ABSTRACT

This paper 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 sued to identify policies and procedures which need to be changed to improve the project delivery and execution process.

The model was is based on the principles of the ISO31000:2009 risk management mode, MS Excel and @Risk software to generate output distributions which are ranked using tornado graphs. The risk and project categories used to in the model include the following:

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

ii. 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.

iii. Risk name: A total of 165 risk names were used to describe 1063 different risks which belonged to the 86 projects.

iv. Project start delays: Certain risks delay the execution start of projects and therefor cause the escalation of project costs due to the time value of money.

v. 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 the uncertainty was proven wrong. Uncertainty in the portfolio was driven by eight large, complex, multi-stakeholder projects. The simulation results related to Project start delays, the different risk types and risks associated with programmes was different when comparing these eight projects with the rest of the portfolio.

Key words: risk simulation, project risk management, Monte Carlo, programmes, port, rail.
INTRODUCTION

Context

The data which was used in this research was collected over a four year period in a South African State Owned Enterprise (SOE) which executes capital projects related to port and rail infrastructure. The SOE used a quantitative approach (MS Excel, @Risk software, the ISO31000:2009 risk management process) to create risk registers for 106 projects which were in various phases of the project lifecycle. All the risk registers were individually captured in a Risk Information Management System and the only available methodology to rank the risks on a programme and portfolio level was to aggregate 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. The organisation knew that this method was mathematically incorrect but at least provided some idea of which risks had the biggest potential consequence.

![Portfolio Risks Diagram](image)

Figure 1: Initial Programme and Portfolio view of project risks

A more scientific method needed to be developed to answer the following questions:

- “Which type of risks matters most in the project portfolio?” and
- “Where should the focus be regarding risk treatment plans?”

This is important for various reasons:

- Treatment plans for certain risks might not be able to be solved on a project or programme level (Hillson, 2009, p. 81).
- From a project resource perspective, the focus might be on risks which are outside the control of the project.

Literature Review

The purpose of the literature review was to find information related to (i) building a simulation model to determine what matters most in a portfolio of capital project programmes and to (ii) identify the difference between project, programme and portfolio risks.


Risk simulation in a portfolio of projects

Limited information was found when searching for articles on simulation models and a quantified view of a portfolio of projects. Both Vose, (Vose Software, 2014, p. 355) and Palisade (2014, p. 502), use the term “portfolio” in relation to finding an optimal portfolio of investments and don’t specifically refer to the modelling of risks in a portfolio of capital projects.

A large quantity of articles refer to the use of the Monte Carlo method in project schedule simulation, including those by Elshaer (2013) and Trietsch & Baker (2012). Jahangirian et al. (2010, p. 8) contains 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. Fuzzy Sets Theory also features frequently, as in Carr & Tah (2001) and Zeng et al. (2011). Cost estimation and cost risk analysis is also covered in great detail by authors such as Chapman & Ward (2000) and Sato & Hirao (2013).

The search for multi-project and programme also yielded some results. Lytvyn & Rishnyak (2014) presented a decision making algorithm which can be used when the multi-project environment influences a project. There a limited number of articles discussing risks common to programmes / multi-project environments. Shehu & Akintoye (2010) does not discuss any risks but gives an overview of the challenges experienced in the United Kingdom with the successful practice of programme management.

Projects, programmes and portfolios

PMBOK (Project Management Institute, 2013, p. 8) defines a project hierarchy where projects rolls up into programs and programs rolls up into portfolios. This view is shared by Hillson (2009, p. 80) and Chapman & Ward (2011, p. 8). 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 and integrated approach that should streamline the effective delivery of projects (Shehu & Akintoye, 2009, p. 203). Aritua et al. (2011, p. 308) differentiated between three types of risks:

Table 1: Programme risk classification

<table>
<thead>
<tr>
<th>Type of risk</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
</table>
| Risks which are common to programmes: | These risks relate to the function of managing multiple projects and aligning them to the organisation’s strategy and policies. | • Challenges in procurement  
• Competition for contractors  
• Stakeholder expectation management |
| Risks which are amplified in programmes. | These risks are simple to deal with but exacerbated as a result of the multi-project environment. | • Reputational risk  
• Fraud  
• Cash flow and funding problems  
• Changes in government policy |
| Generic project risks | These risks are generic to endeavours in project environments. | |
Objective

Taking the above into consideration, this paper proposes a methodology which uses individual quantified risk registers, the Monte Carlo method (@Risk software), risk names, risk type and a project start delay indicator to identify which type of risks matters most in the project portfolio and where the focus should be in implementing treatment plans. It therefore changes the previous figure to give a stochastic view of the various risk categories in programmes and in the entire project portfolio.

