable (Start Delay).
- Project : Logistics - Site Access, External - Influencable (Start Delay).
- Project : Procurement - Tender period/process/constraints, Internal - Project Processes (Start Delay).

From the previous results, yet another question had to be asked: "*What is the influence of controllable risks on the descriptive statistics of the simulation result?*" This will give management an idea regarding the possible outcomes of implementing treatment plans and controls to limit the likelihood/frequency and consequences related to controllable risks delaying project start.

To show the relationship between the following three simulations, Figure 5-25 was created:

- The Red graph represents the entire sample of 86 projects.
- The Blue graph represents a simulation in which all the controllable project start delay risks were turned off.
- The Green graph represents a simulation in which all the controllable risks were turned off.

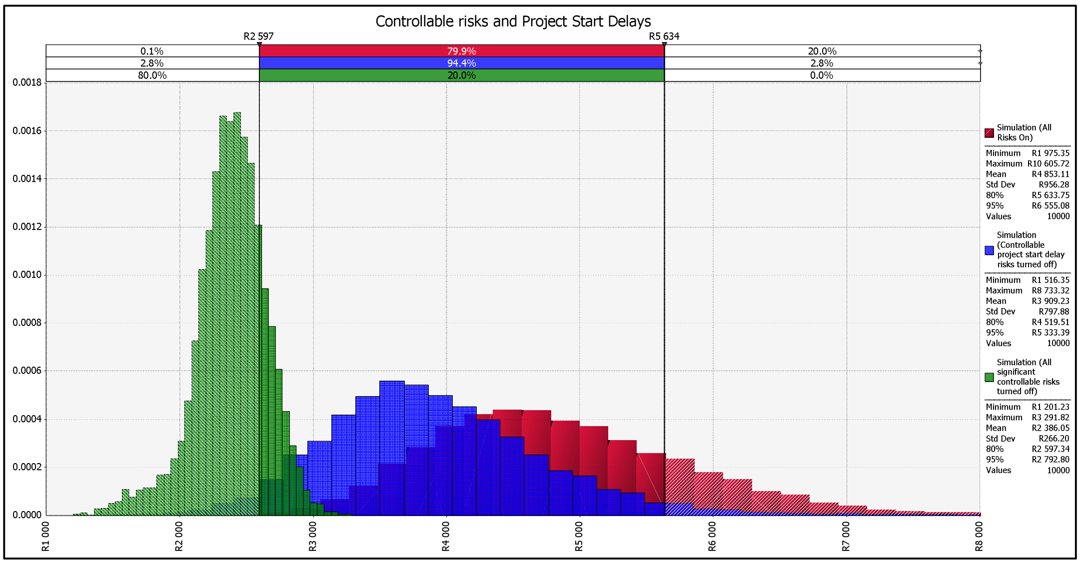


Figure 5-25: Controllable risks and project execution start delays (R million)

When comparing the Means and P80 values from Figure 5-25, Table 5-18 was created. This table shows controllable risks from the project portfolio is material since they reduce the means of the two distributions by 50.8% (R2 476 million).

	R MILLION				
	ALL PROJECTS	CONTROLLABLE PROJECT START DELAY RISKS REMOVED		ALL CONTROLLABLE RISKS REMOVED	
Mean	R4 853.11	R3 909.23	-19.4%	R2 386.05	-50.8%
P80	R5 633.75	R2 386.05	-57.6%	R2 597.34	-53.9%

Table 5-18: Controllable risks and project execution start delays

Alternative Solution: RBS Level 3, Risk Type and Project Start Delays

An alternative solution (Figure 5-26) to this research question is available by simply producing the P80 value of each of the output distributions and applying conditional formatting in MS Excel. The advantage of this method is that it can provide cost related information whereas the previous tornado graphs only provided regression coefficients. It should however, be taken into consideration that a high P80 value does not necessarily refer to high uncertainty, as shown in tornado graphs.

=IFERROR(RiskPercentile(B213,0.8,RiskTruncate(0.0001)),"")

	A	B	C	D	E	F	G	H	I	J	K
290		P80									
291		Does not delay project start					Delays project start				
292		External - Uncontrollable	External - Influencable	Internal - Owner	Internal - Operational	Internal - Project Processes	External - Uncontrollable	External - Influencable	Internal - Owner	Internal - Operational	Internal - Project Processes
293		No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
294	Project : Plans - Construction plans					R 851.56					
295	Project : Contractor - Capacity							R 1240.25			
296	Government : Approvals - Environmental approvals						R 161.83	R 219.50			
297	Project : Logistics - Material supply logistics					R 317.41					
298	Project : Project Team - Project management Team Composit										
299	Project : Procurement - Availability/ lead times					R 124.57					R 344.29
300	Project : Contractor - Contractors' Equipment/Technology					R 507.16					
301	Project : Logistics - Site access					R 26.09		R 12.64		R 1.45	R 1.34
302	Project : Operations - Existing operations	R 356.05			R 14.25						
303	Project : Procurement - Overlap of design and construction										R 299.65
304	Project : Plans - Scope definition					R 52.69					R 58.89
305	Construction : Industrial Relations - Industrial unrest	R 73.14									
306	Client : Participation - Operations				R 84.91						
307	Project : Environment - Environmental incident					R 15.98					
308	Societal : Crime - Theft		R 39.65								
309	Project : Procurement - Tender period/ process/ constraints										R 40.18
310	Project : Operations - Damage to existing facilities	R 30.17				R 4.13					
311	Client : Participation - Commitment to project								R 44.87		
312	Project : Surveys - Geotech surveys					R 23.00					
313	Client : User requirements - User requirement definition								R 28.00		
314	Project : Project Team - Skills shortage			R 4.09		R 1321.91					
315	Project : Commissioning - Training of operational personnel							R 1259.77			
316	Project : Safety - Hazardous substances						R 375.28	R 406.24			
317	Natural : Weather - Extreme weather	R 28.08				R 490.86					
318	Project : Surveys - Existing services surveys										
319	Economic : Local Economy - Inflation					R 184.26					R 494.85
320	Project : Design - Design rework					R 587.45					
321	Project : Safety - Worker injury					R 34.16		R 19.93		R 13.68	R 137.44
322	Project : Plans - Program plans	R 391.08			R 24.00	R 0.88					
323	Project : Environment - Archaeological artefacts										R 352.02
324	Project : Environment - Environmental approval conditions					R 67.04					R 67.03
325	Project : Contractor - Contractors resources	R 101.74									
326	Project : Procurement - Clarity of approach				R 93.02						
327	Societal : Community participation - Ethics, Public Perception					R 89.23					
328	Government : Approvals - Approval Conditions		R 47.82								
329	Client : Participation - Involvement in project										R 54.29
330	Project : Contractor - Quality defects	R 40.82				R 6.35					
331	Government : Approvals - Approvals processes								R 109.11		
332	Project : Cost estimates - Estimate completeness					R 60.54					
333	Project : Cost estimates - Quantity accuracy								R 39.60		

Figure 5-26: Alternative Solution - RBS Level 3, Risk Type and Project Start Delays (R million)

Section Summary

From the risk simulation results, the following summary is provided:

- Project start delays are caused by controllable risks. When turning off all the controllable risks, the mean of the output distribution reduces by R2 476 million (50.8%) (Table 5-18).
- The Project start delay risks with the highest regression coefficients are different when comparing *All Projects* (Project : Logistics - Site Access - 0.83) with the *Eight Projects Removed* sample (Client : Participation - Commitment to project- 0.85) (Table 5-17).

5.5.3 Further questions

From the risk simulation results presented in the previous section, further questions were asked to better understand the risk drivers in the project portfolio. These questions were the following:

- Are planning related risks material in causing uncertainty?
- Are different types of controllable risks associated with the various Operating Divisions?
- Are policy related risks material in causing uncertainty?
- Is there a difference in ranking between controllable risks in the *All Projects* sample when comparing it to the *Eight Project* removed sample?

As previously stated in this chapter, both tornado graphs and probability density graphs were used to answer the research questions.

Planning as a risk driver

Previous simulation results showed that Construction Plans were a significant source of risk. Expanding this question to include all the risks containing the word “plan” in the RBS Level 3 risk drivers, will give an indication of the impact of planning related risks on the project portfolio.

Description of data in the model

As in Table 5-19, 783 open risks were found in the CRR, of which 5.5% contained the word “plan” in RBS Level 3. Of the 43 open risks, the following short risk names made up 35 (81.3%) of the total:

- Scope Definition.
- Planning.
- Unmatched Completion Dates.
- Compressed Schedule.

RISK CATEGORY	RISK STATUS				GRAND TOTAL	
	CLOSED		OPEN			
Project : Plans - Scope Definition	10	55.6%	26	60.5%	36	59.0%
Project : Plans - Construction Plans	5	27.8%	10	23.3%	15	24.6%
Project : Plans - Program Plans	3	16.7%	3	7.0%	6	9.8%
Project : Plans - Commissioning Plans		0.0%	4	9.3%	4	6.6%
Grand Total	18	100%	43	100%	61	100%
	29.5%		**70.5%**			

Table 5-19: RBS Level 3 that containing the word "plan"

Six simulations were executed using the =*RiskSimtable()* command, in exactly the same manner as described in Section 0:

- All the risks were used to create the risk simulation results.
- All risks excluding the Eight Projects.
- All risks, excluding RBS Level 3 risk driver containing the word “plan”.
- All risks, excluding the Eight Projects and RBS Level 3 risk driver containing the word “plan”.
- All planning related risks from the All Projects sample.
- All planning related risks from the Eight *Projects Removed* sample.

Simulation results

The purpose of executing the concurrent simulation on a data set containing all the data and then comparing it with a set where some data was removed enables a comparison between the two scenarios. The following two probability density graphs were produced in Figure 5-27:

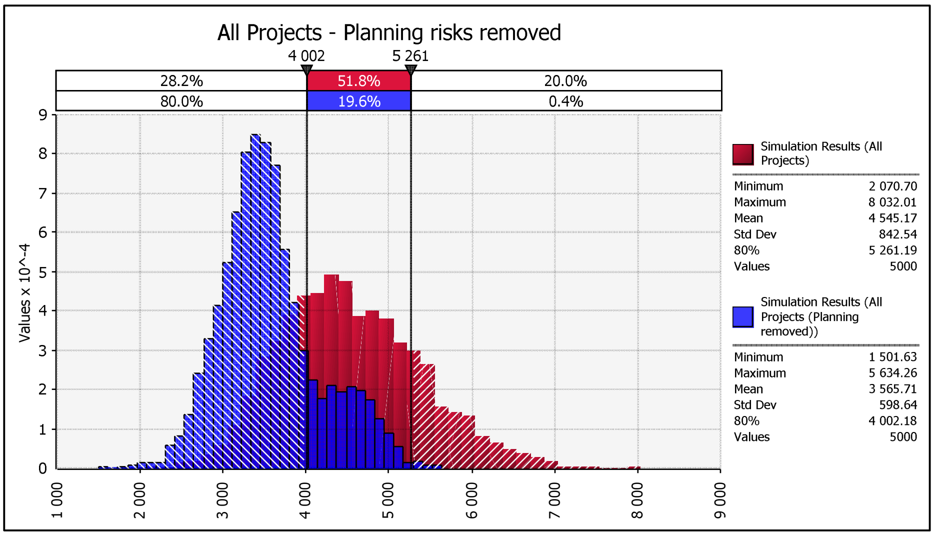


Figure 5-27: Projects and Planning related risks (All projects) (R million)

When planning related risks are removed from the entire sample, the mean reduced from R4 545.17 million to R3 565.71 million (-21.5%) which indicates a material influence of planning related risks on the project portfolio (Figure 5-27).

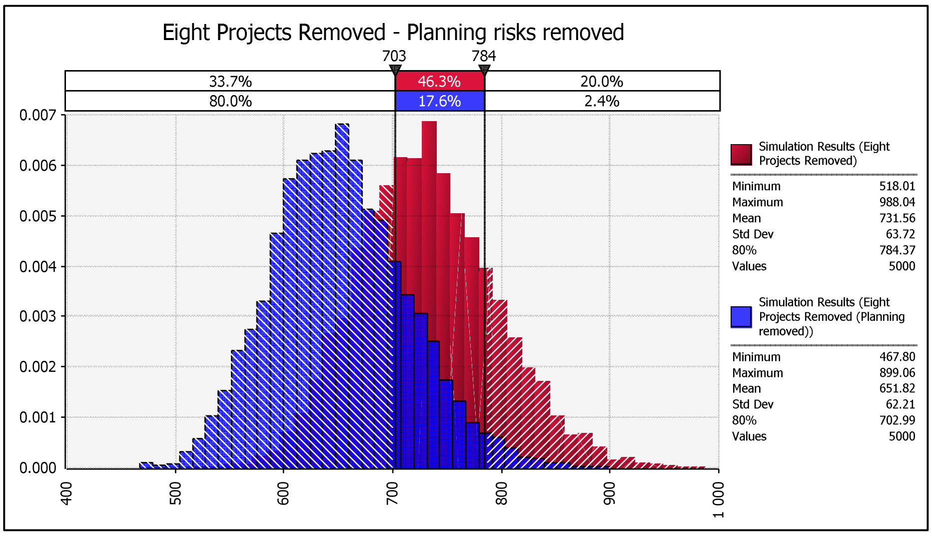


Figure 5-28: Projects and Planning related risks (*Eight Projects Removed*) (R million)

The sample where the *Eight Projects* was removed (Figure 5-28), displayed a similar trend. When planning related risks are removed, the mean value reduced from R731.56 million to R651.82 million (-10.9%) which indicates a material influence of planning related risks on the project portfolio.

The obvious question flowing from this would be "Which planning risks caused the uncertainty in the two samples?".

The same dataset as used previously was employed and the fifth and sixth simulations produced the tornado graphs which showed that *Construction Plans* caused the uncertainty in the *All Projects* sample (Figure 5-29) and that *Scope Definition* caused the most uncertainty in the *Eight Projects Removed* sample (Figure 5-30):

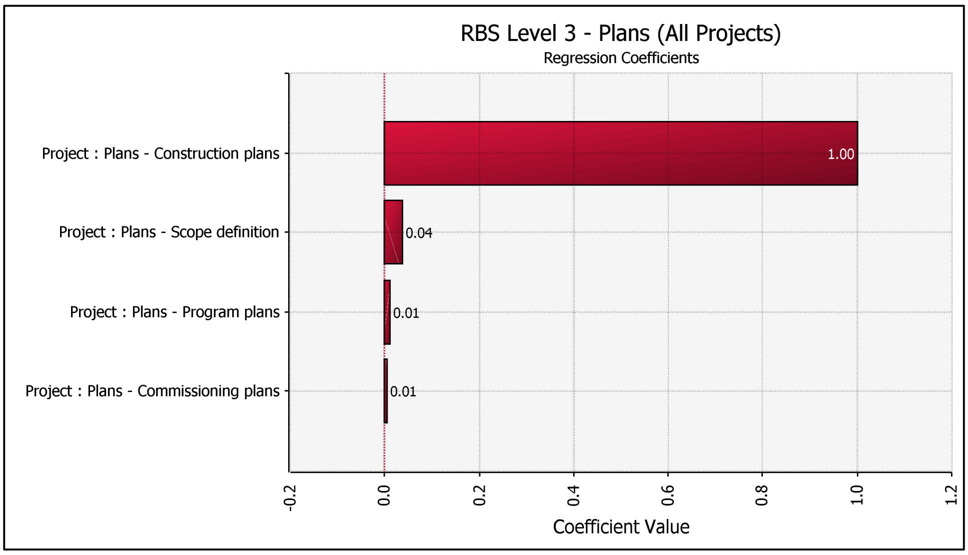


Figure 5-29: Planning as risk driver (*All Projects*)

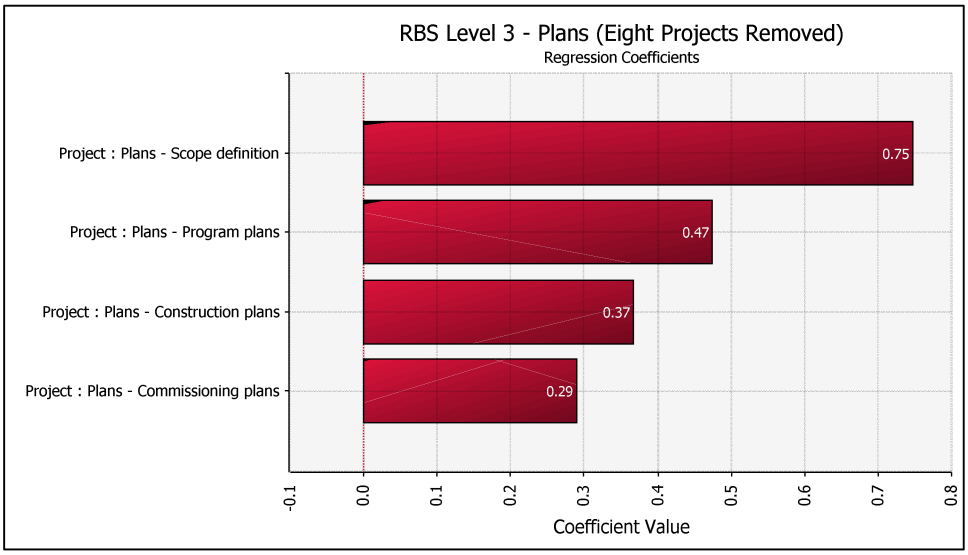


Figure 5-30: Planning as risk driver (*Eight Projects Removed*)

Section Summary

From the risk simulation results, the following summary is provided:

- Planning related risks are material causing uncertainty in the project portfolio since removing them, reduced the mean by 21.59% in the *All Projects* sample (Figure 5-27) and 10.4% in the *Eight Projects Removed* sample (Figure 5-28).
- The highest ranking risk in the *All Projects* sample dealing with planning was *Construction Plans* (Figure 5-29).
- The highest ranking risk in the *Eight Projects Removed* sample dealing with planning was *Scope Definition* (Figure 5-30).

Project Client as risk driver

Section 0 showed that certain types of projects (for example *Rail Power Supply*) caused the most uncertainty in the project portfolio. Since each of Transnet's ODs have different business objectives and operational requirements, which in turn provided the business cases for the projects in their project portfolios, one would expect some relationship between the ODs objectives and risks in the ODs projects.

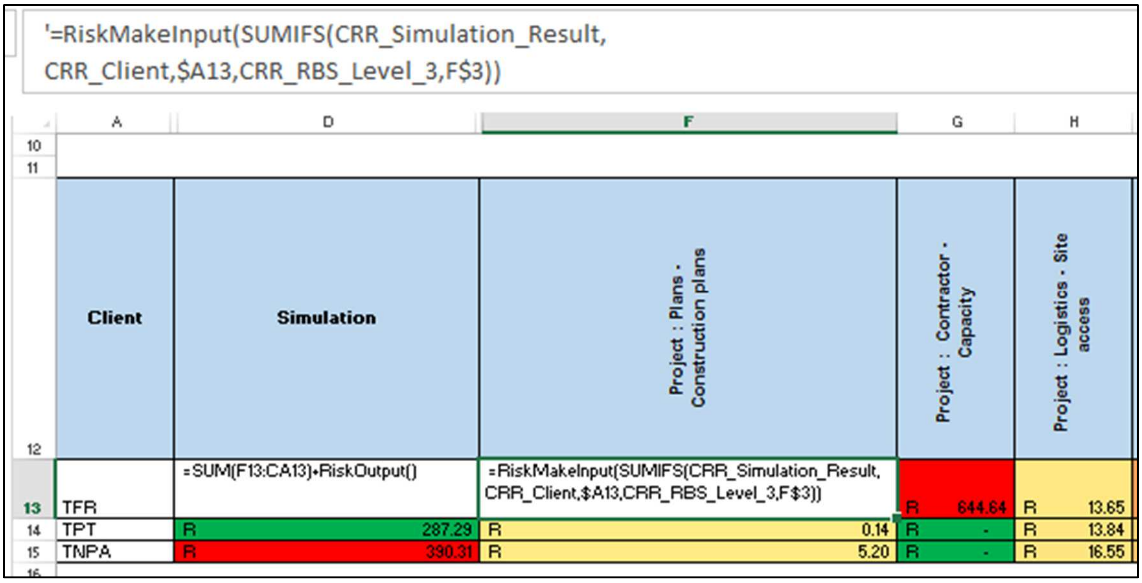
The following question therefore needed to be answered: *"Are different types of controllable risks association with the various ODs?"* The implication of this is that programme wide treatment plans for the various risks can be implemented for the specific risks.

Description of data in the model

The data for this simulation appears in Table 5-5.

Simulation results

The report was set-up as in Figure 5-31 with the headings of the previous RBS Level 3 report and two simulations were executed. The first was for the entire project portfolio and the second for the *Eight Projects Removed*.


'=RiskMakeInput(SUMIFS(CRR_Simulation_Result, CRR_Client,$A13,CRR_RBS_Level_3,F$3))

Client	Simulation	Project : Plans - Construction plans	Project : Contractor - Capacity	Project : Logistics - Site access
TFR	=SUM(F13:CA13)+RiskOutput()	=RiskMakeInput(SUMIFS(CRR_Simulation_Result, CRR_Client,$A13,CRR_RBS_Level_3,F$3))	R 644.64	R 13.65
TPT	R 287.29	R 0.14	R -	R 13.84
TNPA	R 390.31	R 5.20	R -	R 16.55

Figure 5-31: RBS Level 3 and Client

The following results were obtained which shows that the combination of RBS Level 3 risks associated with each of the ODs are unique:

For TFR, (Figure 5-32 and Figure 5-33), material risks relate to *Construction planning* (*All Projects* sample) and *Commitment to project* (*Eight Projects Removed* sample).

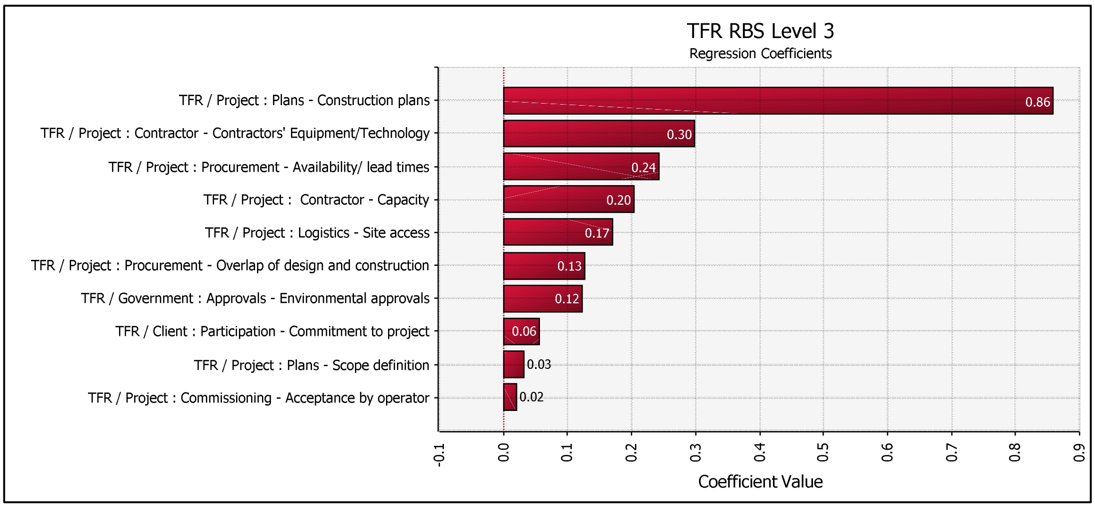


Figure 5-32: TFR *All Projects*

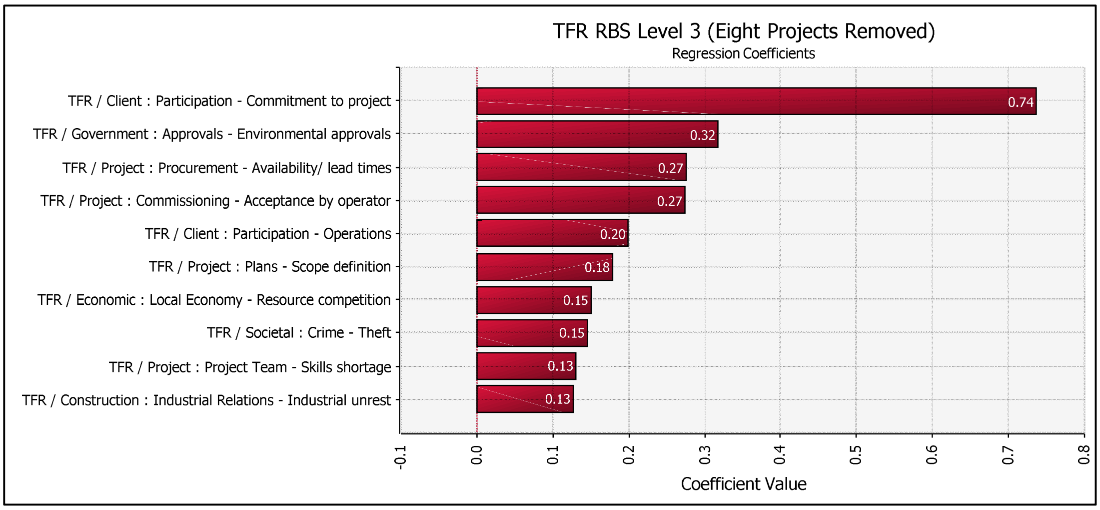


Figure 5-33: TFR Projects (*Eight Projects Removed*)

For TPT (Figure 5-34 and Figure 5-35), material risks relate to *Environmental Approvals* and *Incidents* (*All Projects* sample) and *Damages to Existing Facilities* together with *User Requirement Definition* (*Eight Projects Removed* sample).

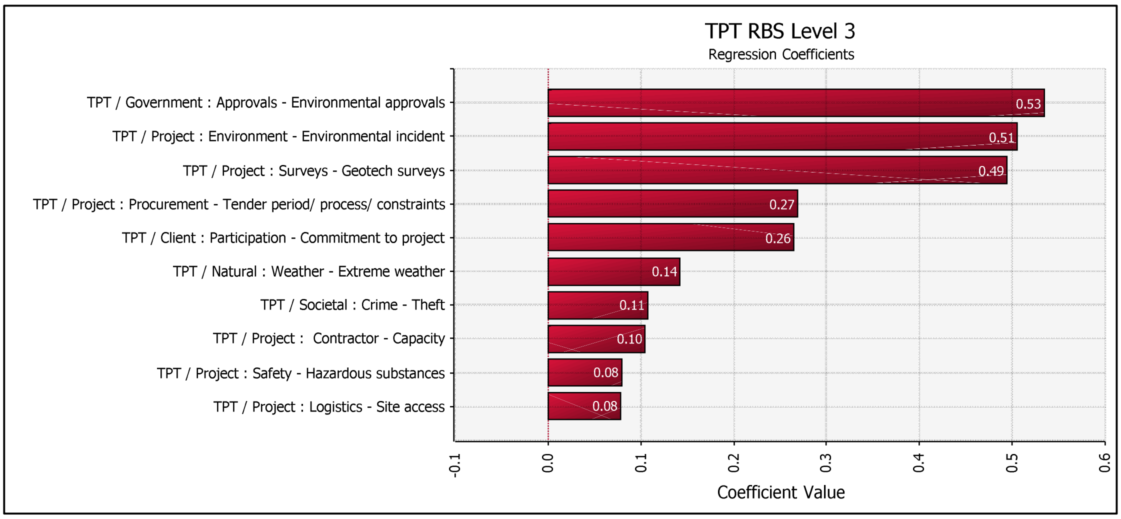


Figure 5-34: TPT All projects

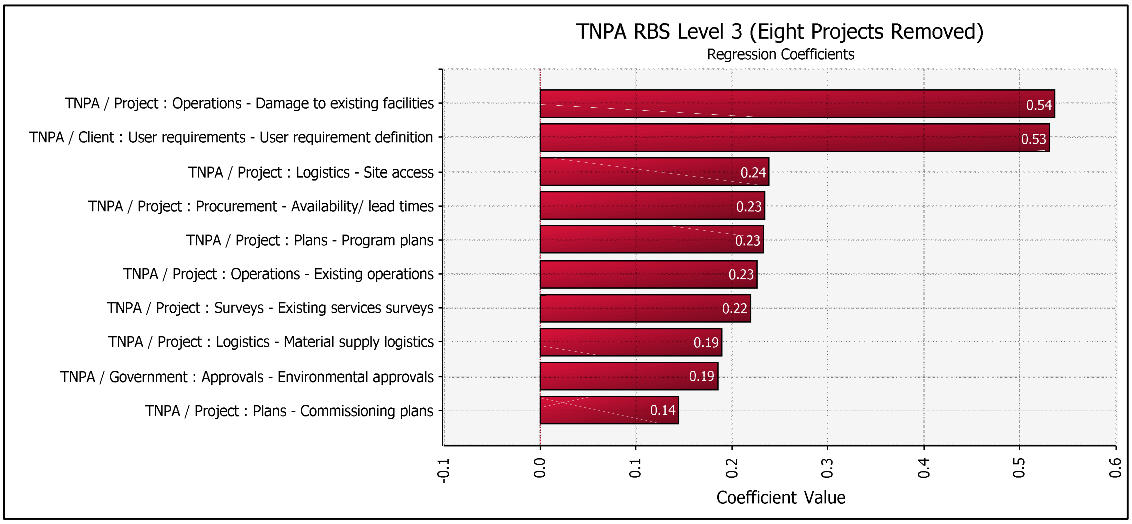


Figure 5-35: TPT Projects (*Eight Projects Removed*)

For TNPA (Figure 5-36 and Figure 5-37) material risks relate to *Site Access* (*All Projects* sample) and *Commitment to project* (*Eight Projects Removed* sample).

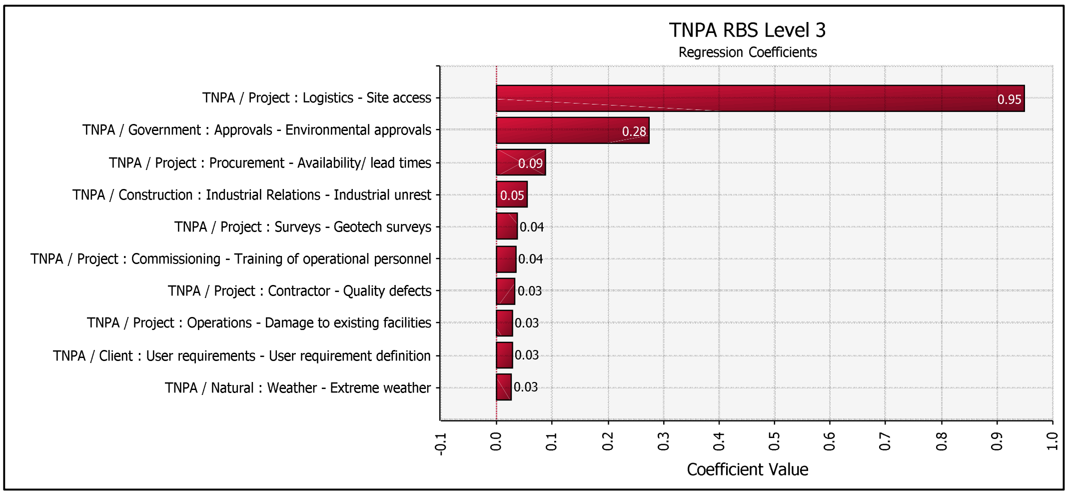


Figure 5-36: TNPA All projects

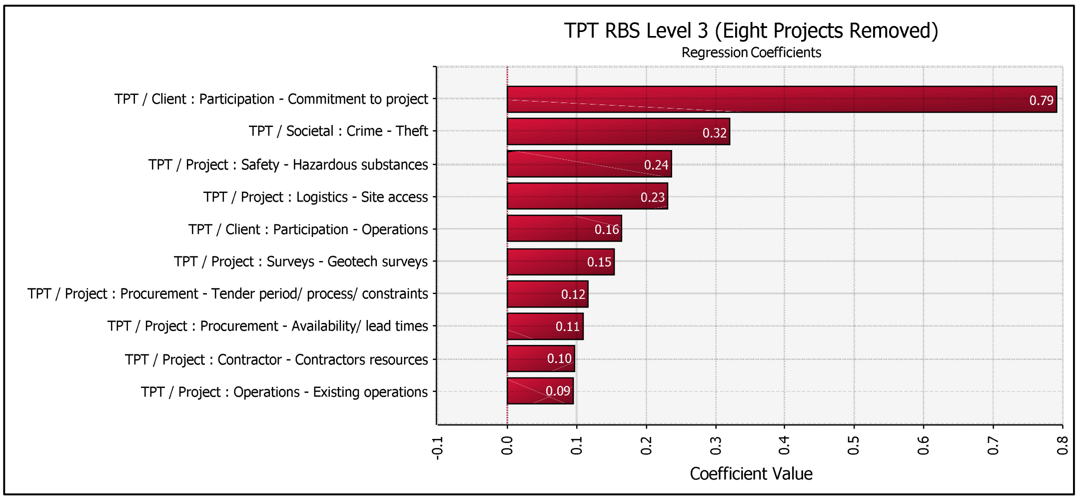


Figure 5-37: TNPA Projects (*Eight Projects Removed*)

When combining Figure 5-32 and Figure 5-37 in one table and ranking the regression coefficients from 1 to 10 for each simulation result, Table 5-20 was produced where the numbers indicate the ranking of the regression coefficients:

RBS LEVEL 3	RANKING OF REGRESSION COEFFICIENTS					
	TFR		TPT		TNPA	
	ALL	EIGHT PROJECTS	ALL	EIGHT PROJECTS	ALL	EIGHT PROJECTS
Government : Approvals - Environmental Approvals	7	2	1	9	2	
Project : Logistics - Site Access	4		9	3	1	4
Project : Procurement - Availability/Lead times	3	3		4	3	8
Client : Participation - Commitment to Project	8	1	5			1
Project : Surveys - Geotechnical Surveys			3		5	6
Society : Crime - Theft		9	7			2
Natural : Weather - Extreme Weather			6		10	
Client : Participation - Operations		5				5
Client : User requirements - User Requirement Definition				2	9	
Construction : Industrial Relations - Industrial Unrest		10			4	
Project : Contractor - Capacity	5		8			
Project : Commissioning - Acceptance by Operator	10	4				
Project : Operations - Damages to Existing Facilities				1	8	
Project : Operations - Existing Operations				5		10
Project : Plans - Scope Definition	9	6				
Project : Procurement - Tender Period/Process			4			7
Project : Safety - Hazardous Substances			10			3
Project : Plans - Commissioning Plans				10		
Project : Plans - Construction Plans	1					
Project : Contractor - Quality Defects					7	
Project : Contractor - Resources						9
Project : Contractor's Equipment/Technology	2					
Project : Plans - Material Supply Logistics				8		
Project : Commissioning - Training of Ops Personnel					6	
Project : Environmental INCIDENT			2			
Project : Local Economy - Resource Competition		7				
Project : Plans - Program Plans				6		
Project : Procurement - Overlap of Design/Construction	6					
Project : Project Team - Skills Shortage		8				
Project : Surveys - Existing Services				7		

Table 5-20: RBS Level 3 and Operating Division

The data in Table 5-20 was ranked according to the number of categories which the RBS Level 3 description appeared in, for example *Government : Approvals - Environmental Approvals* appears in 5 of the 6 categories. The above table is useful in that it gives an overall view of which RBS Category risks appear in which OD when looking at the top 10 tornado graphs. It shows that for all ODs, the following categories require attention because these risks appear in all the ODs:

- Government : Approvals - Environmental Approvals.
- Project : Logistics - Site Access.
- Project : Procurement - Availability/Lead times.
- Client : Participation - Commitment to Project.

Only one of these, *Government : Approvals - Environmental Approvals* falls into the "External" category. This implies that the risks which appear in all the ODs are related to Internal OD related issues and that controls should be easy to implement.

Section Summary

From the risk simulation results, the following summary is provided:

- There are different risk drivers in the various ODs (Table 5-20). It is suspected that the reason for this is partly related to the relationship between the ODs objectives and the projects in their capital programmes. A more detailed investigation forms part of future research.

Policy as risk driver

Since many of the risks in the previous section relate to risks which are internal to the organisation, a further question emerged: *"What is the influence of policy related risks on the project portfolio?"* To do this, all the 163 risk names were classified on whether they have a policy as one of the risk sources.

Description of data in the model

Of the 783 open risks in the CRR, 13.4% were related to policies. Of the 105 open risks, the following short risk names made up 35 (81.3%) of the total:

- Procurement - Availability/Lead Times.
- Participation - Commitment to Project.
- Procurement - Tender Period/Process/Constraints.
- Contractor - Contractors Resources.
- Design - Design Rework.

RISK CATEGORY	RISK STATUS				GRAND TOTAL	
	CLOSED		OPEN			
Project : Procurement - Availability/lead times	23	46.0%	27	25.7%	50	32.3%
Client : Participation - Commitment to project	6	12.0%	23	21.9%	29	18.7%
Project : Procurement - Tender period/process/constraints	6	12.0%	15	14.3%	21	13.5%
Project : Contractor - Contractors resources	6	12.0%	13	12.4%	19	12.3%
Project : Design - Design rework	3	6.0%	8	7.6%	11	7.1%
Rest	6	12.0%	19	18.1%	25	16.1%
Grand Total	50	100%	105	100%	155	100%
	232.3%		**66.7%**			

Table 5-21: RBS Level 3 containing the word "plan"

Simulation results

Six simulations were executed using the =*RiskSimtable()* command:

- All the risks were used to create the risk simulation results.
- All risks excluding the *Eight Projects.*
- All risks, excluding all the policy related risks.
- All risks, excluding the *Eight Projects* and all the policy related risks.
- All policy related risks from the *All Projects* sample.
- All policy related risks from the *Eight Projects Removed* sample.

The probability density graphs in Figure 5-38 were produced:

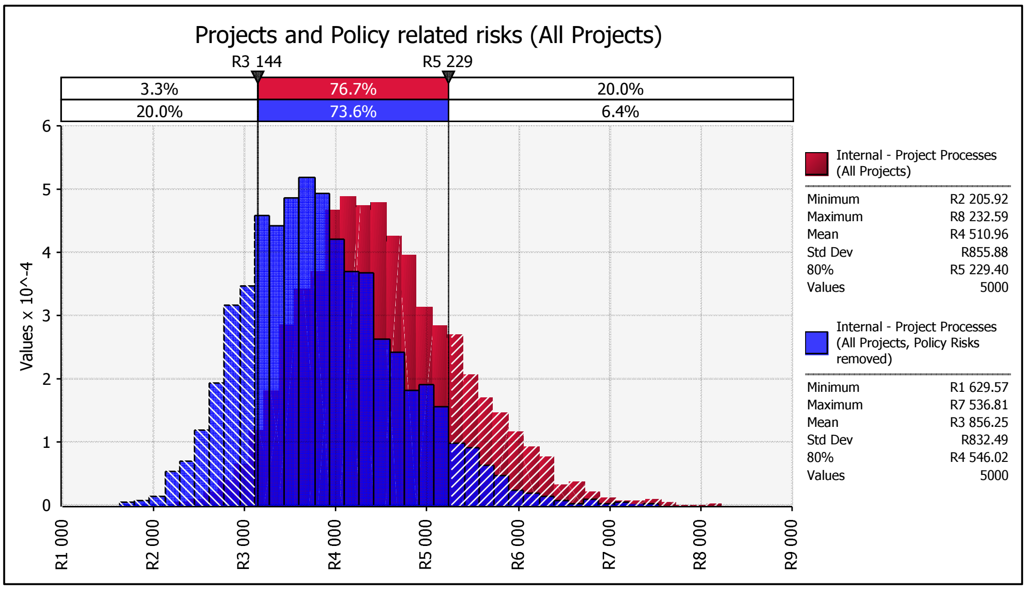


Figure 5-38: Projects and Policy related risks (All projects) (R million)

When policy related risks are removed from the entire sample, the mean reduces by from R4 510.96 million to R3 856.25 (-14.5%) which indicates a material influence of policy related risks on the project portfolio (Figure 5-38).

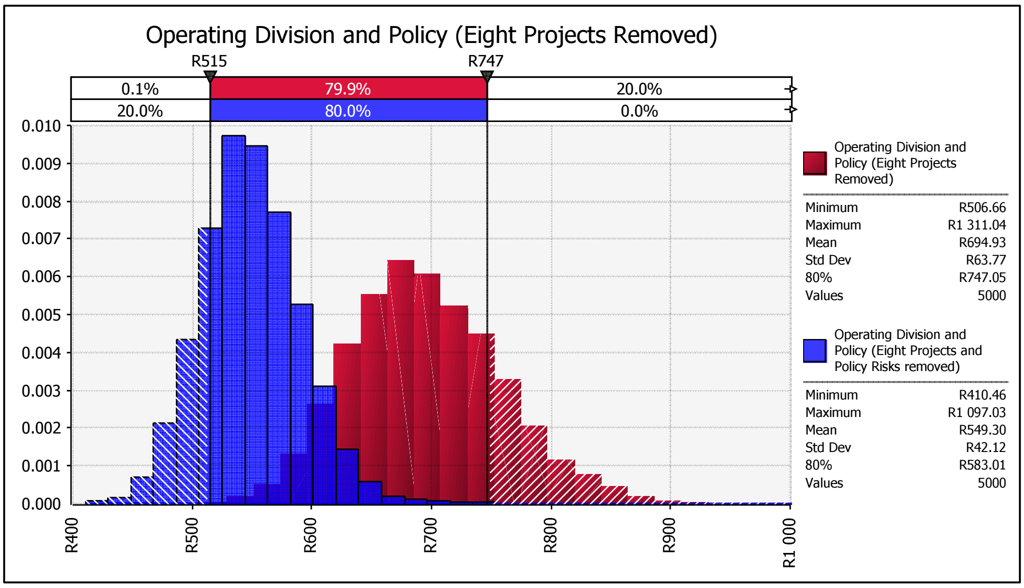


Figure 5-39: Projects and Policy related risks (*Eight Projects Removed*) (R Million)

When looking at the sample where the Eight Projects have been removed, the mean reduced from R694.93 million to R549.3 million (-21.0%) which also indicated a material influence of policy related risks on this group of 78 projects (Figure 5-39). The last two simulation results were used to answer the question *"Which policy related RBS Level 3 risk drivers caused the uncertainty in the project portfolio?"* by generating Figure 5-40 and Figure 5-41:

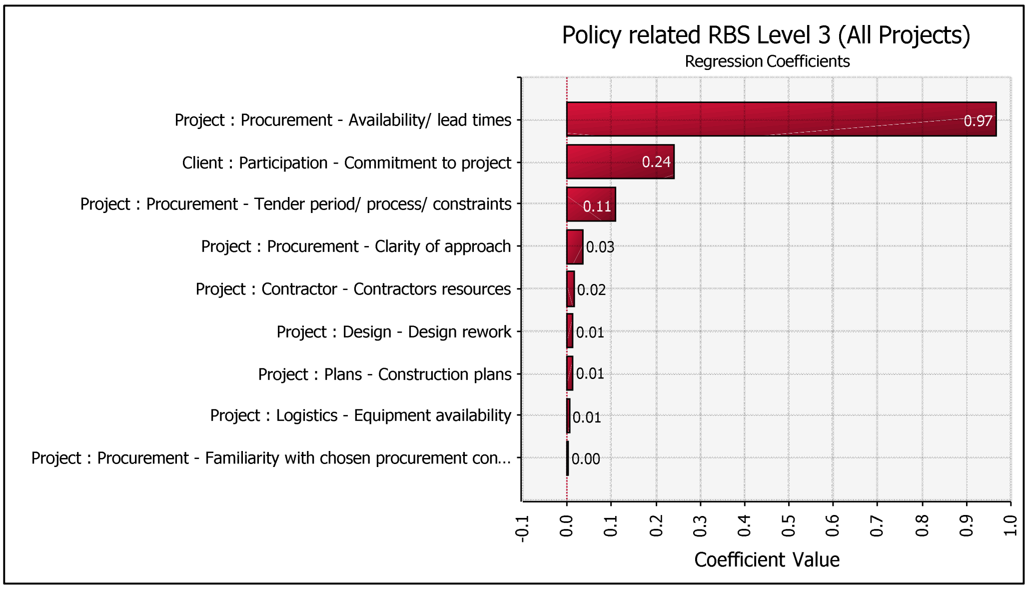


Figure 5-40: Policy as risk driver (*All Projects*)

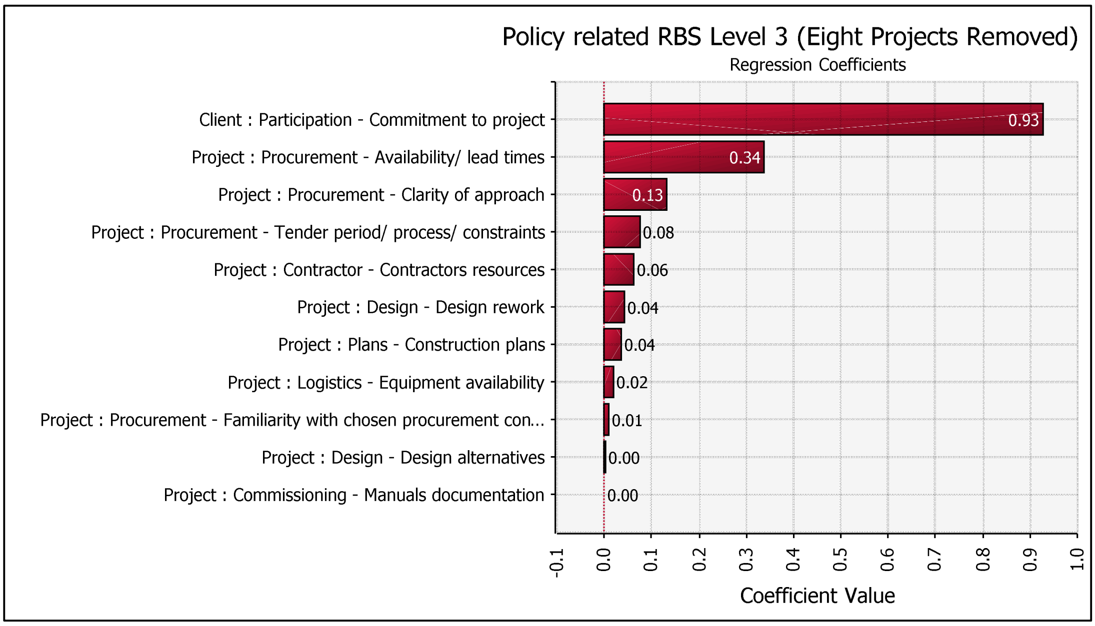


Figure 5-41: Policy as risk driver (*Eight Projects Removed*)

Figure 5-40 shows that *Procurement/Availability lead times* and *Commitment to project* are the top two ranked risk drivers related to policy in the *All Projects sample*. These two risk drivers are swopped around in Figure 5-41 which looks at the risk drivers in the *Eight Projects Removed* sample.

Section Summary

From the risk simulation results, the following summary is provided:

- Policy related risks are significant for both the *All Risks* and the *Eight projects removed* samples but more so in the *Eight Projects Removed* sample. It reduced the mean for the All Risks sample by 14.5% (Figure 5-38) and for the *Eight Projects Removed* sample by 21.0% (Figure 5-39).

5.5.4 Discussion of simulation results

The initial purpose of this research question was to establish the following:

- Are project execution start delays material in causing uncertainty?
- Which programmes/project types affected by start delays caused the most uncertainty in the project portfolio?
- Which controllable risks cause project start delays?

Further questions were developed to understand the risk sources better. These questions were as follows:

- Are planning related risks material in causing uncertainty?
- Are different types of controllable risks associated with the various Operating Divisions?
- Are policy related risks material in causing uncertainty?

These questions can be answered in short:

- Project start delays are caused by controllable risks. When turning off all the controllable risks, the mean of the output distribution reduces by R2 476 million (50.8%) (Table 5-18).
- Project start delays are significant because when removing Project start delays in the *All Projects* sample, the mean of the output distribution reduced by approximately R500 million (-10%) (Figure 5-21).
- Project start delay risks caused the most uncertainty in large, complex projects.
- The most important project start delay risks differ when comparing large complex projects to smaller, less complex projects. With large complex projects, risks related to *Site Access* caused the most uncertainty with the smaller projects, risk related to C*lient Commitment* caused the most uncertainty (Table 5-17).
- Planning related risks are material causing uncertainty in the project portfolio since removing them, reduced the mean by 21.59% in the *All Projects* sample (Figure 5-27) and 10.4% in the *Eight Projects Removed* sample (Figure 5-28).
- The highest ranking risk in the *All Projects* sample dealing with planning was *Construction Plans* (Figure 5-29).
- The highest ranking risk in the *Eight Projects Removed* sample dealing with planning was *Scope Definition* (Figure 5-30).

- There are different risk drivers in the various ODs (Table 5-20). It is suspected that the reason for this is partly related to the relationship between the ODs objectives and the projects in their capital programmes. A more detailed investigation forms part of future research.
- Policy related risks are significant for both the All Risks and the Eight projects removed samples but more so in the *Eight Projects Removed* sample. It reduced the mean for the *All Risks* sample by 14.5% (Figure 5-38) and for the *Eight Projects Removed* sample by 21.0% (Figure 5-39).

Impact on project management

To conclude this section, a short discussion on the potential impact of these findings on project management follows in Table 5-22:

DESCRIPTION	IMPLICATIONS FOR PROJECT MANAGEMENT
Client : Participation - Involvement in Project	Approval delays which leads to compressed schedules because commercial agreements are already in place. The consequence of may include cost increases due to additional resources. Therefore: • The risks associated with top-down schedules should be identified, quantified and communicated with all stakeholders. Appropriate treatment plans should be put in place.
Client : User requirements - User Requirement Definition	These risks relate to the project team questioning the assumptions which were handed to them in the project's owner requirement specification. The implication of this is that projects might be completed and not be fit for purpose. Two types of assumptions are normally questioned: Commercial and Project Technical. Therefore: • These should be identified and quantified and owned by the project owner. Appropriate treatment plans should be identified and implemented. • When risks related to technical assumptions are questioned by the contractors, the potential conversion of a project to an operational risks should be investigated and quantified. Appropriate treatment plans should be identified and implemented.
Project : Plans - Scope Definition	These risks relate to scope changes which take place during project execution due to a variety of reasons which may include (i) the lack of condition assessments for refurbishment projects, (ii) the Project Lifecycle Process not followed, (iii) late design changes due to new operational requirements and design freezes not implemented. Therefore: • A policy regarding scope freeze should be put in place. • Policies should be enforced to prevent the use of project contingency to finance scope definition problems.

Table 5-22: Research Question 4: Impact on project management

5.6 Research Question 6: When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?

As mentioned in section 1.2.2, Aritua et al. (2011, p. 308) differentiated between three types of risks:

- Risks which are *Common to Programme*s. These risks relate to the function of managing multiple projects and aligning them to the organisation's strategy and policies.
- Risks which are amplified in programmes. These risks are simple to deal with but exacerbated as a result of the multi-project environment.
- Risks which are generic to endeavours in project environments.

This research question is important for two reasons:

- Aritua's research was qualitative in nature and based on interviews with employees of five government spending departments whereas this research question attempts to test their outcomes using a quantitative approach. The research question will give some indication on the validity of this approach by comparing the tornado graphs of the three categories with each other.
- If the classification turns out to be material, it will highlight (or not) the need for the implementation of risk treatment plans on a Programme level or that specific risk treatment plans need to be put in place to mitigate the influence of *Amplified risks*.

5.6.1 Description of data in the model

Table 5-23 contains a summary of open risks related to *Generic Project*, *Amplified* and *Common to Programme* risks. *Generic Project* risks made up nearly half the sample with *Amplified* and *Common to Programme* risks each contributing approximately a quarter of the total sample.

CLIENT	CLOSED RISKS		OPEN RISKS		TOTAL	
Generic Project	142	50.7%	367	46.9%	509	47.9%
Amplified	79	28.2%	200	25.5%	279	26.2%
Common to Programmes	59	21.1%	216	27.6%	275	25.9%
TOTAL	**280**	**100%**	**783**	**100%**	**1063**	**100%**
	26.3%		**73.7%**		**100%**	

Table 5-23: Programme type risks and Risk Status

5.6.2 Simulation results

The output distributions were created as in Figure 5-42:

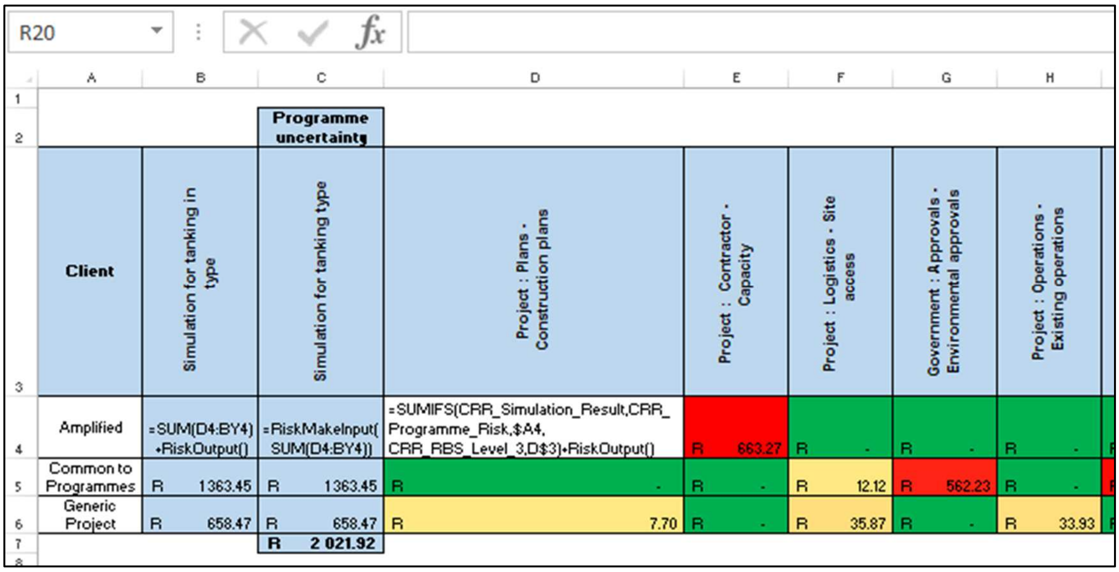


Figure 5-42: Programme risks

As in previous sections, two simulations were executed. The first was the *All Projects* sample and the second the *Eight Projects Removed* sample. The reason for this was to establish if there are similar differences as have been identified previously.

Changes in Ranking: RBS Level 3 and Programme/Amplified risks

The outputs in Column C (Figure 5-42) were used to create the tornado graphs in Figure 5-43 and Figure 5-44. The regression coefficients of the *Generic Project Risks*, *Common to Programme* and *Amplified risks* are all material causing uncertainty in the project portfolio.

One can therefore infer that all three these categories are material in identifying and implementing treatments plans for their associated risks. They also show similar changes in ranking as previously discussed in this chapter. For the more complex projects, *Generic Project* risks are driving uncertainty and for the smaller ones, *Amplified risks* are causing the most uncertainty.

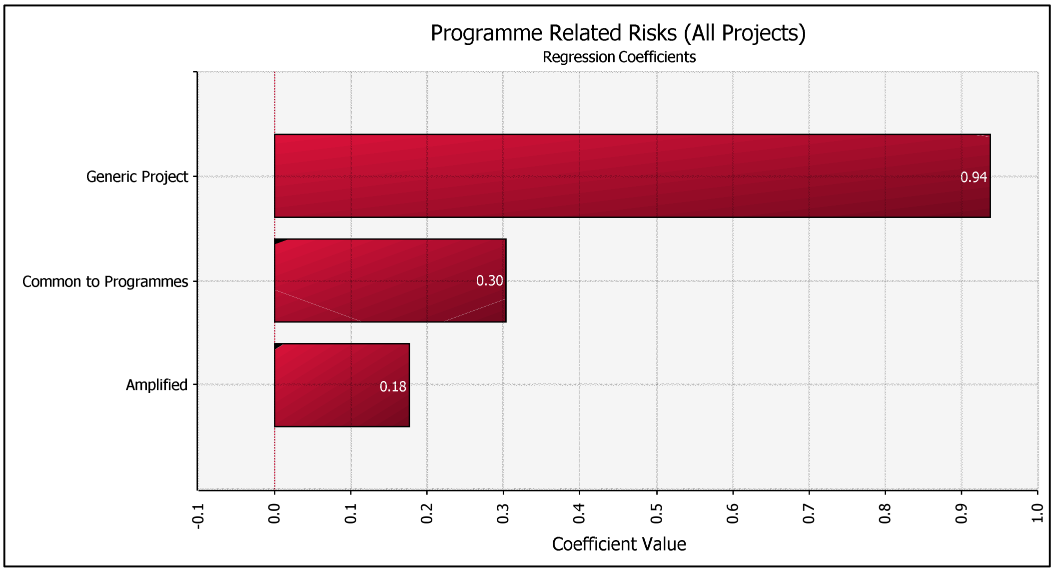


Figure 5-43: Programme Related Risks (*All Projects*)

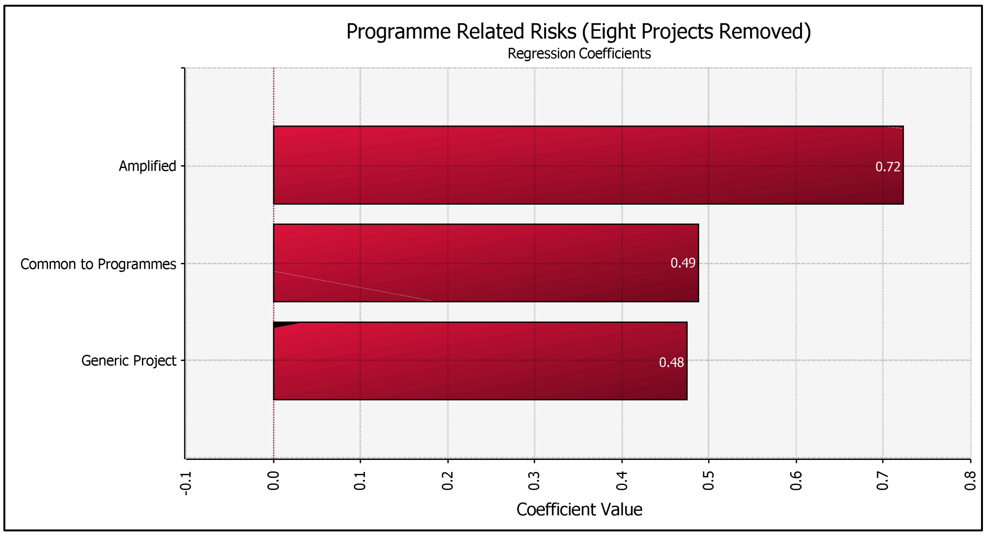


Figure 5-44: Programme Related Risks (*Eight Projects Removed*)

Section Summary

From the risk simulation results, the following summary is provided:

- *Common to Programme* and *Amplified* risks are material to both *the All Projects* and *Eight Projects Removed* samples (Figure 5-43 and Figure 5-44).
- For large complex projects, *Generic Project* risks causes the most uncertainty and the smaller projects, *Amplified* risks are responsible (Figure 5-43 and Figure 5-44).

5.6.3 Further questions

The risk simulation results from Section 5.6.2 could be further investigated by asking the following four questions:

- Which *Amplifie*d risk drivers cause the uncertainty when using the RBS Level 3 risk drivers?
- Which *Common to Programme* risk drivers cause the uncertainty when using the RBS Level 3 risk drivers?
- What is the impact of policy related risks on the output distributions of the *Amplified* and the *Common to Programme* risks?
- Which policy related risks cause the most uncertainty in the *Amplified* and *Common to Programme* RBS Level 3?

- These questions are important because they can be used to create treatment plans which can be implemented across the project portfolio.

RBS Level 3 and Amplified risks

This section will provide an answer to which *Amplified Risks* cause the most uncertainty in the project portfolio. Column B from Figure 5-45 was used to generate the required output distributions for the following:

- Amplified risks (All Projects)
- Amplified risks (Eight Projects Removed)

R20

	A	B	C	D	E	F	G	H
1								
2			Programme uncertainty					
3	Client	Simulation for tanking in type	Simulation for tanking type	Project : Plans - Construction plans	Project : Contractor - Capacity	Project : Logistics - Site access	Government : Approvals - Environmental approvals	Project : Operations - Existing operations
4	Amplified	=SUM(D4:BY4)+RiskOutput()	=RiskMakeInput(SUM(D4:BY4))	=SUMIFS(CRR_Simulation_Result,CRR_Programme_Risk,$A4,CRR_RBS_Level_3,D$3)+RiskOutput()	R 663.27	R -	R -	R -
5	Common to Programmes	R 1363.45	R 1363.45	R -	R -	R 12.12	R 562.23	R -
6	Generic Project	R 658.47	R 658.47	R 7.70	R -	R 35.87	R -	R 33.93
7			R 2 021.92					

Figure 5-45: *Amplified* and *Common to Programme* risks

Simulation Results

After executing the simulation, Figure 5-46 was produced, showing that *Contractor Capacity*, *Commitment to project* and *Industrial unrest* were material risks drivers for *Amplified risks* for the *All Projects* sample.

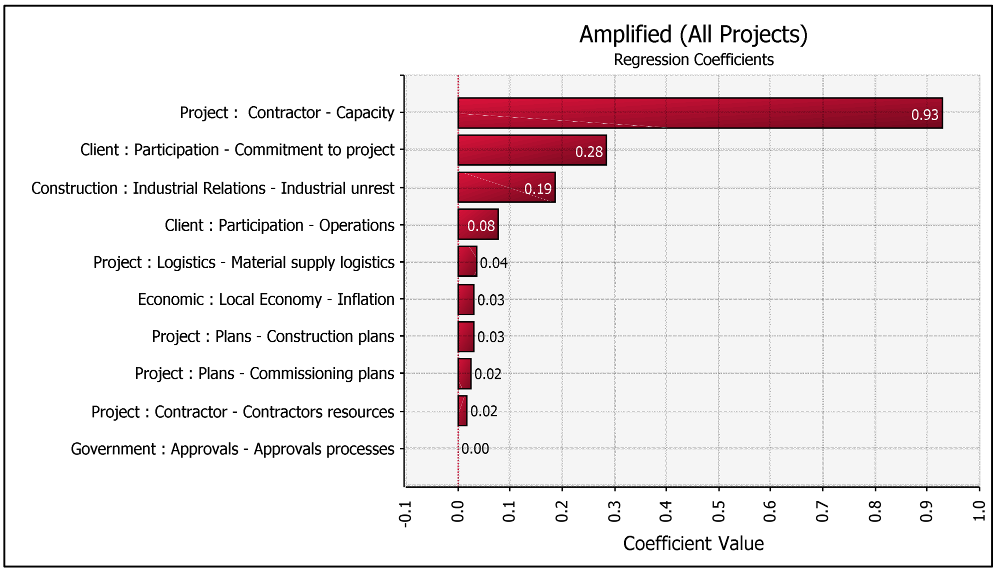


Figure 5-46: *Amplified risks* (*All Projects*)

For the *Eight Projects Removed* sample (Figure 5-47), *Commitment to project* and *Client Operations* were the most important risk drivers for *Amplified risks*.

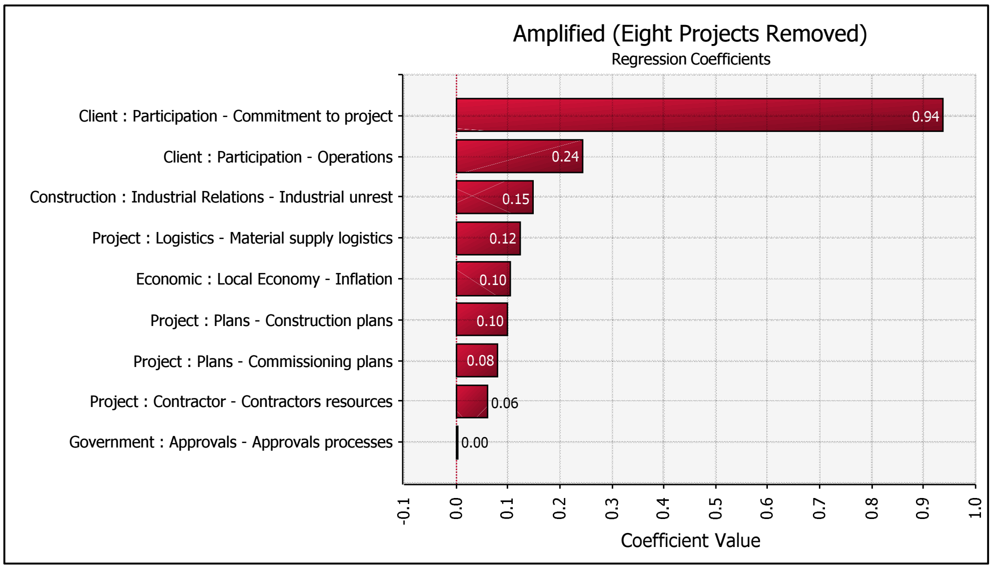


Figure 5-47: *Amplified risks* (*Eight Projects Removed*)

To compare the results from Figure 5-46 and Figure 5-47, their regression coefficients were ranked and Table 5-24 was created:

RBS LEVEL 3 RISK DRIVERS	**REGRESSION COEFFICIENT**	
	ALL	**EIGHT PROJECTS REMOVED**
Project : Contractor - Capacity	0.93	
Client : Participation - Commitment to Project	0.28	0.94
Construction : Industrial Relations/Unrest	0.19	0.15
Client : Participation - Operations	0.08	0.24
Project : Logistics - Material Supply Logistics	0.04	0.12
Economic : Local Economy - Inflation	0.03	0.10
Project : Plans - Construction Plans	0.03	0.10
Project : Plans - Commissioning Plans	0.02	0.08
Project : Contractor - Resources	0.02	0.06

Table 5-24: *Amplified risks* - two simulations

There are two important findings from Table 5-24. The first is that the Top 10 of both the samples contain the same risk drivers and that the rankings differ. The implication for this is that treatment plans for these risks can be applied to both large and small projects and are applicable to the entire project portfolio.

Section Summary

From the risk simulation results, the following summary is provided:

- The risks in both the *All Risks* and *Eight Risks Removed* samples are largely the same which implies that the same treatment plans can be identified and implemented on a programme and portfolio level (Figure 5-46 and Figure 5-47).
- Risks related to *Contractor Capacity* and *Client commitment to project* cause the most uncertainty (Table 5-24).

RBS Level 3 and Common to Programme risks

This section will provide an answer to which *Common to Programme* risks cause the most uncertainty in the project portfolio. Column B from Figure 5-48 was used to generate the required output distributions for the following:

- Common to Programme risks (All Projects)
- Common to Programme (Eight Projects Removed)

R20

	A	B	C	D	E	F	G	H
1								
2			**Programme uncertainty**					
3	**Client**	**Simulation for tanking in type**	**Simulation for tanking type**	**Project : Plans - Construction plans**	**Project : Contractor - Capacity**	**Project : Logistics - Site access**	**Government : Approvals - Environmental approvals**	**Project : Operations - Existing operations**
4	Amplified	=SUM(D4:BY4)+RiskOutput()	=RiskMakeInput(SUM(D4:BY4))	=SUMIFS(CRR_Simulation_Result,CRR_Programme_Risk,$A4,CRR_RBS_Level_3,D$3)+RiskOutput()	R 663.27	R -	R -	R -
5	Common to Programmes	R 1363.45	R 1363.45	R -	R -	R 12.12	R 562.23	R -
6	Generic Project	R 658.47	R 658.47	R 7.70	R -	R 35.87	R -	R 33.93
7			**R 2 021.92**					

Figure 5-48: *Common to Programme* risks

Simulation Results

The simulation produced Figure 5-49, showing that *Procurement - Availability/Lead Times, Environmental Approvals* and *Site Access* were material risks drivers for amplified risks in the *All Projects* sample.

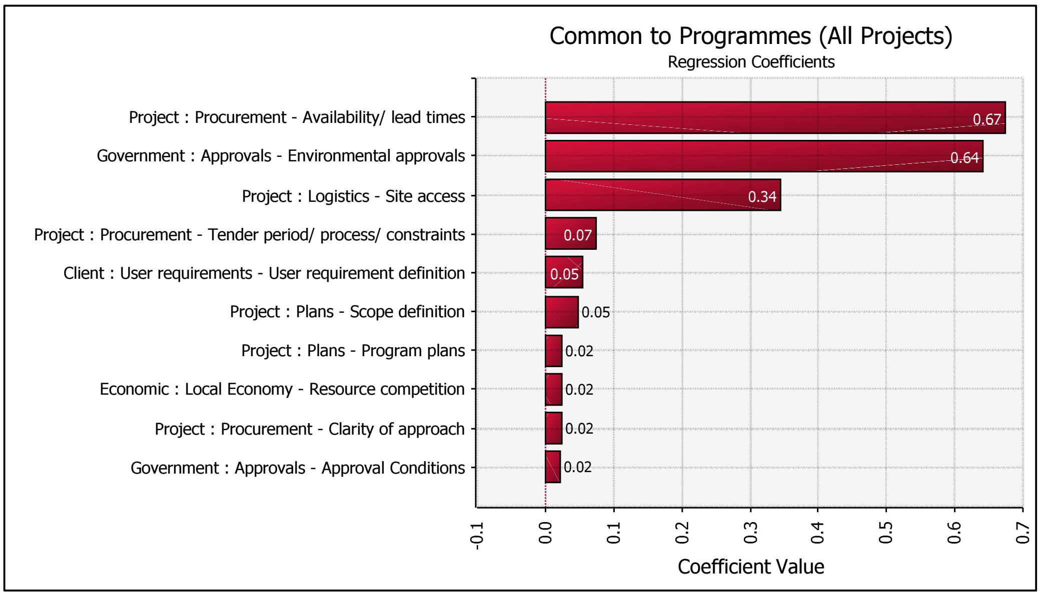


Figure 5-49: *Common to Programme* risks (*All Projects*)

For the Eight Projects Removed sample (Figure 5-50), Environmental Approvals, Procurement - Availability/lead times, User requirement definition and Scope defition were the most important risk drivers for Amplified risks.

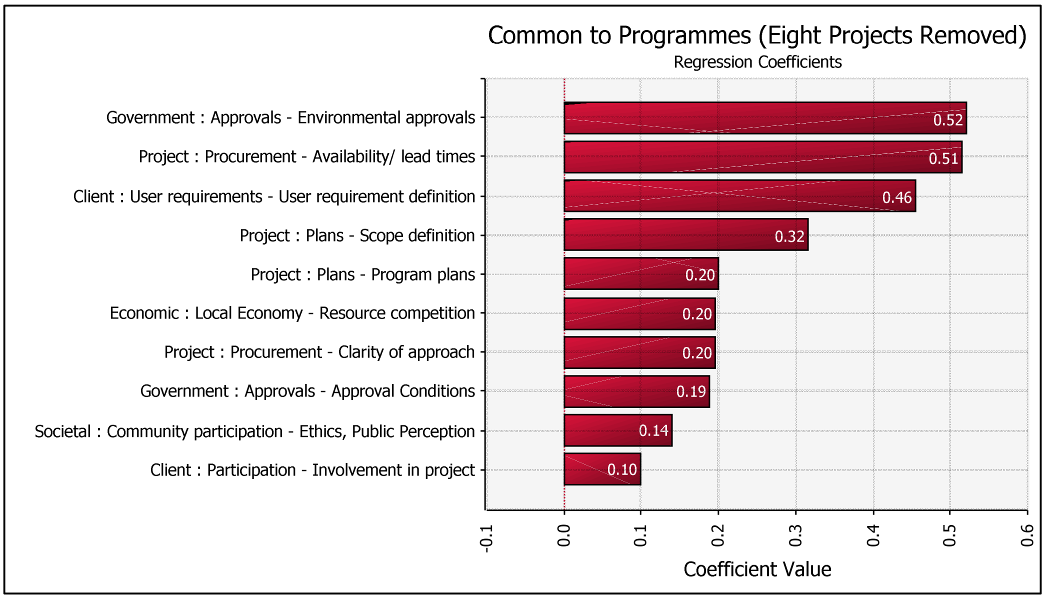


Figure 5-50: *Common to Programme* risks (*Eight Projects Removed*)

To compare the results from Figure 5-49 and Figure 5-50, their regression coefficients were ranked and Table 5-25 was created.

The results for the *Common to Programme* risks are largely similar to that found in *Amplified risks*: the Top 10 of both the samples contain the same risk drivers and that the rankings differ. The implication of this is also that treatment plans for these risks can be applied to both large and small projects and are applicable to the entire project portfolio.

RBS LEVEL 3 RISK DRIVERS	**REGRESSION COEFFICIENTS**	
	ALL	**EIGHT PROJECTS REMOVED**
Project : Procurement - Availability/Lead times	0.67	0.51
Government : Approvals - Environmental Approvals	0.64	0.52
Project : Logistics : Site access	0.34	
Project : Procurement - Tender Period/process/constraints	0.07	
Client : User requirements - User requirement definition	0.05	0.46
Project : Plans - Scope Definition	0.05	0.32
Project : Plans - Program Plans	0.02	0.20
Economic : Local Economy - Resource competition	0.02	0.20
Project : Procurement - Clarity of approach	0.02	0.20
Government : Approvals - Approvals process	0.02	0.19
Societal : Community participation - Ethics, Public Perception		0.14
Client : Participation - Involvement in project		0.10

Table 5-25: *Common to Programme* risks - two simulations

Section Summary

From the risk simulation results, the following summary is provided:

- The risks in both the *All Risks* and *Eight Risks Removed* samples are largely the same which implies that the same treatment plans can be identified and implemented on a programme and portfolio level (Figure 5-49 and Figure 5-50).
- Risks related to *Procurement - Availability/Lead times* and *Approvals - Environmental Approvals* cause the most uncertainty (Table 5-25).

The relationship between of Policy Related risks and Common to Programme and Amplified risks

In the previous section is was determined that both *Amplified* and *Common to Programme* risks are material causing uncertainty in the project portfolio. The question "*What is the impact of policy related risks on the output distributions of the Amplified and the Common to Programme risks?*" can then be asked to determine the extent to which the organization's policies and procedures are causing uncertainty in the project portfolio. If the risk simulation results indicate that the organization is causing the uncertainty to themselves, the appropriate corrective action should be easier to implement as the controls are internal to the organization.

The same MS Excel as shown in Figure 5-42 was used to generate the output distributions below, but using the outputs in Column B. A *=RiskSimtable()* command was used to create the output distributions.

- *Amplified risks* (*All Projects*): The *Amplified risks* for the entire project portfolio were included.
- Amplified risks (Eight Projects Removed): None of the Amplified risks from the Eight Projects were included.
- *Common to Programme* Risks (*All Projects*): The *Common to Programme* risks for the entire project portfolio were included.

- Common to Programme Risks (Eight Projects Removed): None of the Common to Programme risks from the Eight Projects were included.
- *Generic Project Risks* (*All Projects*). The *Generic Project* risks for the entire project portfolio were included.
- Generic Project Risks (Eight Projects Removed): None of the Generic Project risks from the Eight Projects were included.

Description of data in the model

A list of the risk drivers which were categorised as policy related appears in Table 5-26. There were 16 RBS Level 3 Risk drivers which represented 105 open risks (13.4% of the entire set of open risks). Of these risk drivers, 45 (42.9%) were related to Procurement.

RBS LEVEL 3	NUMBER OF CLOSED RISKS		NUMBER OF OPEN RISKS		TOTAL	
Project : Procurement - Availability/Lead Times	23	46.0%	27	25.7%	50	32.3%
Client : Participation - Commitment to Project	6	12.0%	23	21.9%	29	18.7%
Project : Procurement - Tender Period/Process/Constraints	6	12.0%	15	14.3%	21	13.5%
Project : Contractor - Contractors Resources	6	12.0%	13	12.4%	19	12.3%
Project : Design - Design Rework	3	6.0%	8	7.6%	11	7.1%
Project : Contractor - Contractors Experience		0.0%	5	4.8%	5	3.2%
Project : Commissioning - Manuals Documentation	3	6.0%	1	1.0%	4	2.6%
Project : Logistics - Equipment Availability		0.0%	4	3.8%	4	2.6%
Project : Design - Design Alternatives	1	2.0%	2	1.9%	3	1.9%
Project : Procurement - Clarity of Approach		0.0%	2	1.9%	2	1.3%

RBS LEVEL 3	NUMBER OF CLOSED RISKS		NUMBER OF OPEN RISKS		TOTAL	
Project : Plans - Construction Plans		0.0%	2	1.9%	2	1.3%
Project : Procurement - Familiarity with chosen Procurement Contract		0.0%	1	1.0%	1	0.6%
Client : Procedures - Approvals		0.0%	1	1.0%	1	0.6%
Client : Procedures - Approvals	1	2.0%		0.0%	1	0.6%
Project : Environment - Environmental Incident	1	2.0%		0.0%	1	0.6%
Client : Finance - Financial Policies		0.0%	1	1.0%	1	0.6%
TOTAL	**50**	**100.0 %**	**105**	**100%**	**155**	**100%**
	32.3%		**67.7%**		**100%**	

Table 5-26: RBS Level 3 related to policy

Simulation Results

The risk simulation results from Figure 5-51 to Figure 5-56 is summarised in Table 5-27. With the exception of Generic Project Risks (*All Projects*), all the risk simulation results show a reduction in mean. The most material differences were found in the means of *Amplified risks* (*Eight Projects Removed* (-34.1%) and *Common to Programme* Risks (All projects) (-42.4%). This infers that Policy related risks are material causing uncertainty when simulating Amplified as well as *Common to Programme* risks.

RISK CATEGORY	MEAN (R MILLION)		DIFFERENCE	
Amplified risks (All Projects)	R929.2	R842.8	-9.3%	-10.3%
Amplified risks (Eight Projects Removed)	R245.0	R161.6	-34.1%	-38.3%
Common to Programme Risks (All Projects)	R1 267.2	R729.7	-42.4%	-40.1%
Common to Programme Risks (Eight Projects Removed)	R179.0	R142.8	-20.2%	-19.7%
Generic Project Risks (All Projects)	R2 310.3	R2 280.9	-1.3%	-1.0%
Generic Project Risks (Eight Projects Removed)	R269.0	R243.85	-9.3%	-8.6%

Table 5-27: Programme risks and changes in mean

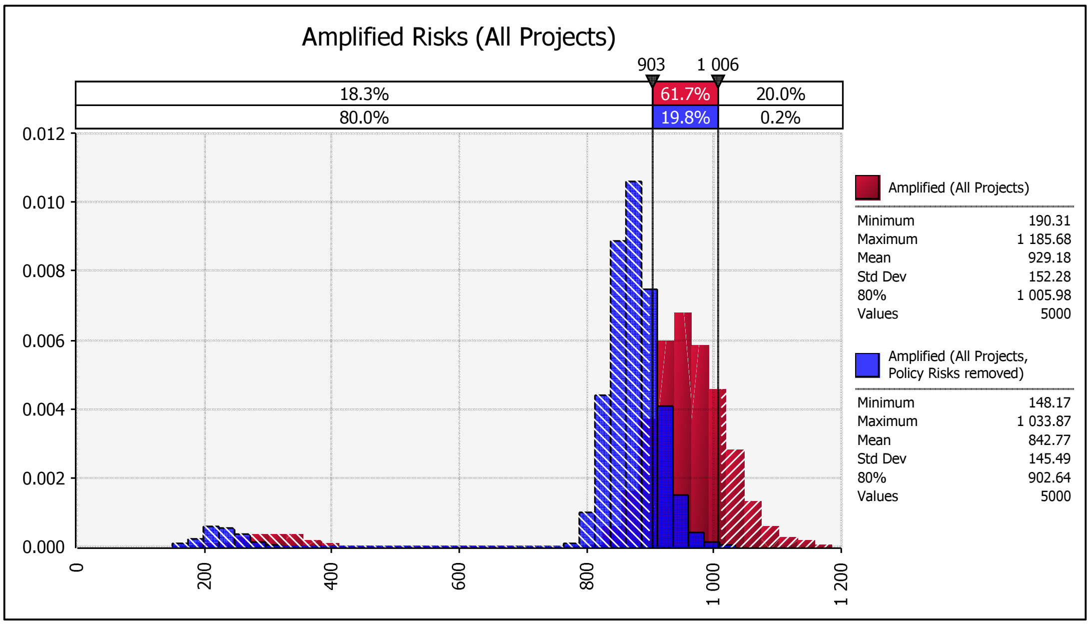


Figure 5-51: *Amplified risks* related to policies (*All Projects*) (R million)

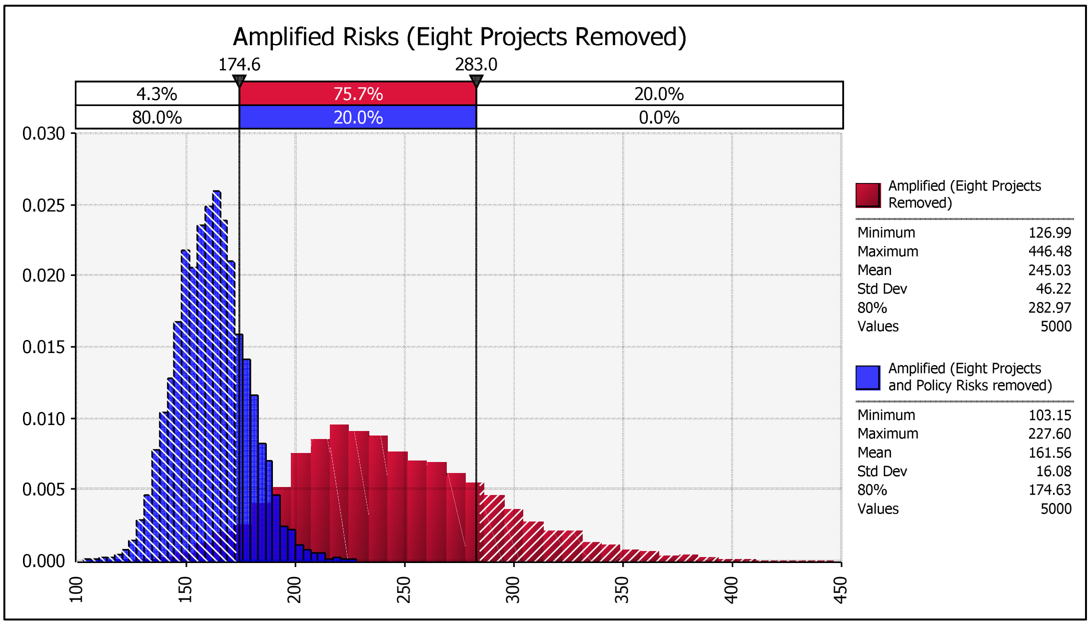


Figure 5-52: *Amplified risks* related to policies (*Eight Projects Removed*) (R million)

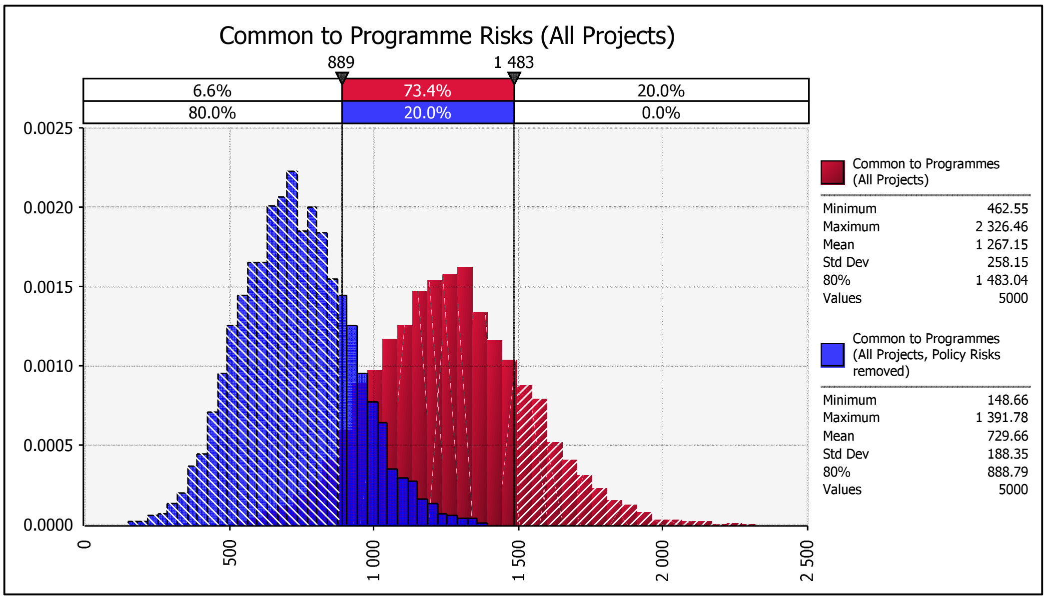


Figure 5-53: *Common to Programme* risks related to policies (*All Projects*) (R Million)

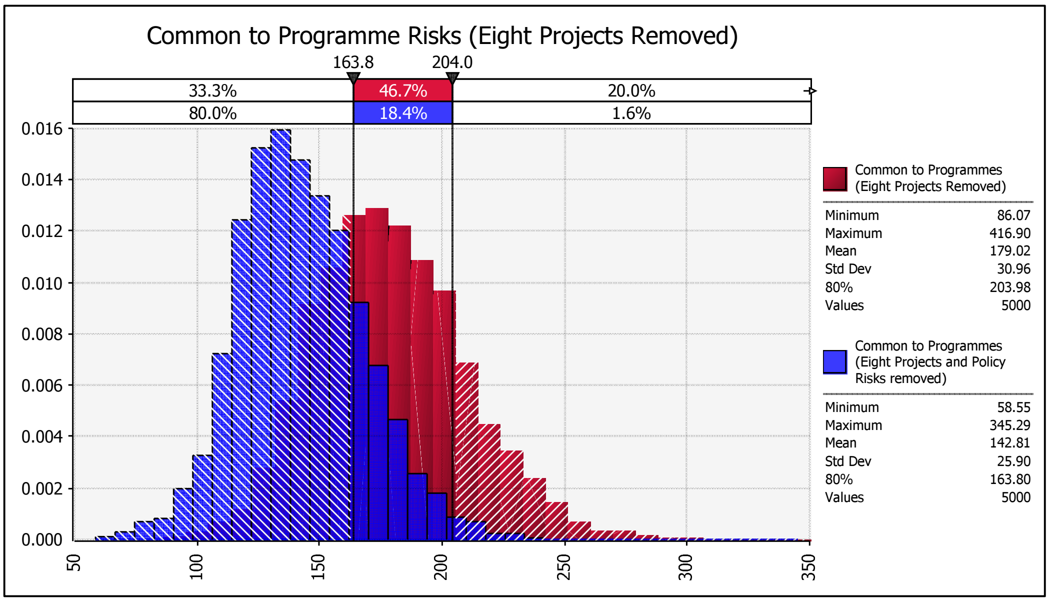


Figure 5-54: *Common to Programme* risks related to policies (*Eight Projects Removed*) (R Million)

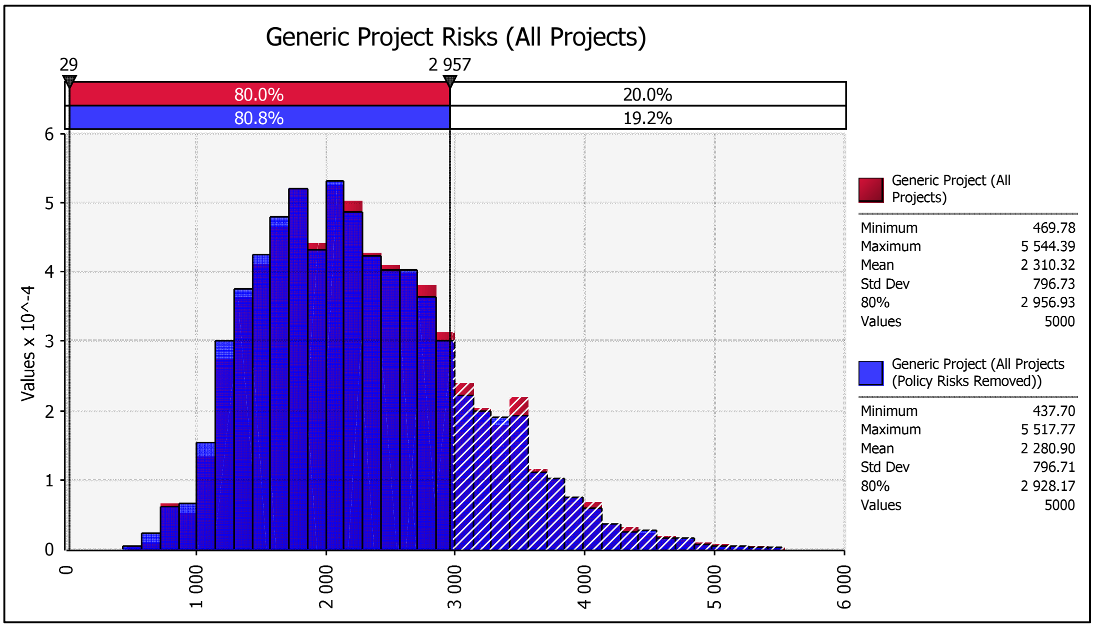


Figure 5-55: Generic Project risks related to policies (*All Projects*) (R million)

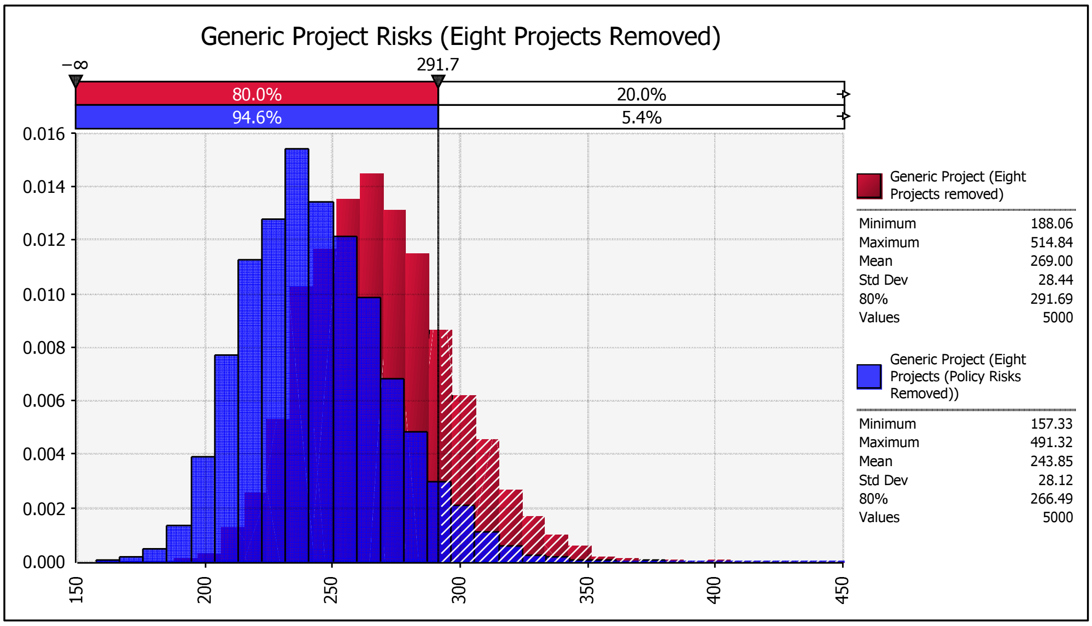


Figure 5-56: Generic Project risks related to policies (*Eight Projects Removed*) (R million)

Section Summary

From the risk simulation results, the following summary is provided:

- Policy related risks are material causing uncertainty in both the *Common to Programmes* and *Amplified risks* and less so in the *Generic Project risks* (Table 5-27).
- The largest differences were found in the means in reduction of the mean of -34.1% (*Amplified risks* in the *Eight Projects Removed* sample) and -42.4% (*Common to Programme Risks* in the *All proj*ects sample) (Table 5-27).