![Figure 2: Quantified view of Programme and Portfolio view of project risks using Monte Carlo Method](image)

METHODOLOGY

Existing Stochastic Model

The model made provision for both single and multiple occurrence risks. For single occurrence risks, the table below describes the probability values used in the CRR. These values were selected from the likelihood ranges prescribed by The SOE’s ERM policy since @Risk requires a discrete value to run a simulation. These use of likelihood ratings like this forms the probability part of probability-impact grids (PIG) 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 criticism 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. Another shortcoming is that they generally do not assess risk urgency and do not make provision for multiple occurrence risks. It was however, what was used in The SOE’s Risk Register Template (RRT).
Table 2: Likelihood Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Qualitative Description</th>
<th>Criteria</th>
<th>Probability Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Rare</td>
<td>Occurrence requires exceptional circumstances, exceptionally unlikely; even in the long term future; only occur as a “100 year event”.</td>
<td>1.0%</td>
</tr>
<tr>
<td>B</td>
<td>Unlikely</td>
<td>May occur but not anticipated, or could occur in “years to decades”.</td>
<td>20.0%</td>
</tr>
<tr>
<td>C</td>
<td>Moderate</td>
<td>May occur shortly but a distinct probability it won’t, or could occur within “months to years”.</td>
<td>45.0%</td>
</tr>
<tr>
<td>D</td>
<td>Likely</td>
<td>Balance of probability will occur, or could occur within “weeks to months”.</td>
<td>80.0%</td>
</tr>
<tr>
<td>E</td>
<td>Almost Certain</td>
<td>Consequence is occurring now, or could occur within “days to weeks”.</td>
<td>95.0%</td>
</tr>
</tbody>
</table>

A binomial distribution was used to model single occurrence risks. The binomial distribution is a discrete distribution returning only integer values greater than or equal to zero (Palisade Corporation, 2014).

Risk such as *Industrial Action*, *Inclement Weather* and *Material Deliveries* can realise more than once on a project and were modelled as such. A Poisson distribution was used to model the frequency of these type of risks. The Poisson distribution is a discrete distribution returning only integer values greater than or equal to zero (Palisade Corporation, 2014).

*Estimating Consequence*

In the RRT the risk consequence was modelled in terms of the financial impact on the project, using the following method:

$$\text{Total Cost} = \text{Time Delays}_\text{Point Estimate} \times \text{Weekly Weighted Average Cost} + \text{Additional Capital Cost}_\text{Point Estimate}$$

Where:

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

The latter is best described by an example: 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 realise, Contractor A will have a 100% loss and Contractor B a 25% loss. The Weekly Weighted Average Cost would therefore be as follows:

$$\text{Weekly Weighted Average Cost} = R50 \ 000 \times 100\% + R100 \ 000 \times 25\%$$

$$= R75 \ 000$$
Two make provision that sampling takes place at the tail end of more uncertain risks, two different distributions were used to estimate 3 Point estimates:

\[ Time\ Delay_{3\ point\ estimate} = RiskPertAlt(0.05, \text{Min}, 0.5, \text{Most\ likely}, 0.95, \text{Max}) \]

or

\[ Time\ Delay_{3\ point\ estimate} = RiskLognormAlt(0.05, \text{Min}, 0.5, \text{Most\ likely}, 0.95, \text{Max}) \]

when

\[(Max – \text{Most likely}) \geq 2 \times (\text{Most likely} – \text{Min})\]

Taking the above, the overall logic used in creating simulation results, appear in Figure 4 on the next page.