Which Policy risks are causing the uncertainty?

In the previous section it has been determined that policy related risks are impacting on both *Common to Programme* and *Amplified risks*. This section will present which of the policy related risks cause the uncertainty.

Simulation results

As the set of simulations as described in Section 0 was already set up to generate the tornado graphs in Figure 5-58 and Figure 5-59, no further simulations were required to be executed. @Risk was simply instructed to produce the tornado graphs.

When looking at *Amplified risks*, *Client Participation - Commitment to project* related risk drivers, specifically related to *Approval delays*, were causing the most uncertainty related to *Amplified risks*. Both samples reflected the same trend.

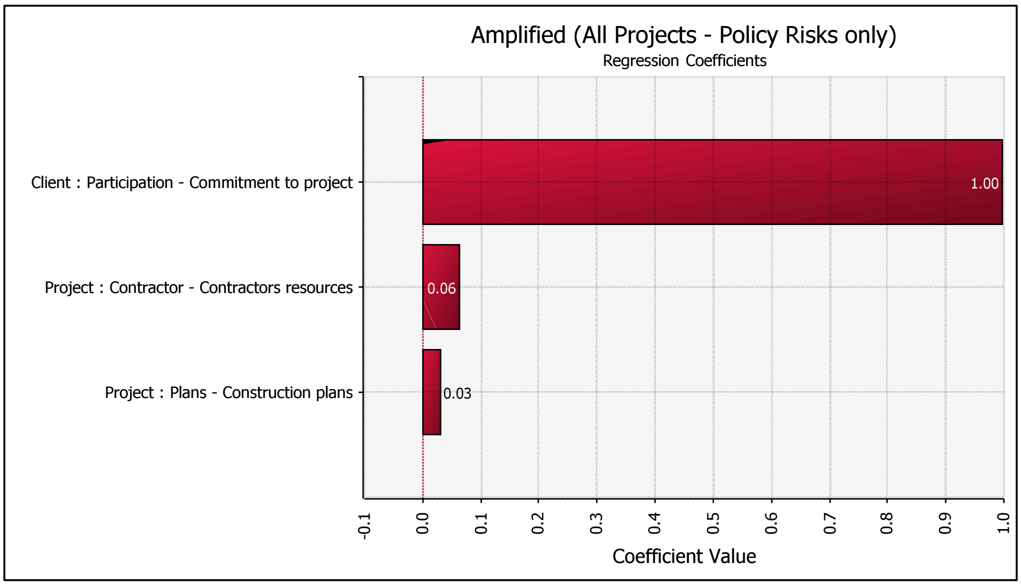


Figure 5-57: *Amplified risks* related to policies (*All Projects*)

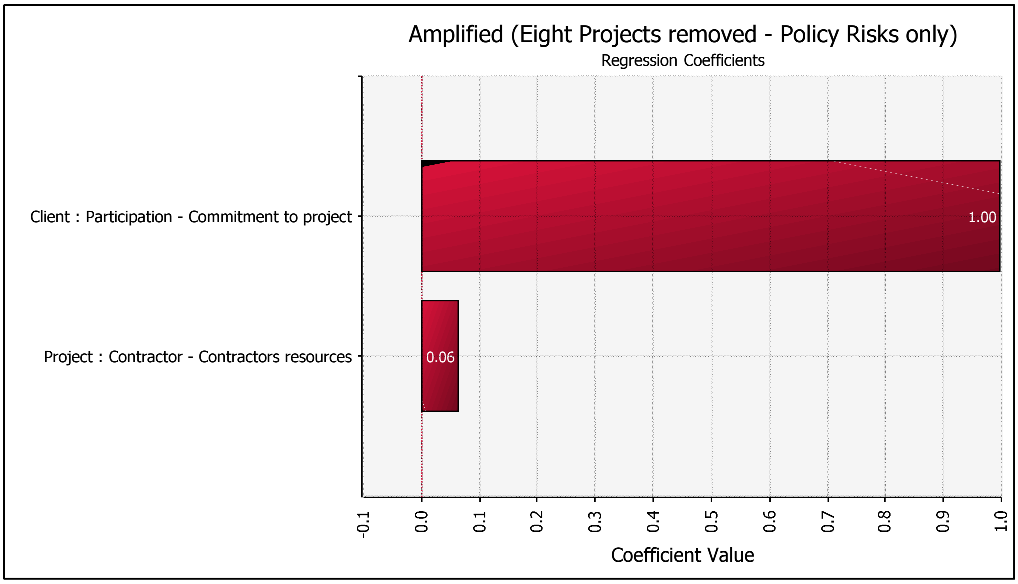


Figure 5-58: *Amplified risks* related to policies (*Eight Projects Removed*)

The results from the *Common to Programme* simulations (Figure 5-59 and Figure 5-60) show that, in both cases, *Procurement* related risk drivers were responsible for causing the described uncertainty. *Availability/Lead times* were by far the most significant risk driver in both cases. When looking at the CRR data, the following short risk names caused the uncertainty:

- Long lead items.
- Late order placement.
- Procurement delays.
- Contracting strategy.
- Procurement strategy.

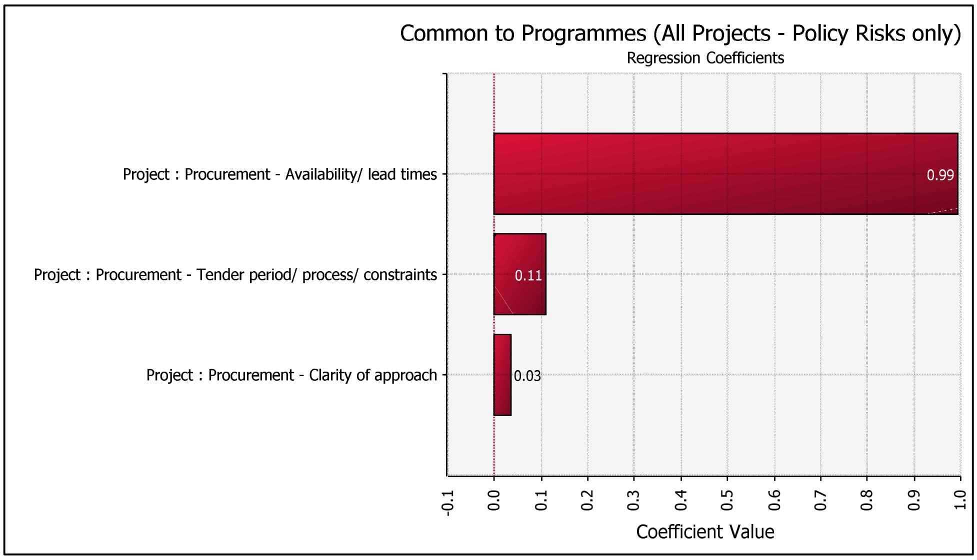


Figure 5-59: *Common to Programme* risks related to policies (*All Projects*)

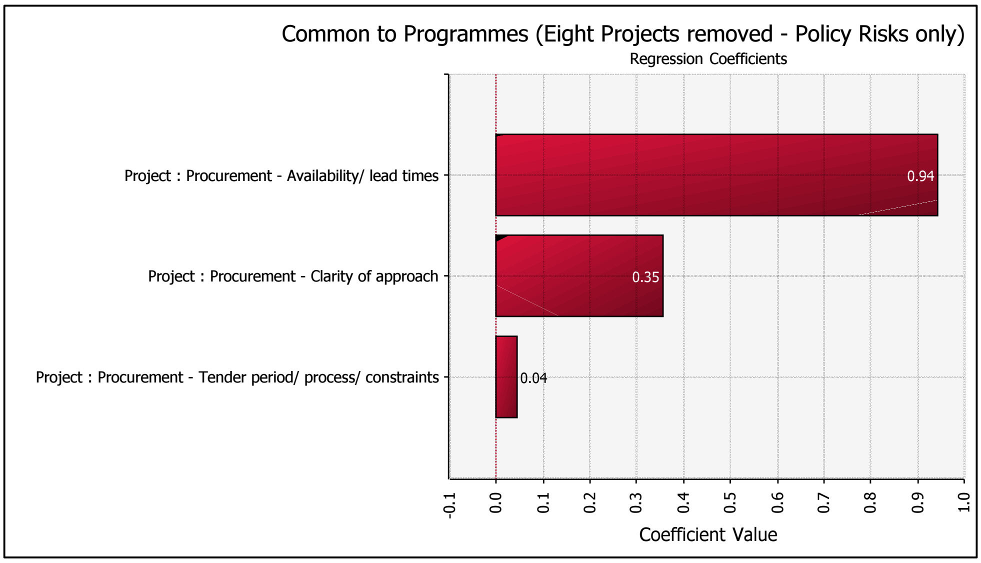


Figure 5-60: *Common to Programme* risks related to policies (*Eight Projects Removed*)

Section Summary

From the risk simulation results, the following summary is provided:

- *Client commitment to project* caused the policy related uncertainty for *Amplified risks* (Figure 5-57 and Figure 5-58).
- *Procurement* related risks caused the policy related uncertainty for *Common to Programme* risks (Figure 5-59 and Figure 5-60).

5.6.4 Discussion of simulation results

The simulation model was used to demonstrate that to put risks in categories related programmes is material in creating greater understanding of the risk drivers in the project portfolio. There are two main findings related to this research question:

- The identification of the causes and treatment plans for *Common to Programme* and *Amplified risks* were important.
- Policy related risks caused significant uncertainty in the project portfolio and treatment plans for risks related to this should be prioritised.

The previous two discussions (Section 0 and Section 0) regarding the impact of the outcome of the research question on project management discussed various risk drivers, their sources and potential treatment plans. For this research question, the argument is different in that the treatment plan for the main findings (as described above) is different as it does not focus on the treatment plans related to the various risk drivers as described in the two sections dealing with the impact on project management. The discussion will therefore focus on potential treatment plans which could be implemented on a programme and/or portfolio level.

The importance of risk treatment plans on a Programme Level

This simulation results quantitatively confirms Aritua's argument (2011, p. 310) that the need exists to distinguish between projects and programmes as management functions in the project environment. This is an important academic contribution since Aritua et al.'s research was qualitative. All the risk simulation results related to this research question supports the hypothesis that in the context to this research, risk which are *Common to Programmes* and *Amplified risks* materially influences uncertainty in the project portfolio.

The implication of this is that treatment plans and associated controls should be implemented on a programme and portfolio level to ensure that the potential likelihood/frequency and/or impact of these risks can be reduced.

Policies causing uncertainty

The finding related to policies causing uncertainty ties in with the previous finding related to the importance of implementing risk treatment plans on a portfolio level. The following two risk drivers caused the most uncertainty in the project portfolio:

- *Procurement* related risks caused the policy related uncertainty for *Common to Programme* risks.
- *Client commitment to project* caused the policy related uncertainty for *Amplified risks.*

The impact of policies on *Common to Programme* risks and *Amplified risks* were significant in that the samples where these risks were removed, the means and P80 values differed up to 42.4% points. Treatment plans for this should be identified and implemented.

5.7 Research Question 7: When simulating various risk categories, which of the categories have the most influence on uncertainty in the project portfolio?

This question is important because it should provide some insight into which of the previously identified risk categories cause the most uncertainty in the project portfolio. There are (at least) two additional ways of asking this question:

- When removing the various categories of risks (Controllable risks, Start delay risks, Planning named risk and Policy related risks) one by one, which of these categories reduces the uncertainty in the project portfolio the most?
- Which of the risk categories require the most attention to implement treatment plans?

The methodology on how this was resolved, together with the answers to the research question, sits at the heart of this thesis because it should provide high level insights into "*What matters most?*".

5.7.1 Description of data in the model

The data which was used in this research question has been described extensively in this chapter. The only difference is that all the risk categories are compared with each other, using @Risk software and cumulative frequency graphs. The latter is also known as S-curves.

5.7.2 Simulation results

The following principle was used to answer this research question:

- When removing a category of risks from the entire portfolio, the resulting S-curve will move to the left. The more uncertainty the category of risks causes, the more the curve will move to the left.
- The risk category which causes the most uncertainty, will cause the resulting curve to move the furthest to the left.
- The categories are removed one at a time, i.e. the removed categories don't aggregate.

To create the various s-curves, *=RiskSimtable()* and *=SumIfs()* were used to create the following simulation output distributions:

- *All Projects*. This sample would enable the question to be answered for the entire portfolio.
- *Eight Projects Removed*. This sample would enable the question to be answered for the smaller, less complex projects.
- *Eight Project Projects* only. This sample would enable the question to be answered for large, complex projects only.

For each of these output distributions, data was collected to create the following S-curves:

- All Risks.
- Eight Projects Removed from All Risks.
- Controllable risks removed from All Risks.
- Start Delay risks removed from All Risks.
- Planning Named risk removed from All Risks.
- Policy Related risks removed from All Risks.

Categories Ranked: All projects

From Figure 5-58, which includes the risks from all 86 projects, the risk category which has the most influence is the removal of the Eight (Complex) projects - the blue S-curve. This means that a certain type of project - complex projects with long lead times - contributes the most to uncertainty in the project portfolio. The second most important factor is the purple curve representing *Controllable* risks. The next is *Start Delay* risks and so forth.

One can argue that the *Policy related* risks have the smallest impact. But when presenting the descriptive statistics (Table 5-28) of these graphs, the difference between the mean values of these two graphs represents R654.02 million - a material amount. The table is ranked according to the risk category which caused the biggest shift in *All Projects* S-curve.

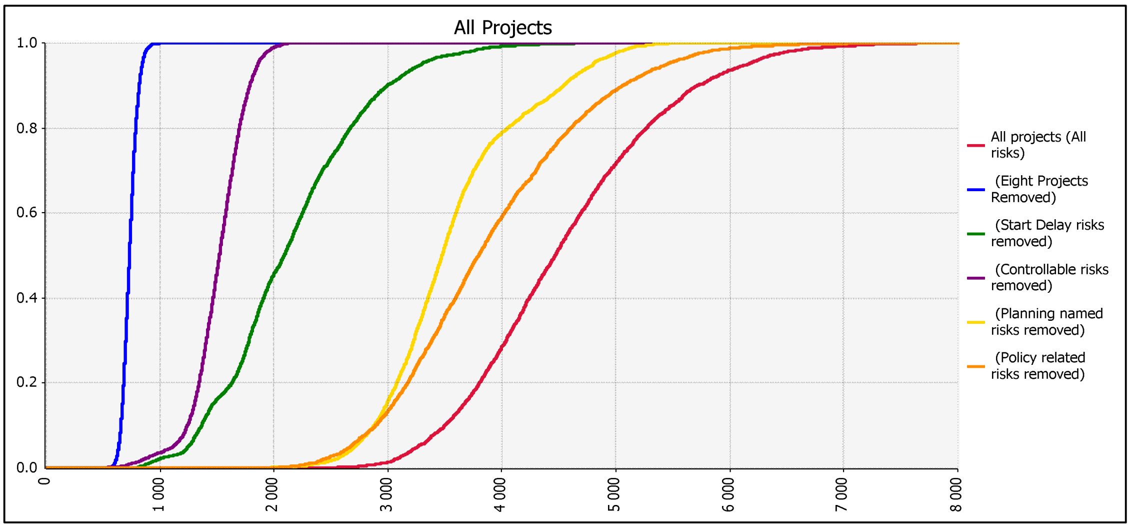


Figure 5-61: *Eight Projects Removed* S-curve

RANK	ALL PROJECTS	MEAN (R MILLION	DIFF MEAN (R MILLION)	%
1	Eight Projects Removed	R 735.0	- R 3 815.2	-83.9%
2	Controllable risks removed	R 1 507.8	- R 3 042.4	-66.9%
3	Start Delay risks removed	R 2 148.6	- R 2 401.6	-52.8%
4	Planning named risk removed	R 3 570.9	- R 979.3	-21.5%
5	Policy related risks removed	R 3 896.2	- R 654.0	-14.4%
	All Risks	R 4 550.2		

Table 5-28: *All Projects* S-curve descriptive statistics

Categories Ranked: Eight Projects Removed

In the sample which had the *Eight Projects Removed*, the removal of the *Controllable risks* (green curve) created the biggest shift in the S-curve. *Planning* and *Policy* risks swapped places with *Planning* risks being the category with the smallest impact (difference of R79 million in mean). They are ranked according to their means in Table 5-29.

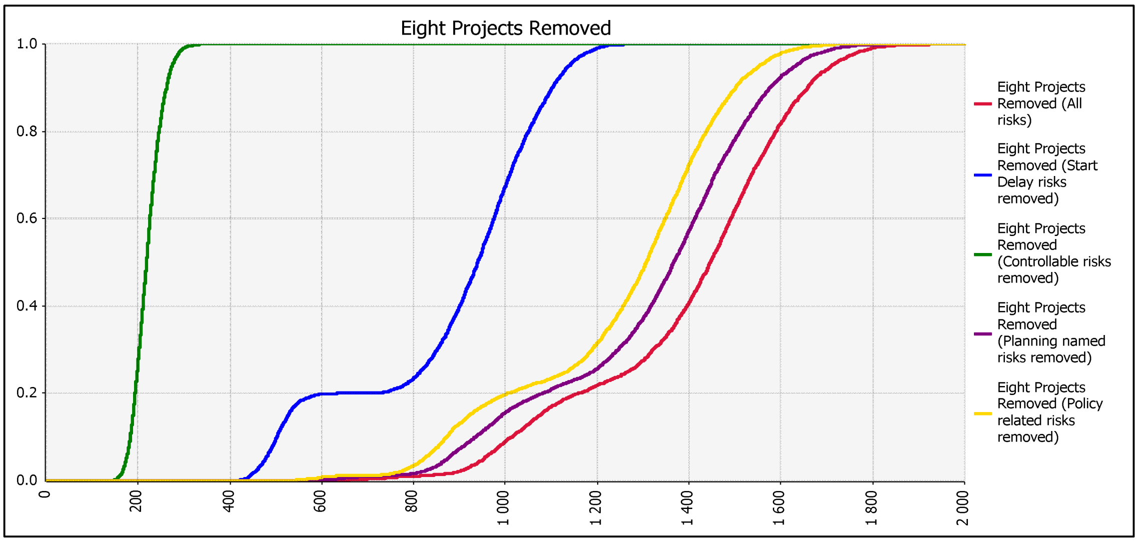


Figure 5-61: *Eight Projects Removed* S-curve

RANK	ALL PROJECTS	MEAN	DIFF MEAN	%
1	Controllable risks removed	R 220.3	R1 173.1	-84.2%
2	Start Delay risks removed	R 881.3	R 512.2	-36.8%
3	Policy related risks removed	R 1 248.7	R 144.7	-10.4%
4	Planning named risk removed	R 1 314.3	R 79.1	-5.7%
	All Risks	R 1 393.4		

Table 5-29: *Eight Projects Removed* S-curve descriptive statistics

Categories Ranked: Eight Projects

The last set ouf S-curves belong to the *Eight Projects* alone (Figure 5-62). In this case, the S-curves for *Controllable risks removed* and *Start Delay risks* removed are very similar with *Planning* and Policy related risks in the 3rd and 4th position.

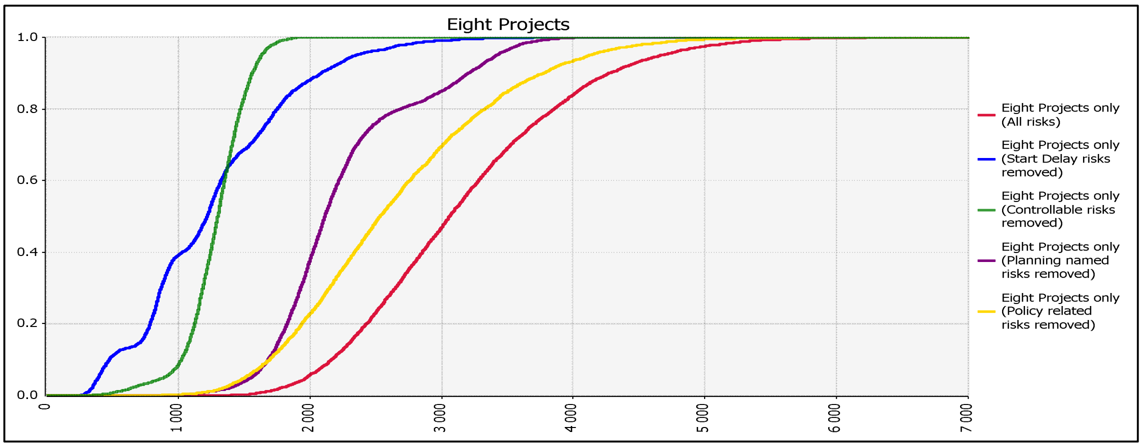


Figure 5-62: Eight Projects S-curves

RANK	ALL PROJECTS	MEAN	DIFF MEAN	%
1	Controllable risks removed	R 1 287.4	R-1 869.3	-59.2%
2	Start Delay risks removed	R 1 267.3	R-1 889.4	-59.9%
3	Planning named risk removed	R 2 256.5	R -900.2	-28.5%
4	Policy related risks removed	R 2 647.4	R -509.3	-16.1%
	All Risks	R 3 156.7		

Table 5-30: Eight Projects S-curve descriptive statistics

5.7.3 Discussion of simulation results: "What matters most?"

In this project portfolio, project complexity has the most significant influence on uncertainty. The most significant concern is that the removal of controllable risks was the risk category which in all three cases caused the largest reduction in when comparing it's mean with that of the *All risks* sample. From this it is easily deducted that the risk drivers are internal to the case study organisation. The reason for this can form part of further research. The question *"What matters most?"* can now be answered: In this context, the extent of which treatment plans are implemented and managed for *Controllable risks*, is what matters most.

"What really matters, are controllable risks."

5.8 Research Question 8: How does the contingency requirement in a portfolio of programmes compare to the contingency requirement of the sum of the individual project's requirements?

There are various ways of calculating project contingency. It may be a percentage of the estimated cost, a fixed number, or be developed by using quantitative analysis methods (Project Management Institute, 2009, p. 173). As mentioned in Thesis Boundaries Section 1.5.4 (Integration of project risk registers into cost estimate and schedule), estimate and schedule integration of the risk registers are excluded from this research. The main reason for this was that the roll-out of a quantified project risk management approach took place in phases and started with the develop risk registers and only later started with the integration of project estimates and risk registers. The initial policy used by TCP was to calculate the P80 value of the risk register and adding that as the project contingency to the project estimate. This means that if there were 86 projects, 86 individual P80 values were added to the various project estimates.

The purpose of this research question was therefore to compare the sum of the individual P80 values with the P80 value of a simulation involving all 86 projects.

5.8.1 Excel and @Risk functions

As shown in Figure 5-63, the results of Cell D91 will be compared with that of E91, where D91 is a sum of P80 values and E91 the P80 value of the output distribution for the entire simulation. As in previous sections, two simulations were executed where the first one included all the projects and the second one excluded the eight high complexity projects.

=SUMIFS(CRR_Simulation_Result,CRR_Project_Name,$A4,CRR_RBS_Level_3,F$3)+RiskOutput($A4&" "&F$3)

	A	B	C	D	E	F	G	
1								
2					1			
3	Project name	Programme	Contingency %	P80 of simulation result	Simulation Result	Project : Plans - Construction plans	Project : Contractor - Capacity	
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	=RiskPercentile(E4,0.8)/'Project Info'!F2	=RiskPercentile(E4,0.8,$D$2)	=RiskMakeInput(SUM(F4:CA4),RiskName(A4))	R -	R -	R
5	Hitachi ship unloader in Richards Bay	Port Bulk handling equipment	15.0%	R 1.50	R 0.24	R 0.14	R -	R
6	CD West	Port Stacking and laydown areas	3.2%	R 10.03	R 2.73	R -	R -	R
7	GP1 GP2 Sheds	Port Stacking and laydown areas	7.1%	R 8.29	R 5.34	R -	R -	R
8	K-hoppers	Port Bulk handling equipment	9.8%	R 4.88	R 3.20	R -	R -	R
9	Dust suppression Rail Wagons	Port Equipment	9.9%	R 4.87	R 3.43	R -	R -	R
10	Dust control K 24 tunnel, Conveyor transfers and compressed air reticulation system	Port Equipment	8.1%	R 5.18	R 3.40	R -	R -	R
11	Open Stockpile Triangle	Port Stacking and laydown areas	7.1%	R 12.75	R 5.34	R -	R -	R
12	Weigh Bridges	Port Bulk handling equipment	170.5%	R 17.05	R 11.18	R -	R -	R
87	Paarden island wash bay	Port & Rail Buildings	0.8%	R 0.24	R 0.17	R -	R -	R
88	Halfweg Housing	Port & Rail Buildings	2.0%	R 1.00	R 0.30	R -	R -	R
89	Oreline Phase 2	Rail Earthworks & OHTE	0.3%	R 42.13	R 11.90	R -	R -	R
90				=SUM(D4:D89)	=SUM(E4:E89) +RiskOutput()	R 851.56	R 1240.25	R
91				=RiskPercentile(D90,0.8)	=RiskPercentile(E90,0.8)			
92								

Figure 5-63: Calculating project contingency

5.8.2 Simulation results

After the simulation was executed, the results were recorded and are contained in Table 5-31:

	ALL PROJECTS (R MILLION)	EIGHT PROJECTS REMOVED (R MILLION)
Simulated P80	R5 266.7	R786.66
Sum of individual project P80 values Total	R6 620.1	R939.00
	-20.4%	**-16.2%**

Table 5-31: Comparing individual P80 values with P80 value of entire simulation

5.8.3 Discussion of simulation results

The implication of this simulation result is that when a company uses the P80 values from a risk register and simply adds them to the project estimate, the contingency requirement can be overstated. The two simulated results show an overestimation of between 16.2% and 20.4% of the total project contingency required (Table 5-31).

5.8.4 Implication for project management

The implication of the above mentioned result becomes material when taking the following case study into consideration:

> *Taking a portfolio of R100 billion, which contains a contingency of R15 billion, the contingency would be over-estimated by R3 billion. The annual interest bill on R3 billion, using a prime rate of 8%, would be R240 million.*

A possible way to legitimately reduce the contingency calculations in the absence of a concurrently run Monte Carlo simulation on the entire project portfolio, is to identify low probability high impact risks which regularly appear in the risk registers and to make provision for them not in the projects themselves, but in a central contingency fund. This should reduce some of the duplication in the project portfolio.

5.9 Research Question 9: How does the simulated contingency requirements compare when using rules of thumb?

Rules of thumb such as "*Add 10% of the project capital cost as contingency to the estimate when going into project execution*" are described in Section 5.7. The purpose of this research question is to test the validity of such rules of thumb.

The required Excel function already appears in Column C of Figure 5-63 where the P80 value of each of the risk simulation results was divided by the project budget. The purpose of this was to determine if one could use a contingency % in cases where there would be no resources to conduct a quantitative risk analysis.

5.9.1 Results

A histogram was created where the horizontal axes represents the P80 of the individual simulation result/Project budget. The result of this appears in Figure 5-64.

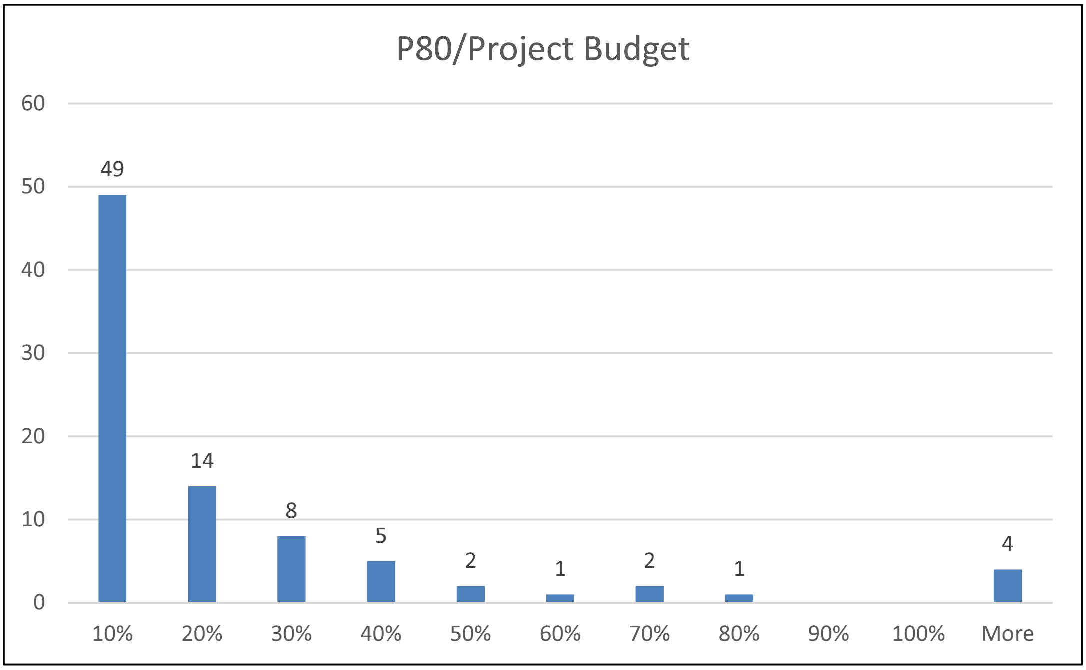


Figure 5-64: Project Contingency as % of project budget

5.9.2 Discussion of simulation results

Figure 5-64 shows that 49 projects had a requirement of less than 10%, 14 between 10.01 and 20% etc. From Figure 5-64, it is clear that a rule of "*10% of project cost added as contingency*" is **not appropriate** in 43% of the projects in the sample. From this result it can be inferred that rules of thumb regarding uncertainty are not appropriate in estimating contingency requirements in capital projects.

5.9.3 Implication for project management

Taking the above mentioned results, as well as the results from the previous research question, the recommendation is that contingency should be estimated over the entire project portfolio using quantitative methods.

This is however, not always practical since the resources required to do quantitative risk assessments together with the integration of risk registers, estimates and schedules are not freely available. Organisations wishing to use these methods therefore have to decide which policies to implement regarding which projects should be put through an integrated project risk quantification process.

5.10 Simulation model validation

As mentioned in Section 2.2, the simulation model needs to be validated to ensure that the model is free from errors and that the risk simulation results are robust. As per Vose (2008, p. 451) the following approaches were used during the validation process:

- Informal audits.
- Checking model behaviour.
- Comparing predictions against reality.

5.10.1 Auditing of the model

The following types of errors were encountered and corrected during the developing of the model:

- Syntax errors where equations were incorrectly used.
- Logic errors.
- Omission errors.

Since the same type of simulation was run many times during the research, the errors were more common during the initial phases of the research. Some software quirks also contributed to this. The latest version of the simulation model produces consistent results.

5.10.2 Checking model behavior

The model's behavior was tested by doing the following:

- Viewing scenarios and checking their credibility.
- Analysing the outputs.

It should be noted that the author has used the model on projects which were started after the data collection for this thesis was concluded (Joubert, 2014).

Scenarios and their credibility

During the research, many different scenarios were presented and their simulation results discussed. There were no obvious logical issues detected, e.g. that removing a set of risks (e.g. the *Eight Projects*) from a sample would move the mean of the output distribution to the left and not to the right. This was presented in various places, with Table 5-31 as a typical example.

Analysing the outputs

The simulation model presented a large number of graphical outputs which are particularly helpful in checking that uncertain input parameters have the expected influence on a model's outputs (Vose, 2008, p. 457) of different outputs which were presented and discussed.

Probability density graphs, tornado graphs and S-curves were used throughout the research and did not present any results which were unexpected, e.g. that the uncertainty in the portfolio would increase after removing some risks from the portfolio.

Comparing predictions against reality

There were several sets of information against which the predictions were compared with reality. This included the following:

- Regular discussion and presentation of the risk simulation results to the case study management.
- Comparison of results to the published Transnet Annual Reports.
- Comparison of results to other publications.

Discussion and presentation of simulation results

The risk simulation results were regularly discussed with Transnet management and several presentations have been conducted. To ensure the validity of the risk classification, the classification was done in conjunction with senior management at the case study organisation.

Comparison of results to Transnet Annual Reports

The 2014 Transnet Integrated Report contains a section on risks facing the business (Transnet SoC Ltd., 2014, p. 34). The following three risks can be tied back to the risks identified in this section which can all be referenced back to the risks identified in Table 5-9.

- Inability to deliver on the capital investment plan due to the ineffective application of current capital and *procurement operating methodology*.
- People management, talent attraction and *skills development* to operate the newly acquired assets.
- *Environmental activism increased* pressure to be a sustainable organisation.

The same applies to the section in the Integrated Report which refers to material issues facing the business (Transnet SoC Ltd., 2014, p. 37) which can also be tied back to Table 5-9. In this section, the response *Optimise Capital Approvals* was identified as a treatment plan for the issue of not completing capital projects on time and within budget.

Comparison of results to academic work

To compare the research results to other published work is problematic as the same risks categories, names and descriptions are not always directly comparable. An example for this is the use of the terms *Bureaucracy* and *Approval Delays* which might not necessarily be the same issue. Nevertheless, some of the risks which were described in other academic work could be related to the outcomes of this research.

The article by Windapo & Cattell (2013) mentions the following challenges in South African construction industry which can be tied back to risks related to skills, resources and procurement, as presented previously:

- Public-sector capacity.
- Mismatches between available skills and required skills.
- Procurement practices and the capacity for sustainable empowerment.

The research by Ugwua & Haupt (2007, pp. 669-670) lists various stakeholder key performance areas for infrastructure sustainability. Some of the risks identified in this thesis, such as environmental issues, health & safety as well as project administration and procurement can be directly linked to the key performance areas as described by Ugwua & Haupt (2007). This provides verification for the model from a sustainability perspective. Chan et al. (2011, p. 759) identified a list of ranked risks based on projects in Hong Kong and Rezakhani (2012) for Korea. Chan et al.'s Top 5 Risks were as follows:

- Changes in scope of work.
- Insufficient design completion during tender invitation.
- Unforeseeable design development risks at tender stage.
- Errors and omissions in tender document.
- Exchange rate variations.

Rezakhani (2012) did not present any ranking and used the identified risks to create a RBS which could be tied back to the RBS which was used in this research effort.

Karim et al. (2012) offered a different perspective as their research focussed on risks confronting contractors. The Top 5 risks in their research included the following:

- Shortage of material.
- Late deliveries of material.
- Shortage of equipment.
- Poor quality of workmanship.
- Cash flow difficulties.

5.11 Research Questions Answered

The results for Research Questions 1 to 9 appear in Table 5-32. In this table, each of the research questions are described in terms of the new questions which were added during the research process, the techniques used as well as high level research results.

RESEARCH QUESTION		NEW QUESTIONS	RESEARCH RESULT
1.	What is available in the literature to provide guidelines in answering the problem statement?	• What has been published regarding simulation as research methodology? •	Although there are some issues with simulation related to complexity and independent verification, it is an acceptable way of doing research. Issues related to model complexity were addressed in developing the simulation model. The simulation model was also independently verified.
		• Which sources are available showing the structure and functioning of a simulation model which produces a quantified view of a project portfolio?	Much has been written regarding various aspects of risk simulation but very little on the simulation of risks in a portfolio of programmes. The latter is especially true when looking for information regarding risk simulation in a portfolio of rail and port programmes.
		• What research has been published regarding the quantification of risks for capital projects such as port and rail infrastructure?	There are several papers dealing with which risks one could expect on capital projects. Risks related to port and rail projects are mainly confined to investment decisions, operational safety and environmental compliance.
2.	How does one develop a model to enable a quantified portfolio view of risk in a set of projects?	Not applicable.	The simulation model and the way in which it was developed is discussed in great detail in Chapter 2.

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
3.	How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?	Where in the RBS was the most uncertainty found?	=*SumIfs()* and Tornado graphs on RBS Levels 1 to 3 to determine where in the RBS the most risk originates.	The most uncertainty was found in the Project environment followed by Government. The following RBS Level 3 categories cause the most uncertainty: • Government : Approvals - Environmental approva • Project : Contractor – Contractors' Equipment/Technology • Project : Logistics - Site access. • Project : Plans - Construction plans. • Project : Procurement - Availability/lead times.
		Which programmes/project types caused the most uncertainty in the project portfolio?	=*SumIfs()* and Tornado graph on defined Programmes to determine which Programme causes the most uncertainty.	The following programmes caused the most uncertainty: • Rail Power Supply. • Port Marine Infrastructure. • Rail Earthworks and OHTE. • Rail Tunnels and Bridges. • Port Bulk handling equipment.
		Is the uncertainty in the programmes driven by specific projects?	=*SumIfs()* and Tornado graph on project names to determine which Project causes the most uncertainty	The following projects caused the most uncertainty: • Tippler Saldanha • Eskom South of Ermelo • Tank Farm • Pier 1 Phase 2 • Berth Deepening • 81 Mtpa Coal Export • Overvaal Tunnel • Tippler Richards Bay

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
3.	How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?	What do these projects have in common?	Discussion with Project Directors and Project Managers.	• Large complex projects with long procurement cycles.
		Does the removal of projects (from the project portfolio) have a change in the ranking of the risks?	=*RiskSimtable()* where the first sample includes all the Projects and the second one excludes the projects which cause the most uncertainty.	• There are different risk drivers in smaller projects (client environment) and large complex projects (project environment) and treatment plans should be adapted accordingly.
4.	When simulating the risks in a portfolio of programmes, are controllable risks material in causing uncertainty?	Are controllable risks causing uncertainty?	=*RiskSimtable()* where the first sample includes all the risks and the second where are controllable risks excluded.	• Controllable risks are material causing uncertainty in the project portfolio.
		Is there a difference in ranking for controllable risks between the *All Projects* and the *Eight Projects Removed* samples?	• =*RiskSimtable()* where the first sample includes all the risks and the second where are controllable risks excluded. • =*SumIfs*() and Tornado graphs on RBS Levels 3 to determine where in the RBS the most risk originates.	• There is a difference in ranking of controllable risks for both the All Projects and the Eight Projects Removed samples.
		Which controllable risks cause the uncertainty?		• The risks appearing with the highest frequency in the project portfolio are Environmental non-compliance, Scope definition, Long lead items, Geotech and Approval delays.

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
5.	When simulating controllable project execution start delay risks, where should the focus area be?	Are start delays material in causing uncertainty?	*=SumIfs()* and Tornado graph on risk type (for example what can be controlled) and start delays to determine if start delays are material causing uncertainty.	• Project start delays matter in the project portfolio since five of the top six bars on the tornado graph for the All Projects sample were related to project execution start delays.
		Which programmes/project types affected by start delays caused the most uncertainty in the project portfolio?	• Probability density graph using *=RiskSimtable()* on start delay risks only. • First sample includes all the projects, second one excludes the projects which cause the most uncertainty.	• Project start delay risks caused the most uncertainty in the Eight Projects:
		Which controllable risks are causing project start delays?	*=SumIfs()* and Tornado graph on risk type (for example what can be controlled) and start delays to determine if start delays are material causing uncertainty.	The uncertainty regarding project start delays was caused by the following RBS Level 3 risk drivers: • Client Participation - Commitment to project • Contractor - Capacity • Environmental approvals • Procurement - Availability/lead times • • Overlap of design and construction • Tender period/process/ constraints • Site access

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
5.	When simulating controllable project execution start delay risks, where should the focus area be?	What is the influence of controllable risks on the descriptive statistics of the simulation result?	• Probability density graph using *=RiskSimtable()* on entire sample. • First sample includes all the risks, second one excludes all the controllable risks.	• When turning off all the controllable risks, the mean of the output distribution reduces by R2 476 billion (50.8%).
		Are planning related risks material in causing uncertainty?	Probability density graph using *=RiskSimtable()* on entire sample. • First sample includes all the risks, second one excludes all the planning related risks. • Tornado graphs to rank the planning related risks.	• Planning related risks are material causing uncertainty in the project portfolio since removing them, reduces the P80 value by 23.9%. • Construction Plans caused the most uncertainty in the All Projects sample and in the Eight Projects Removed sample, it was Scope Definition.
		Are different types of controllable risks associated with the various Operating Divisions?	*=SumIfs()* and Tornado graphs using Risk Type (External - Uncontrollable, External Influencable et) together with OD name (TFR, TNPA, TPT) as inputs.	• The ranking of risks related to the ODs differ for all samples which indicates that there are structural/business reasons for the risk rankings to differ.
		Are policy related risks material in causing uncertainty?	Probability density graph using *=RiskSimtable()* on entire sample. • First sample includes all the risks, second one excludes all the planning related risks. • Tornado graphs to rank the planning related risks.	• Procurement related risks caused the policy related uncertainty for *Common to Programme* risks. • Client commitment to project caused the policy related uncertainty for *Amplified risks*.

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
6.	When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?	Is Aritua's (Aritua, et al., 2011) classification material?	=*SumIfs()* and Tornado graphs on Aritua's classification.	• Common to Programme and Amplified risks are material to both the All Projects and Eight Projects Removed samples. • For large complex projects, *Generic Project* risks causes the most uncertainty and the smaller projects, *Amplified risks* are responsible.
		• Which Amplified risk drivers cause the uncertainty when using the RBS Level 3 risk drivers?	• =SumIfs() and Tornado graphs on Aritua's classification.	• The Top 5 *Amplified risks* were: • Contractor – Capacity. • Participation - Commitment to project. • Industrial Relations - Industrial unrest. • Client Operations. • Material supply logistics.
		• Which *Common to Programme* risk drivers cause the uncertainty when using the RBS Level 3 risk drivers?	• =SumIfs() and Tornado graphs on Aritua's classification.	• The Top 5 *Common to Programme* risks were: • Procurement - Availability/Lead times. • Environmental Approvals. • Site access. • Procurement - Tender Period/process/constraints. • User requirement definition. • There were slight differences between the ranking of the *All Projects* and the Eight Project Removed samples.

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
6.	When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?	• What is the impact of policy related risks on the output distributions of the Amplified and the *Common to Programme* risks?	• Probability density graph using *=RiskSimtable()* on entire sample. • Six simulations were executed.	• The impact is material. • The most material differences were found in the means of *Amplified risks* (*Eight Projects Removed* (-34.1%) and *Common to Programme Risks* (All projects) (-42.4%)).
		• Which policy related risks cause the most uncertainty in the Amplified and *Common to Programme* RBS Level 3?	• Tornado graphs using the output distributions created by the *=RiskSimtable()* function.	• *Procurement* related risks caused the policy related uncertainty for *Common to Programme* risks. • *Client commitment to project* caused the policy related uncertainty for *Amplified risks*.
7.	When simulating various risk categories, which of the categories have the most influence on uncertainty in the project portfolio?	• None.	• Probability density graph using *=RiskSimtable()* on entire sample. • Six simulations were executed.	• In this context, the extent of which treatment plans are implemented and managed for Controllable risks, is what matters most.
8.	How does the contingency requirement in a portfolio of programmes compare to the contingency requirement of the sum of the individual project's requirements?	• None.	• P80 values based on *=SumIfs()* for individual projects.	• The executing of a concurrent Monte Carlo simulation on the entire portfolio reduces the contingency requirement by between 16.2% and 20.4% in comparison to the P80 values of the individual risk registers.

	RESEARCH QUESTION	NEW QUESTIONS	TECHNIQUE USED	RESEARCH RESULT
9.	How does the simulated contingency requirements compare when using rules of thumb?	• None.	• P80 values based on =*SumIfs()* for individual projects.	• Because of the large spread of contingency estimates, rules of thumb regarding uncertainty are not appropriate in estimating contingency requirements in capital projects.

Table 5-32: Summary of Research Questions, Techniques and Research Results

5.12 Chapter Summary

Similar to the introduction to this Chapter, the summary is discussed in terms of the simulation model and the risk simulation results.

5.12.1 Simulation model

This chapter demonstrated how the methodologies discussed in the previous chapters were used to answer Research Questions 3 to 9, as they appear in Table 1-5 and in the related process flow diagram at the beginning of this chapter in Figure 5-1:

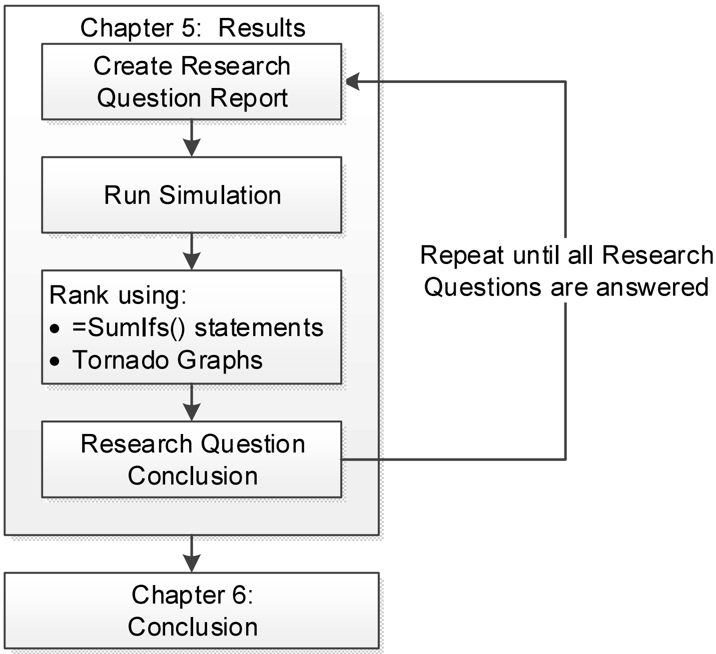


Figure 5-65: Initial process diagram

As the answers to the research questions progressed, it became clear that the initial Research Questions 3 to 6 were not fully adequate to understand the sources of the risks. Some additional questions were therefore developed, as shown in Table 5-32.

To get the risk simulation results related to these additional questions, some changes were required to the initial flow diagram (Figure 5-65) evolved to a flow diagram as shown in Figure 5-66. This process flow was used extensively during the answers to Research Questions 3, 4, 5 and 6. The term “Aspect” in Figure 5-66 refers to what category of risks were being investigated, e.g. “Policy related risks”.

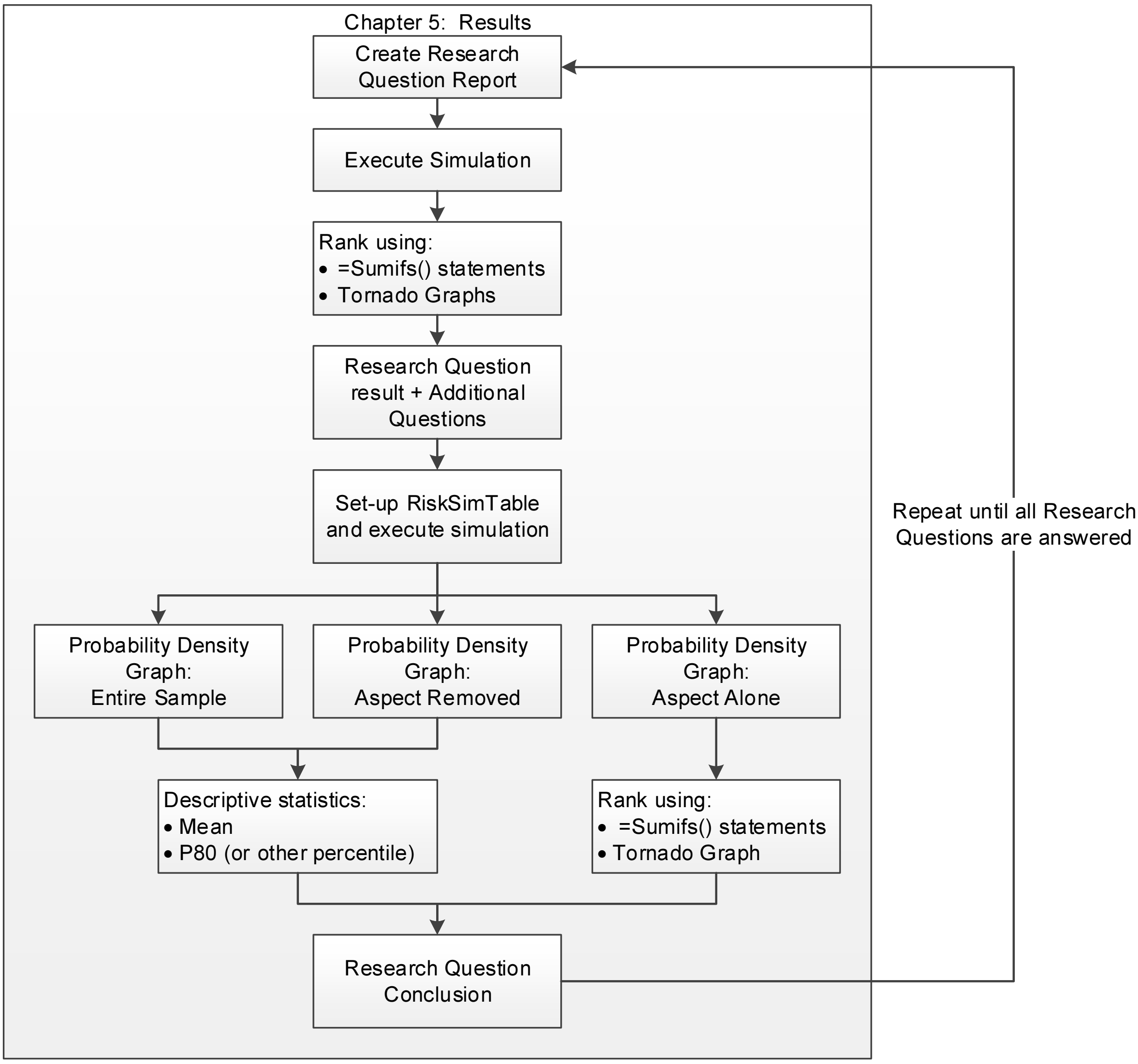


Figure 5-66: Final Flow diagram

Another way of representing Figure 5-66 is found in Figure 5-67 where the question *“Which Common to Programme risks cause the most uncertainty in the Eight Project Removed sample?”* is used to illustrate the process.

It contains five steps and shows which MS Excel and @Risk functions are used in each step and illustrates the combined use of a risk register, probability density graphs and tornado graphs to determine which *Common to Programme* risks cause the most uncertainty in the project portfolio.

It concludes by allocating treatment plans, risk owners and follows the normal ISO31000:2009 risk management process.

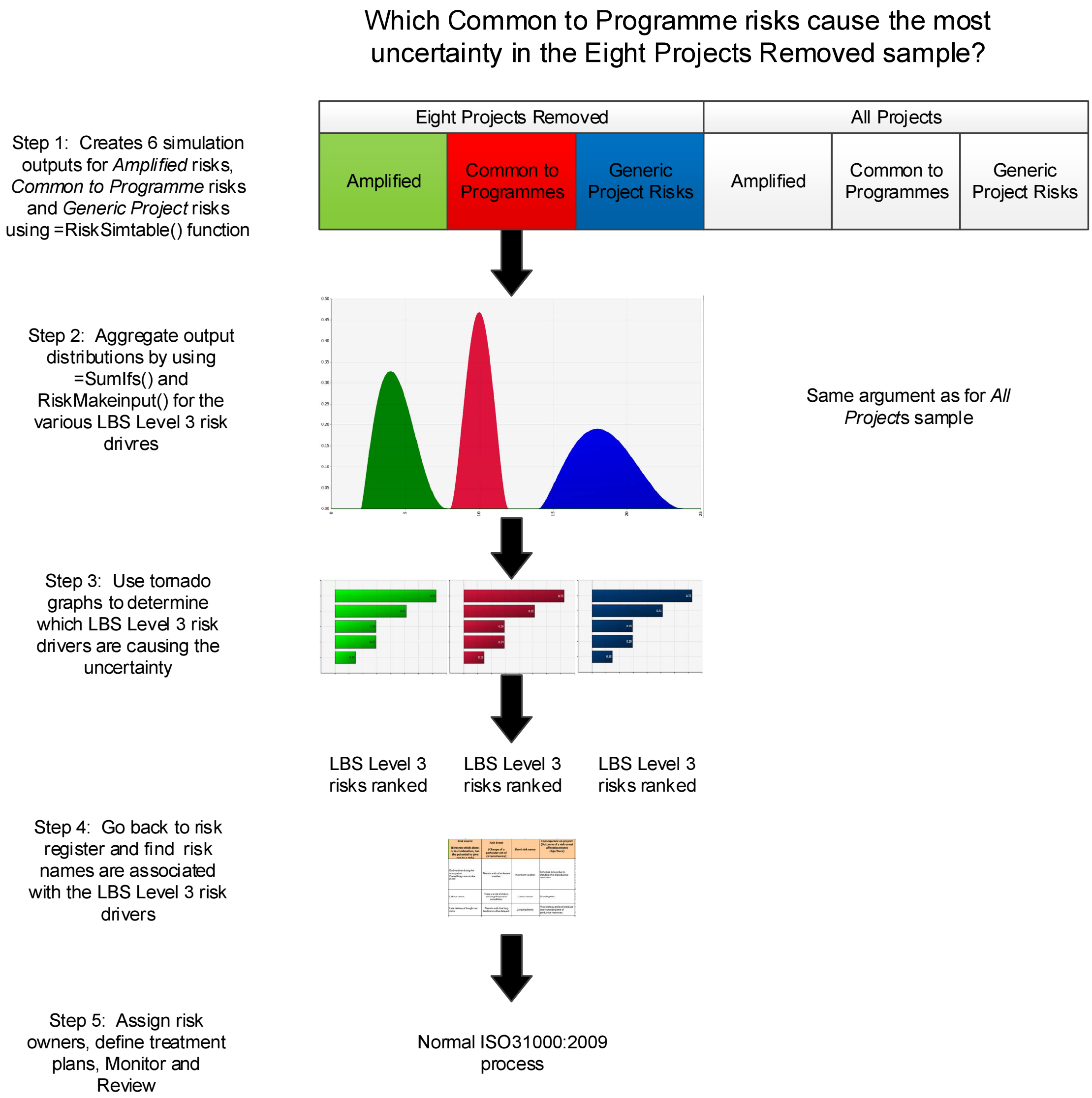


Figure 5-67: Simplified Final Flow diagram

5.12.2 Simulation results

This chapter included the answers to Research Questions 3 to 9 using the methodologies described throughout the chapter. There however, remains some unanswered questions when looking at Research Questions 3 to 6:

- Which risks require the most urgent treatment plans?
- Which of the various risk categories (Complexity/Project start delays/Controllable risks/Planning named risks/Policy related risks) cause the most uncertainty?

These two aspects are of course related to each other because they both relate to “What matters most?”, “Where are these risks found?” and “Where should the focus be on the implementation of risk treatment plans?”.

The results from Research Questions 3 to 6 were combined in a single table (Table 5-33). Each of the research questions appear as headings to the table which was ranked according to the regression coefficient of the risk drivers as identified in Research Question 3, taking the entire project portfolio into consideration. The risks were also arranged in such a manner that the risk simulation results of risks which are related all appear in the same rows.

The table can be used as a decision making tool based on specific user focus. It is best illustrated using an example.

Transnet wants to identify those *Common to Programme* risk drivers to reduce uncertainty in the project portfolio. They would then select the high ranking risks in the column called *Type*. How these risks relate to the other risk drivers (Overall risks and Project Start Delay risks) can then be read from the table.

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Project : Plans - Construction plans	0.70		Project : Plans - Construction Plans	0.71	0.17				Project : Plans - Construction Plans	0.03	0.10	Amplified
									Project : Plans - Construction plans	0.75		Generic Project
Project : Logistics - Site access	0.57	0.14	Project : Logistics : Site access	0.56	0.14	Project : Logistics - Site access, External - Influencable	0.16	0.06	Project : Logistics : Site access	0.34		Common to programmes
						Project : Logistics - Site access, Internal - Operational	0.83	0.04	Project : Logistics - Site access	0.60	0.28	Generic Project
						Project : Logistics - Site access, Internal - Project Processes	0.14					
Project : Contractor - Contractors' Equipment/Technology	0.24		Project : Contractor - Contractors' Equipment/Technology	0.24					Project : Contractor - Contractors' Equipment/Technology	0.26		Generic Project
Project : Procurement - Availability/lead times	0.20	0.25	Project : Procurement - Availability/Lead times	0.20	0.26	Project : Procurement - Availability/lead times, Internal - Project Processes	0.29		Project : Procurement - Availability/Lead times	0.67	0.51	Common to programmes
						Project : Procurement - Clarity of approach, Internal - Project Processes		0.12	Project : Procurement - Clarity of approach	0.02	0.20	Common to programmes
						Project : Procurement - Tender period/process/constraints, Internal - Project Processes	0.03	0.07	Project : Procurement - Tender Period/process/ constraints	0.07		Common to programmes

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Government : Approvals - Environmental approvals	0.19	0.27				Government : Approvals - Environmental approvals, External - Influencable	0.19		Government : Approvals - Environmental Approvals	0.64	0.52	Common to programmes
						Government : Approvals - Environmental approvals, External - Uncontrollable	0.22	0.34	Government : Approvals - Environmental approvals		0.18	Generic Project
						Government : Approvals - Approval Conditions, External - Influencable		0.11				
Project : Contractor - Capacity	0.16		Project : Contractor - Capacity	0.17		Project : Contractor - Capacity, External - Influencable	0.25		Project : Contractor - Capacity	0.93		Amplified
Project : Procurement - Overlap of design and construction	0.10		Project : Procurement - Overlap of design and construction	0.10		Project : Procurement - Overlap of design and construction, Internal - Project Processes	0.15		Project : Procurement - Overlap of design and construction	0.11		Generic Project
Client : Participation - Commitment to project	0.05	0.68	Client : Participation - Commitment to project	0.05	0.74	Client : Participation - Commitment to project, Internal Owner Requirement	0.08	0.85	Client : Participation - Commitment to project	0.28	0.94	Amplified
									Client : Participation - Involvement in project		0.10	Common to programmes

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Client : Participation - Operations		0.18	Client : Participation - Operations		0.19				Client : Participation - Operations	0.08	0.24	Amplified
Client : User requirements - User requirement definition		0.22	Client : User requirements - User requirement definition		0.24	Client : User requirements - User requirement definition, Internal - Owner Requirement		0.28	Client : User requirements - User requirement definition	0.05	0.46	Common to programmes
						Client : Participation - Involvement in project, Internal - Owner Requirement		0.06				
Project : Plans - Scope definition		0.15	Project : Plans - Scope Definition	0.03	0.17	Project : Plans - Scope definition, Internal - Project Processes		0.19	Project : Plans - Scope Definition	0.05	0.32	Common to programmes
									Project : Plans - Scope definition	0.02		Generic Project
Project : Environment - Environmental incident	0.04		Project : Environment - Environmental incident	0.04					Project : Environment - Environmental incident	0.05		Generic Project
Project : Surveys - Geotech surveys	0.04		Project : Surveys - Geotech surveys	0.05					Project : Surveys - Geotech surveys	0.05	0.23	Generic Project
Project : Commissioning - Acceptance by operator		0.22	Project : Commissioning - Acceptance by operator		0.26				Project : Commissioning - Acceptance by operator		0.47	Generic Project
Project : Operations - Damage to existing facilities		0.22	Project : Operations - Damage to existing facilities						Project : Operations - Damage to existing facilities		0.47	Generic Project

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Societal : Crime - Theft		0.17	Societal : Crime - Theft						Societal : Crime - Theft		0.36	Generic Project
			Construction : Industrial Relations - Industrial unrest						Construction : Industrial Relations - Industrial unrest	0.19	0.15	Amplified
			Economic : Local Economy - Inflation						Economic : Local Economy - Inflation	0.03	0.10	Amplified
			Economic : Local Economy - Resource competition						Economic : Local Economy - Resource competition	0.02	0.20	Common to programmes
			Government : Approvals - Approvals process						Government : Approvals - Approvals process	0.02	0.19	Common to programmes
			Government : Approvals - Approvals processes						Government : Approvals - Approvals processes		0.18	Generic Project
			Natural : Weather - Extreme weather						Natural : Weather - Extreme weather	0.02		Generic Project
			Project : Contractor - Resources						Project : Contractor - Resources	0.02	0.06	Amplified
			Project : Plans - Commissioning Plans						Project : Plans - Commissioning Plans	0.02	0.08	Amplified
			Project : Plans - Program Plans		0.10				Project : Plans - Program Plans	0.02	0.20	Common to programmes
			Project : Commissioning - Training of operational personnel						Project : Commissioning - Training of operational personnel	0.02		Generic Project
			Project : Contractor - Quality defects						Project : Contractor - Quality defects	0.02		Generic Project
			Project : Logistics - Material supply logistics						Project : Logistics - Material supply logistics	0.04	0.12	Amplified

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
			Project : Operations - Existing operations						Project : Operations - Existing operations		0.20	Generic Project
			Project : Project Team - Skills shortage						Project : Project Team - Skills shortage		0.24	Generic Project
			Project : Safety - Hazardous substances		0.10				Project : Safety - Hazardous substances		0.21	Generic Project
			Project : Surveys - Existing services surveys		0.12				Project : Surveys - Existing services surveys		0.21	Generic Project
			Societal : Community participation - Ethics, Public Perception						Societal : Community participation - Ethics, Public Perception		0.14	Common to programmes

Table 5-33: Simulation results compared

6. CONCLUSION

To conclude this research, a reminder about the problem statement, as mentioned in Chapter 1:

How can individual Risk Registers and the Monte Carlo method be used to identify focus areas in a project portfolio?

The research questions were all focused on providing answers to this question and were discussed in great detail in Chapter 2 (Literature Review and Simulation as Research Methodology), Chapter 4 (Developing the Simulation Model) and Chapter 5 (Simulation Results). In addition to this, some further questions were identified in Chapter 5 during which the simulation model was used to understand the risks better and expand the simulation model to form a framework which can be applied to similar sets of quantified risk registers.

Since Table 5-32 contains a summary of the Research Questions and their answers, the only parts of this research report which are still outstanding are as follows and are discussed in this chapter:

- Research contributions.
- Limitations and recommendations for future research.

6.1 Research Contributions

In Section 1.4.3, two academic contributions were briefly discussed and were as follows:

- A unique risk simulation methodology which can be used in a portfolio of programmes to determine the risk ranking.
- Presenting and discussing the unique simulation results in terms of "What matters most?" and "Where to focus?".

After completing and addressing the research questions in some detail, the following additional contributions can be added:

- The development of a unique risk simulation model.
- The uniqueness and quality of the risk data which were collected for port and rail capital projects.
- Simulation Results for a unique set of projects.
- Further support for simulation as research methodology.

Each of these contributions are briefly discussed in this section.

6.1.1 The development of a unique risk simulation model

This is a contribution because, as mentioned in Section 0, limited information was available regarding risk simulation in a portfolio or program of projects, especially for a large, complex portfolio. The process of developing such a simulation model was described in great detail in Chapter 4 and applied in various forms in Chapter 5. The contribution is discussed in terms of the following aspects:

- Using risk classification to determine “What matters most?” and “Where to focus?”
- How the initial Research Roadmap changed into a Risk Simulation Framework.

Using risk classification to determine “What matters most?” and “Where to focus?”

After all the risks had been cleaned up, a total of 165 individual risk names remained. Each of these 165 risk names were classified in the MS Excel model in terms of various risk categories. The final model made provision for the following categories:

- A three level Risk Breakdown Structure.
- Five different choices indicating the extent in which the project team and owners can control the likelihood and consequences related to potential risks.
- Three different choices indicating how the individual risk relates to programmes.

- 165 different short risk names.
- If the project belonged to the *Eight Projects* removed sample or not.
- If the risks causes project execution start delays.
- If the risks are open or already closed out.
- If the risks are related to policies.
- If the risks are related to planning.

None of the texts consulted during this research used classification as extensive as described above. Karim et al. (2012, p. 2) and Rezakhani (2012, p. 30) used a classification related to what is commonly found in risk breakdown structures. The risk breakdown structure they used differed from the one employed in this thesis.

Other classifications were also used, such as Chan et al. (2011, p. 759) and Zou et al. (2006, p. 6) both classified according to Client, Contractor & Consultant as well as Cost, Time, Quality, Environment and Safety. This classification can also be linked to the RBS used in this thesis. Aritua et al. (2011) of course classified according to programme and project risks.

Of great importance is that the classification and research done by the above authors was *qualitative* in nature and could therefore not employ the way in which the various categories were combined in the numerous *quantitative* risk simulations which were conducted as part of this research. It therefore adds another method of ranking risks, as described in Table 2-1.

The use of the various categories in conjunction with each other provided a richer analysis of the simulation results. Using only the risk breakdown structure would not have enabled the simulation results to include such comments like (as collected in Table 5-32):

- The most material differences were found in the means of *Amplified* risks (*Eight Projects Removed* (-34.1%) and *Common to Programme Risks* (*All projects*) (-42.4%).
- Procurement related risks caused the policy related uncertainty for *Common to Programme* risks.
- *Client commitment to project* caused the policy related uncertainty for *Amplified risks*.

The academic contributions from Research Questions 3, 4 and 5 could not have been made without the risk classification as described in this section.

How the initial Research Roadmap changed into a Risk Simulation Framework

Neither Palisade (2014) nor Vose (2014) explicitly discusses the way in which a simulation model can be developed to rank the risks in a portfolio of programmes/projects. This process is described in detail in Chapter 4. This part is indicated by the colour yellow in

Figure 6-1.

The simulation model however, is not a free-standing entity and consists of two additional parts. The first is the data used in the simulations and the second the questions which were asked to determine *"What matters most?"* and *"Where to focus?"*. This part is indicated by the colour blue in

Figure 6-1.

The initial research questions were only the starting point in creating the framework which was eventually used to determine the outcomes and recommendations to the research questions. The questions contributing to this framework are indicated by the colour green in

Figure 6-1..

The research contribution therefore sits in the three part Simulation Framework as presented in

Figure 6-1. Should anyone wish to do an analysis on a set of quantified risks registers, this framework can be used to determine *"What matters most?"* and *"Where to focus?"*.

It should be noted that the block called “Data” in in

Figure 6-1 implies that the data needs to be consolidated and cleaned-up before the simulations can be executed, in such future research.

It should also be noted that the list of questions green in in

Figure 6-1 is by no means complete but provides some guidance regarding what is possible and how it can be applied. Figure 5-67 should also assist in understanding how the simulation model works and can be read in conjunction with in

Figure 6-1.

Since the work done is based large on the ISO31000:2009 Risk Management process, it implies that the methodologies followed and the simulation model developed, could be practically applied in any project risk management context. For example, Research and Development projects also have risk breakdown structures, project categories, risk registers, risk identification workshops, quantified risk registers, controllable and uncontrollable risks, risks related to planning, policies and so forth. It means however, for example, that the project categories might differ, according to the context. This does not detract in any manner in which the model functions. It takes “risk categories” not “risk categories related to port and rail projects” as an input.

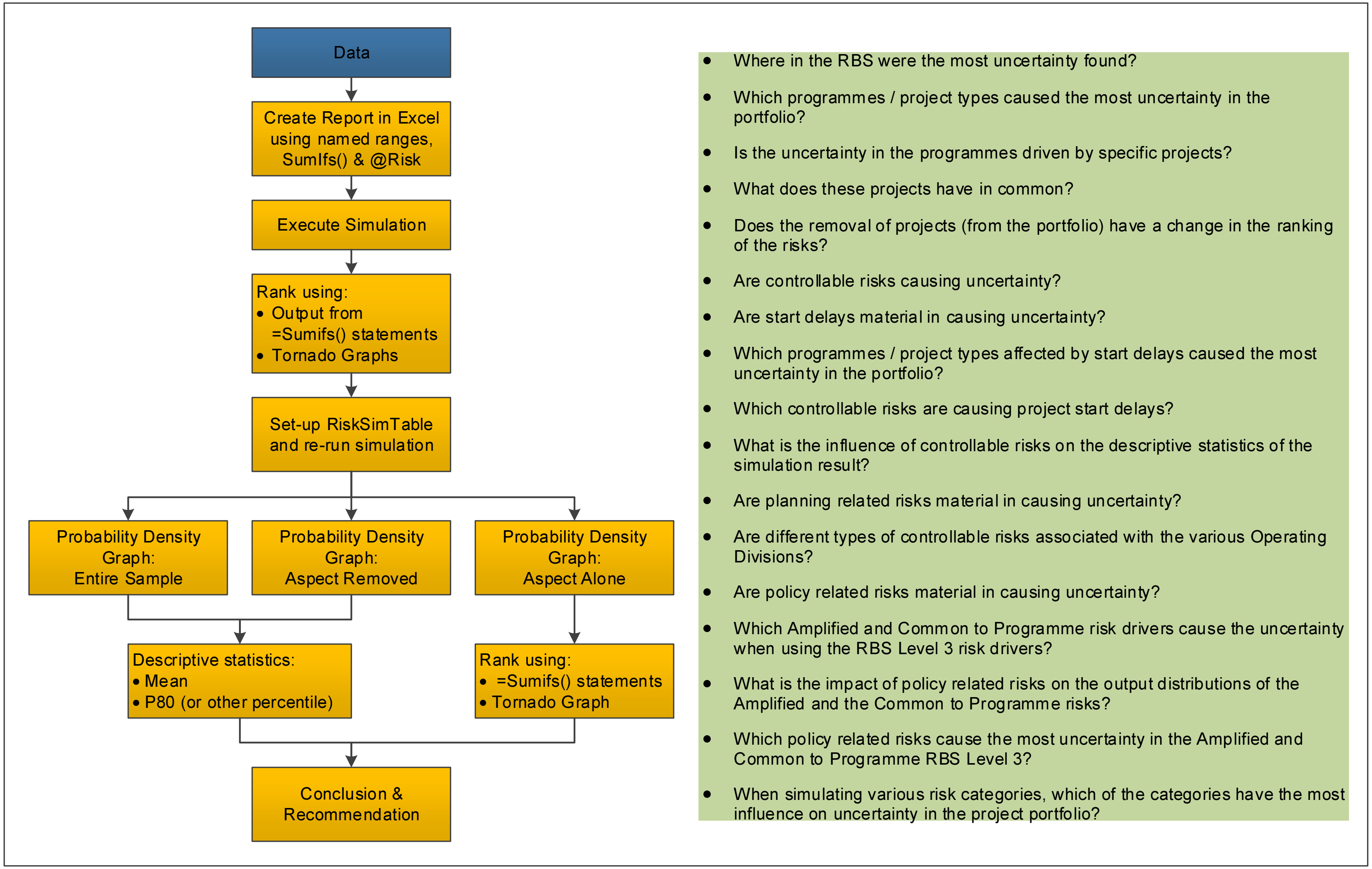


Figure 6-1: Risk simulation framework

6.1.2 The uniqueness and quality of the risk data which were collected for port and rail capital projects.

This is a unique contribution because, as mentioned in Section 0, research on risks related to port and rail capital projects was mostly confined to safety risks related to subways and environmental risks related to ports. The data used in the simulation model was collected from port and rail capital projects over a 3 year period using the prescribed processes and procedures as described in this thesis. Risks were captured during regular risk workshops which were attended by between 2 and 20 participants. This section is discussed in terms of the following:

- Lessons learned during the data collection process.
- The quantity and quality of the collected data.

Lessons learned during the collection process

Since the amount of risk data for port and rail projects have not been collected previously, in at least the South African context, problems encountered during this process are also worth mentioning. The common factor between all the lessons is that they all placed constraints on the data collection process. These lessons are as follows and are discussed in the next two sections:

- The risk model was over simplified and required rework.
- Availability of skilled risk managers able to do quantitative risk analysis.

Over simplified risk model

The initial model was developed in conjunction with a consultant and after implementation required some improvements, mainly because the simulation model couldn't model some of the risks which were identified during the risk workshops. These improvements included the following:

- Accommodate the simulation modelling of multiple occurrence risks.
- Accommodate both time variable cost as well as additional capital cost.

The implication of this is that 25 out of 86 risk registers could not model all the implications of a risk, should it realise. These 25 projects represent 249 (27.0%) out of a total of 921 open risks. Of these 249 risks, 198 are individual risks (representing 42 risk names) which, in the rest of the sample, are treated as multiple-occurrence risks. This means that some of the risk consequences might be under estimated because the multiple occurrence risks were modelled as single occurrence risks.

The contribution then sits in this lesson as well as the way in which the model is able to handle both single and multiple occurrence risks, as shown in Figure 3-6.

Availability of skilled risk managers able to do quantitative risk analysis

This was the most significant problem encountered during the roll-out of quantitative risk assessments at the case study organization. It limited the number of projects which could form part of the programme and limited the number of follow-up meetings which could take place.

The following combination of knowledge and skills is required to use the RRT:

- Project Management.
- Technical knowledge of construction projects.
- Risk Management.
- Excel.
- @Risk (or similar software).
- Quantitative Methods.

As an initial attempt, two graduate trainees with a financial modelling background were appointed. They took nearly a year to be able to run risk workshops of simple projects. A later appointment with a BTech Mechanical degree was able to operate independently after 3 months. The lesson was that it is easier to teach technical people quantitative methods and @Risk than it was teaching financial people technical projects, at least in this case environment.

The lesson here is therefore that dedicated training programmes need to be put in place to ensure that risk practitioners would be able to manage complex capital projects.

Quantity and quality of data for Port and Rail projects

In Section 2, the lack of project risk information related to port and rail capital projects is discussed in great detail. From the risks registers used in this research, a total of 1 063 risks appeared in the simulation model of which 783 (73.7%) were open. The open risks were found throughout the RBS. The closed risks were identified by not having three-point estimates for either *Time Delay* or *Additional Capital Costs*. Open Risks represented 73.7% of the total number of risks of which Project related risks contributed 69.7%. A total of 165 individual risks were identified and were used during risk classification in the various research questions.

RBS LEVEL 1	CLOSED RISKS		OPEN RISKS		TOTAL	
Project	220	78.6%	546	69.7%	766	72.1%
Client	16	5.7%	68	8.7%	84	7.9%
Construction	11	3.9%	50	6.4%	61	5.7%
Societal	13	4.6%	44	5.6%	57	5.4%
Government	6	2.1%	37	4.7%	43	4.0%
Natural	7	2.5%	34	4.3%	41	3.9%
Economic	7	2.5%	4	0.5%	11	1.0%
TOTAL	**280**	**100%**	**783**	**100%**	**1063**	**100%**
	26.3%		**73.7%**		**100%**	

Table 6-1: RBS Level 1 and Risk Status

After the data had been clean-up, 165 individual risk names were identified. The 44 risk names which contribute 80% of the total number of risks in the CRR appear in Table 6-2.

	RISK NAME	CLOSED	OPEN	GRAND TOTAL	CUMULATIVE %
1	Safety non-compliance	13	75	88	8.3%
2	Labour unrest	11	50	61	14.0%
3	Damages to underground services	4	47	51	18.8%
4	Crime	11	37	48	23.3%
5	Occupations	5	35	40	27.1%
6	Inclement weather	4	33	37	30.6%
7	Environmental non-compliance	12	23	35	33.9%
8	Disrupt operations	9	25	34	37.1%
9	Long lead items	13	19	32	40.1%
10	Scope definition	7	23	30	42.9%
11	Skills & Resources	11	19	30	45.7%
12	Geotech	6	18	24	48.0%
13	Late material delivery	1	18	19	49.8%
14	Late order placement	10	8	18	51.5%
15	Approval delays	5	12	17	53.1%
16	RME capacity	4	12	16	54.6%
17	Site congestion	6	10	16	56.1%
18	Operational readiness	7	8	15	57.5%

	RISK NAME	CLOSED	OPEN	GRAND TOTAL	CUMULATIVE %
19	Asbestos	2	13	15	58.9%
20	Contractor Quality	4	10	14	60.2%
21	Equipment breakdown	4	10	14	61.5%
22	Site access	4	9	13	62.7%
23	Late tender documentation	3	10	13	64.0%
24	Underground conditions	8	4	12	65.1%
25	Traffic congestion	5	7	12	66.2%
26	Design Approvals	1	11	12	67.4%
27	Design Change	3	8	11	68.4%
28	Site access - Operational requirements	2	9	11	69.4%
29	Eskom	5	5	10	70.4%
30	Soil contamination	1	8	9	71.2%
31	Damage to assets	2	7	9	72.1%
32	Material shortage	7	2	9	72.9%
33	Procurement delays	3	5	8	73.7%
34	Equipment unavailable	3	5	8	74.4%
35	Stakeholder commitment	3	5	8	75.2%
36	Environmental Approval Delay	2	6	8	75.9%
37	Planning	2	5	7	76.6%
38	Compressed schedule	3	3	6	77.1%
39	Community riots	2	4	6	77.7%
40	Land acquisition	1	5	6	78.3%
41	Bill of Quantity omissions	5	1	6	78.8%
42	Unreliable contractor		5	5	79.3%
43	Unknown entities	2	3	5	79.8%
44	Inexperienced contractor		5	5	80.2%

Table 6-2: Cleaned-up risk names

A contribution is therefore the list of risk names related to port and rail capital projects. This list can be used as a checklist during the risk identification process for similar projects.

6.1.3 Simulation Results for a unique set of projects

As mentioned in Chapter 1, the data on which the risk simulation results are based never existed in the South African context before. This means that the risk simulation results are also new and therefore add to the body of knowledge on project management and project risk management. This contribution is further discussed in terms of the following:

- What *really* matters most?
- Risk quantification supporting qualitative research on the importance of managing programme related risks.
- New ways of representing project risk related data in simple diagrams and tables.

What really matters most?

From the initial five research questions which directly involved MS Excel and @ Risk, a total of 20 new questions were developed during this research. The research also produced at least 33 different sets of simulation results. This included the use of *=RiskSimtable()* where in some cases, up to six simulations were executed in sequence.

The most important set of simulation results, sits in the question regarding which of the various risk categories caused the most uncertainty in the project portfolio. This was discussed in detail in Section 5.7 where it was concluded that the main drivers of risk in the project portfolio were (ranked in order of descending importance):

- Project Complexity.
- Controllable Risks.
- Project Start Delay Risks.
- Planning Named Risks.
- Policies.

This result is displayed in Table 6-3 which includes six different sets of data. In each set, a category of risks were removed and S-curves were created.

All the risks from all the projects appear in the graph on the right hand side. The category which has the most influence on the project portfolio is Project Complexity (the blue S-curve). This means that complex projects with long lead times contributes the most to uncertainty in the project portfolio. The second most important factor is the purple curve representing controllable risks. The next is start delay risks and so forth.

One can argue that the policy related risks have the smallest impact. But when presenting the descriptive statistics of these graphs (Table 6-3), the difference between the mean values of these two graphs represents R654.02 million - a material amount. The table is ranked according to the risk category which caused the biggest shift in *All Projects* S-curve.

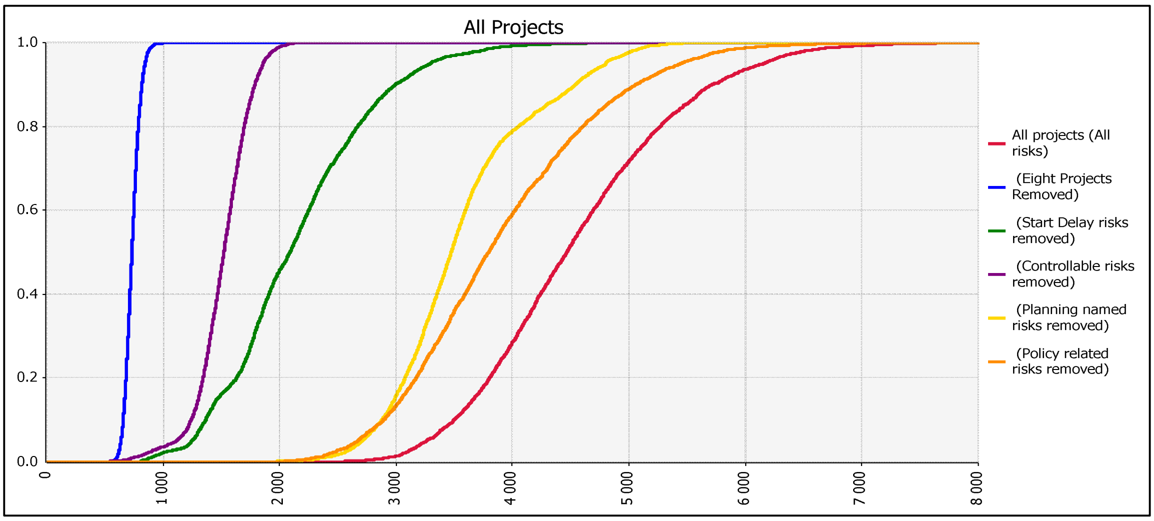


Figure 6-2: *Eight Projects Removed* S-curve

RANK	ALL PROJECTS	MEAN	DIFF MEAN	%
1	Eight Projects Removed	R 735.0	- R 3 815.2	-83.9%
2	Controllable risks removed	R 1 507.8	- R 3 042.4	-66.9%
3	Start Delay risks removed	R 2 148.6	- R 2 401.6	-52.8%
4	Planning named risk removed	R 3 570.9	- R 979.3	-21.5%
5	Policy related risks removed	R 3 896.2	- R 654.0	-14.4%
	All Risks	R 4 550.2	-	

Table 6-3: *All Projects* S-curve descriptive statistics

The (perhaps very obvious) lesson is that in the context of the case study organisation, the ability to manage controllable risks sits at the heart of successful project execution.

Risk quantification supporting qualitative research on the importance of managing programme related risks

The category related to programme risks (amplified and common to) did not form part of the initial research questions in this research. It was added as a research question after reading Aritua et al.'s work on Common or Amplified risks in programmes (Aritua, et al., 2011, p. 303) because it seemed applicable to the context in which the case study organisation plans and executes capital projects.

Aritua et al.'s research was limited to quantitative research based on 34 interviews (Aritua, et al., 2011, p. 307) whereas this research is based on 86 quantified risk registers which each went through at least two iterations.

The risk simulation results quantitatively confirms Aritua's argument (2011, p. 310) that the need exists to distinguish between projects and programmes as management functions in the project environment. All the risk simulation results related to this research question supported the hypothesis that in this context, risk which are *Common to Programmes* and *Amplified risks* influence uncertainty in the project portfolio.

The implication of this is that treatment plans and associated controls should be implemented on a programme and portfolio level to ensure that the potential likelihood/frequency and/or impact of these risks can be reduced.

New ways of representing project risk related data in simple diagrams and tables

During this research, various graphical representation techniques were developed. Some were discarded after consultation with Palisade (Oldfield, 2014). Two of the methods used however, were found to be very successful when presenting some of the risk simulation results to various stakeholders. They were as follows:

- Comparing different sets of regression coefficients using tree diagrams.
- Combining various risk categories in tables.

Comparing different sets of regression coefficients using tree diagrams

@Risk software does not allow tornado graphs based on different simulations runs to be plotted on the same graph and a way had to be created to present simulation results from two data sets with each other, using the tornado graphs as input.

This was used to show that the tornado graphs from two samples (*All projects* vs. *Eight Projects Removed*) had different risk drivers. For each sample (in this case the *All Projects* and *Eight Projects removed* samples), three sets of coefficients (RBS Level 1, Level 2 and 3) were all plotted on one diagram, presenting (sort of) a tree fallen on its side. It is also similar to an organogram turned 90° anti-clockwise (Figure 6-3).

This worked particularly well since @Risk allows various probability denting graphs to be plotted on the same graph but not tornado graphs. The colour coding applied helped to identify the problem areas. A fourth level - the Short Risk names - could also be added to the sideways trees.

The contribution therefor can be found in how easy it is to identify where the focus areas should be when comparing two sets of projects. The result of this comparison could be (as in the case of the case study organisation), that different risk drivers affect different projects and that tailored treatment plans should therefore be developed and implemented.

Combining various risk categories in tables

This was used to represent the risk simulation results from Research Questions 3 to 6 on the same table. The results from Research Questions 3 to 6 were combined in a single table (Table 6-4).

Each of the research questions appear as headings to the table which was ranked according to the regression coefficient of the risk drivers as identified in Research Question 3, taking the entire project portfolio into consideration. The risks were also arranged in such a manner that the risk simulation results of risks which are related all appear in the same rows.

The table can be used as a decision making tool based on specific user focus. It is best illustrated using an example.

An organisation wants to identify those *Common to Programme* risk drivers to reduce uncertainty in the project portfolio. They would then select the high ranking risks in the column called *Type*. How these risks relate to the other risk drivers (Overall risks and Project Start Delay risks) can then be read from the table.