**Existing Risk Type Classification**

This refers to the extent in which the project manager / project team has control over the likelihood and consequences of a risk. The SOE already used the following five types of risk categories:

**Table 3: Risk Types**

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Risk Source</th>
<th>Client Control</th>
<th>Project Team Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>External - Uncontrollable</td>
<td>Events occurs due to circumstances outside of the project's control</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Internal - Owner Requirement</td>
<td>Even occurs due to actions(s) taken by the client organisation</td>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>Internal - Operational</td>
<td>Event occurs due to actions(s) taken by the client and the project team.</td>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>Internal - Project Processes</td>
<td>Event occurs due to actions(s) taken by the project team.</td>
<td>Some</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Create Complete Risk Register**

The first step in the process was to combine the existing risk registers into one MS Excel workbook, on a single sheet. The sheet and related formulas was based on the existing RRT. Various supporting sheets such as *Project Info, Risk Names* and *Table references* were also created.
The initial sample contained 106 risk registers of which 86 were copied into the Complete Risk Register (CRR). The final CRR contained 1063 different risks, with a total of 329 different risk names.

**Categorise Projects**

Projects have many characteristics and attributes of projects which can be used as criteria to categorize them. These characteristics are summarized by Crawford et al. (2004) as follows: (I) Application area or product, (ii) Stage of life-cycle, (iii) Grouped or single, (iv) Strategic importance, (v) Strategic driver, (vi) Geography, (vii) Scope, (viii) Timing, (ix) Uncertainty, (x) Risk, (xi) Complexity, (xii) Customer, (xiii) Ownership and (xiv) Contractual. Of these, **Scope** was selected because the internal clients which The SOE delivers the projects to, have specific business (which defines they type of project they would require) and public mandates to fulfil. Fifteen project types were defined and each of the projects was assigned to a type. The contents of a type would make up a programme.

![Figure 3: Project categories](image)

**Clean-up Risk Names**

After all the risk registers were copied into the CRR, the 329 risk names were reduced to 165 as the result of a clean-up and consolidation exercise. This process was necessary to enable the accurate creation of output distributions. The output distributions would be inaccurate if risks descriptions such as “**Industrial action**”, “**Labour unrest**” and “**Strikes**” were not consolidated into “**Industrial Action**” and “**Inclement weather**” and “**Bad Weather**” not combined into “**Inclement weather**” etc.

**Categorise Risk Names and Link to Crr**

The cleaned-up risk names were copied to a new sheet “Risk Names” where risk categorisation took place. As in the next figure, each of the 165 risks were categorised in terms of the **Risk Type**, **Delay execution start** and **Programme Type**.
Figure 4: Risk names categorised
Can risk be quantified?

Yes

Select and quantify likelihood

Select Likelihood (n):
- A – 1%
- B – 20%
- C – 45%
- D – 80%
- E – 99%

 Decide average Number of occurrences (λ)

RiskPoisson(λ)

RiskBinomial(1,n)

No, multiple occurrences

Once off?

Yes

Add % loss/additional labour per supplier to calculate Weekly Weighted Cst (WWC)

(WWW) x

No

Select Likelihood (n):
- A – 1%
- B – 20%
- C – 45%
- D – 80%
- E – 99%

Delay as 3 Point Estimate (Weeks)

3 Point Estimate (R Million)

Quantify time variable cost (if any)