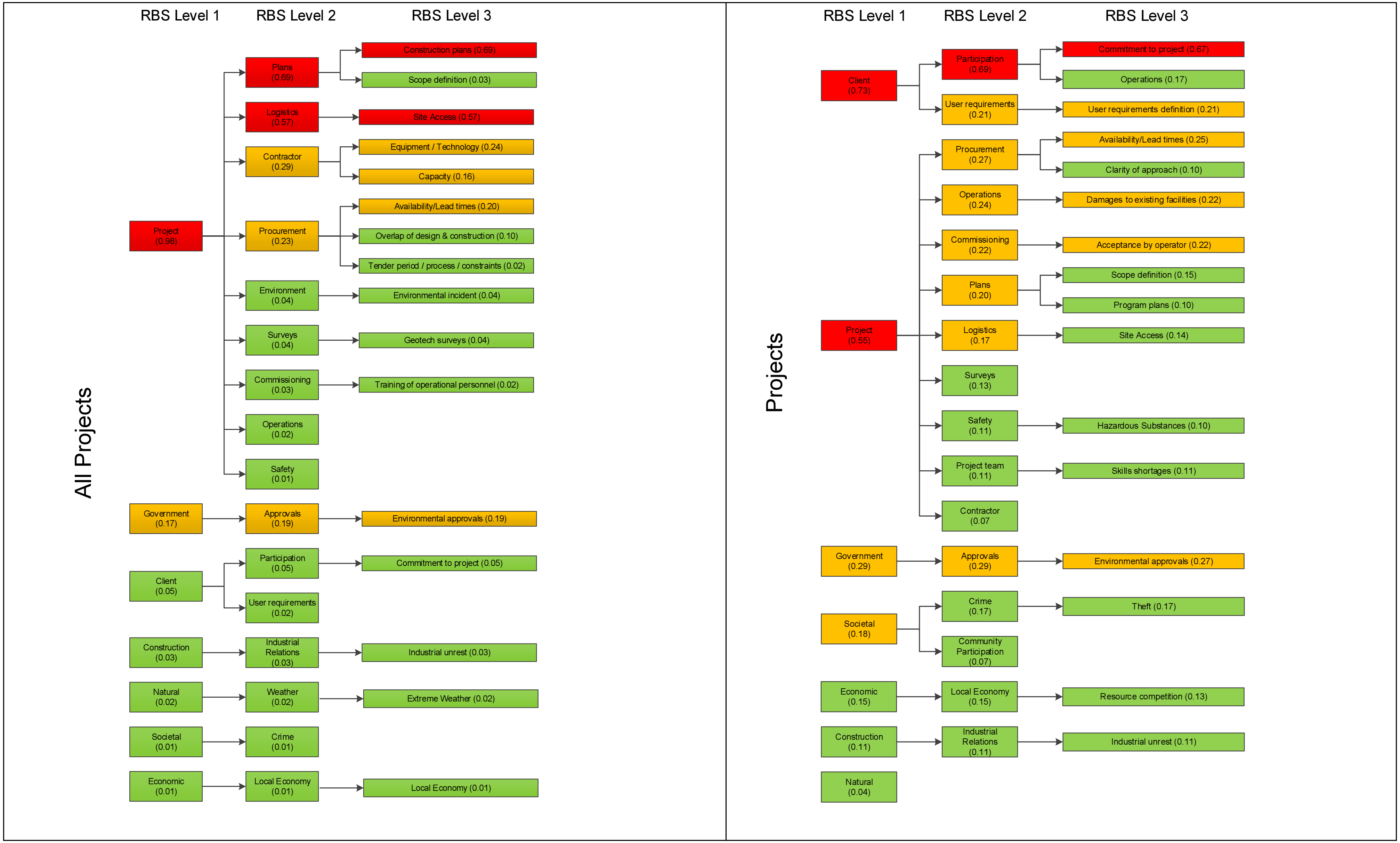


Figure 6-3: Tornado graphs presented as trees

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Project : Plans - Construction plans	0.70		Project : Plans - Construction Plans	0.71	0.17				Project : Plans - Construction Plans	0.03	0.10	Amplified
									Project : Plans - Construction plans	0.75		Generic Project
Project : Logistics - Site access	0.57	0.14	Project : Logistics : Site access	0.56	0.14	Project : Logistics - Site access, External - Influencable	0.16	0.06	Project : Logistics : Site access	0.34		Common to programmes
						Project : Logistics - Site access, Internal - Operational	0.83	0.04	Project : Logistics - Site access	0.60	0.28	Generic Project
						Project : Logistics - Site access, Internal - Project Processes	0.14					
Project : Contractor - Contractors' Equipment/Technology	0.24		Project : Contractor - Contractors' Equipment/Technology	0.24					Project : Contractor - Contractors' Equipment/Technology	0.26		Generic Project
Project : Procurement - Availability/lead times	0.20	0.25	Project : Procurement - Availability/Lead times	0.20	0.26	Project : Procurement - Availability/lead times, Internal - Project Processes	0.29		Project : Procurement - Availability/Lead times	0.67	0.51	Common to programmes
						Project : Procurement - Clarity of approach, Internal - Project Processes		0.12	Project : Procurement - Clarity of approach	0.02	0.20	Common to programmes
						Project : Procurement - Tender period/process/constraints, Internal - Project Processes	0.03	0.07	Project : Procurement - Tender Period/process/constraints	0.07		Common to programmes

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Government : Approvals - Environmental approvals	0.19	0.27				Government : Approvals - Environmental approvals, External - Influencable	0.19		Government : Approvals - Environmental Approvals	0.64	0.52	Common to programmes
						Government : Approvals - Environmental approvals, External - Uncontrollable	0.22	0.34	Government : Approvals - Environmental approvals		0.18	Generic Project
						Government : Approvals - Approval Conditions, External - Influencable		0.11				
Project : Contractor - Capacity	0.16		Project : Contractor - Capacity	0.17		Project : Contractor - Capacity, External - Influencable	0.25		Project : Contractor - Capacity	0.93		Amplified
Project : Procurement - Overlap of design and construction	0.10		Project : Procurement - Overlap of design and construction	0.10		Project : Procurement - Overlap of design and construction, Internal - Project Processes	0.15		Project : Procurement - Overlap of design and construction	0.11		Generic Project
Client : Participation - Commitment to project	0.05	0.68	Client : Participation - Commitment to project	0.05	0.74	Client : Participation - Commitment to project, Internal Owner Requirement	0.08	0.85	Client : Participation - Commitment to project	0.28	0.94	Amplified
									Client : Participation - Involvement in project		0.10	Common to programmes

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Client : Participation - Operations		0.18	Client : Participation - Operations		0.19				Client : Participation - Operations	0.08	0.24	Amplified
Client : User requirements - User requirement definition		0.22	Client : User requirements - User requirement definition		0.24	Client : User requirements - User requirement definition, Internal - Owner Requirement		0.28	Client : User requirements - User requirement definition	0.05	0.46	Common to programmes
						Client : Participation - Involvement in project, Internal - Owner Requirement		0.06				
Project : Plans - Scope definition		0.15	Project : Plans - Scope Definition	0.03	0.17	Project : Plans - Scope definition, Internal - Project Processes		0.19	Project : Plans - Scope Definition	0.05	0.32	Common to programmes
									Project : Plans - Scope definition	0.02		Generic Project
Project : Environment - Environmental incident	0.04		Project : Environment - Environmental incident	0.04					Project : Environment - Environmental incident	0.05		Generic Project
Project : Surveys - Geotech surveys	0.04		Project : Surveys - Geotech surveys	0.05					Project : Surveys - Geotech surveys	0.05	0.23	Generic Project
Project : Commissioning - Acceptance by operator		0.22	Project : Commissioning - Acceptance by operator		0.26				Project : Commissioning - Acceptance by operator		0.47	Generic Project
Project : Operations - Damage to existing facilities		0.22	Project : Operations - Damage to existing facilities						Project : Operations - Damage to existing facilities		0.47	Generic Project

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
Societal : Crime - Theft		0.17	Societal : Crime - Theft						Societal : Crime - Theft		0.36	Generic Project
			Construction : Industrial Relations - Industrial unrest						Construction : Industrial Relations - Industrial unrest	0.19	0.15	Amplified
			Economic : Local Economy - Inflation						Economic : Local Economy - Inflation	0.03	0.10	Amplified
			Economic : Local Economy - Resource competition						Economic : Local Economy - Resource competition	0.02	0.20	Common to programmes
			Government : Approvals - Approvals process						Government : Approvals - Approvals process	0.02	0.19	Common to programmes
			Government : Approvals - Approvals processes						Government : Approvals - Approvals processes		0.18	Generic Project
			Natural : Weather - Extreme weather						Natural : Weather - Extreme weather	0.02		Generic Project
			Project : Contractor - Resources						Project : Contractor - Resources	0.02	0.06	Amplified
			Project : Plans - Commissioning Plans						Project : Plans - Commissioning Plans	0.02	0.08	Amplified
			Project : Plans - Program Plans		0.10				Project : Plans - Program Plans	0.02	0.20	Common to programmes
			Project : Commissioning - Training of operational personnel						Project : Commissioning - Training of operational personnel	0.02		Generic Project
			Project : Contractor - Quality defects						Project : Contractor - Quality defects	0.02		Generic Project
			Project : Logistics - Material supply logistics						Project : Logistics - Material supply logistics	0.04	0.12	Amplified
			Project : Operations - Existing operations						Project : Operations - Existing operations		0.20	Generic Project

Research Question 3 - Overall, where in the RBS	All	Eight Removed	Research Question 4 - Controllable risks	All	Eight Removed	Research Question 5 - Project Execution Start Delays	All	Eight Removed	Research Question 6 - Programme Type Risks	All	Eight Removed	Type
			Project : Project Team - Skills shortage						Project : Project Team - Skills shortage		0.24	Generic Project
			Project : Safety - Hazardous substances		0.10				Project : Safety - Hazardous substances		0.21	Generic Project
			Project : Surveys - Existing services surveys		0.12				Project : Surveys - Existing services surveys		0.21	Generic Project
			Societal : Community participation - Ethics, Public Perception						Societal : Community participation - Ethics, Public Perception		0.14	Common to programmes

Table 6-4: Simulation results in one table

6.1.4 Further support for simulation as research methodology

Axelrod (1997) suggested that there are three research purposes of simulation models:

- Prediction - The analysis reveals relationships among variables, for example: *"For new projects, it can be expected that the contingency requirements for Rail projects will be half that of Port projects"*. The outcome of the research is applied on future projects.
- Proof - A simulation can show that it is possible for the simulation modelled processes to produce certain types of behaviour, for example: "*The simulation model supplies evidence that the biggest risks are associated with Scope Definition"*. The outcome of the research is compared to an expected outcome.
- Discovery - Simulations can be used to discover unexpected consequences of the interaction of simple processes, for example "When run at the same time, the combined consequence of 34 instances of Risk A across the project portfolio of 86 projects is bigger than the consequence of 2 instances of Risk B" or "The risks category with the highest P80 value is Category XYZ". The outcome of the research is new.

The academic contribution is associated with allocating the answers of the risk simulation results to the various categories. This provides support to Axelrod's argument, specifically related to the simulation of risks in a capital project portfolio.

The results were therefore compared to the three categories as in Table 6-5. During the classification process, the placement of answers into the *Prediction* and *Proof* categories were not always clear cut. What falls in the Proof category, could be used to predict future behaviour. This however, does not detract from using the research results to support his arguments that simulation is a valid research method.

RESEARCH QUESTION		PREDICTION (Simulation reveals relationships among variables and the outcome can be applied on future projects)	PROOF (Simulation produces certain types of behaviour where the outcome compared to an expected outcome)	DISCOVERY (Simulations used to discover unexpected consequences)
3.	How is the simulation model used to identify focus areas in the risk simulation results when taking programmes and the RBS into consideration?		• It was expected and proven that: • The most uncertainty was found in the Project environment followed by Government. • Large complex projects with long procurement cycles cause the most uncertainty.	• It was discovered: • Which programmes caused the most uncertainty. • Which projects caused the most uncertainty. • That there are different risk drivers in smaller projects (client environment) and large complex projects (project environment).
4.	When simulating the risks in a portfolio of programmes, are controllable risks material in causing uncertainty?		• It was expected and proven that controllable risks are material causing uncertainty in the project portfolio.	• It was discovered: • The uncertainty caused by Controllable risks by far outweighs the uncertainty caused by Not Controllable risks (Table 5 12).
5.	When simulating controllable project execution start delay risks, where should the focus area be?	• When turning off all the controllable risks, the mean of the output distribution reduces by 2 476 billion (50.8%).	• It was expected and proven that: • Project start delays matter in the project portfolio and caused the most uncertainty in the large complex projects with long procurement cycles.	• *Construction Plans* caused the most uncertainty in the *All Projects* sample and in the *Eight Projects Removed* sample, it was *Scope Definition*. • The ranking of risks related to the ODs differ for all samples which indicates that there are structural/business reasons for the risk rankings to differ.

RESEARCH QUESTION		PREDICTION (Simulation reveals relationships among variables and the outcome can be applied on future projects)	PROOF (Simulation produces certain types of behaviour where the outcome compared to an expected outcome)	DISCOVERY (Simulations used to discover unexpected consequences)
5.	When simulating controllable project execution start delay risks, where should the focus area be?	• Planning related risks are material causing uncertainty in the project portfolio since removing them, reduces the P80 value by 23.9%.	• Project start delays were caused by Client Participation - Commitment to project, Contractor - Capacity and Environmental approvals. • Planning delays are material causing uncertainty.	• Procurement related risks caused the policy related uncertainty for *Common to Programme* risks. • Client commitment to project caused the policy related uncertainty for *Amplified risks*.
6.	When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?		• It was expected and proven that: • Common to Programme and Amplified risks are material to both the All Projects and Eight Projects Removed samples.	• For large complex projects, *Generic Project* risks causes the most uncertainty and the smaller projects, *Amplified risks* are responsible • The Top 5 *Amplified risks* were Contractor - Capacity, Client Participation - Commitment to project, Industrial Relations - Industrial unrest, Client Operations and Material supply logistics • The Top 5 *Common to Programme* risks were Procurement - Availability/Lead times, Environmental Approvals, Site access, Procurement - Tender Period/process/constraints and User requirement definition

RESEARCH QUESTION		PREDICTION (Simulation reveals relationships among variables and the outcome can be applied on future projects)	PROOF (Simulation produces certain types of behaviour where the outcome compared to an expected outcome)	DISCOVERY (Simulations used to discover unexpected consequences)
6.	When simulating the risks in a portfolio of programmes, are the risks related to programmes material in causing uncertainty?			• *Procurement* related risks caused the policy related uncertainty for *Common to Programme* risks. • *Client commitment to project* caused the policy related uncertainty for *Amplified risks*.
7.	When simulating various risk categories, which of the categories have the most influence on uncertainty in the project portfolio?			• In this context, the extent of which treatment plans are implemented and managed for Controllable risks, is what matters most.
8.	How does the contingency requirement in a portfolio of programmes compare to the contingency requirement of the sum of the individual project's requirements?		• Because of the large spread of contingency estimates, rules of thumb regarding uncertainty are not appropriate in estimating contingency requirements in capital projects.	

RESEARCH QUESTION		PREDICTION (Simulation reveals relationships among variables and the outcome can be applied on future projects)	PROOF (Simulation produces certain types of behaviour where the outcome compared to an expected outcome)	DISCOVERY (Simulations used to discover unexpected consequences)
9.	How does the simulated contingency requirements compare when using rules of thumb?	•	• The executing of a concurrent Monte Carlo simulation on the entire portfolio reduces the contingency requirement by between 16.2% and 20.4% in comparison to the P80 values of the individual risk registers.	•

Table 6-5: Simulation results categorised according to research purpose

6.2 Limitations and Recommendations for future research

There are broadly two recommendations for future research, based on the following two related topics:

- Limitations of the research.
- Additional risk categories.

6.2.1 Limitations of the research and associated recommendations

During the initial phases of the implementation of a risk quantification approach at the case study organisation, focus was placed on risks associated with project execution. This means that risks associated with project development were not necessarily taken into consideration. The implication of this is that the risk simulation results associated with project planning might be understated.

The fact that the data was collected in only one company might also be seen as a limitation. This however, does not detract from the simulation model which was developed and tested by using the data from just on company.

It is therefore suggested, that should the research be replicated, these issues be addressed:

- During the risk identification workshops, risks which are associated with the project development should be specifically considered as these risks tend to delay project execution start, which in turns increase project cost and delays benefit realisation.
- The initial RRT which was used didn't not make provision for multiple occurrence risks and could only accommodate variable cost OR additional capital cost. The implication of this is that 25 out of 86 risk registers do not make provision for these risks and model and therefore might be underestimating the output distributions for these particular projects and the related risk categories. These 25 projects represents 249 (27.0%) out of a total of 921 open risks. Of this 249, 198 are individual risks (representing 42 risk names) which, in the rest of the sample, are treated as multiple-occurrence risks.

- The methodology should be applied in a different context to establish if the model applies and if the results can be replicated.

6.2.2 Recommendations for future research

As this research progressed, various opportunities for future research were identified. The first of this was to expand the research to include other risk categories such as:

- The influence of where the project is being executed in terms of brownfield or greenfield projects and the other categories as described in Section 4.3.1.
- When looking at equipment projects, is *like-for-like replacement/like-for-better replacement* or *refurbishment* relevant in determining the project risk drivers?
- The ranking of risks related to specific ODs were different. The reason for this might be the scope of the projects or internal or related reasons. The specific reasons for this could be researched further.

The most important recommendation however, is as follows:

The main finding related to *"What matters most?"* and *"Where to focus?"* was that the case study organisation itself was the cause for the most uncertainty in their project portfolio. The reasons for this should be further researched and the appropriate treatment plans developed and implemented.

To do this, the risk sources (as already contained in the CRR), can be cleaned up, analysed and used to created questionnaires which can be used to interview the executive management, identify the main causes of these and implement appropriate treatment plans. It will, after all, close the Communication and Consultation, Monitor and Review aspect of the ISO31000:2009 risk management process related to the outcomes of this research.

7. BIBLIOGRAPHY AND LIST OF REFERENCES

Akintoye, A. & MacLeod, M., 1996. Risk analysis and management in construction. *International Journal of Project Management,* 15(1), pp. 31-38.

Albert, A. & Hallowell, M., 2013. Safety risk management for electrical transmission and distribution line construction. *Safety Science,* 51(1), pp. 118-126.

Alises, A. et al., 2014. Overtopping hazards to port activities: Application of a new methodology to risk management. *Reliability Engineering & Systems Safety,* Volume 123, pp. 8-20.

American Society of Safety Engineers, 2011. *American National Standard: ISO31010 Risk Assessment Techniques.* Des Plaines, Illinois: American National Standards Institute Inc.

American Society of Safety Engineers, 2011. *American National Standards: Risk Assessment Techniques.* Des Plaines, Illinois: American Society of Safety Engineers.

American Society of Safety Engineers, 2011. *ANSI/ASSE/ISO Guide 73 (Z690.1-3011) Vocabulary for Risk Management.* Des Plaines, Illinois: American Society of Safety Engineers .

Aritua, B., Smith, N. & Bower, D., 2009. Construction client multi-projects - A Complex adaptive systems perspective. *International Journal of Project Management,* 27(1), pp. 72-79.

Aritua, B., Smith, N. & Bower, D., 2011. What risks are common to or amplified in programmes: Evidence from UK public sector infrastructure schemes. *International Journal of Project Management,* 29(3), pp. 303-312.

Axelrod, R., 1997. The complexity of cooperation: Agnet-based models of competition and collaboration. Princeton, New York: Princeton University Press.

Baccarini, D., 1996. The concept of project complexity - a review. *International Journal of Project Management,* 14(4), pp. 201-204.

Barkley, B., 2004. *Project Risk Management.* 1st ed. New York: McGraw-Hill.

Berends, P. & Romme, G., 1999. Simulation as a Research Tool in Management Studies. *European Management Journal,* 17(6), pp. 576-583.

Blumberg, B., Cooper, D. & Schindler, P., 2008. *Business Research Methods.* 2nd ed. Maidenhead, Berkshire: McGraw-Hill Higher Education.

Broadleaf Capital International Pty. Ltd., 2014. *Weaknesses in common project cost risk modelling methods.* Cammeray: Broadleaf Capital International Pty. Ltd.

Business Day, 2013. *http://www.bdlive.co.za/africa/africanbusiness/2013/12/18/mozambique-raises-coal-railway-port-project-costs-to-5bn.* [Online] Available at: http://www.bdlive.co.za/africa/africanbusiness/2013/12/18/mozambique-raises-coal-railway-port-project-costs-to-5bn
[Accessed 09 07 2014].

Carr, V. & Tah, J., 2001. A fuzzy approach to construction project risk assessment and analysis: construction project risk management system. *Advances in Engineering Software,* 32(10-11), pp. 847-857.

Chan, D. C. A., Lam, P. & Yeung, J. C. J., 2011. Risk ranking and analysis in target cost contacts: Empirical evidence from the construction industry. *International Journal of Project Management,* 29(6), pp. 751-763.

Chapman, C. & Ward, S., 2000. Estimating and evaluation of uncertainty: a minimalist fist pass approach. *International Journal of Project Management,* 18(6), pp. 369-383.

Chapman, C. & Ward, S., 2011. *How to Manage Project Opportunity and Risk.* 1st ed. Chichester: John Wiley & Sons Limited.

Chapman, R., 1998. The effectiveness of working group risk identification and assessment techniques. *International Journal of Project Management,* 16(6), pp. 333-343.

Chou, J., 2011. Cost simulation in an item-based project involving construction engineering and management. *International Journal of Project Management 29,* Volume 29, pp. 706-717.

Cooper, D., Grey, S., Raymon, G. & Walker, P., 2005. *Project Risk Management Guidelines.* Chischester: John Wiley & Sons Limited.

Cox, L., 2008. What's wrong with Risk Matrices?. *Risk Analysis,* 28(2), pp. 497-512.

Crawford, L., Hobbs, J. & Turner, R., 2004. Project Categorization Systems and their Use in Organisations: an empirical study. London, PMI Research Conference.

Cruz, C. & Marques, R., 2013. Flexible contracts to cope with uncertainty in public-private partnerships. *International Journal of Project Management,* 31(3), pp. 473-483.

Dali, A., 2013. Certification in ISO 31000 (3 day masterclasses). Cape Town, G3100.

Dartmouth College, 2015. *Dartmouth College.* [Online] Available at: http://www.dartmouth.edu/~control/capitalproj/index.html [Accessed 12 06 2015].

Edwards, P. & Bowen, P., 2005. *Risk management in project organisations.* 1st ed. Oxford: Elsevier.

Elshaer, R., 2013. Impact of sensitivity information on the prediction of project's duration using earned schedule method. *International Journal of Project Management,* 31(4), pp. 579-588.

Eppen, G., Gould, F. & Schmidt, C., 1988. *Quantitative concepts for management: decision making without algorithms.* 3rd ed. Engelwood Cliffs, New Jersey: Prentice-Hall.

Evaristo, R. & van Fenema, P., 1999. A typology of project management: emergence and evolution of new forms. *International Journal of Project Management,* 17(5), pp. 275-281.

Fang, Q., Zang, D. & Wong, L., 2011. Environmental risk management for cross interchange subway station construction in China. *Tunnelling and underground space technology,* 26(6), pp. 750-763.

Flyvbjerg, B., Bruzelius, N. & Rothengatter, W., 2003. *Megaprojects and risk - an anatomy of ambition.* 1st ed. Cambridge: Cambridge University Press.

Gilfillan, M., 2012. *Risk Register Template* [Interview] 2012.

Harrison, R., Lin, Z., Carroll, G. & Carley, K., 2007. Simulation modelling in organizational and management research. *Academy of Managment Review,* Volume 32, pp. 1229-1245.

Hillson, D., 2002. Use a Risk Breakdown Structure (RBS) to understand your risks. San Antonio, Texas, USA, s.n.

Hillson, D., 2009. *Managing Risk in Projects.* 2nd ed. Farnham: Gower Publishing Limited.

Huang, H., 2006. State-of-the-Art of the Research on Risk Management in Construction of Tunnel and Underground Works. *Chinese journal of underground space and engineering.*

International Organization for Standardization, 2009. *Risk management - Principles and guidelines.* 1st ed. Geneva: International Organization for Standardization.

International Organization for Standarization, 2014. *International Organization for Standardization.* [Online] Available at: http://www.iso.org/iso/home/standards.htm [Accessed 24 07 2014].

Investopedia, 2014. *Investopedia.* [Online] Available at: http://www.investopedia.com/terms/c/capital-project.asp [Accessed 15 05 2014].

Jahangirian, M. et al., 2010. Simulation in manufacturing and business. *European Journal of Operational Research,* Volume 203, pp. 1-13.

Kakimoto, R. & Seneviratne, P., 2000. Financial Risk of Port Infrastructure Development. *Journal of Waterway, Port, Coastal and Ocean Engineering,* 126(6), pp. 281-287.

Karim, N., Rahman, I., AH, M. & Jamil, N., 2012. *Significant Risk Factors in Construction Projects: Contractor's Perception.* Kota Kinabalu, Sabah Malaysia, 2012 IEEE Colloquium on Humanities, Science and Engineering Research (CHUSER 2012).

Kendrick, T., 2003. *Identifying and managing project risk.* 1st ed. New York: American Management Association.

Khodakarami, V. & Abdi, A., 2014. Project cost risk analysis: A Bayesian networks approach for modeling dependencies between cost items. *International Journal of Project Management,* Volume 32, pp. 1233-1245.

Kim, D. & Kim, S., 2009. Multi Criteria Decision on Selecting Optimal Ship Accident Rate for Port Risk Mitigation. *The Asian Journal of Shipping and Logistics,* 25(1), pp. 7-17.

Krane, H. & Johansen, A., 2014. Exploiting Opportunities in the Uncertainty Management. *Procedia - Social and Behavioral Sciences,* Volume 119, pp. 615-624.

Kuo, Y. & Lu, S., 2013. Using fuzzy multiple criteria decision making approach to enhance risk assessment for metropolitan construction projects. *International Journal of Project Management,* Volume 31, pp. 602-614.

Kwak, Y., Chih, Y. & Ibbs, W., 2009. Towards a Comprehensive Understanding of Public Private Partnerships for Infrastructure Development. *California Management Review,* Volume January 2009, pp. 51-78.

Kwak, Y. & Ingall, L., 2007. Exploring Monte Carlo Simulation Applications for Project Management. *Risk Management,* Volume 9, pp. 44-57.

Lam, K., Wang, D., Lee, P. & Tsang, Y., 2007. Modelling risk allocation decision in construction contracts. *International Journal of Project Management,* Volume 25, pp. 485-493.

Lam, P., 1999. A sectoral review of risks associated with major infrastructure projects. *International Journal of Project Management,* 17(2), pp. 77-87.

Lam, P., 1999. A sectoral review of risks associated with major infrastructure projects. *International Journal of Project Management,* 17(2), pp. 77-87.

Lin, P., Tsergn, H. & Lin, C., 2006. Automated construction of the Paghuashan tunnel for Taiwan High Speed Rail (THSR) project. *Automation in Construction,* 15(5), pp. 627-639.

Lyons, T. & Skitmore, M., 2004. Project risk management in the Queensland engineering construction industry: a survey. *International Journal of Project Management,* Volume 22, pp. 51-61.

Lytsyn, V. & Rishnyak, I., 2014. Modeling and evaluation of project risks in multi-project environment. *IAPGOS,* Volume 2, pp. 34-36.

Marsh, C., 2013. *Business and Financial Models.* 1st ed. London: Kogan Page.

Microsoft, 2013. *Microsoft Office.* [Online]
Available at: http://office.microsoft.com/en-za/excel-help/define-and-use-names-in-formulas-HA010147120.aspx
[Accessed 30 06 2014].

New Era, 2014. *New Era.* [Online]
Available at: http://www.newera.com.na/2014/03/26/trans-kalahari-railway-deal-signed/
[Accessed 09 07 2014].

Oldfield, D., 2014. *Discussion on tornado graphs* [Interview] (03 09 2014).

Olsson, R., 2008. Risk management in a multi-project environment: An approach to manage portfolio risks. *International Journal of Quality & Reliability Management,* 25(1), pp. 60 - 71.

Palisade Corporation, 2014. *@Risk Help File,* Ithaca: Palisade Corporation.

Palisade Corporation, 2014. *www.palisade.com.* [Online] Available at: http://www.palisade.com/risk/monte_carlo_simulation.asp [Accessed 12 05 2014].

Patterson, F. & Neailey, K., 2002. A Risk Register Database System to aid the management of project risk. *International Journal of Project Management 20,* Volume 20, pp. 365-374.

Prabhakar, R., 2012. *Risk register methodology* [Interview] (18 09 2012).

Prabhakar, R., 2014. E-mail correspondence on risk aggregation in a project portfolio [Interview] (20 05 2014).

Project Management Institute, 2009. *Practice Standard for Project Risk Management.* s.l.:Project Management Institute.

Project Management Institute, 2013. *A Guide to the Project Management Body of Knowledge.* 5th ed. Newton Square(Pennsylvania): Project Management Institute, Incorporated.

Pugh, L. & Soden, R., 1996. Use of risk analysis techniques in assessing the confidence of project cost estimates and schedules. *International Journal of Project Management,* 4(3), pp. 158-162.

Purdy, G., 2010. ISO 31000:2009 – setting a new standard for risk management. *Risk Analysis, the journal of the Society for Risk Analysis,* Issue June 2010.

Rao Tummala, V. et al., 1997. Practices, barriers and benefits of using risk management approaches in selected Hong Kong industries. *Internattonal Journal of Project Management,* Volume 15, pp. 297-312.

Rehbock-Sander, M., 2004. The construction of the Gotthard Base Tunnel for high speed rail. *Tunnelling and Underground Space Technology,* 19(4-5), pp. 406-407.

Rezakhani, P., 2012. Classifying Key Risk Factors In Construction Projects. The Bulletin of the Polytechnic Institute of Jassy, Construction and Architecture Section.

Royal Institution of Chartered Surveyors, n.d. *http://www.rics.org.* [Online] Available at: https://consultations.rics.org/consult.ti/managementofrisk/viewCompoundDoc?docid=4951220&partId=4953556&sessionid=&voteid=
[Accessed 28 06 2014].

Sato, T. & Hirao, M., 2013. Optimum budget allocation method for projects with critical risks. *International Journal of Project Management,* 31(1), pp. 126-135.

Shehu, Z. & Akintoye, A., 2009. Construction programme management theory and practice: Contextual and pragmatic approach. *International Journal of Project Management,* 27(7), pp. 703-716.

Shehu, Z. & Akintoye, A., 2010. Major challenges to the successful implementation and practice of programme management in the construction environment: A critical analysis. *International Journal of Project Management,* 28(1), pp. 26-39.

Smith, N., Merna, T. & Jobling, P., 2006. *Managing risk in construction projects.* 2nd ed. Oxford: Blackwell Publishing.

Sousa, V., Almeida, N. & Dias, L., 2015. Risk-based management of occupational safety and health in the construction industry – Part 2: Quantitative model. *Safety Science,* Volume 74, pp. 184-194.

South African Bureau of Standards, 2014. *SABS.* 1st ed. Pretoria: South African Bureau of Standards.

Tang, L., Shen, Q. & Cheng, E., 2010. A review of studies on Public-Private Partnership projects in the construction industry. *International Journal of Project Management,* 28(7), pp. 683-694.

Taroun, A., 2014. Towards a better modelling and assessment of construction risk: Insights from a literature review. *International Journal of Project Management,* 32(1), pp. 101-115.

Teller, J., 2013. Portfolio Risk Management and Its Contribution to Project Portfolio Success: An Investigation of Organization, Process, and Culture. *Project Management Journal,* 44(2), pp. 36-51.

Transnet SoC Ltd., 2013. *Annual Report,* Johannesburg: Transnet SoC Ltd.

Transnet SoC Ltd., 2014. *Integrated Report,* Johannesburg: Transnet SoC Ltd.

Transnet, 2011. *Project Scalability Model.* Johannesburg: Transnet.

Transnet, 2012. *Transnet.* [Online] Available at: http://www.transnet.net/PressOffice/Press 20Office 20Release/TRANSNET LAUNCHES R300BN PLAN WHICH WILL CREATE THOUSANDS OF JOBS.pdf
[Accessed 19 05 2014].

Transport World Africa, 2015. *Transnet wrestles with market share.* [Online] Available at: http://www.transportworldafrica.co.za/2015/07/14/transnet-wrestles-with-market-share/
[Accessed 17 10 2015].

Trietsch, D. & Baker, K., 2012. PERT 21: Fitting PERT?/PM for use in the 21st century. *International Journal of Project Management,* 30(4), pp. 490-502.

Ugwua, O. & Haupt, T., 2007. Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective. *Building and Environment,* Volume 42, pp. 665-680.

Vose Software, 2014. *Vose Software.* [Online] Available at: http://www.vosesoftware.com/content/ModelRiskHelp.pdf
[Accessed 25 07 2014].

Vose, D., 2008. *Risk Analysis: A Quantitative Guide.* 3rd ed. Chichester, England: John Wiley & Sons.

Wikipedia, 2014. *www.wikipedia.org.* [Online] Available at: http://en.wikipedia.org/wiki/Three-point_estimation
[Accessed 25 05 2014].

Windapo, A. & Cattell, K., 2013. The South African Construction Industry: Perceptions of Key Challenges Facing Its Performance, Development and Growth. *Journal of Construction in Developing Countries,* 18(2), pp. 65-79.

Yang, Z. & Ng, A. W. J., 2014. A new risk quantification approach in port facility security assessment. *Transportation Research Part A: Policy and Practice,* Volume 59, pp. 72-90.

Zammori, F., Braglia, M. & Frosolini, M., 2009. A fuzzy multi-criteria approach for critical path definition. *International Journal of Project Management,* Volume 27, pp. 278-291.

Zeng, J., An, M. & Smith, N., 2007. Application of a fuzzy based decision making methodology to construction project risk assessment. *International Journal of Project Management,* 25(6), pp. 589-600.

Zheng, L., Zhaob, B., Wang, H. & Liu, H., 2011. *Environmental Risk Identification of Port Construction Project.* s.l., 2011 3rd International Conference on Environmental Science and Information.

Zou, P., Zhang, G. & Wang, J., 2006. *Identifying Key Risks in Construction Projects: Life Cycle and Stakeholder Perspectives.* Auckland, New Zealand, Proceedings of the 12th Pacific Rim Real Estate Society Conference, pp. 61-77.

Zou, P., Zhang, G. & Wang, J., 2007. Understanding the key risks in construction projects in China. *International journal of Project Management,* Volume 25, pp. 601-614.

8. APPENDIX A: RISK BREAKDOWN STRUCTURE

ENVIRONMENT	RISK AREA	RISK GENERATOR
Natural Environment	Environmental conditions	Aesthetics
		Air Quality
		Fauna
		Flora
		Noise
		Water Quality
		Geology
	Manmade disasters	Climate change
		Fire
		Pollution
	Natural disasters	Earthquake
		Floods
	Water Quality	Water availability
	Weather	Extreme weather
		Sandstorms
Economic Environment	Global Economy	Exchange rates
		International resource availability
	Local Economy	Inflation
		Resource competition
Government Environment	Approvals	Approval Changes
		Approval Conditions
		Approvals processes
		Environmental approvals
		Heritage approvals
		Import approvals
		Land transfer
		Land use
		License requirements
		Lobby Groups
		OH & S requirements
		Training requirement
	Government participation	Government Commitment
		Government Involvement
		Government Stability
	Policies	Economic development
		Environment
		Importation
		Labour

ENVIRONMENT	RISK AREA	RISK GENERATOR
Societal Environment	Community participation	Community diversification
		Community involvement
		Cultural events
		Ethics, Public Perception
		Marketing
		Public Perception
	Crime	Political unrest
		Terrorism
		Theft
Client Environment	Finance	Availability of Funds
		Bonds
		Cash Flow constraints
		Competing Projects
		Currency conversions
		Financial policies
		Payment terms
	Participation	Commitment to project
		Construction involvement
		Design involvement
		Information availability
		Involvement in project
		Knowledge/Experience of similar projects
		Language barriers
		Management complexity
		Operations
		Project Ownership
		Representative availability
		Reputation
		Stability of structures
	Procedures	Approvals
		Contingency calculations
		Escalation procedures
		Legal Entity definitions
		Payment authorisations
		Payment procedures
	User requirements	User requirement completeness
		User requirement definition
		User requirement variations
Construction Environment	Construction Economy	Contractor competition
		Contractor rates
		Contractor stability
	Industrial Relations	Industrial unrest
Project Environment	Commissioning	Acceptance by operator
		Asset records
		Manuals documentation

ENVIRONMENT	RISK AREA	RISK GENERATOR
		Programme
		Site constraints
		Spares
		Testing and certification
		Training of operational personnel
	Contractor	Contractor interface
		Contractors' Capacity
		Contractors' Equipment/Technology
		Contractors' experience
		Contractors' financial standing
		Contractors' methodology
		Contractors' organisation
		Contractors' Payment Terms
		Contractors' Team (Personnel)
		Supplier availability
		Contractors resources
		Subcontractors resources
		Quality defects
Project Environment	Contracts	Contract commercial terms
		Contract conditions
		Contract Dispute Resolution
		Contract Form
		Contract Insurance
		Contract Intellectual Property
		Contract Termination
		Contract validity
		Contract Variations
		Contractual arrangements
		Contractual Legal Entities
		Contractual Liability
		Contractual obligations
		Design liabilities
		Financial liabilities
		Guarantees
		Penalties
		Warranties
	Cost estimates	Estimate completeness
		Estimate validity
		Quantity accuracy
		Rate accuracy
		Cost objectives
	Design	Design alternatives
		Design freeze
		Design rework
		Designer interface
		Technical design
		Technical specification

ENVIRONMENT	RISK AREA	RISK GENERATOR
	Interfaces	Related Projects
		Stakeholders interface
		Subcontractors
		Project Team organisations
Project Environment	Logistics	Equipment availability
		Material supply logistics
		Site access
		Site power supply
		Site water supply
	Materials	Component Failure
		Material availability
	Operations	Operational requirements
		Operations plans
		Existing operations
		Damage to existing facilities
	Plans	Change Management plans
		Commissioning plans
		Construction plans
		Design plans
		Maintenance plans
		Mobilisation plans
		OH & S plans
		Procurement plans
		Procurement Strategy
		Program plans
		Project Definition
		Project Structure
		Quality objectives
		Review/Verification plans
		Risk Allocation
		Scope definition
		Test and Acceptance plans
		Time objectives

Environment	Risk Area	Risk Generator
Project Environment	Procurement	Availability/lead times
		Clarity of approach
		Clarity of benefits of risk ownership vs risk transfer
		Degree of contractor design
		Design information completeness
		Familiarity with chosen procurement contract
		Framework agreements/partnerships/alliances
		Overlap of design and construction
		Package integration
		Packaging information
		Tender period/process/constraints
		Tender returns
		Understanding of alternative routes
	Project Team	Culture
		Project management commitment
		Project management Team Composition
		Project management Team Experience
		Team Continuity
		Skills shortage
	Resources	Resources Availability
		Resources Cost
		Resources Language
		Resources Location
		Resources Quantity
		Resources Reliability
		Resources Skills
		Resources Training
		Resources Work load
		Resources Accommodation
	Surveys	Existing services surveys
		Geotech surveys
		Land surveys
	Systems	Logistics systems
		Project management Systems

Environment	Risk Area	Risk Generator
Project Environment	Technology	Construction technology
		Project technology
		Technological alternatives
		Technology assumptions
	Safety	Deep digs
		Equipment
		Hazardous substances
		Member of public injury
		Radioactivity
		Vehicles
		Worker injury
		Working at heights
		X-ray equipment
		Fire
	Environment	Environmental approval conditions
		Archaeological artefacts
		Environmental incident
		Fauna impact
		Flora impact
		Air Quality impact
		Noise impact
		Aesthetic impact

9. APPENDIX B: CREATE COMPLETE RISK REGISTER AND ASSOCIATED SHEETS

9.1 Purpose and Outline

This section describes in more detail the techniques and tools used to create a risk register in MS Excel which, in conjunction with suitable reports, is able to answer Research Questions 3 to 9. The complete CRR appears at the end of the section.

Each risk will be linked to a project, a project type, a three level RBS, and an indicator which shows whether the risk delays project execution start or not. The method described below can be applied in any other fields using the same steps.

The first step in creating the CRR is to create five new sheets in the MS Excel workbook:

- Table References.
- CRR (Complete Risk Register).
- Project Information.
- All Risks.
- RBS (Risk Breakdown Structure).

At the end of this section, the workbook CRR will be ready to be populated by all the risk registers which are in the capital project portfolio. The steps in creating the CRR are described in Figure 9-1. Each of the blocks in the process is described in the rest of this section.

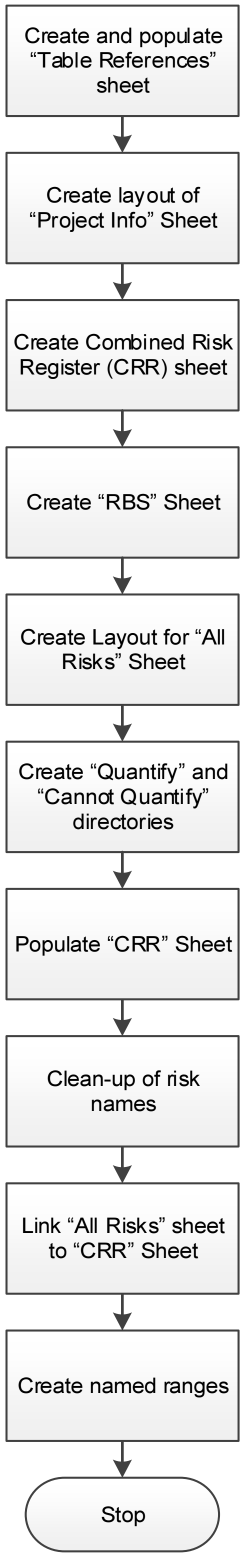


Figure 9-1: Flow diagram on developing the CRR

9.2 Create and populate the "Table References" sheet

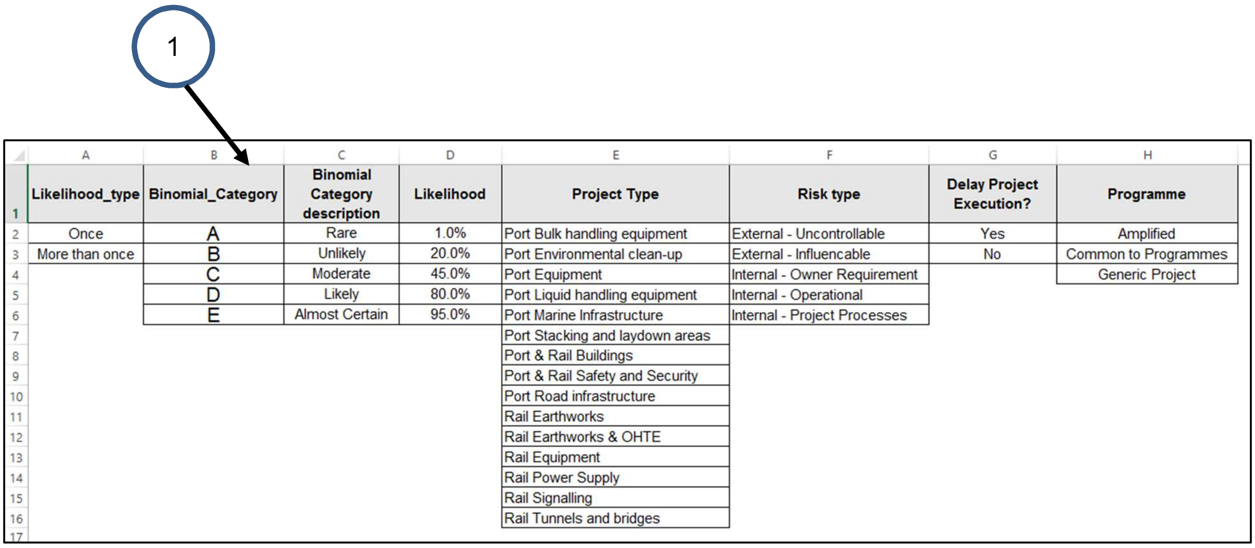
Purpose:

- The "Table References" sheet contains all information (except the RBS) used in dropdown boxes which were available in the CRR.
- It is convenient to have all these on one page as it enables quick changes and easy troubleshooting and validation purposes.

Steps:

The numbers which appear on the MS Excel screenshots in this section, are related to the steps as outlined below. Please note that all the steps are not necessarily described using screen shots, i.e. the use of the Name Manager in MS Excel.

1. Create a new sheet "Table References" and populate/copy Columns A - D from the original risk register template as in Figure 4-4.
2. Use DATA/NAME MANAGER to name the first two inputs "TR_Likelihood_type" (Column A) and the second "TR_Binomial_Category" (Column B). These names will be used in dropdown boxes on the sheet "CRR" (Combined Risk Register) and should be the same as used in the risk registers which will be copied into the sheet "CRR".
    - Named ranges are meaningful shorthand that makes it easier to understand the purpose of a cell reference, constant, equation, or table, each of which may be difficult to comprehend at first glance (Microsoft, 2013).
    - The "TR" in front of the name refers to the sheet where the named ranges is found - "Table References" in this case. This naming convention is used in all the named ranges during the developing of the simulation model. It sorts them to their page of origin which makes finding them easy when using the Name Manager in MS Excel.



Likelihood_type	Binomial_Category	Binomial Category description	Likelihood	Project Type	Risk type	Delay Project Execution?	Programme
Once	A	Rare	1.0%	Port Bulk handling equipment	External - Uncontrollable	Yes	Amplified
More than once	B	Unlikely	20.0%	Port Environmental clean-up	External - Influencable	No	Common to Programmes
	C	Moderate	45.0%	Port Equipment	Internal - Owner Requirement		Generic Project
	D	Likely	80.0%	Port Liquid handling equipment	Internal - Operational		
	E	Almost Certain	95.0%	Port Marine Infrastructure	Internal - Project Processes		
				Port Stacking and laydown areas			
				Port & Rail Buildings			
				Port & Rail Safety and Security			
				Port Road infrastructure			
				Rail Earthworks			
				Rail Earthworks & OHTE			
				Rail Equipment			
				Rail Power Supply			
				Rail Signalling			
				Rail Tunnels and bridges			

Figure 9-2: Risk likelihood information added to “Table References” sheet

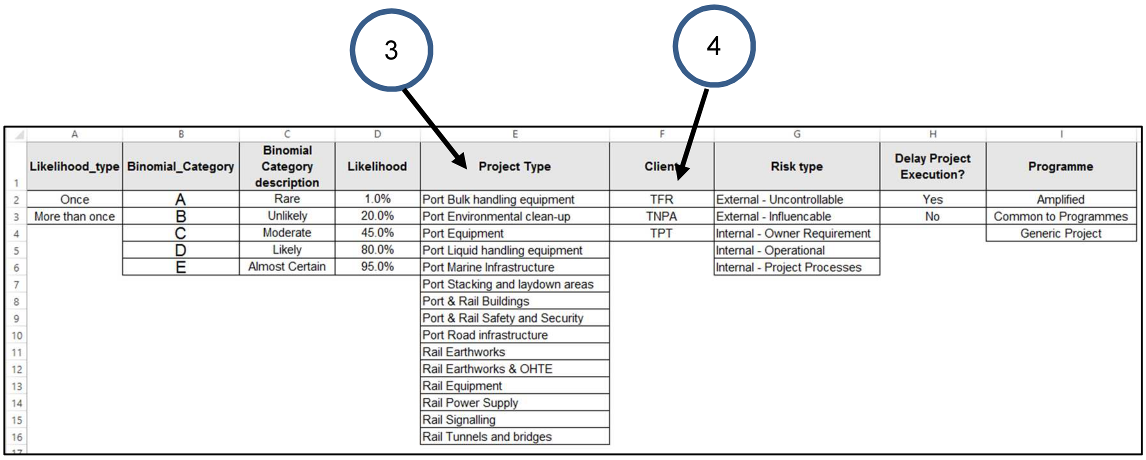
9.2.1 Add project categories

Purpose:

- This list was used to categorise projects according to type which in turn, linked each risk (and by definition, the risk categories), to a project type.

Steps:

3. Create a heading “Project Type” and populate with the list of project types as defined (Section 4.3). Use DATA/NAME MANAGER to name the list “TR_Project_Type”.
4. Create a heading “Client” and populate TFR, TNPA and TPT. Use DATA/NAME MANAGER to name the list “TR_Client”.



Likelihood_type	Binomial_Category	Binomial Category description	Likelihood	Project Type	Client	Risk type	Delay Project Execution?	Programme
Once	A	Rare	1.0%	Port Bulk handling equipment	TFR	External - Uncontrollable	Yes	Amplified
More than once	B	Unlikely	20.0%	Port Environmental clean-up	TNPA	External - Influencable	No	Common to Programmes
	C	Moderate	45.0%	Port Equipment	TPT	Internal - Owner Requirement		Generic Project
	D	Likely	80.0%	Port Liquid handling equipment		Internal - Operational		
	E	Almost Certain	95.0%	Port Marine Infrastructure		Internal - Project Processes		
				Port Stacking and laydown areas				
				Port & Rail Buildings				
				Port & Rail Safety and Security				
				Port Road infrastructure				
				Rail Earthworks				
				Rail Earthworks & OHTE				
				Rail Equipment				
				Rail Power Supply				
				Rail Signalling				
				Rail Tunnels and bridges				

Figure 9-3: Project Type added to “Table References” sheet

9.2.2 Add risk categories

Purpose:

- This list of risk categories will be used to categorise the risk names and is used to answer Research Questions 3 to 6.

Steps:

5. Create a “Risk Type” list (Column F).
6. Use DATA/NAME MANAGER to name the list “TR_Risk_Type” (Column F). The meanings of these risk types are described in Table 4-3: Risk types.
7. Create a “Delay Project Execution?” list (Column G).
8. Use DATA/NAME MANAGER to name the list “TR_Delay_Project_Execution” (Column G).
9. Create a “Programme” list (Column H).
10. Use DATA/NAME MANAGER to name the list “TR_Programme_Risk” (Column H).

	A	B	C	D	E	F	G	H
1	Likelihood_type	Binomial_Category	Binomial Category description	Likelihood	Project Type	Risk type	Delay Project Execution?	Programme
2	Once	A	Rare	1.0%	Port Bulk handling equipment	External - Uncontrollable	Yes	Amplified
3	More than once	B	Unlikely	20.0%	Port Environmental clean-up	External - Influencable	No	Common to Programmes
4		C	Moderate	45.0%	Port Equipment	Internal - Owner Requirement		Generic Project
5		D	Likely	80.0%	Port Liquid handling equipment	Internal - Operational		
6		E	Almost Certain	95.0%	Port Marine Infrastructure	Internal - Project Processes		
7					Port Stacking and laydown areas			
8					Port & Rail Buildings			
9					Port & Rail Safety and Security			
10					Port Road infrastructure			
11					Rail Earthworks			
12					Rail Earthworks & OHTE			
13					Rail Equipment			
14					Rail Power Supply			
15					Rail Signalling			
16					Rail Tunnels and bridges			
17								

Figure 9-4: Risk categories added to “Table References” sheet

9.3 Create layout for “Project Information” Sheet

Purpose:

- To create a worksheet in the simulation model into which all the required project related information will be copied into. The “CRR” sheet will look up the following information from this sheet:
    - Weekly project cost to calculate Weighted Weekly Average Cost.
    - Project Type. This is used to aggregate the simulation output for various project types, for example: “The P80 value Safety related risks for Rail Equipment projects is R4.5 million”.

Steps:

11. Open a new sheet and rename it as “Project Information”
12. Create a table with the headings as in Figure 9-5:

Line nr	Location	Project name	Budget	Contingency	Cost 1 (R million per week)	Contractor 1	Cost 2 (R million per week)	Contractor 2	Cost 3 (R million per week)	Contractor 3	Cost 4 (R million per week)	Contractor 4	Cost 5 (R million per week)	Contractor 5	Project Type	Client
1																
2																
3																
4																
5																
6																
7																
8																
9																

Figure 9-5: “Project information” sheet

13. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “TR_Project_Type” to the column “Project Type”. Do the same for the Client column but use “TR_Client” instead.
14. Copy the dropdown boxes down in the spreadsheet as required.
15. All the cells contain text with the exception of the Cost columns (1 - 5) which contain currency.

9.4 Create Combined Risk Register (CRR) sheet

Purpose:

- To create a single worksheet in the simulation model into which all the information used in the Monte Carlo simulation will be displayed. If all the information is in one place, it is easier to do troubleshooting and model validation.
- The CRR sheet needs to contain all the equations required in generating simulation output distributions. Output distributions are presented in terms of probability density graphs previously displayed in Figure 3-6.

Steps:

16. Take the latest version of the Risk Register Template and copy all the headings into the “CRR” sheet.
17. Add columns “Line Number”. This is used as a unique identifier. Later in this Section, the entire risk register is sorted to the “Risk Name” field. When the entire risk register is sorted to the “Line Number”, it returns to its original sequence.
18. Add column “Project Name”. This will be used to bring project information from the “Project Information” sheet into the “CRR” sheet.
19. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “TR_Likelihood_Type” to the column “How Many times can the risk occur?”. The dropdown will allow either a “Once” or a “More than once” risk.
20. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “TR_Binomial_Category” to the column “Occurrence Type (A-E)”. The dropdown will allow A, B, C, D or E.
21. Use a =*VLookup()* in the field “Likelihood” to bring the associated likelihood from the sheet “Table References”. If one selects “A”, the function should look up / find “1%”.

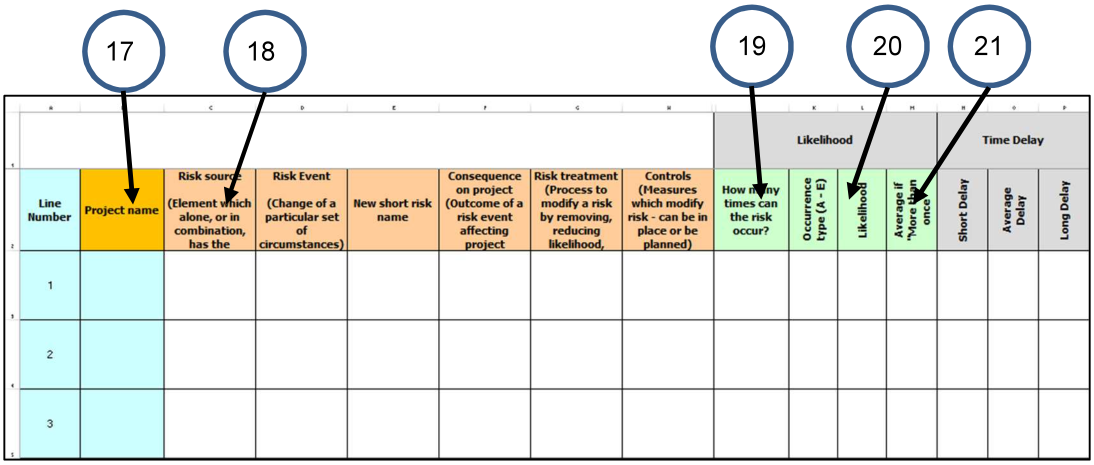


Figure 9-6: Adding columns to existing risk register

22. Insert a column "Likelihood Simulation" and populate it with the equation as indicated in Figure 9-7. The function determines if a =*RiskBinomial()* or =*RiskPoisson()* function will be used.

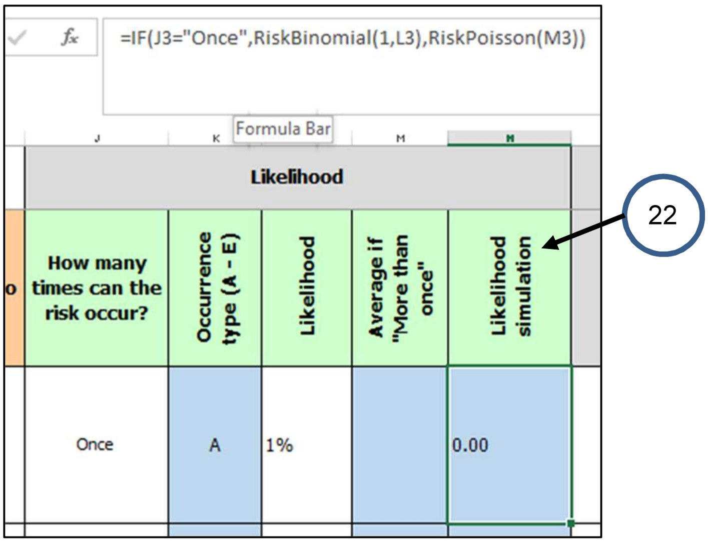


Figure 9-7: Likelihood simulation

23. Insert a column "Delay Simulation" and populate it with the equation as indicated in Figure 9-8. The equation simulates time delay based on the equation contained in Figure 3-4.

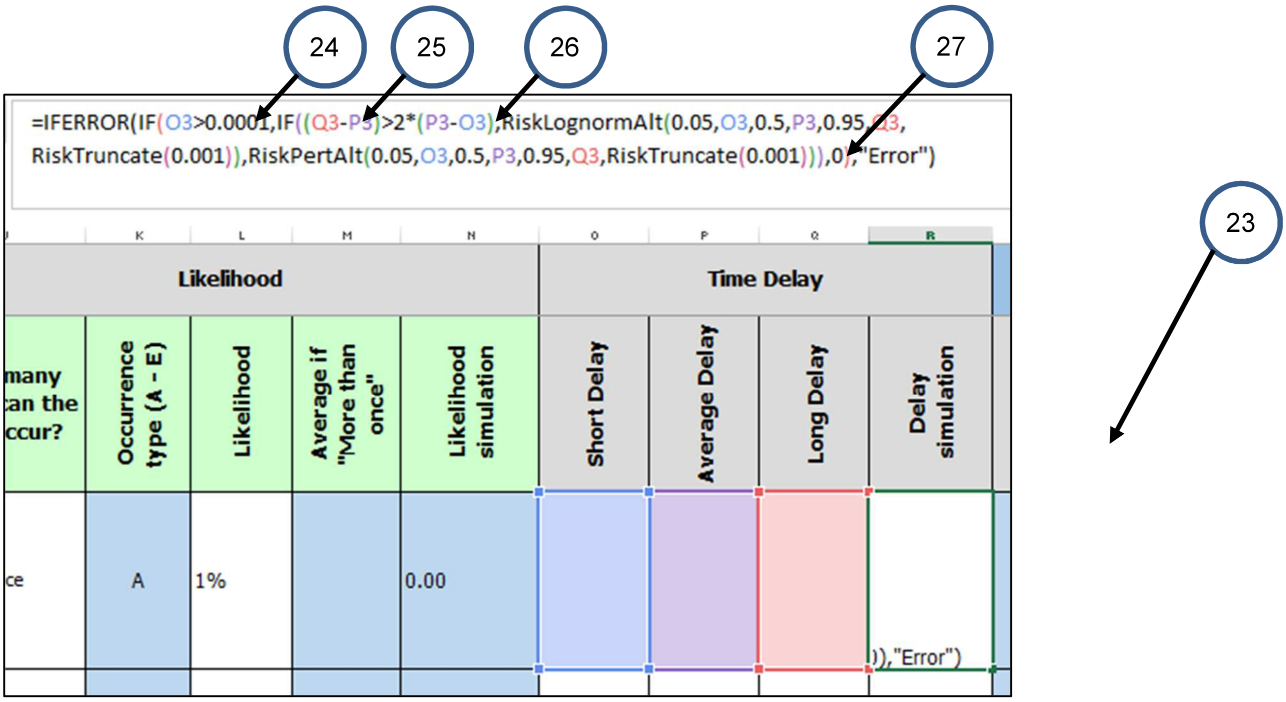


Figure 9-8: Delay simulation

24. The *=IfError()* statement is useful because it returns the word “Error” should @Risk not be loaded or there be a problem with the three-point estimate. These estimates have to be in ascending order, e.g. 1,2,3 and not 1,3,2.
25. The *=If(O3>0.0001*, tests if there are any values entered as “Short Delay”. It assumes that if there are values entered, the subsequent If(((Q3.) statement should occur. If there are no values entered, no simulation will take place.
26. The *If((Q3-P3)>2*(P3-O3)* determines if a *=RiskLognormAlt()* or a *=RiskPertAlt()* function will be used. This is in line with the function as described in Section 0.
27. The *RiskTruncate(0.001)* function removes all simulation values <0.001 and prevents negative values included in the risk simulation results. Time delays cannot be negative in this context.
28. Insert columns after the column “Project name” and name them as in Figure 9-9.

29. These will be used later in this Section to look up project cost, project category and RBS information. The RBS information will be linked in Section 0.

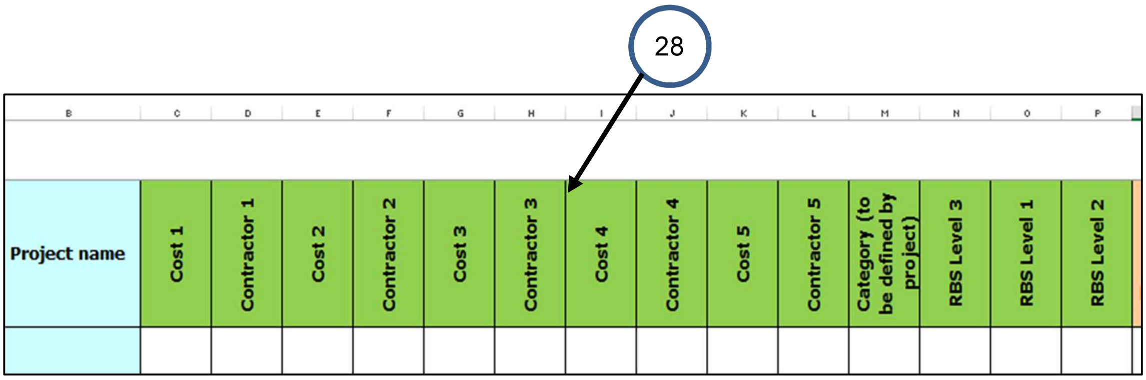


Figure 9-9: Additional columns for looking up cost information

30. After the above cost columns have been created, the equations for Weekly Weighted Average Cost (as described in Figure 3-5) can be inserted, as in Figure 9-10 (note that some columns have been hidden to enable the screenshot to fit on the page):

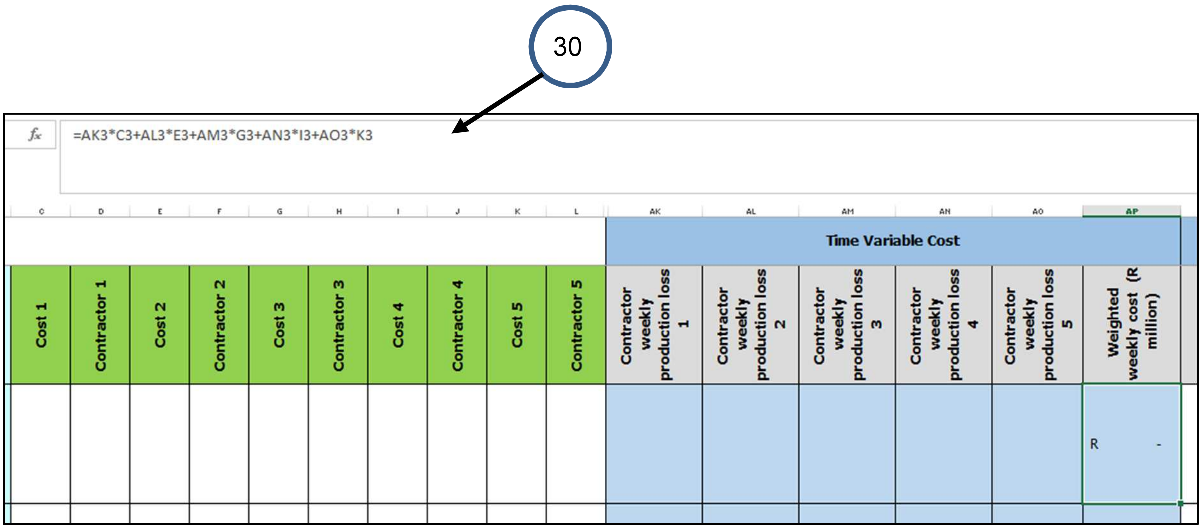


Figure 9-10: Weekly Weighted Average Cost equation

31. The last part of the risk consequence, Additional Capital Cost, needs to be added: It uses the same logic as described in the equation for "Time Delay Simulation" (Figure 9-8). A new column "Extra Capital Simulation" (Column AT) was inserted and populated with the equation as in Figure 9-11.

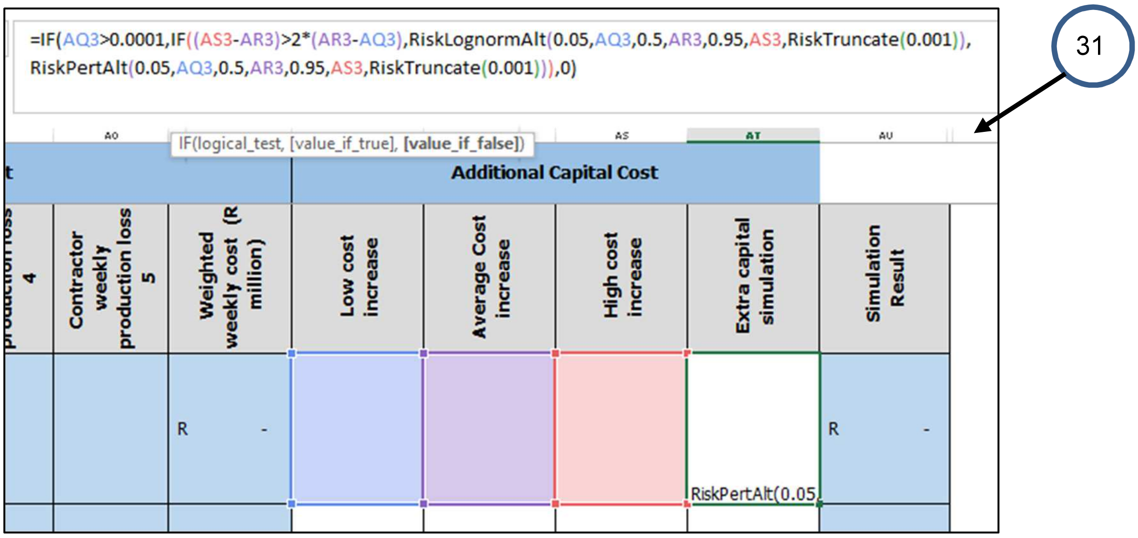


Figure 9-11: Additional capital simulation

32. The simulation result is obtained as follows which is in line with Figure 3-6: Overview of simulation logic where:

$$Simulation\ Result = Likelihood\ Simulation * (Delay\ simulation * Weighted\ weekly\ cost + Additional\ Capital\ simulation)$$

32

=AF3*(AJ3*AP3+AT3)

Likelihood		Time Delay	Time Variable Cost	Additional Capital Cost	
How many times can the risk occur?	Likelihood simulation	Delay simulation	Weighted weekly cost (R million)	Extra capital simulation	Simulation Result
More than once	2.00	1.48	R 0.12	R -	R 0.37
Once	0.00	0.70	R 0.16	R -	R -
Once	0.00	0.39	R 0.04	R -	R -
Once	1.00	0.00	R -	R 0.20	R 0.20

Figure 9-12: Simulation result

33. Test the dropdown boxes and if they are working as required, copy down in spreadsheet as required.
34. Copy all the equations down in the spreadsheet, as per requirement.
35. Number formats are as indicated. Where no formatting appears, the contents will be text.

9.5 Create "RBS" sheet

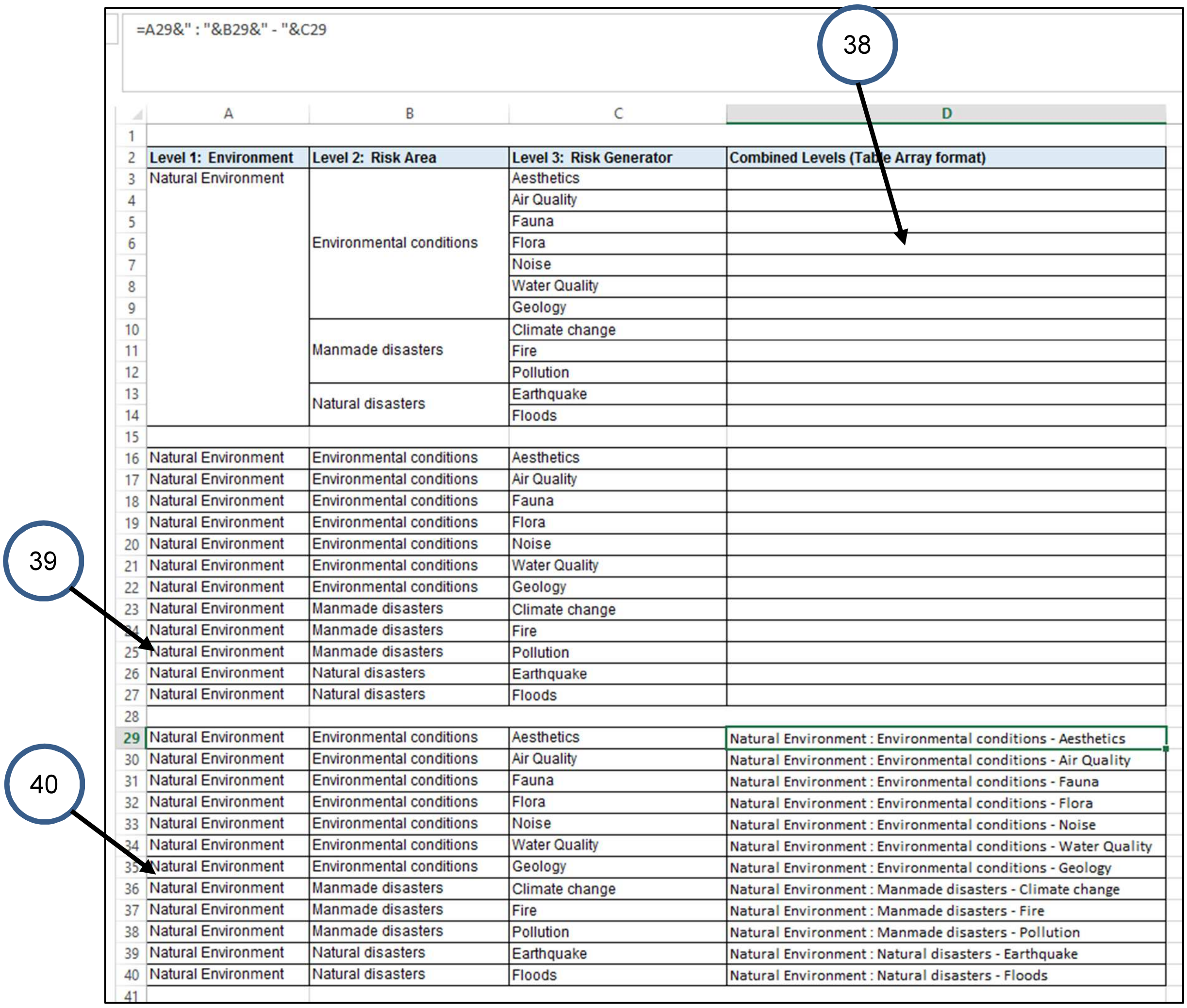
Purpose:

- The RBS which was included in the simulation model is used to identify recurring themes and identifies areas which require special attention (Hillson, 2002, p. 1).
- The RBS needs to be copied into the worksheet and converted into a table array which can be used in a *=VLookup()* function to answer Research Questions 3 and 4.

Steps:

36. Create a sheet called "RBS"
37. Copy the existing RBS into this sheet.

38. Insert column called “Combined Levels (Table Array format)”.
39. If the RBS is not in a table array format, it needs to be converted into a table array. The steps in this process are illustrated Figure 9-13.
40. Step 1 (Rows 16 - 27): Unmerge the merged cells and copy as appropriate.
41. Step 2 (Rows 29 - 40): Concatenate all the levels of the RBS using different punctuation to separate each level.
42. Please note that on the actual “RBS” Sheet, only one step will appear at a time.
43. Apply this to the entire “RBS” Sheet.
44. Use DATA/NAME MANAGER to name the list “RBS_All_Levels” (Column D).



	A	B	C	D
1				
2	Level 1: Environment	Level 2: Risk Area	Level 3: Risk Generator	Combined Levels (Table Array format)
3	Natural Environment		Aesthetics	
4			Air Quality	
5			Fauna	
6		Environmental conditions	Flora	
7			Noise	
8			Water Quality	
9			Geology	
10			Climate change	
11		Manmade disasters	Fire	
12			Pollution	
13		Natural disasters	Earthquake	
14			Floods	
15				
16	Natural Environment	Environmental conditions	Aesthetics	
17	Natural Environment	Environmental conditions	Air Quality	
18	Natural Environment	Environmental conditions	Fauna	
19	Natural Environment	Environmental conditions	Flora	
20	Natural Environment	Environmental conditions	Noise	
21	Natural Environment	Environmental conditions	Water Quality	
22	Natural Environment	Environmental conditions	Geology	
23	Natural Environment	Manmade disasters	Climate change	
24	Natural Environment	Manmade disasters	Fire	
25	Natural Environment	Manmade disasters	Pollution	
26	Natural Environment	Natural disasters	Earthquake	
27	Natural Environment	Natural disasters	Floods	
28				
29	Natural Environment	Environmental conditions	Aesthetics	Natural Environment : Environmental conditions - Aesthetics
30	Natural Environment	Environmental conditions	Air Quality	Natural Environment : Environmental conditions - Air Quality
31	Natural Environment	Environmental conditions	Fauna	Natural Environment : Environmental conditions - Fauna
32	Natural Environment	Environmental conditions	Flora	Natural Environment : Environmental conditions - Flora
33	Natural Environment	Environmental conditions	Noise	Natural Environment : Environmental conditions - Noise
34	Natural Environment	Environmental conditions	Water Quality	Natural Environment : Environmental conditions - Water Quality
35	Natural Environment	Environmental conditions	Geology	Natural Environment : Environmental conditions - Geology
36	Natural Environment	Manmade disasters	Climate change	Natural Environment : Manmade disasters - Climate change
37	Natural Environment	Manmade disasters	Fire	Natural Environment : Manmade disasters - Fire
38	Natural Environment	Manmade disasters	Pollution	Natural Environment : Manmade disasters - Pollution
39	Natural Environment	Natural disasters	Earthquake	Natural Environment : Natural disasters - Earthquake
40	Natural Environment	Natural disasters	Floods	Natural Environment : Natural disasters - Floods
41				

Figure 9-13: Creating table array for RBS

9.6 Create layout for “All Risks” sheet

Purpose:

- All the risk names used in the simulation model needed to be categorised.
- The CRR sheet used the “Risk Name” column to recall various risk related information from the “All Risk” sheet, using functions such as =*VLookup().* The reason for the creation of this sheet is that when making changes to a single risk on this sheet, all the changes will be automatically carried over to the “CRR” sheet.
- Four dropdown boxes which were used for risk categorisation (as defined in Section 4.3.2) were created:
    - RBS.
    - Delay Project Execution.
    - Risk Type.
    - Programme Type.

Steps:

45. Create a sheet in the MS Excel workbook called “All Risks” with the headings as in Figure 9-14Please note that this table can only be populated after the risk names have been cleaned (i.e. *Inclement weather* replaces *Bad Weather*, *Incclement Weather* etc.) up to ensure that . This takes place as indicated in Section 4.4.10.

Risk Name	RBS (Level 1: Level 3 - Level 3)	Execution delay	Type	Programme
Regulatory approval delays	Government : Approvals - Approval Conditions	Yes	External - Influencable	Common to Programmes
Local authority approval delays	Government : Approvals - Approvals processes	Yes	External - Influencable	Amplified
Water licence	Government : Approvals - Approvals processes	Yes	External - Influencable	Generic Project
Certification	Government : Approvals - Approvals processes	No	External - Influencable	Generic Project
CIDB	Government : Approvals - Approvals processes	Yes	External - Influencable	Generic Project
Fire Authority	Government : Approvals - Approvals processes	Yes	External - Influencable	Generic Project
Certificates	Government : Approvals - Approvals processes	No	External - Influencable	Generic Project

Figure 9-14: Risk names and levels

46. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “RBS_All_Levels” to the column “RBS” (Column B). The dropdown will allow only the items in the RBS as in the “RBS” sheet.

47. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “TR_Delay_Project_Execution” to the column “”Execution Delay” (Column C). The dropdown will only allow “Yes” or “No”.
48. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “TR_Risk_Categories” to the column “Type” (Column D). The dropdown will allow the five risk categories as described in the table references sheet.
49. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range “TR_Programme_Risk” to the column “Programme” (Column E). The dropdown will allow the 3 categories as described in the table references sheet. (Not shown on the figure).
50. Test the dropdown boxes and if they are working as required, copy down in spreadsheet as required.

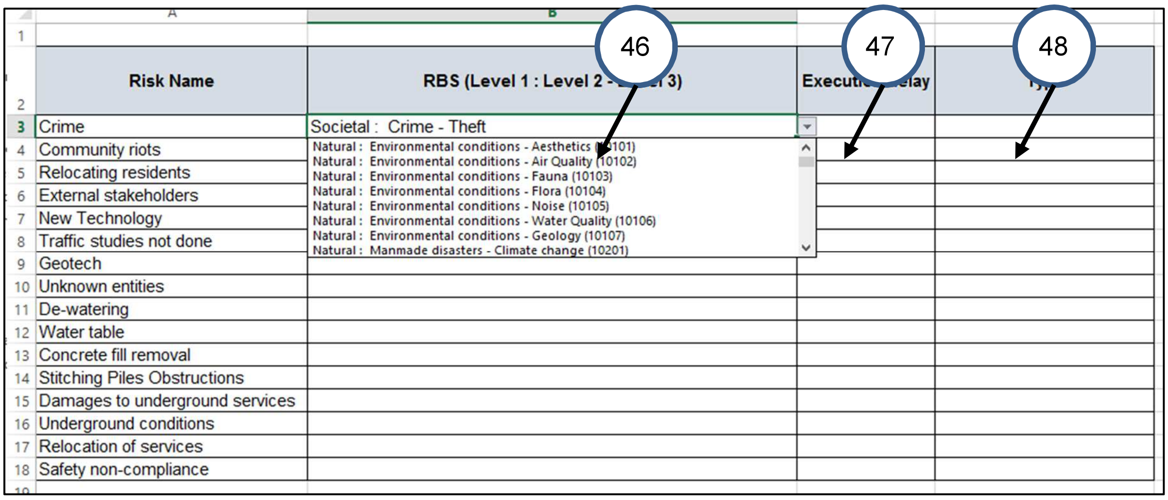


Figure 9-15: Dropdown boxes on "All Risks Sheet"

9.7 Create "_Cannot Quantify" and "_Quantify" directories

Purpose:

- Keeping track of which risk registers have been copied into the CRR sheet can be troublesome. Therefore, two directories were created to track progress.

Steps:

51. In the directory where the original risk registers are stored, create two new directories as displayed in Figure 9-16.
    - _Cannot Quantify
    - _Quantify
52. The "_" before the names ensures that these two directories appear at the top of the directory, should the directory be sorted alphabetically. This is convenient as they stay in the same place and are easier to find when copying many risk registers into the CRR sheet.

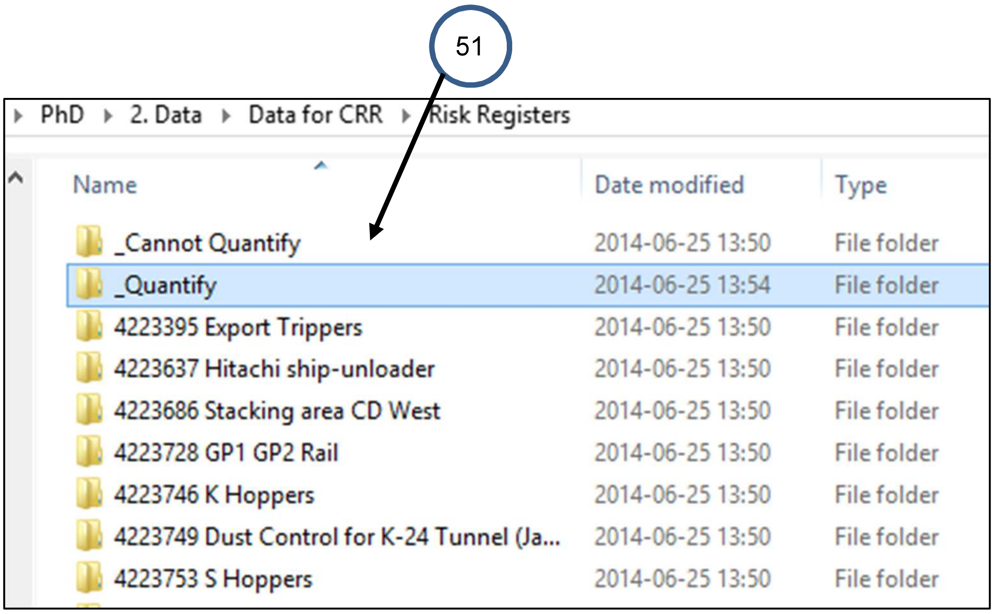


Figure 9-16: Create new directories

9.8 Populate "CRR" sheet

In the previous section, the CRR sheet was prepared and the related lookup sheets (RBS, Project Information) were created in the simulation model. This section describes how the "CRR" sheet was populated using individual risk registers.

9.8.1 Flow diagram

The process of populating the CRR sheet follows the steps as shown below and is repeated until all risk registers have been processed.

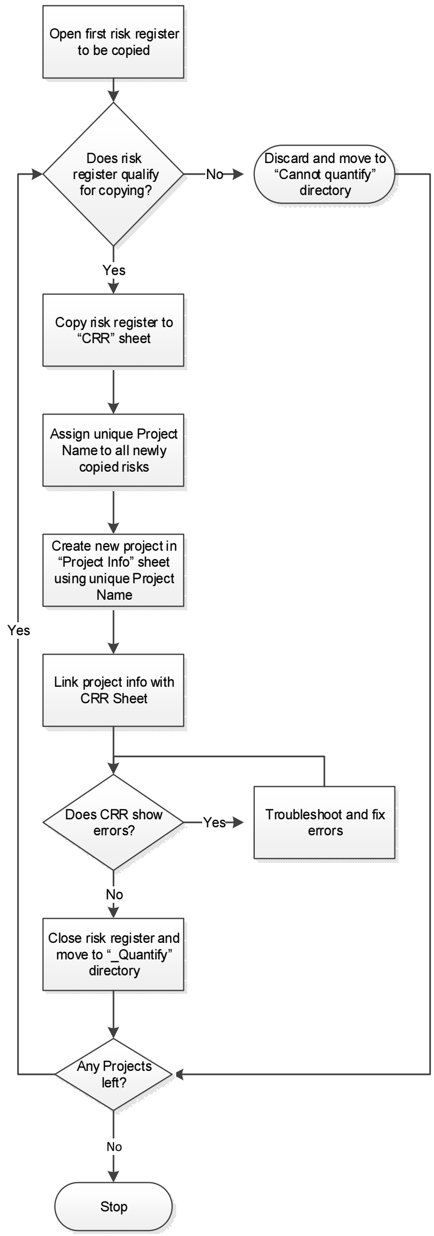


Figure 9-17: Copy risk register into "CRR" sheet

9.8.2 Does risk register qualify for copying?

Purpose:

- To check if a risk register qualifies for being copied to CRR.
- The following disqualifies a risk register from being copied to the CRR sheet:
  - Risk Register was not quantified.
  - Risk Register is incomplete with some risks quantified and others not.

Steps:

53. Open risk register and check if it qualifies for copying to CRR.
54. If it qualifies, copy the data to the appropriate places in the CRR sheet.
55. If it does not qualify, close it and move to next risk register. Move the closed risk register to the "Cannot_Quantify" directory.

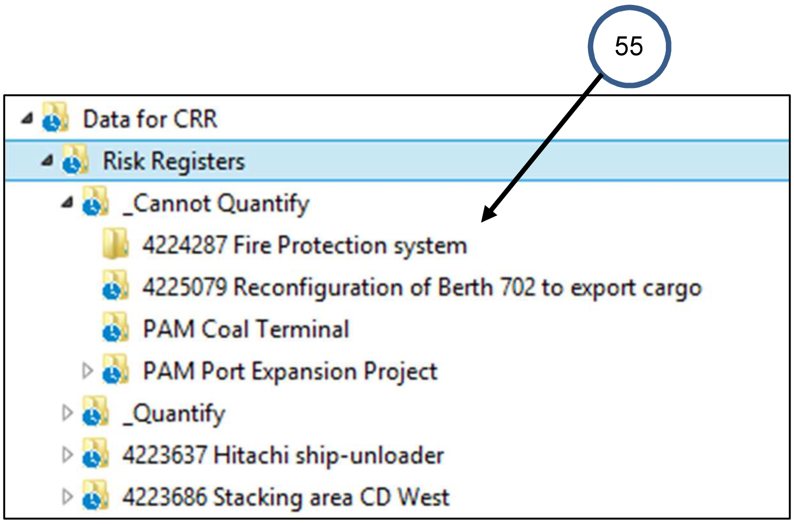


Figure 9-18: Move risk register to "_Cannot Quantify" directory

- Please note that Figure 9-19 focussed on the quantification part of the individual risks displayed. Their causes, description, short risk name, treatment plans are also copied to the CRR sheet but are hidden to ensure that the appropriate columns fit onto the page.

Line Number	Short risk name	How many times can the risk occur?	Occurrence type (A - E)	Description	Likelihood	Average if "More than once"	Likelihood simulation	Short Delay	Average Delay	Long Delay	Delay simulation	Contractor weekly production loss 1	Contractor weekly production loss 2	Contractor weekly production loss 3	Contractor weekly production loss 4	Contractor weekly production loss 5	Weighted weekly cost (R million)	Low cost increase	Average Cost increase	High cost increase	Extra capital simulation	Simulation Result
1	Inclement weather	once	E	Almost Certain	95%	2.00	1.00	0.15	1.00	2.00	1.54	50%	30%				R 0.12				R -	R 0.19
2	Labour unrest	Once	B	Unlikely	20%		0.00	0.15	0.45	1.00	0.19	100%	30%				R 0.16				R -	R -
3	Long lead items	Once	C	Moderate	45%		0.00	0.30	0.45	1.00	0.41	10%	10%				R 0.04				R -	R -
4	Scope definition	Once	E	Almost Certain	95%		1.00				0.00						R -	R 0.15	R 0.20	R 0.25	R 0.20	R 0.20
5	Safety non-compliance	Once	B	Unlikely	20%		0.00	0.15	0.30	0.45	0.32	100%	10%				R 0.11				R -	R -
6	Safety non-compliance	Once	C	Moderate	45%		0.00	0.15	0.45	1.00	0.17	100%	20%				R 0.14				R -	R -

Figure 9-19: Copied risk register into CRR sheet

9.8.3 Assign unique Project Name to all newly copied risks

Purpose:

- To provide a unique Project Name in the CRR sheet which can be used to link information from the “Project Information” sheet. The linked information is used to calculate “Weekly Average Weighted cost”.

Steps:

56. Insert an extra column (Column B) and populate all the rows of the newly copied project risk data with a unique project name. The risk register name of the project being copied should normally be sufficient but it has to be ensured that the name is unique. If there are duplicate names, the risk provision for each project will not be calculated correctly.

56

Line Number	Project name	Risk source (Element which alone, or in combination, has the potential to give rise to a risk)	Risk Event (Change of a particular set of circumstances)	Short risk name	Consequence on project (Outcome of a risk event affecting project objectives)	Risk treatment (Process to modify a risk by removing, reducing likelihood, reducing impact)	Controls (Measures which modify risk - can be in place or be planned)	How many times can the risk occur?	Occurrence type (A - E)
1	'Export Trippers, Port of Richards Bay	Bad weather during the occupation. Crane lifting cannot take place.	There is a risk of inclement weather.	Inclement weather	Schedule delays due to standing time of productive resources.	Crane lifting to be scheduled in good weather times. Due communication between project and TPT operations. Monitor weather forecast. Comprehensive rigging study in place. Experienced rigging company. Ensure that cranes are equipped with wind speed meters.	Rigging study completed. Reviewed competency of rigging company. Speed meters fitted.	More than once	E
2	'Export Trippers, Port of Richards Bay	Labour unrest.	There is a risk of strikes, delaying the project completion.	Labour unrest	Standing time.	Proper communication between Transnet and Unions.	Contractor needs to have strike action plan in place. Refer to Transnet Strike action plans.	Once	B
3	'Export Trippers, Port of Richards Bay	Late delivery of bought out items	There is a risk that long lead items wil be delayed.	Long lead items	Project delay and cost increase due to standing time of productive resources.	Liaison with contracor and suppliers. Expedite order.	Minutes of meetings. Equipment approved for use. Purchase orders placed.	Once	C
4	'Export Trippers, Port of Richards Bay	Misallignment of existing long travel rails. Lack of maintenance on existing asset. FEL3 with NO FEL-2 done.	There is a risk that additional work needs to be done to ensure that asset is operational.	Scope definition	Change or increased cost due to design changes.	Structural survey on rails ompleted. Design changes to tripper car rails and chutes. Change to PLP to accomodate similar problems "Investigate historical maintenance issues	Signed of survey. Signed of design changes. Agreed changes to PLP. PCNs signed.	Once	E
5	'Export Trippers, Port of Richards Bay	Not adhering to regulations. Fatalities. Injuries. Site access for emergency equipment not sufficient. Hot work plan not in place	There is a possiblity that the site might be closed by the DoL due to regulations and processes regarding safety not being followed.	Safety non-compliance	Site closed.	Approved emergency plan for construction. Approved hot work plan.	Approved emergency plan. Approved hot work plan.	Once	B

Figure 9-20: Copied risk register into CRR sheet

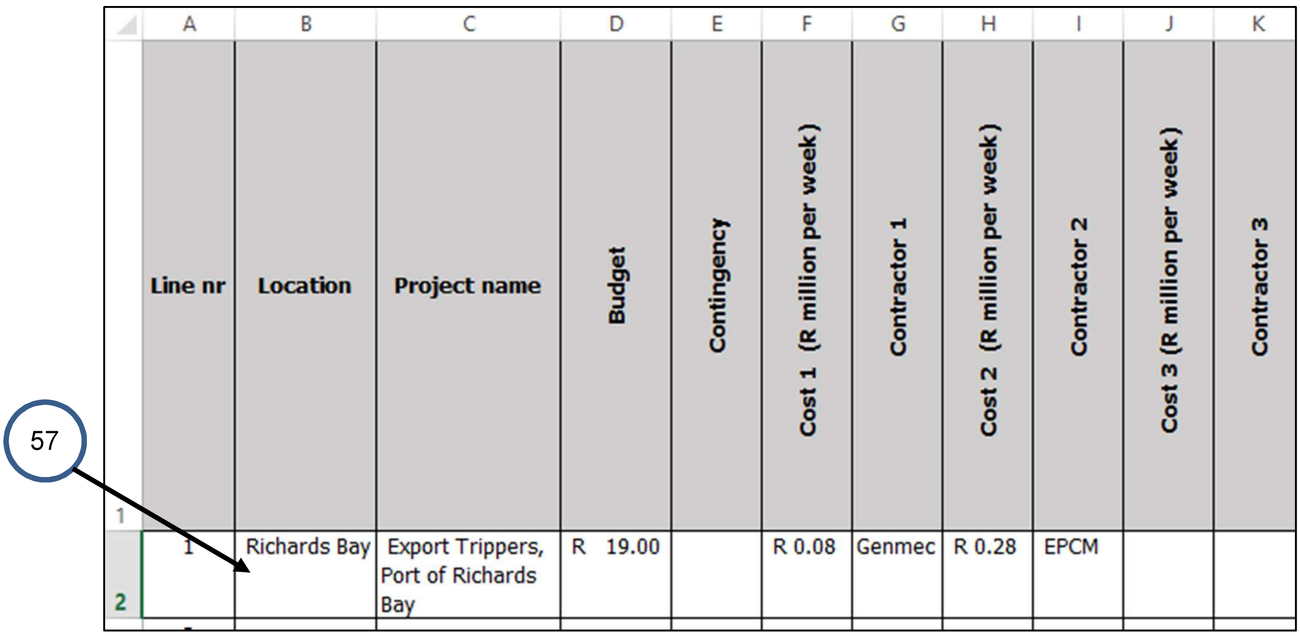
9.8.4 Create new project in "Project Information" sheet using unique Project Name

Purpose:

- To update the "Project Information" sheet with project related information from the original risk register.
- The information in the "Project Information" sheet was pulled into the "CRR" sheet using a =*VLookup()* function.