Step 1

Step 2

Step 3

Step 4

Step 4

Step 5

Figure 5: Overall method followed in creating simulation results for the Combined Risk Register
<table>
<thead>
<tr>
<th>Line Number</th>
<th>Project Name</th>
<th>Programme</th>
<th>Risk Name</th>
<th>How many times can the risk occur?</th>
<th>Occurrence Type (A-E)</th>
<th>Description</th>
<th>Likelihood</th>
<th>Average</th>
<th>Short</th>
<th>Average</th>
<th>Long</th>
<th>Weighted weekly cost (R million)</th>
<th>Additional Capital (R million)</th>
<th>Risk</th>
<th>Extra capital limitation (R million)</th>
<th>Simulation Result (R million)</th>
<th>Risk Type</th>
<th>Execution Start Delay</th>
<th>Programme Risk Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project 1</td>
<td>Port Bulk handling equipment</td>
<td>Inclement weather</td>
<td>More than once</td>
<td>A</td>
<td></td>
<td>2.00</td>
<td>0.15</td>
<td>1.00</td>
<td>2.00</td>
<td>R 0.12</td>
<td></td>
<td></td>
<td>R -</td>
<td>-</td>
<td>External - Uncontrollable</td>
<td>No</td>
<td>Generic Project</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Project 1</td>
<td>Port Bulk handling equipment</td>
<td>Labour unrest</td>
<td>Once</td>
<td>B</td>
<td>Unlikely</td>
<td>20%</td>
<td></td>
<td>0.15</td>
<td>0.45</td>
<td>1.00</td>
<td></td>
<td>R 0.16</td>
<td></td>
<td></td>
<td>R -</td>
<td>-</td>
<td>External - Uncontrollable</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Project 1</td>
<td>Port Bulk handling equipment</td>
<td>Safety non-compliance</td>
<td>More than once</td>
<td>A</td>
<td></td>
<td>2.00</td>
<td>0.30</td>
<td>0.45</td>
<td>1.00</td>
<td></td>
<td>R 0.04</td>
<td></td>
<td></td>
<td>R -</td>
<td>-</td>
<td>Internal - Project Processes</td>
<td>No</td>
<td>Common to Programmes</td>
</tr>
<tr>
<td>4</td>
<td>Project 2</td>
<td>Rail Earthworks</td>
<td>Scope definition</td>
<td>Once</td>
<td>E</td>
<td>Almost Certain</td>
<td>95%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Project 2</td>
<td>Rail Earthworks</td>
<td>Approval Delay</td>
<td>Once</td>
<td>B</td>
<td>Unlikely</td>
<td>20%</td>
<td></td>
<td>0.15</td>
<td>0.30</td>
<td>0.45</td>
<td></td>
<td>R 0.11</td>
<td></td>
<td></td>
<td>R -</td>
<td>-</td>
<td>Internal - Owner Requirement</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Project 2</td>
<td>Rail Earthworks</td>
<td>Safety non-compliance</td>
<td>Once</td>
<td>C</td>
<td>Moderate</td>
<td>45%</td>
<td></td>
<td>0.15</td>
<td>0.45</td>
<td>1.00</td>
<td></td>
<td>R 0.14</td>
<td></td>
<td></td>
<td>R -</td>
<td>-</td>
<td>Internal - Project Processes</td>
<td>No</td>
</tr>
</tbody>
</table>

*Figure 6: CRR with linked risk categories*
The next step was to use  =Vlookup() functions to link the (i) Project name with the programme and (ii) the Risk Name with the various categories. Column R contains the simulation result as described by Figure 6 (p. 8).

Create Reports

After the CRR was linked with the risk categories, reports were created.

Creating Named Ranges

The first step in this process was to use the MS Excel Name Manager tool to identify the columns in the CRR which were going to create the reports. This was done because it simplified the creation and reading of formulas. Five named were created: (i) Project_Category, (ii) Risk_Name, (iii) Simulation_Result, (iv) Risk_Type, (v) Start_Delay and (vi) Programme_Risk_Type.

Create 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() was used to generate output distributions based on various sets of simulation results (project type, risk name, risk type etc.). When all these output distributions inputs are summed, tornado graphs are produced. Tornado graphs are the results of a sensitivity analysis which displays a ranking of the input distributions which impact on the simulation results. Inputs that have the largest impact on the distribution of the output will have the longest bars in the graph (Palisade Corporation, 2014, p. 254), i.e. the simulation inputs and outputs are highly correlated.

The following syntax was used:

=SumIfs(Simulation_Result, Project_Category "Rail Power Supply", Risk_Type,"External - Uncontrollable") + RiskOutput()

Which means: Produce an output distribution for the simulation results where the Project Category equals “Rail Power Supply” and the Risk Type equals “External: Uncontrollable”.

In certain cases, the use of =RiskOutput() could not produce the required tornado graphs. In these cases, the =RiskMakeInput() function was used since it specifies that the calculated value for a formula will be treated as a simulation input, the same way as a distribution function.