Steps:

57. Copy information (location, budget, costs information) to the correct column in "Project Information" sheet.



	A	B	C	D	E	F	G	H	I	J	K
1	Line nr	Location	Project name	Budget	Contingency	Cost 1 (R million per week)	Contractor 1	Cost 2 (R million per week)	Contractor 2	Cost 3 (R million per week)	Contractor 3
2	1	Richards Bay	Export Trippers, Port of Richards Bay	R 19.00		R 0.08	Genmec	R 0.28	EPCM		

Figure 9-21: Project information updated in "Project Information" sheet

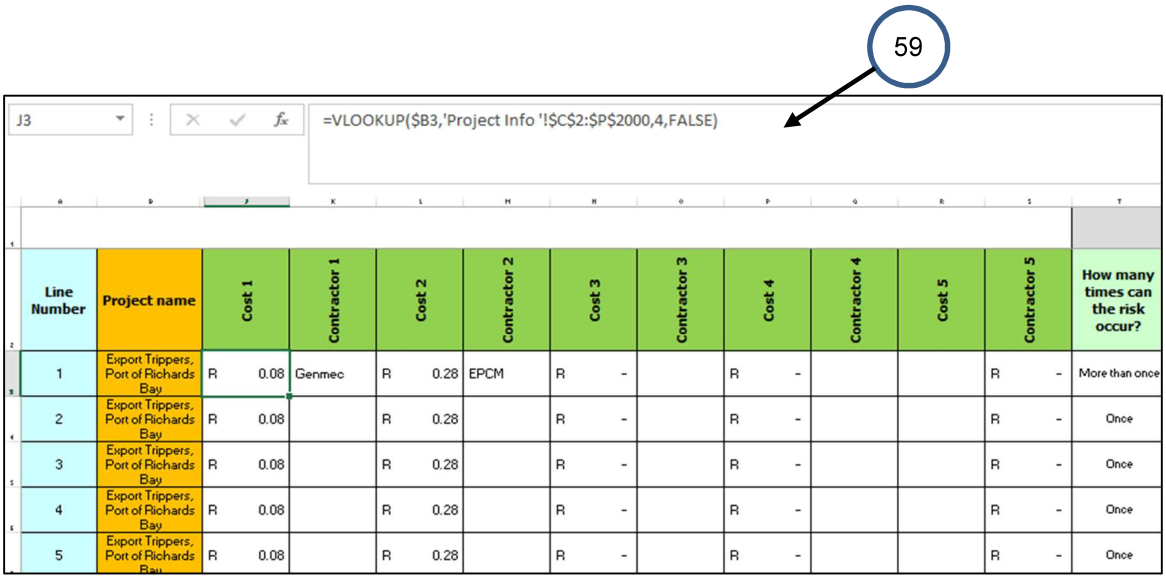
9.8.5 Link project information with CRR Sheet

Purpose:

- To look up the related information from the “Project Information” sheet to the “CRR” sheet. The information will be used to calculate the weekly cost of each risk, should the risk realise.

Steps:

58. Use =*VLookup()* function to look up cost information.
59. Copy the function down in spreadsheet for other projects’ information to be looked up too.



Line Number	Project name	Cost 1	Contractor 1	Cost 2	Contractor 2	Cost 3	Contractor 3	Cost 4	Contractor 4	Cost 5	Contractor 5	How many times can the risk occur?
1	Export Trippers, Port of Richards Bay	R 0.08	Genmec	R 0.28	EPCM	R -		R -			R -	More than once
2	Export Trippers, Port of Richards Bay	R 0.08		R 0.28		R -		R -			R -	Once
3	Export Trippers, Port of Richards Bay	R 0.08		R 0.28		R -		R -			R -	Once
4	Export Trippers, Port of Richards Bay	R 0.08		R 0.28		R -		R -			R -	Once
5	Export Trippers, Port of Richards Bay	R 0.08		R 0.28		R -		R -			R -	Once

Figure 9-22: Project information linked to “CRR” sheet

9.8.6 Does CRR show errors?

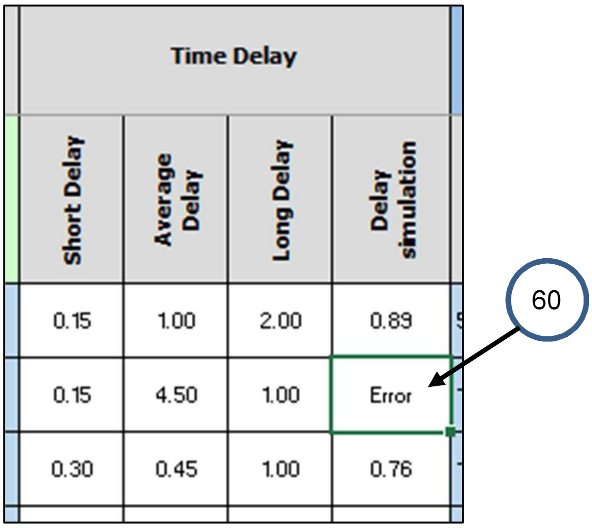
Purpose:

- To ensure that there are no calculation errors in the simulation result, thus ensuring that the research results are verifiable.

Steps:

60. Use filters to check if there are any error messages in the cells which contain @Risk equations. The message “Error” will appear.

61. If there are any errors, correct. The errors would mainly relate to three-point estimates which are not in sequence (low, medium, high), as shown in Figure 9-23.
62. Use filters to check if there are any errors in the following columns and correct where required using the dropdown boxes.



Time Delay			
Short Delay	Average Delay	Long Delay	Delay simulation
0.15	1.00	2.00	0.89
0.15	4.50	1.00	Error
0.30	0.45	1.00	0.76

Figure 9-23: Error checking

9.8.7 Close risk register and move to "_Quantify" directory

Purpose:

- After error checking, the information required from the Risk Register is complete and it can be closed and moved to the "_Quantify" directory.

Steps:

63. Close risk register "Export Trippers".
64. Move entire directory to "_Quantify" directory
65. Go to next risk register and repeat "Copy Risk Register to "CRR" sheet" process.

Figure 9-24: Completed risk register moved to "_Quantify" directory

9.9 Categorise Projects

- The previous section added a list of unique project names in the "Project Information" sheet to the simulation model.
- The Project categories were defined in the beginning of this chapter and each project in the "Project Information" Sheet needed to be put into a category to answer the associated research questions.
- Although the project categories were defined, there might be projects which cannot be assigned, as described in Figure 9-25.

9.9.1 Flow diagram

The following diagram describes the process of categorising the various projects.

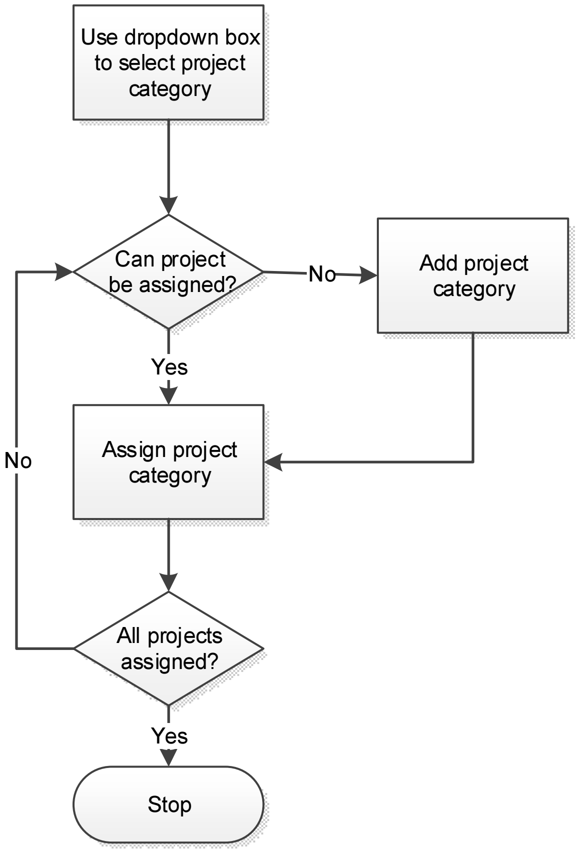


Figure 9-25: Categorise projects flow diagram

Steps:

66. Since a column "Project Type" has already been created in the "Project Information" sheet, only a dropdown box needs to be created.
67. Use DATA/DATA VALIDATION/DATA VALIDATION/LISTS and link the named range "TR_Project_Type" to the column "Project Type".
68. Copy the dropdown box down in the spreadsheet as required.
69. Allocate a project category to each project (Column P in Figure 9-26).
70. If a project cannot be allocated to a category, create a new category and update the "Project Type" column on the "Project Information" sheet and update the Project Type dropdown box on the "Project Information" sheet.
71. Use FORMULAS/NAME MANAGER and name the range "PI_Project_Type.

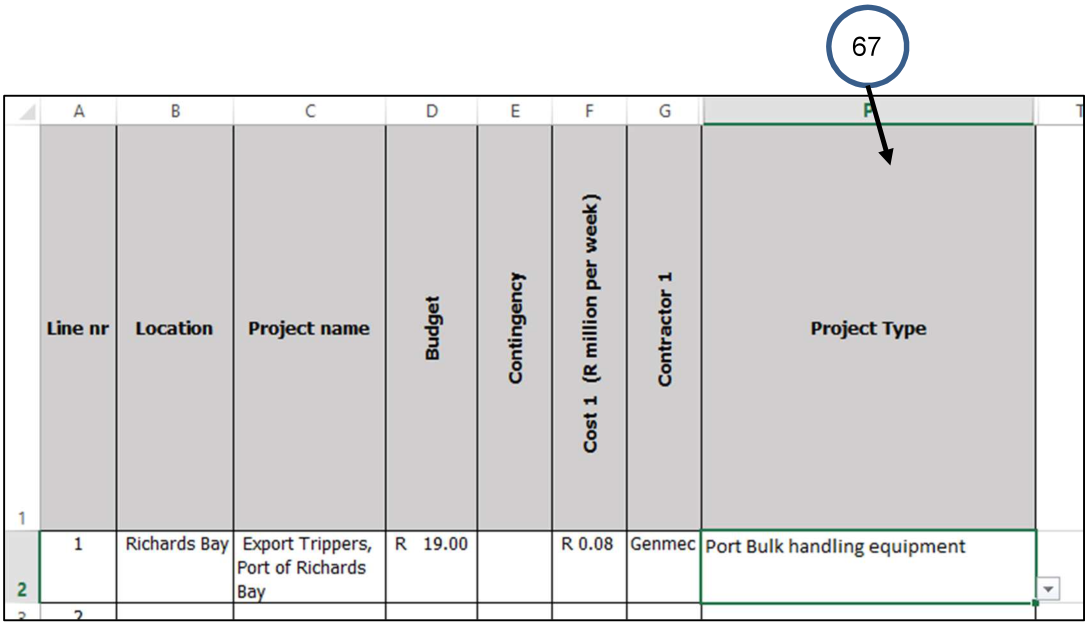


Figure 9-26: Allocate Project Type to each project

9.9.2 Categorise risks

Purpose:

- This section describes how the risk names were cleaned up during the development of the simulation model. During the creation of the risk registers, various risk names were used to describe the same risk. Risk names such as “Industrial Action”, “Industrail Action”, “Industrial Actions” and “Strikes” were all used during the data collection and should be re-named to the same name, for example, “Industrial action”.
- These risk names were used together with =*SumIfs()* statements to answer Research Questions 3 to 6.

Flow Diagram

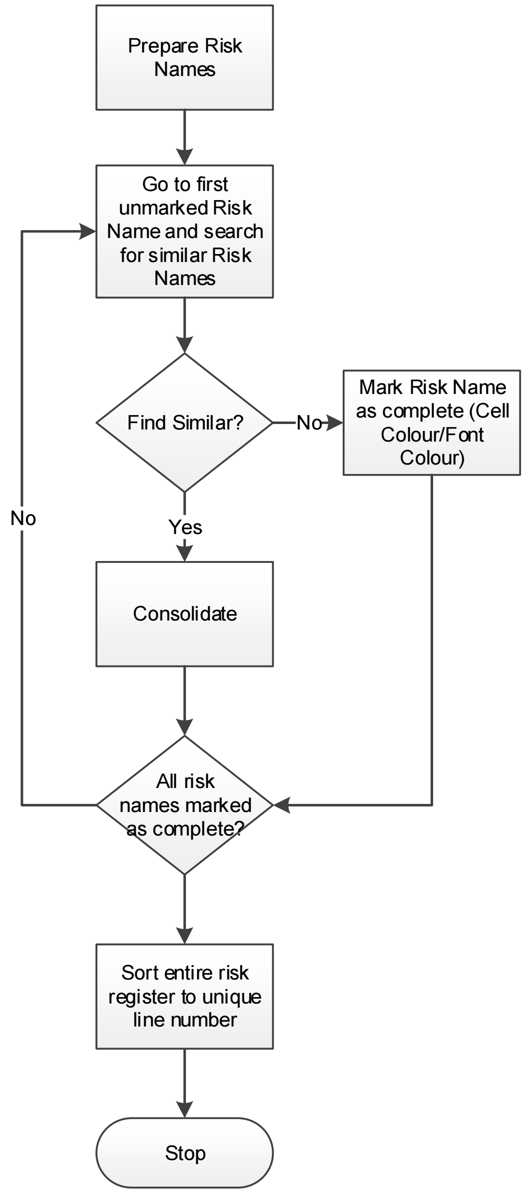


Figure 9-27: Consolidate risk names flow diagram

Prepare risk names

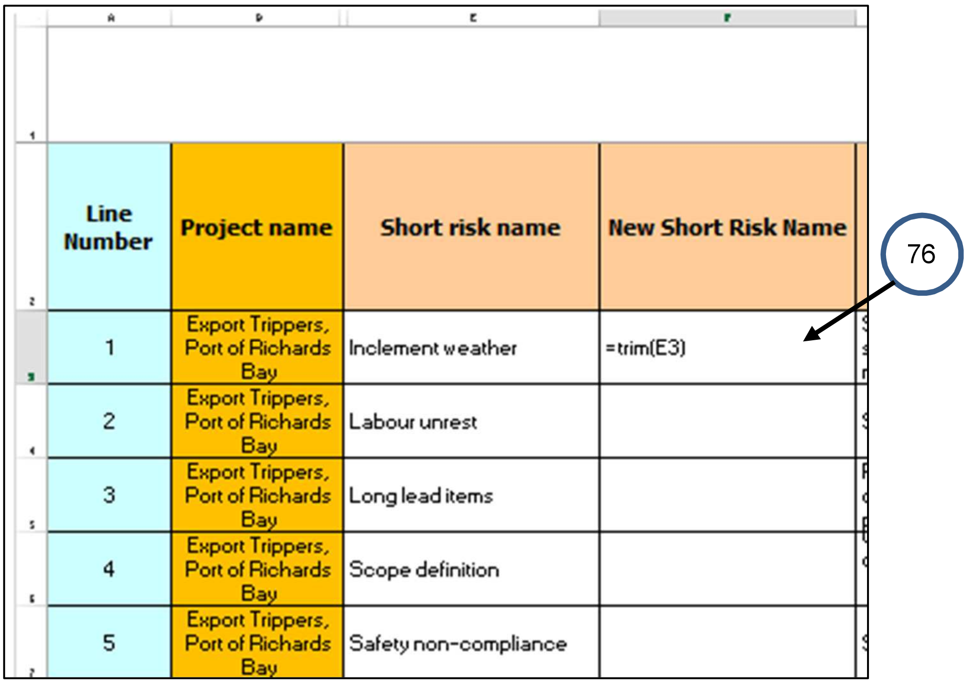
Purpose:

- When copying information from various sources into the same worksheet, various duplicates are invariably created. These duplicates have the same meaning but are not necessarily spelled in the same way. To ensure that the risk simulation delivers verifiable results, the risk names therefore needed to be de-duplicated.

- The risk names need to be prepared before clean-up to speed up the de-duplication process of the risk names.
- This process will remove punctuation marks and extra spaces in the risk names. This step reduces variety in risk names (for example: "Inclement-weather", "Inclement weather" and "Inclement weather" all become one risk).

Steps:

72. Do a spell check on the risk names.
73. Highlight the column "Short Risk Name", repeat FIND and REPLACE punctuation marks with "" until everything has been removed.
74. Remove double spaces: Highlight the column "Short Risk Name", FIND and REPLACE all double spaces "__" with single spaces "_".
75. Insert a new column (column F) after the "Short Risk Name" column and call it "New Short Risk name".
76. Remove leading and trailing spaces: Insert a =*Trim(E3)* into column F and copy down as per Figure 9-28. This function will remove all spaces before and after the risk names.
77. Take Column F and paste the contents as static values in Column E. Delete column F.
78. Column E will now contain text with no spaces before or after the risk names, no punctuation and no double spaces.
79. Sort the entire spreadsheet to "New Short Risk Name".



Line Number	Project name	Short risk name	New Short Risk Name
1	Export Trippers, Port of Richards Bay	Inclement weather	=trim(E3)
2	Export Trippers, Port of Richards Bay	Labour unrest	
3	Export Trippers, Port of Richards Bay	Long lead items	
4	Export Trippers, Port of Richards Bay	Scope definition	
5	Export Trippers, Port of Richards Bay	Safety non-compliance	

Figure 9-28: Preparing Risk Names

Consolidate Risk Names

Purpose:

- Similar risk names need to be consolidated. If the same risk event appears under different risk names, the risk simulation results would not be verifiable.
- Examples:
  - “Industrial action”, “Labour unrest” and “Strikes” became “Industrial action”
  - “Inclement weather”, “Heavy rains” and “Bad Weather” became “Inclement weather”.

Steps:

80. Since the entire risk register has already been sorted according to “Risk Name”, start at the beginning of the risk register and go through the list and consolidate risk names. “Labour Unrests” became “Labour Unrest”.

80

Line Number	Project name	Risk source (Element which alone, or in combination, has the potential to give rise to a risk)	Risk Event (Change of a particular set of circumstances)	New short risk name
2	Export Trippers, Port of Richards Bay	Labour unrest.	There is a risk of strikes, delaying the project completion.	Labour unrests
42	GP1GP2 Sheds	Labour unrest. Intimidation by unemployed locals. Particular to Sentrarand.	There is a risk of intimidation, delaying the project completion.	Labour unrest

81

Line Number	Project name	Risk source (Element which alone, or in combination, has the potential to give rise to a risk)	Risk Event (Change of a particular set of circumstances)	New short risk name
2	Export Trippers, Port of Richards Bay	Labour unrest.	There is a risk of strikes, delaying the project completion.	Labour unrest
42	GP1GP2 Sheds	Labour unrest. Intimidation by unemployed locals. Particular to Sentrarand.	There is a risk of intimidation, delaying the project completion.	Labour unrest

Figure 9-29: Clean-up of similar risk names

81. When completed with a risk name, mark it (in this case green) to show that it has been completed. Proceed to the next one until the entire list of short risk names has been completed.
82. It might be required to go through the list more than once to ensure that all the risks have been renamed appropriately.

Add Risk categories

Purpose:

- The sheet “All Risks” was created in the simulation model (with the appropriate dropdown boxes) and could not be populated with the risk names since the risk names first needed to be cleaned-up and de-duplicated.
- The previous section produced the required list of cleaned-up and de-duplicated risk names.

- At the end of this step, it will be known where each risk fits into the RBS, whether the risk delays project execution start, what type of risk it is as well as how this risk relates to programme risks.
- Figure 9-30 describes this process which ensures that all risks names are assigned to an appropriate place in the RBS.

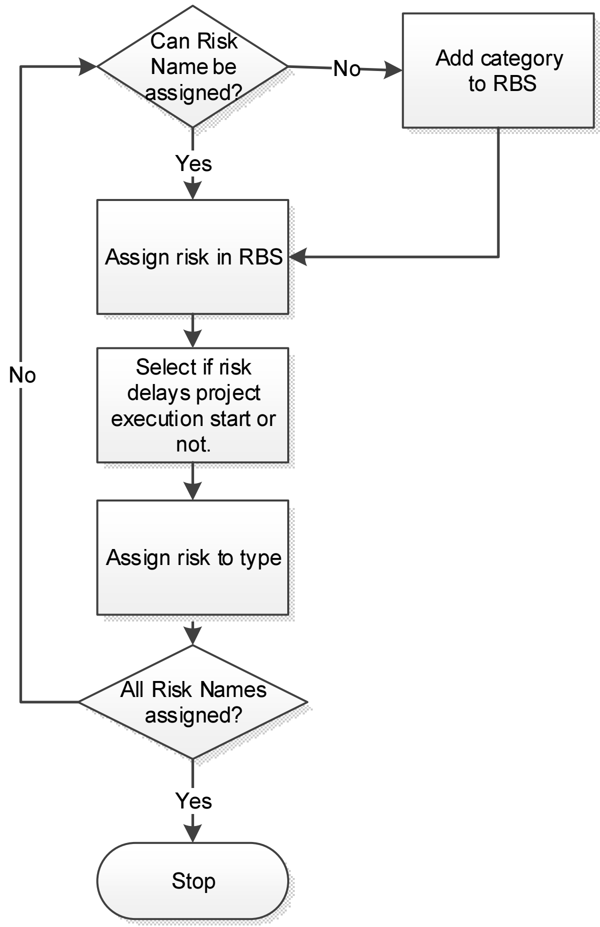
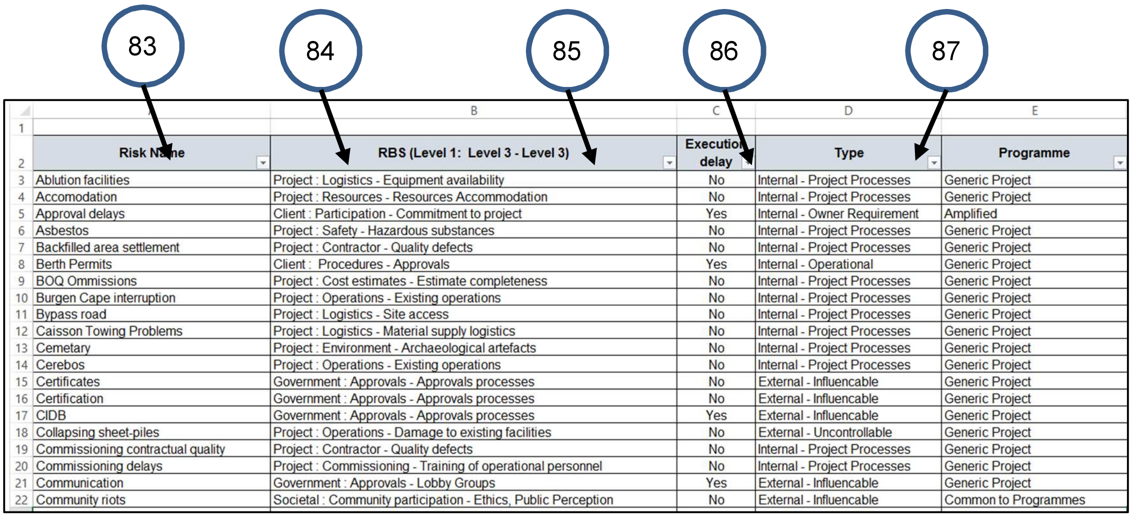


Figure 9-30: Categorising Risks flow diagram

Steps:

83. Copy the entire contents of the column “Short Risk Name” from the “CRR” Sheet into column A of the “All Risks” Sheet. Use the built-in Excel de-duplication function and remove all duplicates from the list and then sort the list in alphabetical order.
84. Link the risk in Column A to an item in the RBS (Column B).
85. Decide if the risk in Column A delays project execution start (Column C).
86. Link the risk in Column A to an appropriate risk type (Column D).

87. Decide how the risk in Column A is related to Programmes (Column D).



	A	B	C	D	E
1					
2	Risk Name	RBS (Level 1: Level 3 - Level 3)	Execution delay	Type	Programme
3	Ablution facilities	Project : Logistics - Equipment availability	No	Internal - Project Processes	Generic Project
4	Accomodation	Project : Resources - Resources Accommodation	No	Internal - Project Processes	Generic Project
5	Approval delays	Client : Participation - Commitment to project	Yes	Internal - Owner Requirement	Amplified
6	Asbestos	Project : Safety - Hazardous substances	No	Internal - Project Processes	Generic Project
7	Backfilled area settlement	Project : Contractor - Quality defects	No	Internal - Project Processes	Generic Project
8	Berth Permits	Client : Procedures - Approvals	Yes	Internal - Operational	Generic Project
9	BOQ Ommissions	Project : Cost estimates - Estimate completeness	No	Internal - Project Processes	Generic Project
10	Burgen Cape interruption	Project : Operations - Existing operations	No	Internal - Project Processes	Generic Project
11	Bypass road	Project : Logistics - Site access	No	Internal - Project Processes	Generic Project
12	Caisson Towing Problems	Project : Logistics - Material supply logistics	No	Internal - Project Processes	Generic Project
13	Cemetary	Project : Environment - Archaeological artefacts	No	Internal - Project Processes	Generic Project
14	Cerebos	Project : Operations - Existing operations	No	Internal - Project Processes	Generic Project
15	Certificates	Government : Approvals - Approvals processes	No	External - Influencable	Generic Project
16	Certification	Government : Approvals - Approvals processes	No	External - Influencable	Generic Project
17	CIDB	Government : Approvals - Approvals processes	Yes	External - Influencable	Generic Project
18	Collapsing sheet-piles	Project : Operations - Damage to existing facilities	No	External - Uncontrollable	Generic Project
19	Commissioning contractual quality	Project : Contractor - Quality defects	No	Internal - Project Processes	Generic Project
20	Commissioning delays	Project : Commissioning - Training of operational personnel	No	Internal - Project Processes	Generic Project
21	Communication	Government : Approvals - Lobby Groups	Yes	External - Influencable	Generic Project
22	Community riots	Societal : Community participation - Ethics, Public Perception	No	External - Influencable	Common to Programmes

Figure 9-31: "All Risks" sheet

Final clean-up of risk names

Purpose:

- After all the risks have been categorised, there remains a possibility that some of the risk names have not been consolidated as previously mentioned in this Section. Since one of the research questions (Section 1.4: Problem Statement p. 38) refers to individual risks, it is important to ensure that risks are consolidated as far as possible.

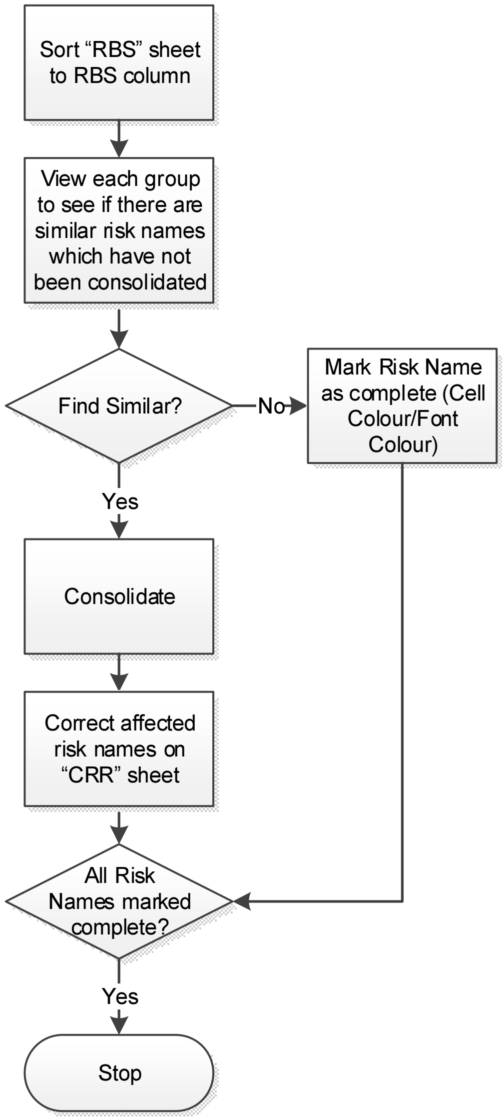
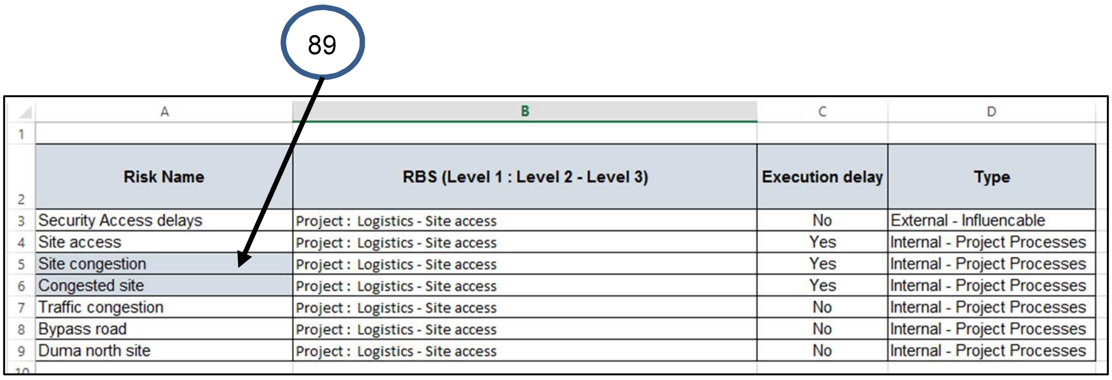


Figure 9-32: Final clean-up of risks names flow diagram

Steps:

88. Sort the entire sheet according to the “RBS” column (Column B).
89. Review, per group (Figure 9-33), and for example, consolidate *Site Congestion* and *Congested site*.

90. Consolidate and correct risk name as per the example on the Figure. "Site congestion" and "Congested site" to *Site Congestion* and change all the risk names Congested Site in the CRR sheet to Site Congestion.



	A	B	C	D
1				
2	Risk Name	RBS (Level 1 : Level 2 - Level 3)	Execution delay	Type
3	Security Access delays	Project : Logistics - Site access	No	External - Influencable
4	Site access	Project : Logistics - Site access	Yes	Internal - Project Processes
5	Site congestion	Project : Logistics - Site access	Yes	Internal - Project Processes
6	Congested site	Project : Logistics - Site access	Yes	Internal - Project Processes
7	Traffic congestion	Project : Logistics - Site access	No	Internal - Project Processes
8	Bypass road	Project : Logistics - Site access	No	Internal - Project Processes
9	Duma north site	Project : Logistics - Site access	No	Internal - Project Processes

Figure 9-33: Final clean-up of risk names using RBS sheet

After this clean-up, a total of 1063 risks were linked to 165 individual risk names of which 44 different risk names made up 80% of the total number of risks in the CRR, as appearing in Table 9-1.

	RISK NAME	CLOSED	OPEN	GRAND TOTAL	CUMULATIVE %
1	Safety Non-Compliance	13	75	88	8.3%
2	Labour Unrest	11	50	61	14.0%
3	Damages to Underground Services	4	47	51	18.8%
4	Crime	11	37	48	23.3%
5	Occupations	5	35	40	27.1%
6	Inclement Weather	4	33	37	30.6%
7	Environmental Non-Compliance	12	23	35	33.9%
8	Disrupt Operations	9	25	34	37.1%
9	Long Lead Items	13	19	32	40.1%
10	Scope Definition	7	23	30	42.9%
11	Skills & Resources	11	19	30	45.7%
12	Geotech	6	18	24	48.0%
13	Late Material Delivery	1	18	19	49.8%
14	Late Order Placement	10	8	18	51.5%
15	Approval Delays	5	12	17	53.1%
16	RME Capacity	4	12	16	54.6%

	RISK NAME	CLOSED	OPEN	GRAND TOTAL	CUMULATIVE %
17	Site Congestion	6	10	16	56.1%
18	Operational Readiness	7	8	15	57.5%
19	Asbestos	2	13	15	58.9%
20	Contractor Quality	4	10	14	60.2%
21	Equipment Breakdown	4	10	14	61.5%
22	Site Access	4	9	13	62.7%
23	Late Tender Documentation	3	10	13	64.0%
24	Underground Conditions	8	4	12	65.1%
25	Traffic Congestion	5	7	12	66.2%
26	Design Approvals	1	11	12	67.4%
27	Design Change	3	8	11	68.4%
28	Site access - Operational requirements	2	9	11	69.4%
29	Eskom	5	5	10	70.4%
30	Soil Contamination	1	8	9	71.2%
31	Damage to Assets	2	7	9	72.1%
32	Material Shortage	7	2	9	72.9%
33	Procurement Delays	3	5	8	73.7%
34	Equipment Unavailable	3	5	8	74.4%
35	Stakeholder Commitment	3	5	8	75.2%
36	Environmental Approval Delay	2	6	8	75.9%
37	Planning	2	5	7	76.6%
38	Compressed Schedule	3	3	6	77.1%
39	Community Riots	2	4	6	77.7%
40	Land Acquisition	1	5	6	78.3%
41	Body of Quantity Omissions	5	1	6	78.8%
42	Unreliable Contractor		5	5	79.3%
43	Unknown Entities	2	3	5	79.8%
44	Inexperienced Contractor		5	5	80.2%

Table 9-1: Cleaned-up risk names

9.10 Link "All Risks" to "CRR" sheet

After the "All Risk" sheet has been completed, the "CRR" sheet can be completed by linking the following:

- "Project name" with "Project Type" from "Project Information" sheet.
- "New Short Risk name" with:
  - RBS Level 1, RBS Level 2 and RBS Level 3 from "RBS".
  - "Delay Project Execution" from "All risks".
- The main reason for this is that the information which is contained in these tables needs to be available in the CRR sheet.

9.10.1 Flow Diagram

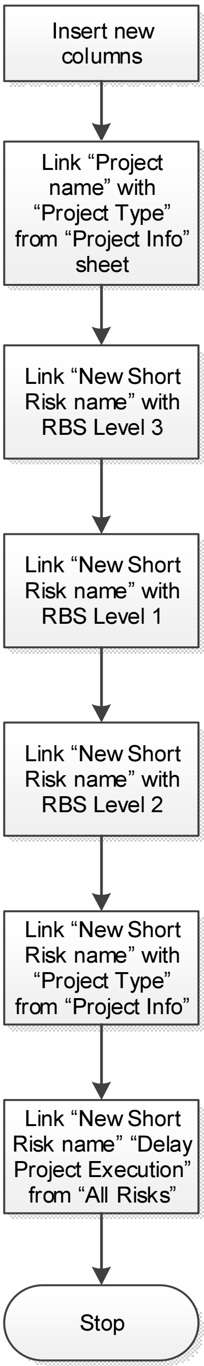


Figure 9-34: Link "All Risks" to "CRR" sheet flow diagram

9.10.2 Insert new columns

Purpose:

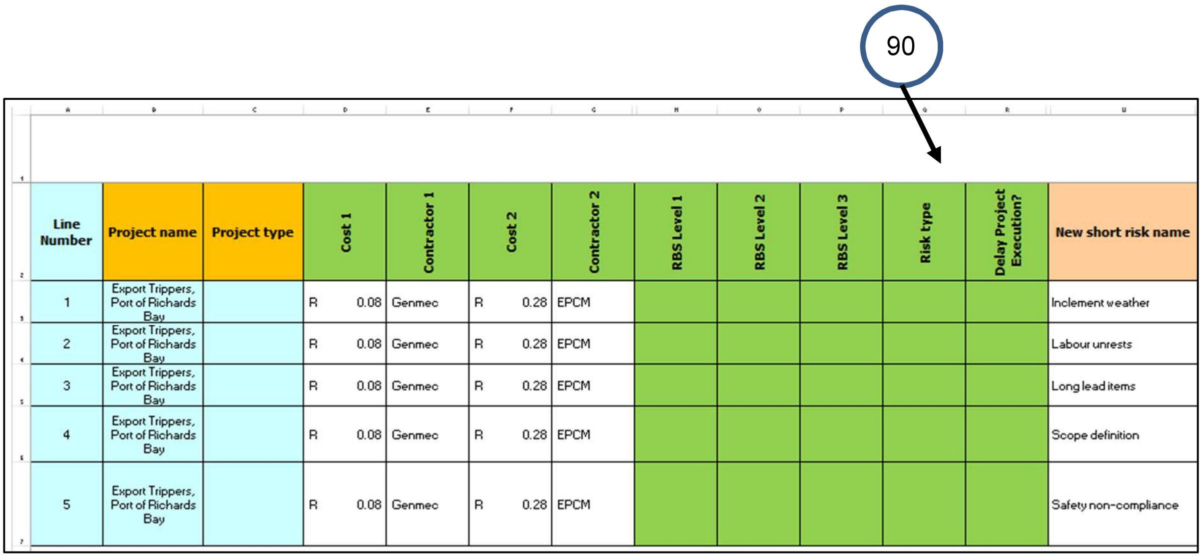
New columns need to be added to accommodate the following:

- Project Type.
- RBS Level 1, RBS Level 2, RBS Level 3.

- Risk Type.
- Yes/No indicator for “Delay in Project Execution Start”.
- Programme type (not indicated on Figure).

Steps:

91. Insert columns as shown on Figure 5-37 (columns C, N - R).



Line Number	Project name	Project type	Cost 1	Contractor 1	Cost 2	Contractor 2	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name
1	Export Trippers, Port of Richards Bay		R 0.08	Genmec	R 0.28	EPCM						Inclement weather
2	Export Trippers, Port of Richards Bay		R 0.08	Genmec	R 0.28	EPCM						Labour unrests
3	Export Trippers, Port of Richards Bay		R 0.08	Genmec	R 0.28	EPCM						Long lead items
4	Export Trippers, Port of Richards Bay		R 0.08	Genmec	R 0.28	EPCM						Scope definition
5	Export Trippers, Port of Richards Bay		R 0.08	Genmec	R 0.28	EPCM						Safety non-compliance

Figure 9-35: Insert columns for “Project Type", “RBS”, “Risk Type", and "Delay Project Execution?"

9.10.3 Link “Project name” with “Project Type” from “Project Information” Sheet

Purpose:

- To link “Project name” with “Project Type” from “Project Information” sheet and therefore indicate what type of project each line item represents.

Steps:

92. Use a =*VLookup()* function to look up the information from the named range “PI_Project_Type”.

92

=VLOOKUP(B3,Project_Type_Info_sheet,14,FALSE)

Line Number	Project name	Project type	Cost 1	Contractor 1	Cost 2	Contractor 2	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name
1	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM						Inclement weather
2	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM						Labour unrests
3	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM						Long lead items
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM						Scope definition
5	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM						Safety non-compliance

Figure 9-36: Link "Project name" with "Project Type" from "Project Information" sheet

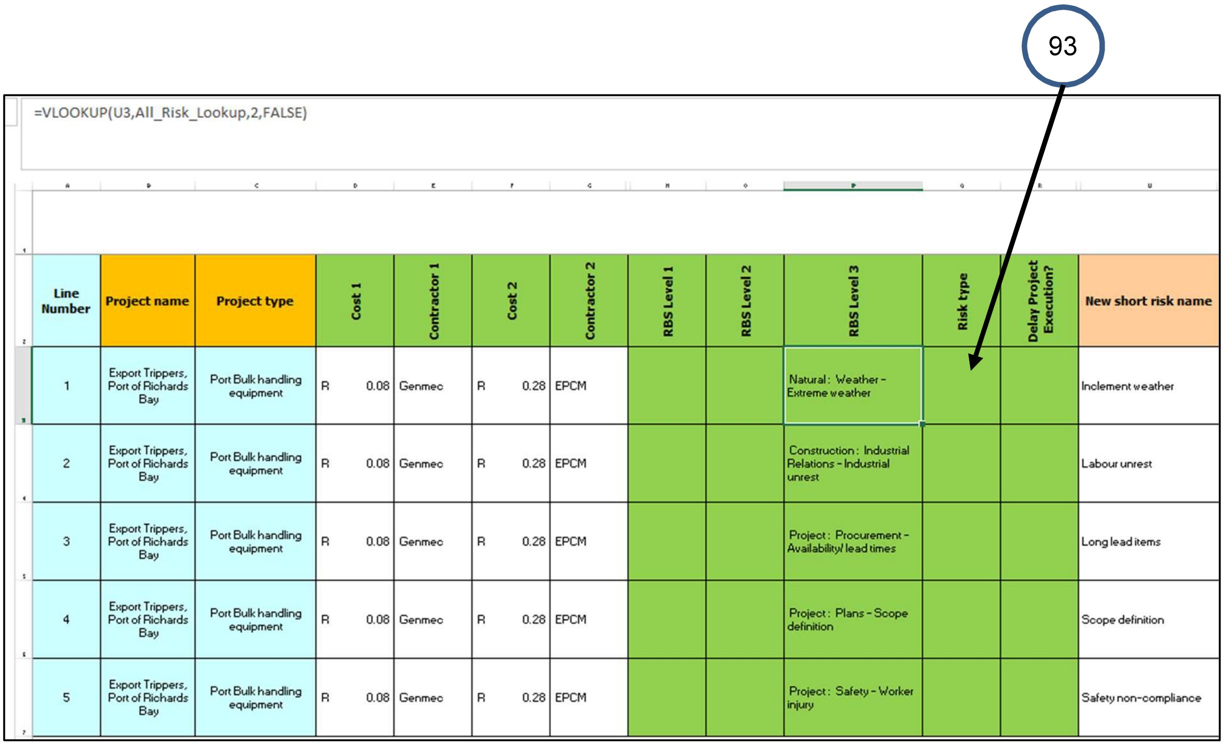
9.10.4 Link "New Short Risk name" with RBS Level 3

Purpose:

- To link "New short risk name" with "RBS Level 3" from "All Risks" sheet and therefore indicate where in RBS Level 3 the risk can be found.

Steps:

93. Use a =*VLookup()* function to look up the information from the named range "All_Risk_Lookup".
94. Copy the function down in the sheet as required.
95. Use a filter to check for any errors and fix appropriately.



=VLOOKUP(U3,All_Risk_Lookup,2,FALSE)

Line Number	Project name	Project type	Cost 1	Contractor 1	Cost 2	Contractor 2	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name
1	Export Tippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM			Natural: Weather - Extreme weather			Inclement weather
2	Export Tippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM			Construction: Industrial Relations - Industrial unrest			Labour unrest
3	Export Tippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM			Project: Procurement - Availability/ lead times			Long lead items
4	Export Tippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM			Project: Plans - Scope definition			Scope definition
5	Export Tippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM			Project: Safety - Worker injury			Safety non-compliance

Figure 9-37: Link “Project name” with “RBS Level 3” from “All Risks” sheet

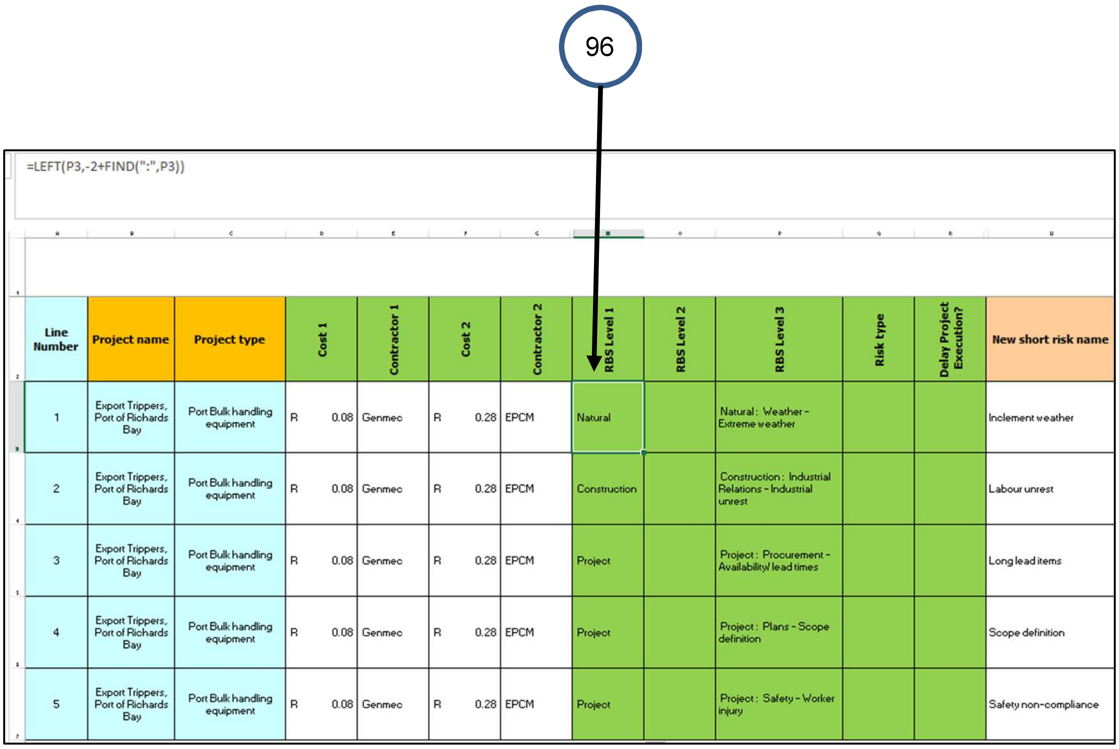
9.10.5 Link “New Short Risk name” with RBS Level 1

Purpose:

- This links the *New Short Risk name* with the appropriate RBS levels.

Steps:

96. Since the first level of the RBS already appears in the “RBS Level 3” column, a *=Left()* combined with a =Find() function is used to extract the Level 1 RBS. The *=Find()* function finds the position of the “:” - this is the reason why different punctuation marks were used in Section 9.9.2.
97. Copy the function down in the sheet as required.
98. Use a filter to check for any errors and fix as appropriately.



Line Number	Project name	Project type	Cost 1	Contractor 1	Cost 2	Contractor 2	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name
1	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Natural		Natural: Weather - Extreme weather			Inclement weather
2	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Construction		Construction: Industrial Relations - Industrial unrest			Labour unrest
3	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project		Project: Procurement - Availability/ lead times			Long lead items
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project		Project: Plans - Scope definition			Scope definition
5	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project		Project: Safety - Worker injury			Safety non-compliance

Figure 9-38: Extract RBS Level 1 from RBS Level 3

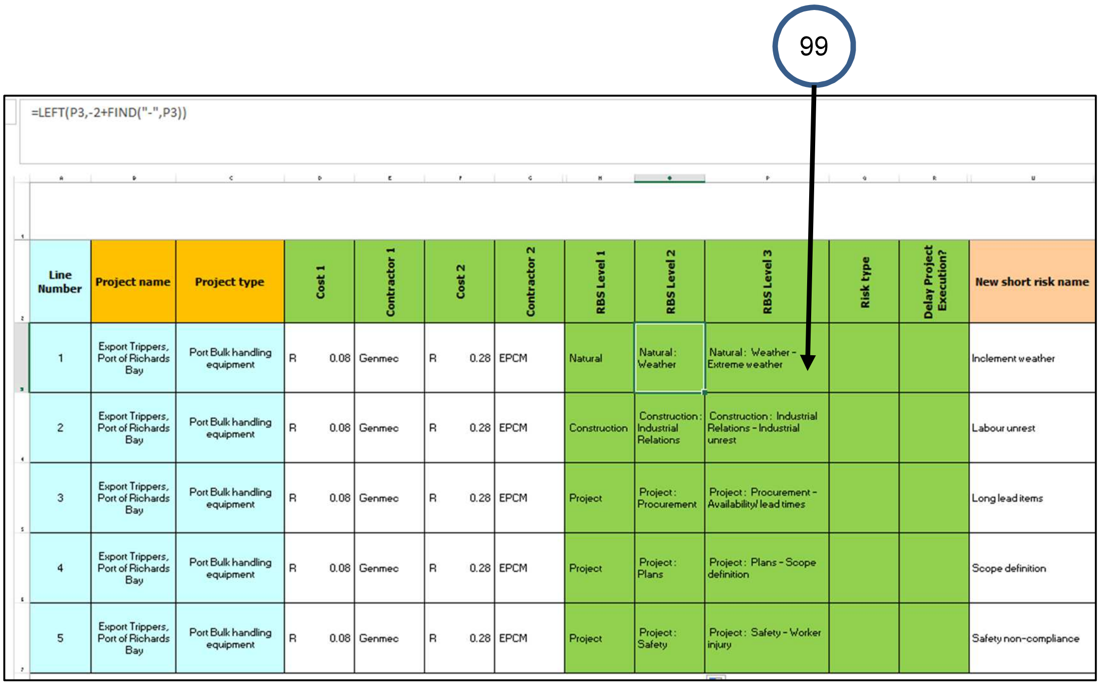
9.10.6 Link "New Short Risk name" with RBS Level 2

Purpose:

- To indicate where the risk can be found in RBS Level 2.

Steps:

99. Since the first level of the RBS already appears in the "RBS Level 3" column, a =*Left()* combined with a =*Find()* function is used to extract the Level 1 RBS. The =*Find()* function finds the position of the "-".
100. Copy the function down in the sheet as required.
101. Use a filter to check for any errors and fix as appropriate.



Line Number	Project name	Project type	Cost 1	Contractor 1	Cost 2	Contractor 2	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name
1	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Natural	Natural : Weather	Natural : Weather - Extreme weather			Inclement weather
2	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Construction	Construction : Industrial Relations	Construction : Industrial Relations - Industrial unrest			Labour unrest
3	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project	Project : Procurement	Project : Procurement - Availability/ lead times			Long lead items
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project	Project : Plans	Project : Plans - Scope definition			Scope definition
5	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project	Project : Safety	Project : Safety - Worker injury			Safety non-compliance

Figure 9-39: Extract RBS Level 2 from RBS Level 3

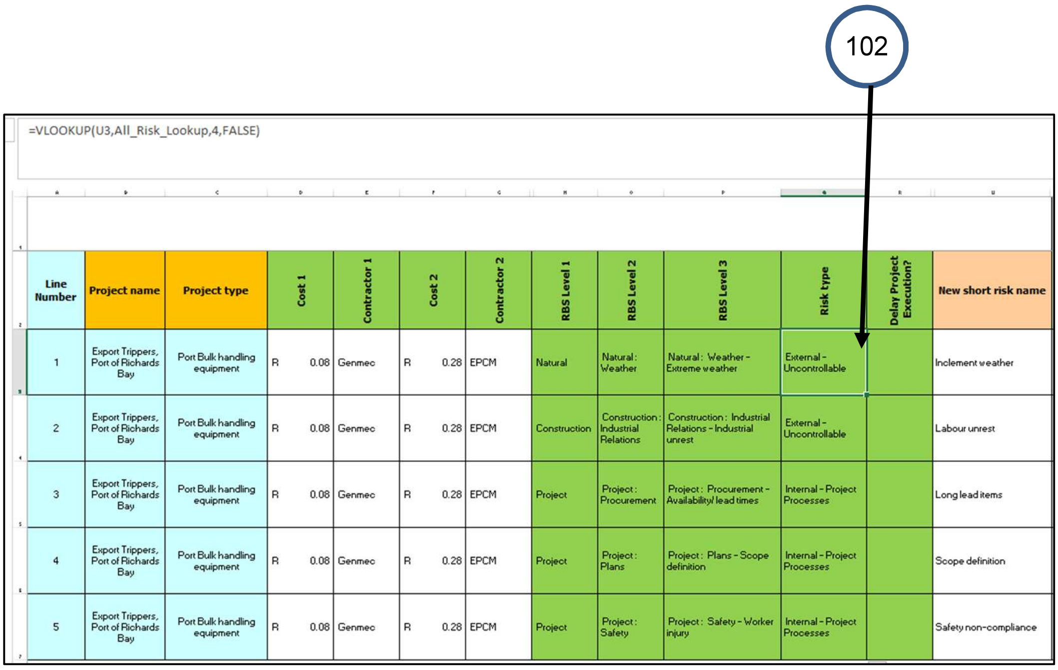
9.10.7 Link "New Short Risk name" with "Project Type" from "All Risks" Sheet'

Purpose:

- To link "New short risk name" with "Risk Type" from "All Risks" sheet and therefore indicate each risks' type.

Steps:

102. Use a =*VLookup()* function to look up the information from the named range "All_Risk_Lookup".
103. Copy the function down in the sheet as required.
104. Use a filter to check for any errors and fix as appropriate.
105. Follow the same principle and link "Delay Project Execution" and "Programme Type.



Line Number	Project name	Project type	Cost 1	Contractor 1	Cost 2	Contractor 2	RBS Level 1	RBS Level 2	RBS Level 3	Risk type	Delay Project Execution?	New short risk name
1	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Natural	Natural: Weather	Natural: Weather - Extreme weather	External - Uncontrollable		Inclement weather
2	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Construction	Construction: Industrial Relations	Construction: Industrial Relations - Industrial unrest	External - Uncontrollable		Labour unrest
3	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project	Project: Procurement	Project: Procurement - Availability/ lead times	Internal - Project Processes		Long lead items
4	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project	Project: Plans	Project: Plans - Scope definition	Internal - Project Processes		Scope definition
5	Export Trippers, Port of Richards Bay	Port Bulk handling equipment	R 0.08	Genmec	R 0.28	EPCM	Project	Project: Safety	Project: Safety - Worker injury	Internal - Project Processes		Safety non-compliance

Figure 9-40: Extract Risk Type from “All Risks” sheet

9.11 Create named ranges

Purpose:

- Before any of the reports could be created, the named ranges, which were used in the reports, were created. As mentioned in Section 9.2, named ranges improve clarity and understanding when creating and reading equations.
- It also makes selecting data much simpler to do because a Named Range appears from a list, and the programmer does not need to go back and forth between various sheets in the workbook.

Steps:

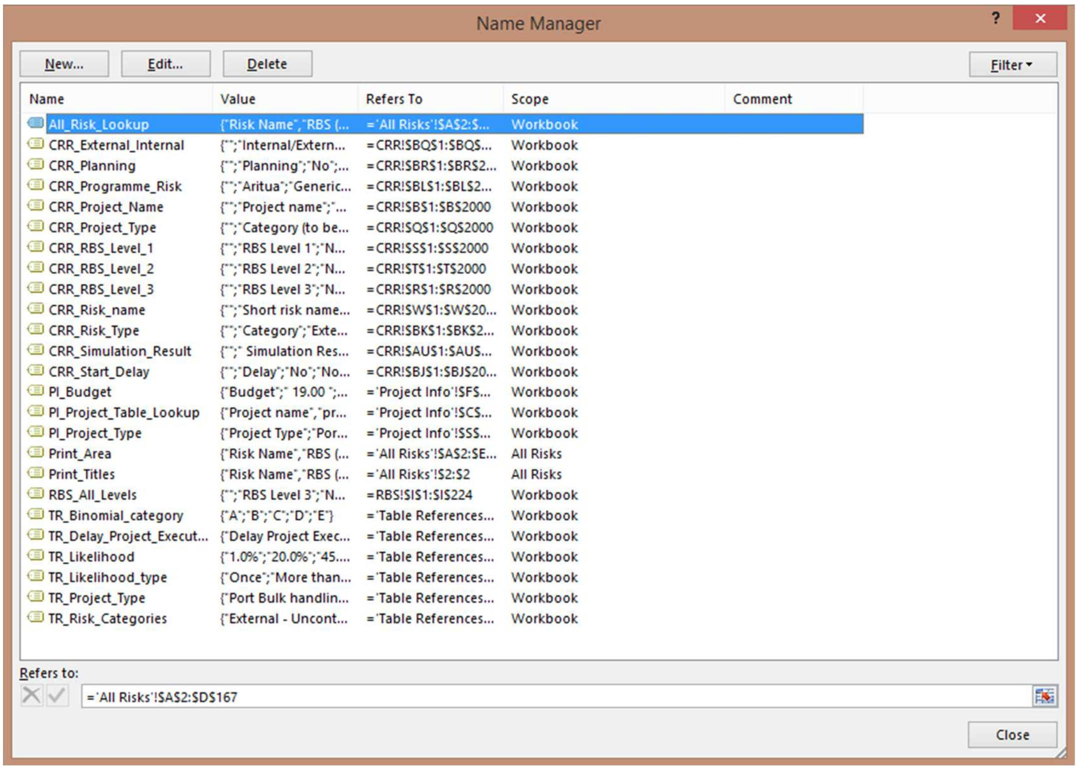
106. Using the column headings as the names, use DATA/NAME MANAGER and name the following columns:

   - Project name
   - Project type
   - RBS Level 1
   - RBS Level 2
   - RBS Level 3
   - Risk type
   - Delay Project Execution
   - New short risk name
   - Simulation Result
   - Programme Risk
   - And any other Named Range which might be required.

Please note:

- Use only the number of rows required and not the entire column to create the range. The simulation runs are significantly faster when the former is used.
- Please ensure that all the named ranges are the same length. The simulation runs **will not** work if one is for example from A1:A2000 and the other one is from B1:B1500.
- If there are named ranges on other sheets in the workbook, name the ranges in such a way that they can be easily identified, for example all the ones the CRR sheet were named starting with "CRR", Table References with "TR" etc.

The named ranges used the simulation model appear in Figure 9-41:



Name Manager

Name	Value	Refers To	Scope	Comment
All_Risk_Lookup	{"Risk Name","RBS (...	='All Risks'!$A$2:$...	Workbook	
CRR_External_Internal	{"";"Internal/Extern...	=CRR!$BQ$1:BQ...	Workbook	
CRR_Planning	{"";"Planning";"No";...	=CRR!$BR$1:$BR$2...	Workbook	
CRR_Programme_Risk	{"";"Aritua";"Generic...	=CRR!$BL$1:$BL$2...	Workbook	
CRR_Project_Name	{"";"Project name";"...	=CRR!$B$1:$B$2000	Workbook	
CRR_Project_Type	{"";"Category (to be...	=CRR!$Q$1:$Q$2000	Workbook	
CRR_RBS_Level_1	{"";"RBS Level 1";"N...	=CRR!$S$1:$S$2000	Workbook	
CRR_RBS_Level_2	{"";"RBS Level 2";"N...	=CRR!$T$1:$T$2000	Workbook	
CRR_RBS_Level_3	{"";"RBS Level 3";"N...	=CRR!$R$1:$R$2000	Workbook	
CRR_Risk_name	{"";"Short risk name...	=CRR!$W$1:$W$20...	Workbook	
CRR_Risk_Type	{"";"Category";"Exte...	=CRR!$BK$1:$BK$2...	Workbook	
CRR_Simulation_Result	{"";" Simulation Res...	=CRR!$AU$1:AU...	Workbook	
CRR_Start_Delay	{"";"Delay";"No";"No...	=CRR!$BJ$1:$BJ$20...	Workbook	
PI_Budget	{"Budget";" 19.00 ";...	='Project Info'!F...	Workbook	
PI_Project_Table_Lookup	{"Project name","pr...	='Project Info'!C...	Workbook	
PI_Project_Type	{"Project Type";"Por...	='Project Info'!S...	Workbook	
Print_Area	{"Risk Name","RBS (...	='All Risks'!$A$2:$E...	All Risks	
Print_Titles	{"Risk Name","RBS (...	='All Risks'!$2:$2	All Risks	
RBS_All_Levels	{"";"RBS Level 3";"N...	=RBS!$I$1:$I$224	Workbook	
TR_Binomial_category	{"A";"B";"C";"D";"E"}	='Table References...	Workbook	
TR_Delay_Project_Execut...	{"Delay Project Exec...	='Table References...	Workbook	
TR_Likelihood	{"1.0%";"20.0%";"45....	='Table References...	Workbook	
TR_Likelihood_type	{"Once";"More than...	='Table References...	Workbook	
TR_Project_Type	{"Port Bulk handlin...	='Table References...	Workbook	
TR_Risk_Categories	{"External - Uncont...	='Table References...	Workbook	

Refers to:

='All Risks'!$A$2:$D$167

Figure 9-41: All named ranges

10. APPENDIX C: CREATION OF REPORTS

10.1 Report Example 1: RBS Level 3

Steps:

- Create a new sheet called “Reports”.
- Create the first four row headings as in Figure 10-1.
- To get the headings of the Level 3 RBS, take the heading “RBS Level 3” from the “CRR” sheet, copy to a clean sheet, remove duplicates (DATA/REMOVE DUPLICATES) and PASTE/PASTE SPECIAL/TRANSFORM the result from cell E3 onwards. This step ensures that only the populated categories in RBS Level 3 will be used in the report.
- Add =*Sum*() in columns B and C.
- Add =*Sum*() and =*RiskOutput()* from Column D up to the end of the table. =*RiskOutput()* is included because it is required that the report stores the results of these cells for further use.

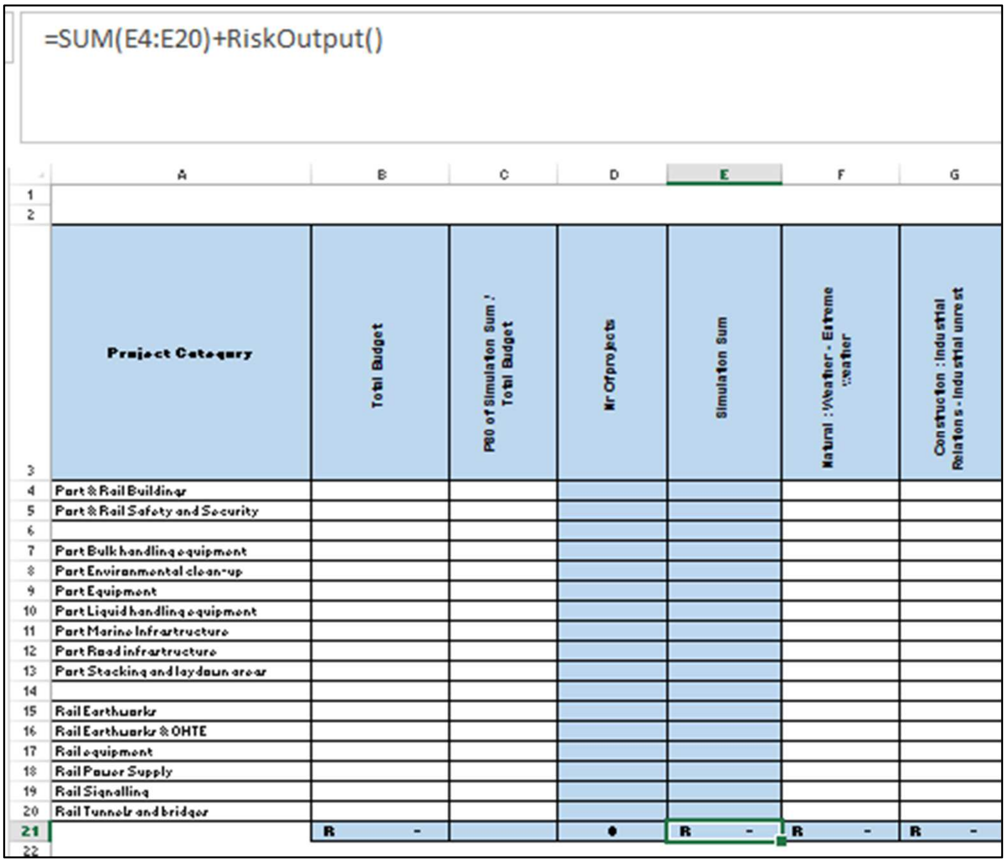


Figure 10-1: Create RBS Level 3 report Totals

- Insert and copy a =*SumIfs()* function to calculate budget totals for each project category. It can be interpreted in the following manner:
- “Sum all the cells in the named range “PI_Budget” if the cells in the named range “PI_Project_Type” is equal to what is written in the cell A4”.

=SUMIFS(PI_Budget,PI_Project_Type,A4)

	A	B	C	D	E	F	G
1							
2							
3	Project Category	Total Budget	P80 of Simulation Sum / Total Budget	Nr Ofprojects	Simulation Sum	Natural : Weather - Extreme weather	Construction : Industrial Relations - Industrial unrest
4	Port & Rail Buildings	R 828.50					
5	Port & Rail Safety and Security	R 331.00					
6							
7	Port Bulk handling equipment	R 3 070.70					
8	Port Environmental clean-up	R 30.00					
9	Port Equipment	R 118.30					
10	Port Liquid handling equipment	R 19.60					
11	Port Marine Infrastructure	R 15 570.00					
12	Port Road infrastructure	R 90.00					
13	Port Stacking and laydown areas	R 1071.00					
14							
15	Rail Earthworks	R 18.60					
16	Rail Earthworks & OHTE	R 25 438.40					
17	Rail equipment	R 420.00					
18	Rail Power Supply	R 2 889.48					
19	Rail Signalling	R 459.00					
20	Rail Tunnels and bridges	R 2 010.00					
21		R 52 364.58		•	R -	R -	R -

Figure 10-2: Calculate project group budget totals

- Insert a function in Column C which will divide the Simulation sum (Column E) by the Total Budget (Column B). This is done to show the calculated contingency as a function of the total project budget and not only to display contingency - which might be a large number but a smaller % of the Total Budget.
- Insert and copy a =COUNT=IF() function to calculate number of each type of project:

=COUNTIF(PI_Project_Type,A4)

	A	B	C	D	E	F	G
1							
2							
3	Project Category	Total Budget	P80 of Simulation Sum / Total Budget	Nr Of projects	Simulation Sum	Natural : Weather - Extreme weather	Construction : Industrial Relations - Industrial unrest
4	Port & Rail Buildings	R 828.50	0.0%	8			
5	Port & Rail Safety and Security	R 331.00	0.0%	6			
6							
7	Port Bulk handling equipment	R 3 070.70	0.0%	11			
8	Port Environmental clean-up	R 30.00	0.0%	1			
9	Port Equipment	R 118.30	0.0%	3			
10	Port Liquid handling equipment	R 19.60	0.0%	1			
11	Port Marine Infrastructure	R 15 570.00	0.0%	9			
12	Port Road infrastructure	R 90.00	0.0%	1			
13	Port Stacking and laydown areas	R 1 071.00	0.0%	7			
14							
15	Rail Earthworks	R 18.60	0.0%	2			
16	Rail Earthworks & OHTE	R 25 438.40	0.0%	12			
17	Rail equipment	R 420.00	0.0%	4			
18	Rail Power Supply	R 2 889.48	0.0%	17			
19	Rail Signalling	R 459.00	0.0%	2			
20	Rail Tunnels and bridges	R 2 010.00	0.0%	2			
21		R 52 364.58		86	R -	R -	R -

Figure 10-3: Count each type of project

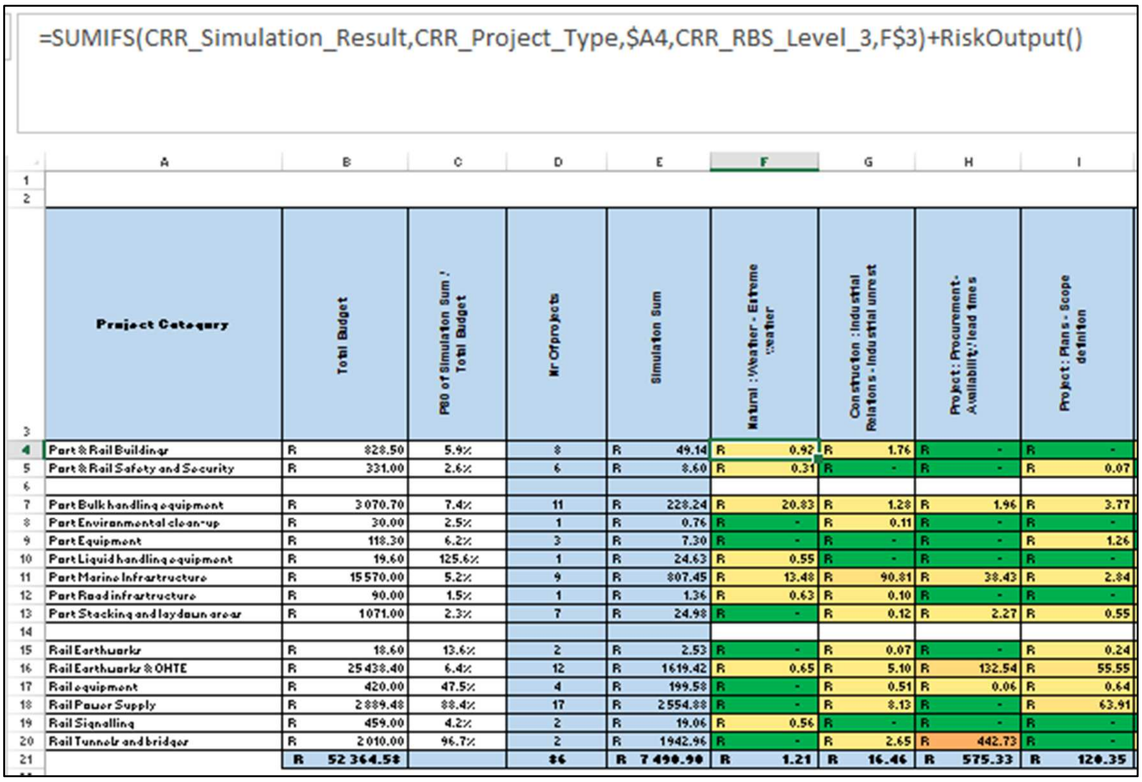
- Insert and copy =*Sum*() and =*RiskOutput()* function to aggregate and store the distribution produced by all the risks in RBS Level 3. The P80 value of this result will show in which project group the most significant risks are.

=SUM(F4:BS4)+RiskOutput()

	A	B	C	D	E	F	G
1							
2							
3	Project Category	Total Budget	P80 of Simulation Sum / Total Budget	Nr Of projects	Simulation Sum	Natural : Weather - Extreme weather	Construction : Industrial Relations - Industrial unrest
4	Port & Rail Buildings	R 828.50	0.0%	8	R -		
5	Port & Rail Safety and Security	R 331.00	0.0%	6	R -		
6							
7	Port Bulk handling equipment	R 3 070.70	0.0%	11	R -		
8	Port Environmental clean-up	R 30.00	0.0%	1	R -		
9	Port Equipment	R 118.30	0.0%	3	R -		
10	Port Liquid handling equipment	R 19.60	0.0%	1	R -		
11	Port Marine Infrastructure	R 15 570.00	0.0%	9	R -		
12	Port Road infrastructure	R 90.00	0.0%	1	R -		
13	Port Stacking and laydown areas	R 1071.00	0.0%	7	R -		
14							
15	Rail Earthworks	R 18.60	0.0%	2	R -		
16	Rail Earthworks & OHTE	R 25 438.40	0.0%	12	R -		
17	Rail equipment	R 420.00	0.0%	4	R -		
18	Rail Power Supply	R 2 889.48	0.0%	17	R -		
19	Rail Signalling	R 459.00	0.0%	2	R -		
20	Rail Tunnels and bridges	R 2 010.00	0.0%	2	R -		
21		R 52 364.58		86	R -	R -	R -

Figure 10-4: Simulation output for all inputs for Level 3 RBS.

- The next step demonstrates the technique to generate distributions for specific groups of risks and is the heart of the simulation model.
- Insert and copy a =*SumIfs()* function to simulate and store distributions which have more than one argument. For Cell E4:
- "Sum all the cells in the named range "CRR_Simulation_Result"
- If the project type in the named range "CRR_Project_Type" = "Port and Rail Buildings" AND
- If the RBS Level 3 in the names range "CRR_RBS_Level_3" = "Natural : Weather - Extreme weather".



=SUMIFS(CRR_Simulation_Result,CRR_Project_Type,$A4,CRR_RBS_Level_3,F$3)+RiskOutput()

	A	B	C	D	E	F	G	H	I
1									
2									
3	Project Category	Total Budget	P80 of Simulation Sum / Total Budget	Nr Of projects	Simulation Sum	Natural : Weather - Extreme weather	Construction : Industrial Relations - Industrial unrest	Project : Procurement - Availability / lead times	Project : Plans - Scope definition
4	Port & Rail Buildings	R 828.50	5.9%	8	R 49.14	R 0.92	R 1.76	R -	R -
5	Port & Rail Safety and Security	R 331.00	2.6%	6	R 8.60	R 0.31	R -	R -	R 0.07
6									
7	Port Bulk handling equipment	R 3 070.70	7.4%	11	R 228.24	R 20.83	R 1.28	R 1.96	R 3.77
8	Port Environmental clean-up	R 30.00	2.5%	1	R 0.76	R -	R 0.11	R -	R -
9	Port Equipment	R 118.30	6.2%	3	R 7.30	R -	R -	R -	R 1.26
10	Port Liquid handling equipment	R 19.60	125.6%	1	R 24.63	R 0.55	R -	R -	R -
11	Port Marine Infrastructure	R 15 570.00	5.2%	9	R 807.45	R 13.48	R 90.81	R 38.43	R 2.84
12	Port Road infrastructure	R 90.00	1.5%	1	R 1.36	R 0.63	R 0.10	R -	R -
13	Port Stacking and laydown areas	R 1071.00	2.3%	7	R 24.98	R -	R 0.12	R 2.27	R 0.55
14									
15	Rail Earthworks	R 18.60	13.6%	2	R 2.53	R -	R 0.07	R -	R 0.24
16	Rail Earthworks & OHTE	R 25 438.40	6.4%	12	R 1619.42	R 0.65	R 5.10	R 132.54	R 55.55
17	Rail equipment	R 420.00	47.5%	4	R 199.58	R -	R 0.51	R 0.06	R 0.64
18	Rail Power Supply	R 2 889.48	88.4%	17	R 2 554.88	R -	R 8.13	R -	R 63.91
19	Rail Signalling	R 459.00	4.2%	2	R 19.06	R 0.56	R -	R -	R -
20	Rail Tunnels and bridges	R 2 010.00	96.7%	2	R 1942.96	R -	R 2.65	R 442.73	R -
21		R 52 364.58		86	R 7 490.90	R 1.21	R 16.46	R 575.33	R 120.35

Figure 10-5: Creating output distribution for RBS Level 3

- HOME/CONDITIONAL FORMATTING is used to provide the green, yellow, orange and red as in the previous Figure. It is convenient because it graphically displays where the significant risks are.

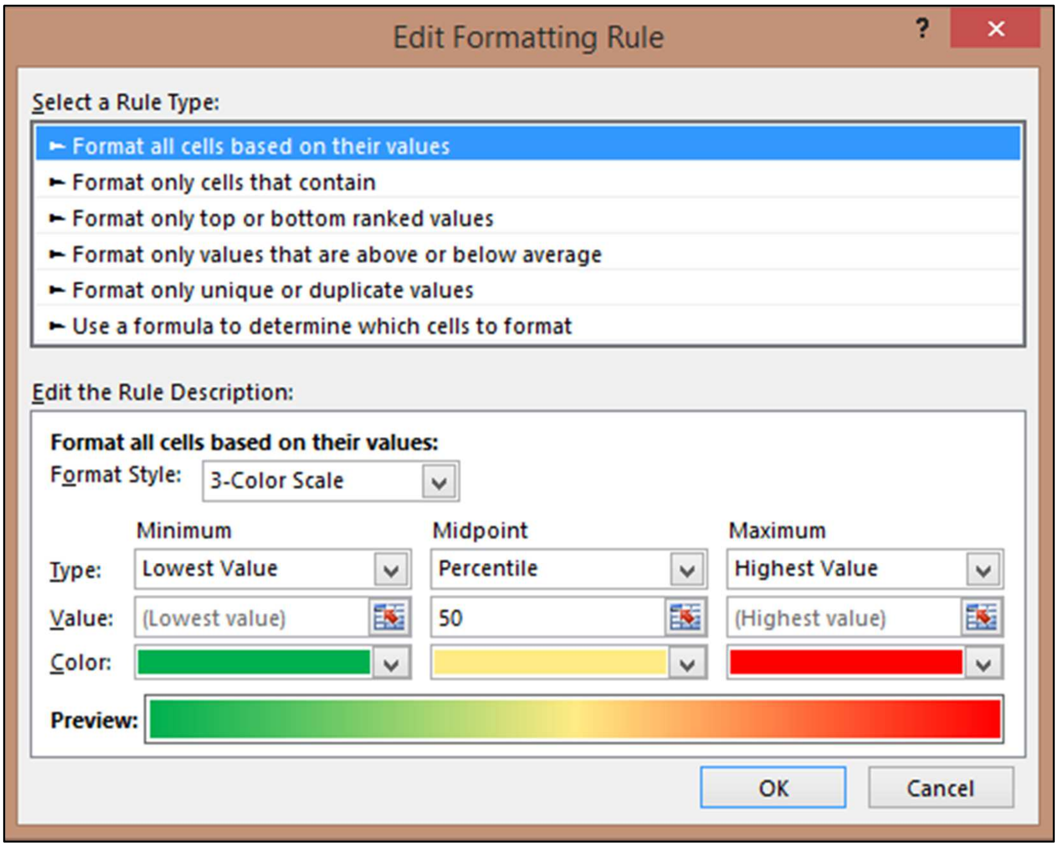


Figure 10-6: Conditional formatting

10.2 Report Example 2: RBS Level 2

Steps:

- Copy and paste the entire table created for RBS Level 3 underneath the table for RBS Level 3.
- To get the headings of the Level 2 RBS, take the heading “RBS Level 2” from the “CRR” sheet, copy to a clean sheet, remove duplicates (DATA/REMOVE DUPLICATES) and PASTE/PASTE SPECIAL/TRANSFORM the result in the appropriate cells.
- Delete the contents of the unused columns.
- Replace the named range RBS_Level_3 with RBS_Level_2 and copy as required.

=SUMIFS(CRR_Simulation_Result,CRR_Project_Type,$A25,CRR_RBS_Level_2,F$24)+RiskOutput()

Project Category	Total Budget	P80 of Simulation Sum / Total Budget	Nr Of projects	Simulation Sum	Natural : Weather	Construction : Industrial Relations	Project : Procurement	Project : Plans	Project : Safety	Project : Commissioning
Port & Rail Buildings	R 828.50	10.5%	8	R 87.29	R 1.87	R -	R 1.94	R 25.25	R 4.93	R 0.23
Port & Rail Safety and Security	R 331.00	3.1%	6	R 10.38	R 0.14	R -	R 2.63	R 0.37	R 0.06	R -
					R -	R -	R -	R -	R -	R -
Port Bulk handling equipment	R 3 070.70	11.5%	11	R 352.54	R 1.67	R 2.99	R 17.46	R 4.95	R 3.06	R -
Port Environmental clean-up	R 30.00	6.2%	1	R 1.85	R -	R -	R -	R -	R 0.59	R -
Port Equipment	R 118.30	5.4%	3	R 6.39	R -	R -	R -	R 4.10	R -	R -
Port Liquid handling equipment	R 19.60	189.0%	1	R 37.03	R 0.62	R 0.33	R -	R -	R -	R -
Port Marine Infrastructure	R 15 570.00	6.0%	9	R 941.89	R -	R 53.43	R 93.61	R 11.03	R 17.72	R 24.74
Port Road infrastructure	R 90.00	2.5%	1	R 2.27	R -	R 0.53	R 0.39	R -	R -	R -
Port Stacking and laydown areas	R 1071.00	3.0%	7	R 32.42	R -	R 0.50	R 11.85	R 0.53	R 9.92	R 0.09
					R -	R -	R -	R -	R -	R -
Rail Earthworks	R 18.60	22.5%	2	R 4.18	R 0.87	R 0.02	R -	R 0.28	R 0.66	R -
Rail Earthworks & OHTE	R 25 438.40	6.3%	12	R 1601.52	R 3.43	R 6.54	R 124.52	R 53.51	R 0.93	R 1.17
Rail equipment	R 420.00	74.6%	4	R 313.36	R -	R 0.41	R 0.04	R 0.78	R 0.07	R -
Rail Power Supply	R 2 889.48	54.8%	17	R 1583.08	R -	R 7.40	R 0.68	R 806.58	R 0.32	R -
Rail Signalling	R 459.00	3.3%	2	R 15.26	R 0.71	R -	R -	R -	R 5.12	R -
Rail Tunnels and bridges	R 2 010.00	66.0%	2	R 1326.41	R -	R 1.80	R 917.77	R -	R 0.48	R -
	R 52 364.58		86	R 6 315.88	R 5.00	R 16.18	R 1 043.02	R 861.14	R 7.57	R 1.17

Figure 10-7: Creating output distribution for RBS Level 2

10.3 Report example 3: Project type and Risk category

Purpose:

- This report needs to show which type of risks, and in which type of projects, the most significant risks appear.

Steps:

- The steps are not described in detail since they closely follow the method as described in the previous sections.
- Copy the RBS Level 1 Figure and replace the headings with the Risk Categories.
- Delete the contents of the unused columns.
- Replace the named range RBS_Level_1 with CRR_Risk_Type and copy as required.

=SUMIFS(CRR_Simulation_Result,CRR_Project_Type,$A46,CRR_Risk_Type,D$67)+RiskOutput()

			Risk Type					Project start Delay	
Project Category	Total Budget	Nr Of projects	External - Uncontrollable	External - Influencable	Internal - Owner Requirement	Internal - Operational	Internal - Project Processes	No	Yes
Port & Rail Buildings	R 828.50	8	R 3.44	R 16.84	R -	R 7.71	R 25.71	R 35.63	R 18.08
Port & Rail Safety and Security	R 331.00	6	R 0.02	R 2.97	R -	R 0.50	R 7.00	R 3.40	R 7.10
								R -	R -
Port Bulk handling equipment	R 3070.70	11	R 27.61	R 5.42	R 105.94	R 9.59	R 143.48	R 151.05	R 140.98
Port Environmental clean-up	R 30.00	1	R -	R -	R -	R 0.00	R 1.08	R 1.08	R -
Port Equipment	R 118.30	3	R -	R -	R -	R 2.61	R 3.82	R 5.56	R 0.87
Port Liquid handling equipment	R 19.60	1	R 0.65	R 0.11	R -	R 13.38	R 17.39	R 31.53	R -
Port Marine Infrastructure	R 15570.00	9	R 455.88	R 83.27	R 0.32	R 10.74	R 145.76	R 529.26	R 166.71
Port Road infrastructure	R 90.00	1	R 1.11	R -	R 0.20	R 0.04	R 7.36	R 8.09	R 0.62
Port Stacking and laydown areas	R 1071.00	7	R 0.09	R 0.50	R -	R 0.22	R 20.10	R 15.65	R 5.24
								R -	R -
Rail Earthworks	R 18.60	2	R 0.02	R 2.65	R -	R 0.09	R 2.93	R 5.13	R 0.57
Rail Earthworks & OHTE	R 25438.40	12	R 23.40	R 50.43	R 597.78	R 66.42	R 1225.30	R 1284.99	R 678.34
Rail equipment	R 420.00	4	R 12.73	R 4.69	R 4.00	R -	R 125.03	R 28.27	R 118.19
Rail Power Supply	R 2889.48	17	R 48.16	R 11.35	R 637.14	R 10.19	R 828.25	R 857.23	R 677.85
Rail Signalling	R 459.00	2	R 1.09	R 21.82	R -	R 0.29	R 4.35	R 27.55	R -
Rail Tunnels and bridges	R 2010.00	2	R 2.69	R 261.45	R -	R -	R 1452.46	R 642.71	R 1073.89
	52364.58	86	R 576.89	R 461.49	R 1345.39	R 121.79	R 4010.02	R 3627.14	R 2888.43
			R 14.39	R 11.51	R 33.55	R 3.04	R 100.00		R 79.63

Figure 10-8: Creating output distribution for Risk Type

10.4 Report Example 4: Risk type and Project start delays

Purpose:

- This report compares the P80 value of risks which delay project execution start with the P80 value of those risk which do not.

Steps:

- Add two more columns, and complete the headings to the table shown below.
- Replace the named range RBS_Level_1 with CRR_Start_Delay and copy as required.
- Format new cells with the same format as the others to display the conditional formatting.

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YUNIBESITHI YA PRETORIA

=SUMIFS(CRR_Simulation_Result,CRR_Project_Type,$A46,CRR_Start_Delay,I$67)+RiskOutput()

	A	B	C	D	E	F	G	H	I	J
64										
65										
66				Risk Type					Project start Delay	
67	Project Category	Total Budget	Nr Of projects	External - Uncontrollable	External - Influencable	Internal - Owner Requirement	Internal - Operational	Internal - Project Processes	No	Yes
68	Port & Rail Buildings	R 828.50	8	R 3.44	R 16.84	R -	R 7.71	R 25.71	R 35.63	R 18.08
69	Port & Rail Safety and Security	R 331.00	6	R 0.02	R 2.97	R -	R 0.50	R 7.00	R 3.40	R 7.10
70									R -	R -
71	Port Bulk handling equipment	R 3070.70	11	R 27.61	R 5.42	R 105.94	R 9.59	R 143.48	R 151.05	R 140.98
72	Port Environmental clean-up	R 30.00	1	R -	R -	R -	R 0.00	R 1.08	R 1.08	R -
73	Port Equipment	R 118.30	3	R -	R -	R -	R 2.61	R 3.82	R 5.56	R 0.87
74	Port Liquid handling equipment	R 19.60	1	R 0.65	R 0.11	R -	R 13.38	R 17.39	R 31.53	R -
75	Port Marine Infrastructure	R 15570.00	9	R 455.88	R 83.27	R 0.32	R 10.74	R 145.76	R 529.26	R 166.71
76	Port Road infrastructure	R 90.00	1	R 1.11	R -	R 0.20	R 0.04	R 7.36	R 8.09	R 0.62
77	Port Stacking and laydown areas	R 1071.00	7	R 0.09	R 0.50	R -	R 0.22	R 20.10	R 15.65	R 5.24
78									R -	R -
79	Rail Earthworks	R 18.60	2	R 0.02	R 2.65	R -	R 0.09	R 2.93	R 5.13	R 0.57
80	Rail Earthworks & OHTE	R 25438.40	12	R 23.40	R 50.43	R 597.78	R 66.42	R 1225.30	R 1284.99	R 678.34
81	Rail equipment	R 420.00	4	R 12.73	R 4.69	R 4.00	R -	R 125.03	R 28.27	R 118.19
82	Rail Power Supply	R 2889.48	17	R 48.16	R 11.35	R 637.14	R 10.19	R 828.25	R 857.23	R 677.85
83	Rail Signalling	R 459.00	2	R 1.09	R 21.82	R -	R 0.29	R 4.35	R 27.55	R -
84	Rail Tunnels and bridges	R 2010.00	2	R 2.69	R 261.45	R -	R -	R 1452.46	R 642.71	R 1073.89
85		52364.58	86	R 576.89	R 461.49	R 1345.39	R 121.79	R 4010.02	R 3627.14	R 2888.43
86										
87				R 14.39	R 11.51	R 33.55	R 3.04	R 100.00		R 79.63
88										

Figure 10-9: Creating output distribution for Project Start Delay