Create Reports

Two reports were created on a new sheet, using the principles described above. The screenshot on the next page shows how =SumIfs(), =MakeRiskInput() and =RiskMakeOutput() were used to generate output distributions for all the (i) different project categories, (ii) the total of the all the Project Categories, (iii) each of the each Risk types, (iv) the total of each risk type, as well as the (v) simulation result for the all the risk types. Columns representing Amplified Risks, Common to Programme risks and Generic Project risks also appeared on this report but is not included on the screenshot (Figure 7).
Figure 7: Report 1 formulas
This screenshot shows how \texttt{=Sumifs()}, \texttt{=MakeRiskInput()} and \texttt{=RiskMakeOutput()} were used to generate output distributions for all the (i) risk type and project start delays, (ii) project start delays and programme risk type.

![Figure 8: Report 2 formulas](image)

The total columns were done in the same manner as in Report 1.
FINDINGS

The following simulation results are presented and discussed:

i. Programmes which cause the most uncertainty

ii. Projects which cause the most uncertainty and their characteristics

iii. The relationship between programmes, risk category and project start delays

Report 1A: Identifying which Programme causes the most uncertainty in the Portfolio

The simulation results showed that the variance in the portfolio was caused by the (i) Rail Power Supply, (ii) Port Marine Infrastructure, (iii) Rail Tunnels & Bridges, (iv) Port Bulk Handling equipment and (v) Rail Earthworks & Overhead Traction Equipment programmes. The question “Is there a correlation between these programmes and the individual projects which cause the most uncertainty in the portfolio?” automatically flowed from this result. Instead of using the Project type as input, the Project Name was used and the following tornado graph was produced:
Figure 10: Simulation Results: Projects causing uncertainty

It was found that these projects all belonged to the top 5 categories as displayed in Figure 10:

Table 4: Programmes and high uncertainty projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Programme</th>
<th>Programme ranking according to Figure 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eskom South of Ermelo</td>
<td>Rail Power Supply</td>
<td>1</td>
</tr>
<tr>
<td>Tank Farm</td>
<td>Port Marine Infrastructure</td>
<td>2</td>
</tr>
<tr>
<td>Pier 1 Phase 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berth Deepening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>81 Mtpa Coal Export</td>
<td>Rail Earthworks &amp; OHTE</td>
<td>5</td>
</tr>
<tr>
<td>Overvaal Tunnel</td>
<td>Rail Tunnels &amp; Bridges</td>
<td>3</td>
</tr>
<tr>
<td>Tippler Richards Bay</td>
<td>Port Bulk handling equipment</td>
<td>4</td>
</tr>
<tr>
<td>Tippler Saldanha</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The eight projects (representing 42.9% of the portfolio budget) which had a regression coefficient >0.03 was therefore removed from the sample and two concurrent simulations were run.

Figure 11: Simulation Results: Eight projects removed

From the output statistics on the graph, (Maximum, Mean, Standard Deviation and P80) it was clear that that projects of a certain type were causing the uncertainty in the project portfolio. The question which then came was “What does these projects have in common?” and the following table was created after consultation with some managers at The SOE:
**Table 5: Project characteristics driving uncertainty**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance and approvals</td>
<td>• Project approval delays due to governance requirements for projects with a cost of higher than R1 billion (Ganesh, 2014).</td>
</tr>
<tr>
<td></td>
<td>• Environmental approvals (including water use and borrow pit licenses) (Budler, 2014)</td>
</tr>
<tr>
<td></td>
<td>• Procurement eligibility requirements are often onerous, restricting the number of bids; and the procurement process is complex and lengthy (Budler, 2014)</td>
</tr>
<tr>
<td>Physical project characteristics</td>
<td>• Complex, high capital cost, multi-disciplinary engineering projects (Ganesh, 2014).</td>
</tr>
<tr>
<td></td>
<td>• Complex hydrogeological conditions (i.e. lots of water and rock).</td>
</tr>
<tr>
<td></td>
<td>• Projects are not repeated regularly, i.e. comparing the following:</td>
</tr>
<tr>
<td></td>
<td>• The same project team working for many years on various railway building projects</td>
</tr>
<tr>
<td></td>
<td>• A project team working on a once every 30 year project such as a new quay wall with associated landside infrastructure, like the Port of Ngqura.</td>
</tr>
<tr>
<td></td>
<td>• Large foreign content due to economics and/or skills availability in South Africa (Ganesh, 2014)</td>
</tr>
<tr>
<td></td>
<td>• 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 (Budler, 2014).</td>
</tr>
<tr>
<td>Commercial</td>
<td>• The business cases are often difficult to quantify in order to satisfy investment committees.</td>
</tr>
<tr>
<td></td>
<td>• Obtaining realistic construction estimates during study phases. Study-based cost estimates are often not realistic, and can only be adjusted once the bids start coming in, re-starting commercial approval processes (Budler, 2014).</td>
</tr>
<tr>
<td>Stakeholder issues</td>
<td>• Multiple, changing stakeholders with competing interests (Budler, 2014).</td>
</tr>
<tr>
<td></td>
<td>• It’s difficult to obtain stakeholder consensus on scope, and to freeze the scope (Budler, 2014).</td>
</tr>
<tr>
<td></td>
<td>• Commitment to projects by Eskom (Budler, 2014).</td>
</tr>
<tr>
<td></td>
<td>• Land acquisition or temporary land rights issues – land owners often demand excessive concessions/payments (Budler, 2014).</td>
</tr>
<tr>
<td></td>
<td>• Multiple interfaces with other projects and business streams (Bierman, 2014), complicating the authorisation and granting of necessary permits to execute project during operations (Budler, 2014).</td>
</tr>
</tbody>
</table>

**Report 1B: Programme Risk Type**

The simulation results as presented in Figure 13 shows that although the most uncertainty in the portfolio was caused by Generic Project Risks, risks which were Common to Programmes and Amplified risks were not negligible. This provides quantified evidence certain risks need to be managed on a programme and profile level.
The simulation with the Eight Projects removed presented different results where Amplified risks now provided the most uncertainty in the portfolio. The implication of this result is that in one project portfolio, the focus regarding the treatment of programme and portfolio risks might differ and this difference might be associated with project scale and complexity. This also means that the causes and related treatment plans differ.

**Figure 12: Simulation Result: Programme Risk Type**

**Figure 13: Simulation Result: Programme Risk**

**Report 2: Risk Type, Programmes and Start Delays**

The relationship between risk type, programme type risks and project start delays was modelled in Report 2 (p. 12) and the results again showed that the different risk drivers were present in the two simulations. In the simulation which included all the projects (Figure 14), risks which were common to programmes made up three of the top 5 tornado graphs. The risks were also driven primarily by risks which had their sources inside the SOE. In the second simulation (Figure 15), amplified internal owner requirements cause the most uncertainty in the portfolio. The next two bars on the graph referred to common to programme risks, which highlighted the need to manage and treat these on a programme and portfolio level.
CONCLUSION

Various findings were made from the simulation results:

i. It was initially expected that certain risk types the most uncertainty in the portfolio. This was an incorrect hypothesis. The model used the Monte Carlo method to prove that there were different risk drivers when comparing large complex projects with smaller, less complex ones. From the tornado graphs it was clear that a set of eight projects cause the uncertainty in the project portfolio. As mentioned earlier, 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.
ii. The model quantified the importance of identifying and treating risks on a programme and portfolio level and also demonstrated that more complex projects are driven by generic project risks and that uncertainty is caused by amplified risks in the other projects. This suggests that there is a difference in risk treatment related to complex programmes than in simpler ones. Risk categories related to project start delays reflected the same.

iii. In the context of these projects, risks which are caused by internal factors have significant influence on the uncertainty in the project portfolio, in both the complete and the eight projects removed simulations. The reasons for this needs to be further researched, using the data as contained in the CRR.

The scale on which the data was collected and analysed has never been done in the context of South African port and rail capital projects. These results contribute to the Technology Management body of knowledge because it shows how readily accessible simulation packages (like @Risk) can be used to determine the risk drivers in a portfolio of capital projects. The results – and subsequent further research – should also provide some knowledge regarding the risks and risk drivers in similar capital project environments.

REFERENCES


